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Original Article

The Role of Microorganisms in Biogenic Elements Cycling in the Dry Steppe Ecosystems of Central Asia

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Abstract

Key words: biological cycle, steppe ecosystems, aboveground phytomass, microbial decomposers

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The following primary variables were studied in order to understand which part microbial decomposers play in biogenic elements cycle in the steppe ecosystems of Central Asia: species composition and productivity of plant communities; chemical composition of dead plant material; fungal abundance and abundance of various ecological trophic groups of bacteria (saprophytic, proteolytic, cellulolytic); degradation rate of model substrates and plant litter (protein and cellulose). The total stock of chemical elements (*N*, *P*, *Ca*, *Mg* and *K*) involved in the biological cycles in the steppe of Buryatia (Russia) amounted from 6.478 to 10.130 kg/ha, and from 8.826 to 31.802 kg/ha in the Mongolian steppe. The chemistry of elements' cycles in the ecosystems under study is of a nitrogen type.

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Introduction

Biological cycle of chemical elements in the biosphere and in various ecosystems, and how it is disrupted by human activity are among the most topical issues of our days. Nowadays, many researchers in Russia and in other countries are looking at biological cycles in various natural ecosystems (Rodin & Bazilevich, 1965; Rodin *et al*., 1968; Titlyanova, 1992, 1995; Titlyanova, *et al*., 1993). However, there are very few works that take more or less close look at these processes from microbiological point of view, whilst microbiological destruction of organic matter in plant residues is an important process that determines the existence of biological cycle.

Considering insufficiency of the knowledge and the utmost importance of these ecosystems for life and agricultural activities of the indigenous people, microbiological studies of the steppe ecosystems of Central Asia are of special academic interest.

This work primarily aimed to evaluate the rate of microbiological destruction of organic matter in the plant residues within the steppe ecosystems of Central Asia (Buryat Republic of Russia and Mongolia), as well as the total stock of chemical elements involved in the biological cycle.

Materials and methods

The investigated forb-feather-grass communities of the dry steppes were located in Buryatia and Mongolia (Fig. 1).

These communities under study were located in the Involginskiy and Mukhorshibirskiy districts of Buryatia, and in Khentii, Sukhbaatar and Dornod provinces of Mongolia. A brief

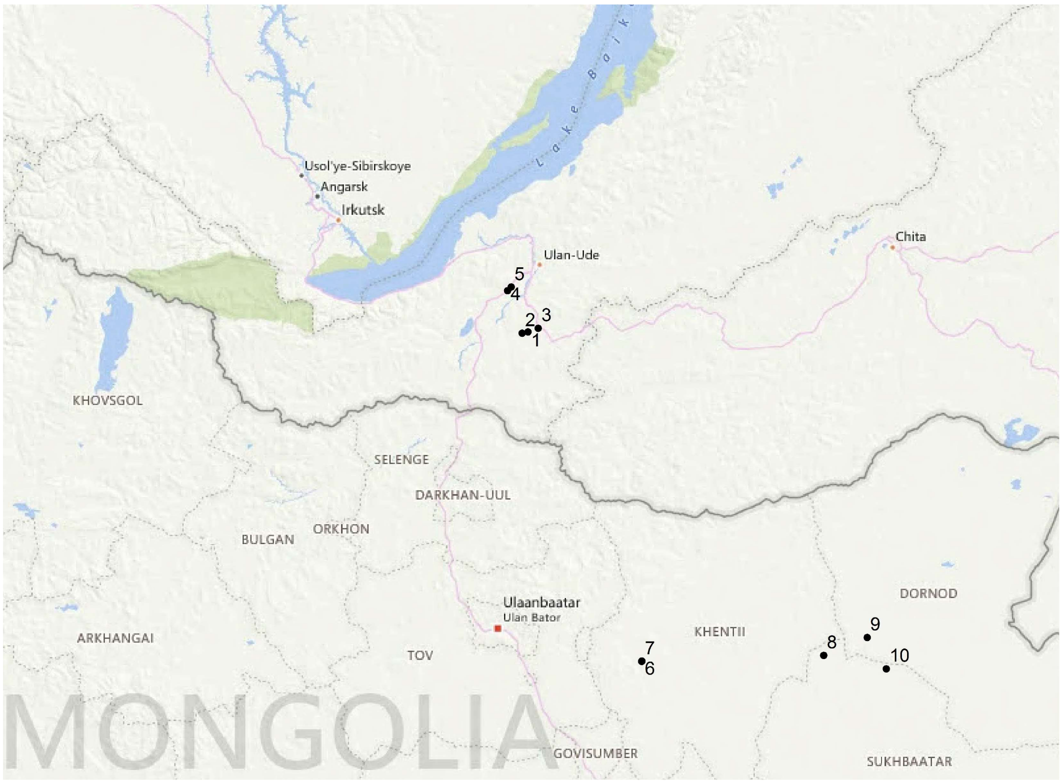

Fig. 1. Study sites in Buryat Republic of Russia, and in Mongolia. 1-5: Buryatia, 6-10: Mongolia.

description of each study site is given in Table 1.

Modified Kirshner–Ganek method was used to measure cellulose content, while fats were extracted using Soxhlet extractor. Protein levels were calculated from total nitrogen multiplied by the factor 6.25. Sugar and starch content was determined with anthrone reagent (Biochemical approaches to study plants, 1987). *Fe*, *Cu*, *Zn*, *Mn*, *Co*, *Cr*, *Cd* levels in mineralization products were calculated using atomic absorption spectrophotometer SOLAAR M6; Ca and *Mg* were determined following complexometry; *N* — following Kjeldahl titrimetric method; *P* — through vanadate-molybdate photometry; *Na* and *K* — following spectrophotometry (using spectrophotometer) (Ermakov, 1987; Yagodin, 1987).

Degradation intensity of plant material was

Table 1. Geographical coordinates, altitude, dominant and codominant plant species of the study sites.

Site	District / Province	Latitude	Longitude	Altitude (m)	Dominant and codominant species
			Russia, Buryatia		
1	Mukhorshibirskiy	51°08’977”	107°24’423”	613	*Stipa krylovii*
2	Mukhorshibirskiy	51°08’169”	107°18’598”	598	*Stipa krylovii, Agropyron cristatum, Artemisia frigid*a
3	Mukhorshibirskiy	51°11’254”	107°34’768”	698	*Stipa krylovii, Poa botryoides, Artemisia frigid*a, *Potentilla acaulis*
4	Involginskiy	51°34’849”	107°03’939”	637	*Stipa krylovii*, *Artemisia frigida*, *Cleistogenes squarrosa, Poa attenuate*, *Potentilla acaulis*
5	Involginskiy	51°37’033”	107°07’701”	686	*Stipa krylovii, Cleistogenes squarrosa*, *Poa attenuate*
			Mongolia		
6	Khentii	47°33’812”	109°18’883”	1486	*Stipa krylovii, Cleistogenes squarrosa*, *Poa botryoides*
7	Khentii	47°33’595”	109°18’771”	1488	*Stipa krylovii, Cleistogenes squarrosa*
8	Sukhbaatar	47°37’569”	112°21’629”	978	*Stipa krylovii, Clestogenes squarrosa*, *Leymus chinensis*
9	Dornod	47°49’680”	113°05’143”	939	*Stipa krylovii*, *Clestogenes squarrosa*
10	Sukhbaatar	47°28’522”	113°24’234”	1012	*Stipa krylovii*, *Cleistogenes squarrosa, Leymus chinensis*

investigated with the help of mechanical isolation (Perel & Karpachevsky, 1968). Cellulose and protein degradation intensity was measured on model substrates (filter paper and photographic paper) following the application by Khaziev *et al*. (2005).

The abundance of different ecological trophic groups of microorganisms in sample of living and dead aboveground phytomass and roots was evaluated on selective media following limiting dilution culture approach with the help of McCready table (Tepper *et al*., 2004). A Sabouraud's medium (Dudka *et. al*., 1982) was used to evaluate the fungal abundance. The saprophytic bacteria were secured using glucose-yeast-peptone medium (Subba Rao, 1977). The abundance of cellulolytic and proteolytic bacteria was measured in Pfennig's medium adding filter paper and peptone, respectively (Pfennig, 1965).

Results

The floristic composition of the investigated plant communities is typical for steppe ecosystems of Central Asia; it is rather limited, with 11–15 families, among which the most speciose of which are *Asteraceae, Poaceae* and *Rosales*. Buryat steppe plant community is of a moderate familial diversity (11) and fewest of species (34). Species composition of the flora of the Mongolian communities under study is more diverse, represented by 51 species from 15 families.

The total stock of aboveground phytomass in the plant communities under study ranges from 2.7 to 17.3 dt/ha.

Measuring the yearly amount of mineral elements received from litter-fall is one of significant intensity factors of the minor biological cycle. To a certain extent, elementary chemical compositions of the steppe ecosysytems under study are of a similar content. *N*, *K* and *Ca* are being dominant, and their levels in plant residues are 0.99-1.87%, 0.74-2.16% and 0.33-1.00%, respectively. Our study on macro- (*N*, K, Ca, *Mg*, *P*, *N*a) and microelements (*Cu*, *Zn*, *Mn*, *P*b, *Cd*) levels in the plant samples of the steppe communities under study compared to concentration levels of the same elements in forage plants in terms of meeting animals' need for these elements, showed the deficiency of *P* and *Zn* in almost every sample, and partial *Mn* and Mg deficiency. *Ca* levels are within normal range and slightly exceed the limits. The levels of highly toxic *Pb* and *Cd* heavy metals in the plants are within maximum permissible concentrations, due to protective barriers that prevent plants from accumulation of these elements. According to their biochemical parameters (protein, cellulose and water-soluble carbohydrates levels), the herbages of Mongolian and Buryat steppe plant communities have relatively sufficient forage value.

As primary decomposers of organic matter, microorganisms play a critical role in the accumulation and transformation of biogenic elements, as evidenced by the previous data about carbon isotopic composition of plants and soil of the ecosystems under study (Dambaev *et al*., 2016).

Limiting dilution culture in selective media enabled us to measure fungal abundance, as well as the levels of different ecological trophic groups of bacteria, such as saprophytic, proteolytic and cellulolytic in our plant samples, namely, in the living and dead aboveground phytomass, and roots of the steppe plants (Table 2).

Saprophytic bacteria turned to outnumber other microbial decomposers, and their levels in living aboveground phytomass of all plants under study are amounted to 10^5–10^7 cells/g. There were from ten to hundred times as much of saprophytic bacteria in the dead plant material and roots, amounting to 10^6–10^8 cells/g. Cellulolytic bacterial abundance in the plant residues of the communities under study was minor, with 10–10^3 cells/g. Proteolytic bacteria counts in the plant samples ranged from 10^5 to 10^8 cells/g. Fungal abundance in the aboveground phytomass of the plant samples varied from 10^5 to 10^7 CFU/g.

The study of microbial abundance highlights certain consistency in their dispersal across all the plant communities. In terms of abundance, they fall into the following ascending order: living aboveground phytomass, dead aboveground phytomass, and roots. Lower bacterial and fungal counts in living aboveground phytomass can likely be explained by high phytoncide levels that are destructive to microorganisms. Roots and dead aboveground phytomass are the most favorable environment for microorganisms.

Degradation rate of plant litter is one of the

Table 2. Abundance of microbial decomposers in plant samples of the Buryat and Mongolian plant communities.

Site	saprophytic bacteria, c/g			proteolytic bacteria, c/g			cellulolytic bacteria, c/g			fungi, CFU/g.		
	lp	dp	r	lp	dp	r	lp	dp	r	lp	dp	r
Buryatia, Russia												
1	10^6	10^6	10^8	10^6	10^6	10^8	10^2	10^2	10^3	10^6	10^7	10^8
2	10^7	10^8	10^8	10^6	10^8	10^8	10	10^2	10^2	10^5	10^5	10^8
3	10^7	10^8	10^8	10^6	10^8	10^8	10^2	10^2	10^3	10^6	10^7	10^8
4	10^7	10^7	10^8	10^6	10^7	10^8	10	10^2	10^2	10^7	10^7	10^8
5	10^5	10^6	10^7	10^4	10^6	10^7	10	10^2	10^3	10^7	10^8	10^7
Mongolia												
6	10^7	10^8	10^8	10^7	10^8	10^8	10^2	10^2	10^2	10^6	10^7	10^8
7	10^5	10^7	10^7	10^6	10^8	10^8	10	10	10^2	10^5	10^6	10^6
8	10^6	10^7	10^7	10^6	10^8	10^8	10	10^2	10^2	10^5	10^5	10^8
9	10^5	10^7	10^8	10^7	10^8	10^8	10^3	10^2	10^2	10^5	10^6	10^7
10	10^6	10^8	10^8	10^7	10^8	10^8	10^3	10^3	10^4	10^5	10^6	10^8

lp – sample of living aboveground phytomass; dp – sample of dead aboveground phytomass; r – sample of roots.

important parameters of destruction processes. Comparisons to literature addressed to rate measurement of plant residues degradation in steppes ecosystems (Striganova & Kozlovskaja, 1985; Grishkan, 1995; Belyakova, 1996; Buyantueva, 1999; Sandanova, 2007; Oorzhak, 2007) showed that degradation of plant residues in the Buryat and Mongolian steppes is a slower process.

Over a year, only from 22.1% to 29.7% of the plant residues underwent microbial degradation, amounting to 1.54–2.83 dt/ha. The reason for this is likely to be high content of decomposition-resistant grasses, as well as natural and climatic characteristics of the regions: low temperatures for a long annual period, average annual temperature below zero point, dry soil for long periods, and unequal distribution of precipitations throughout a year, are visibly inhibit microbial destruction rates.

Degradation intensity of the model (protein and cellulose) substrates were studied in the field in the Buryat steppe ecosystems of interest to understand how environmental factors influence the fermentation (protease and cellulase) capacity of microbial decomposers.

Protease and cellulase capacity of microorganisms has been observed to naturally be of an exponential kind. During cold periods, in winters and early springs, low temperatures and, consequently, low microbial metabolism results in moderate microbial destruction of model substrates. Degradation intensity was 0.0005-0.01% a day for protein, and 0.048–0.097 mg a day for cellulose. During spring and summer (first half) periods, from 0.020 to 0.160 % of protein, and from 0.05 to 0.16 mg of cellulose a day underwent degradation.

Summer (second half) and early fall show degradation of 0.05–0.32% of protein, and 0.05–0.46 mg of cellulose a day. Thus, the direction and rate of biological cycle of matter within Buryat steppe ecosystems under study are significantly determined by summer and early fall period, hydrothermic characteristics of which are most favorable for microbial activity.

The intensity of biological cycle is one of the most representative factors of an ecosystem's stability. Studying the productivity of the aboveground phytomass and the processes of microbiological destruction enabled us to evaluate the rate and intensity of release of the food compounds accumulated in green plants in the Buryat and Mongolian steppe ecosystems. The total stock of chemical elements (*N*, *P*, *Ca*, *Mg* and *K*) involved in the biological cycles in the steppe ecosystems of Buryatia amounted from 6.478 to 10.130 kg/ha, and from 8.826 to 31.802 kg/ha in the Mongolian steppe. The chemistry of elements' cycles in the ecosystems under study is of a nitrogen type.

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