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The physiological groups of microorganisms in different soils at Admiralty Bay region (King George Island, South Shetland Islands, Antarctica)*

ABSTRACT: There were tested microorganisms in differents soils at Admiralty Bay region. The physiological groups of microorganisms were restricted by the kind of organic matter. There were found in ornithogenic soils in higher number the following groups of microorganisms; proteolytic bacteria, uric acid and L-asparagine ammonifying bacteria, chitin degrading bacteria, lecithin degrading bacteria and calcium phosphate dissolving bacteria. The nitrifying bacteria were found in lower horizons of ornithogenic soils in higher number. The nitrogen fixing bacteria were found in mineral soils covered by plant associations, only. The spore-forming bacteria were detected in ornithogenic soils and in soil influenced by man.

Key words: Antarctica, microorganisms, physiological groups, ornithogenic soils, peat soils, protoranker soils, regosol soils.

1. Introduction

The soils at Admiralty Bay region (62°09′ S, 58°28′ W) on King George Island are strongly differentiated because this area belongs to the "Maritime Antarctic Zone" (Holdgate, 1964). This region has much ice-free lowland and a variety of plant and animal life (Presler 1980, Rakusa-Suszczewski 1980, Jabłoński 1984, Ochyra and Wieczorek in preparation) as well as has milder climate with higher summer air and soil temperatures and there is a great deal of precipitation (Nowosielski 1980, Zubek 1980). These conditions stimulated formation of different soils

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(Syroečkovskij 1959, Tedrow and Ugolini 1966, Ugolini 1972, Tatur and Myrcha 1984).

There is not so much data about physiological groups of microorganisms which take part in mineralization of organic matter in this region. The total numbers of bacteria, fungi and algae were counted and correlated with increase of organic matter content (bird excrements, plant residues), moisture, pH and temperature (Boyd W. L. and Boyd J. W. 1963, Ugolini and Starkey 1966, Benoit and Hall 1970, Boyd et al. 1970, Cameron et al. 1970, Claridge et al. 1971, Zabawski and Piasecki 1981). The presence of microorganisms which take part in transformation of mineral compounds (N and S) and the presence of coliform and spore-forming bacteria were also recorded. The data of Pietr et al. (1983) presented the role of different physiological groups of microorganisms in degradation of penguin excrements.

The aim of this work was the comparative study of the physiological groups of microorganisms in ornithogenic, protoranker, regosols, and peat soils at Admiralty Bay region.

2. Materials and methods

Soil samples

The samples were collected at Thomas Point and Llano Point at Admiralty Bay region on King George Island during austral summer 1979/1980. The samples were taken from each testing horizon of tested soil profiles in about 100 grams amount. There were collected the 5—7 randomly selected samples from 0—10 cm layer of soil at testing places up to 100 grams weight. These materials were brought to the laboratory in steril glass bags and were analyzed during 24 hours after collection. These samples were kept at about 0°C before analyses.

Ornithogenic soils: There were collected the samples of ornithogenic soils at Llano Point, according to Jabłoński (1984) the area most inhabited by penguins at Admiralty Bay. Tatur and Myrcha (1984) described the tested area in details.

Soil profiles: Profile no. 17 of ornithogenic soil from area of the old rookery of penguins (description see Tatur and Myrcha, 1984);

— 0—10 cm horizon (sample 0—3 cm) of organic-mineral matter of black colour containing visible unchanged fresh fragments of excrements among pebbles from the nests,

— 10—30 cm horizon (sample 10—15 cm) of amorphous substances of brown or beige colour among stones and gravels of skeleton.

Profile no. 6 of phosphatized ornithogenic soil from the surrounding of rookery (description see Tatur and Myrcha, 1984);

— 0—5 cm horizon (samples 0—2 cm and 2—5 cm) of semi-liquid excrements of black colour,

— 5—45 cm horizon (sample 30—40 cm) of rocky debris filled by unstable aggregation of leucophosphatite of light yellow-brown colour,

— 60—110 cm horizon (sample 70—80 cm) of stony boulder clay of brown colour of unstable aggregation of secondary phosphates.

— 110—150 cm horizon (sample 110—120 cm) of wet clay with high content of white plastic aluminium-potassium-ammonium phosphates (ground water below 130 cm),

Profile no. 1 of sediment of detritus (mineral, organic and phosphate) on te beach at Llano Point (description see Tatur and Myrcha, 1984);

— 0—12 cm horizon (sample 2—10 cm) pulpy sediment of gray-brown colour,

— 12—16 cm horizon (sample 12—16 cm) of weak concise sediment of black colour,

— 16—20 cm horizon (sample 16—20 cm) of weak concise sediment of brown colour.

Surface samples: Sample no. 11 from surrounding of rookery of Adelie penguins, about 3 m outside the last nests and outside the run of birds to the sea (Llano Point). Single agglomerations of *Priasola crispa* were found here.

Sample no. 12 from the above described place; 10 m outside the rookery. *P. crispa* and *Polytrichum alpine* were found in several agglomerations.

Sample no. 13 from the above described place; about 25 m outside the rookery. *P. crispa*, *P. alpine* and *Drepanocladus uncinatus* were found in several agglomerations.

Sample no. 16 from the old rookery of gentoo penguins not inhabited during last several years and covered by *Deschampsia antarctica* on the beach at Llano Point.

Sample no. 17 from the place of the moulting of penguins without plants at Llano Point (the surface sample of profile no. 15 of Tatur and Myrcha, 1984).

Peat soils: Sample no. 34 from the Antarctic peat (*D. antarctica*, *P. alpine*, *Colobanthus crassifolius*, *D. uncinatus* and others). The samples was taken near to the water outflow from the rookeries of gentoo penguins at Thomas Point near the Arctowski Station.

Sample no. 35 from the above described peat. The sample was taken outside the influence of the above mentioned water outflow.

Sample no. 43 from the peat of *Calliergidium austro-stramineum* and *D. uncinatus*. The sample was taken above the rookeries of penguins but near the nests of *Macronectes giganteus* at Llano Point.

Sample no. 44 from the peat of *C. austro-stramineum*, *P. alpine* and *D. uncinatus* above the rookeries of penguins at Thomas Point.

Protoranker soil: Samples no. 45 from the old moraine of Ecology Glacier. The sample was collected at the place covered by *Usnea antarctica*.

Regosol soils: Sample no. 41 from the debris of the Panorama at Thomas Point. The sample was taken near the dump area of Arctowski Station.

Sample no. 42 from the youngest moraine of Ecology Glacier at Llano Point.

Chemical analyses.

Extracted mineral compounds were analyzed. The extractions were done with 100 ml of 1 N K_2SO_4 (pH 6.0) per 20 g of tested dry soil without skeleton. The chemical methods were described elsewhere (Pietr et al., 1983).

Microbiological analyses.

The microbiological analyses were done analogically as was described elsewhere (Pietr et al., 1983). The Taylor's soil extracts were used for additional counting of the total number of bacteria (Harrigan and McCance, 1966). They were prepared from each group of tested soils separately. The number of microorganisms was calculated per 1 g of dry soil without skeleton.

Analyses were done at the Arctowski Station of Polish Academy of Sciences during austral summer 1979/1980.

3. Results and discussion

Table I presents the number of microorganisms in profiles of ornithogenic soils. The number of saprophytic bacteria (total number, proteolytic, ammonifying, chitin degrading and lecithin degrading) was significantly reduced in lower layers in comparison to organic horizons. This was similar to observation of microbial population in organic matter washed away from rookeries to the sea (Pietr et al., 1983). The number of autotrophic nitrifying bacteria increased from 80—100 cells to 460—750 cells per 1 g of soil in lower phosphatized rock zone in comparison to the surface organic horizons (Table I). These results show higher activity of nitrification in soil profiles than during transportation of excrements over the surface (Pietr et al., 1983). Tatur and Myrcha (1983) found the highest content of $N-NO_3$ in ground water after percolation through ornithogenic soils. These results are correlated with the number of nitrifying bacteria in soil profiles. The number of calcium dissolving bacteria was significantly higher in sub-surface sample (3—5 cm) in profile no. 6 than in lower and upper layers (Table I). The accumulation of calcium phosphates in sub-surface

Table I

The physiological groups of microorganisms in the tested profiles of ornithogenic soils (number per 1 g o dry soil without skeleton)

Profiles, date of sampling	Horizons	Bacteria	Proteolitic	Amonifying		Nitrifying	Chitin degrading	Lecithin degrading	$Ca_3(PO_4)_2$ – dissolving	Spore – forming	Moulds
				L-aspara-gine	uric acid						
No 17	0—3 cm	32×10^6	7×10^6	78×10^3	2×10^3	40	20×10^3	21×10^3	900×10^3	28×10^3	900
1980-02-10	10—15 cm	100×10^3	23×10^3	30×10^3	700	460	8×10^3	3×10^3	100	+*	0
No 6	0—2 cm	9×10^6	1×10^6	2.7×10^6	42×10^3	100	41×10^3	95×10^3	75×10^3	15×10^3	3×10^3
1980-02-10	2—5 cm	6×10^6	300×10^3	700×10^3	45×10^3	80	12×10^3	70×10^3	360×10^3	+	+
	30—40 cm	3×10^6	400×10^3	N.D.**	N.D.	200	13×10^3	80×10^3	50×10^3	0	+
	70—80 cm	500×10^3	200×10^3	700×10^3	7×10^3	360	6×10^3	18×10^3	20×10^3	0	0
	110—120 cm	82×10^3	10×10^3	18×10^3	3×10^3	750	+	300	25×10^3	0	0
No 1	2—10 cm	200×10^3	1×10^3	90×10^3	90×10^3	200	3×10^3	800	100	1×10^3	200
1980-02-10	12—16 cm	60×10^3	700	5×10^3	3×10^3	800	0	500	+	500	+
	16—20 cm	180×10^3	800	50×10^3	20×10^3	600	0	200	+	+	+

* + — single isolates, ** N.D. — not determined.

leached guano after mineralization of organic matter was observed (Tatur and Myrcha, 1984). This mineral was identified as a hydroxylapatite by Tatur and Barczuk (1984).

The chemical and microbiological analyses showed significant differences between soil samples from rich in guano layers of ornithogenic soils and others (Table II, III and IV). High content of $N-NH_3$ (12—400 ppm), $N-NO_3$ (1.2—40 ppm) and P_{ortho} (26—145 ppm) were observed in the ornithogenic soils and Antarctic peat near the rookeries of penguins (Table II). The level of ammonium and phosphorus was lower outside the rookeries and in the old nesting place of penguins (sample 12—16) in comparrison with the soils from the surrounding of rookeries and from the place of moulting (samples 11 and 17). The similar results were described by Smith (1978; 1979) and by Campbell and Claridge (1966) in soils under influence of bird excrements as well as at the old nesting place. Low content of $N-NH_3$ (below 6 ppm), $N-NO_3$ (below 1 ppm) and P_{ortho} (below 15 ppm) was found in the protoranker, regosols and peat soils without the influence of organic matter of bird origin (Table II). The sample no. 43 had the

Table II

The content of extractable different forms of nitrogen and phosphorus in the tested soils and pH in 1 N KCl

Samples	pH_{KCl}	Nitrogen (ppm)			P_{ortho} (ppm)
		$N-NH_3$	$N-NO_2$	$N-NO_3$	
№ 11	3.2	140	0.9	18.8	50
№ 12	3.2	98	0.3	7.0	70
№ 13	3.2	12	0.6	1.9	41
№ 16	3.5	6	0.0	1.2	5
№ 17	4.2	400	8.3	35.0	145
№ 34	3.2	14	0.3	40.0	26
№ 35	3.2	44	0.6	4.0	43
№ 41	5.0	2	0.0	0.0	2
№ 42	5.8	2	0.0	0.8	1
№ 43	4.4	6	0.6	1.0	15
№ 44	4.4	4	0.0	0.6	5
№ 45	4.1	4	N.D.*	0.0	3

* N.D. — not determined.

higher level of the tested nutrients in comparison with others. This result could be connected with the presence of several nests of *Macronectes giganteus* nearby. The number of saprophytic bacteria was found to be similarly differentiated as chemical analyses. It was observed that the total number of saprophytic bacteria in tested samples, which were collected from the ornithogenic soils and Antarctic peat, varied from 0.2×10^6 to

Table III

The physiological groups of microorganisms in the ornithogenic soils and the peat soils influenced by nutrients from some rookeries of penguins (number per 1 g of dry soil without skeleton)

Samples, date of sampling	Bacteria		Proteolitic	Ammonifying		Nitrifying	Chitin degrading	Lecithin degrading	$Ca_3(PO_4)_2$ – dissolving	Spore – forming	N_2 – fixing	Moulds
	PEM	Soil extracts		L-aspara-gine	uric acid							
№ 11, 1980-01-26 3—5 m outside of the rookery	5.1×10^6	N.D.*	2.5×10^6	0.7×10^6	14×10^3	140	0.4×10^6	0.2×10^6	7×10^3	1×10^3	0	60×10^3
№ 12, 1980-01-26 10 m outside of the rookery	5.5×10^6	N.D.	1.5×10^6	0.1×10^6	70×10^6	N.D.	9×10^3	6×10^3	5×10^3	1.2×10^3	0	17×10^3
№ 13, 1980-01-26 25 m outside of the rookery	2.2×10^6	N.D.	1.6×10^6	60×10^3	0.2×10^6	280	4×10^3	5×10^3	4×10^3	0.8×10^3	10	20×10^3
№ 16, 1980-01-26 old rookery	1.4×10^6	N.D.	0.6×10^6	0.9×10^6	0.2×10^6	750	+**	30×10^3	65×10^3	0.3×10^3	N.D.	4×10^3
№ 17, 1980-01-29 place of moulting	0.2×10^6	0.2×10^6	28×10^3	83×10^3	1×10^3	110	+	0.2×10^3	0.3×10^3	0.5×10^3	0	10×10^3
№ 34, 1980-02-10 Antarctic peat	6.3×10^6	5.4×10^6	3×10^6	0.2×10^6	N.D.	75	6×10^3	0.3×10^6	13×10^3	3×10^3	30	40×10^3
№ 35, 1980-02-10 Antarctic peat	2.8×10^6	0.5×10^6	2.1×10^6	80×10^3	70×10^3	75	2×10^3	0.2×10^6	7×10^3	1.2×10^3	30	70×10^3

* N.D. — not determined, ** + — single isolates.

Table IV

The physiological groups of microorganisms in the mineral soils outside the influence of nutrients from the rookeries of penguins (number per 1 g of dry soil without skeleton)

Samples, date of sampling	Bacteria		Proteolitic	Ammonifying		Nitrifying	Chitin degrading	Lecithin degrading	$Ca_3(PO_4)_2$ – dissolving	Spore – forming	N_2 – fixing	Moulds
	PEM	Soil extracts		L-aspara-gine	uric acid							
№ 41, 1980-01-21 regosols	70×10^3	60×10^3	1.7×10^3	110	0	0	N.D.*	1.1×10^3	550	550	N.D.	+**
№ 42, 1980-01-21 regosols	17×10^3	18×10^3	0.7×10^3	150	0	0	N.D.	0.8×10^3	0.7×10^3	0	+	+
№ 43, 1980-01-21 peat	33×10^3	34×10^3	3×10^3	3×10^3	50	390	100	1.8×10^3	1.4×10^3	+	340	1.6×10^3
№ 44, 1980-01-21 peat	38×10^3	31×10^3	1.9×10^3	150	0	750	50	1.7×10^3	350	+	750	1.9×10^3
№ 45, 1980-01-21 protoranker	47×10^3	27×10^3	0.8×10^3	200	10	0	N.D.	1.1×10^3	0.7×10^3	0	550	1.9×10^3

* N.D. — not determined, ** + — single isolates.

6.3×10^6 per 1 g of dry soil. The analogical count showed the total number of saprophytic bacteria from 17×10^3 to 70×10^3 per 1 g of dry soil in the case of mineral soils (Table IV). Several authors reported similar number of bacteria in mineral soils in this region (Cameron et al. 1970; Boyd et al. 1970).

The percentage of the proteolytic bacteria varied from 14% to 75% of the total number of bacteria in the tested ornithogenic soils (Table III). The analogical count was below 9% of the total number of bacteria in mineral soils and poor peat (Table IV). It was found the analogical differentiation of the ammonifying bacteria utilized L-asparagine as was described above for the proteolytic ones (Table III and IV). Ammonifying bacteria, which utilized the uric acid were found only in the samples from the soils supplied by the excrements of sea birds (Tables I, III and IV). The chitin degrading bacteria were isolated from ornitogenic soils in significant numbers (Table I and III). The higher number of the lecithin degrading and the calcium phosphate dissolving bacteria were observed in the samples obtained from rich in guano layers of ornithogenic soils (Table I and III). These results as well as chemical analyses showed some influence on the soil ecosystem of even few nests of such a large bird as *Macronectes giganteus*, what was found in the case of the sample no. 43.

The spore-forming bacteria were isolated from the surface samples of tested profiles (Table I) as well as from the samples, which were collected in the environment of the rookery (Table III). Spore-forming bacteria were found also in the sample no. 41 (Table IV). This could be related to the dump area of Arctowski Station. Margini and Castrelos (1963) isolated some strains of *Bacillus* from *P. adeliae* and from the air but Boyd et al. (1970) did not isolate the spore-forming bacteria from the rookery of gentoo penguins.

The number of N_2-fixing bacteria was significantly high only in the samples from poor soils covered by plant association (Table IV).

The nitrifying bacteria were observed in the ornithogenic soils and their number was correlated with a decrese of the total number of saprophytic bacteria in tested soils (Table III) as well as in lower horizons of the tested profiles (Table I). Similar results were observed during transportation of organic matter of bird origin to the sea over the surface (Pietr et al. 1983).

The number of moulds was correlated with the developement of some plant associations (Table III and IV); the higher number was found in the Antarctic peat supplied by water with nutrients from rookeries (samples nos. 34 and 35). The dominant fungi in the ornithogenic soils could belong to the keratinolitic genus (*Sporotrichus* and *Chrysospirum*) according to Zabawski and Piasecki (1981).

4. Conclusion

At Maritime Antarctic Zone the differences between microbiological populations in various soils were found, which depended from the sources of organic matter. The overall higher counts of microbial population in the soils manured by birds were observed.

The kind of organic matter defined the physiological characteristic of population in the tested soil. Some groups of bacteria preferred the excrements of penguins. This was found in the case of chitin degrading bacteria and uric acid ammonifying bacteria. Additionally, the following groups of microorganisms were isolated in high number from ornithogenic soils: proteolytic, L-asparagine ammonifying, lecithin degrading and calcium phosphates dissolving bacteria. The nitrifying bacteria were found in lower horizons of the tested profiles in higher number because they used the ammonium after the mineralization of excrements of penguins in the surface layers. The moulds were observed in higher number in Antarctic peat.

These results indicated to the ornithogenic character of the soils not only on the rookeries but also in the surrounding area, which is under influence of solutions running off from the rookeries. Tatur and Myrcha (1984) proposed as well the term "ornithogenic soils" after pedological investigation of the above mentioned area.

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5. Резюме

Проведено исследования химического состава и численности различных физиологических групп бактерий в почвах района залива Адмиральти на острове Кинг Джордж. Химические анализы растворимых нутриентов в 1 N K_2SO_4, а также численность микроорганизмов отчетливо выделили две группы почв. Первая группа — это орнитогенные почвы, а также антарктические торфы, пополняемые стоками из территории колонии пингвинов. Вторая группа почв — это минеральные почвы (проторанкеры и регосоли), а также бедные торфы.

Почвы орнитогенные, а также антарктический торф характеризовались высокими содержаниями минеральных форм азота $N—NH_3$ (12—400 ppm), $N—NO_3$ (1.2—40 ppm) и P_{ortho} (26—145 ppm) по сравнению с аналогичными данными для минеральных почв. Результаты анализов минеральных почв и бедных торфов обнаружила величины для $N—NH_3$ ниже 6 ppm, для $N—NO_3$ ниже 1 ppm и для фосфора — ниже 15 ppm (таблица II). Общая численность сапрофитных бактерий формировалась в похожих пропорциях между орнитогенными и минеральными почвами, как результаты химических анализов. Максимальную численность констатировано в образце № 24, представляющим поверхностный, богатый в гуано, слой орнитогенных почв (6.3×10^6 в I г почвы), при

определенной наибольшей численности бактерий в минеральных почвах лишь 70×10^3 в I г почвы (образец № 41). Процентная доля протеолитических бактерий в популяции исследуемых орнитогенных почв достигала 75% (образец № 35), а в минеральных почвах не превышала 9% (таблицы III и IV). Численность аммонификаторов, использующих l-аспаргин, является тесно связанной с активностью протеолитических бактерий. Аммонификаторы, использовающие мочевую кислоту и бактерии, разлагающие хитин, констатировано только в почвах, удобряемых экскрементами морских птиц (пингвинов и гигантских буревестников). Значительные количества нитрозных бактерий обнаружено в более низких горизонтах исследуемых профилей орнитогенных почв (табл. I). Эти результаты показывают на значительную активность нитрификации в глубочайших партиях исследуемых почв. Бактерии, связывающие свободный азот, выделили из образцов, представляющих минеральные почвы, покрытые растительностью (табл. IV). Присутствие склероцирующих бактерий констатировано в почвах, находящихся под воздействием экскрементов пингвинов, а также в образце № 41, который отбирали вблизи свалки Антарктической станции им. Г. Арцтовского.

6. Streszczenie

Przeprowadzono badania składu chemicznego oraz liczebności różnych grup fizjologicznych mikroorganizmów w glebach rejonu Zatoki Admiralicji na Wyspie Króla Jerzego. Analizy chemiczne rozpuszczalnych w 1 N K_2SO_4 związków azotu i fosforu oraz oznaczenia liczebności mikroorganizmów wyraźnie wyodrębniły dwie grupy gleb. Pierwsza grupa to gleby ornitogenne oraz torfy antarktyczne zasilane spływami z terenów kolonii pingwinów. Druga grupa gleb to gleby mineralne (protorankery i regosole) oraz ubogie torfy.

Gleby ornitogenne oraz torfy antarktyczne zasilane spływami z terenów kolonii pingwinów charakteryzowały się wysokimi zawartościami mineralnych form azotu $N - NH_3$ (12—400 ppm), $N - NO_3$ (1.2—40 ppm) i P_{ortho} (26—145 ppm) w porównaniu do analogicznych danych dla gleb mineralnych i ubogich torfów. Wyniki analiz gleb mineralnych oraz ubogich torfów wykazywały wartości dla $N - NH_3$ poniżej 6 ppm, dla $N - NO_3$ poniżej 1 ppm i dla fosforu poniżej 15 ppm. Ogólna liczebność bakterii saprofitycznych układała się w podobnych proporcjach jak wyniki analiz chemicznych dla badanych grup gleb. Maksymalną liczebność stwierdzono w próbce nr 34 reprezentującą powierzchniową bogatą w odchody ptasie warstwę gleb ornitogennych (6.3×10^6 w 1 g gleby) przy oznaczonej największej liczebności bakteri w glebach mineralnych tylko 70×10^3 w 1 g gleby (próbka nr 41). Procentowy udział bakterii proteolitycznych w populacji mikroorganizmów w badanych glebach ornitogennych sięgał 75% (próbka nr 35) a w glebach mineralnych nie przekraczał 9% (tabele III i IV). Liczebność amonifikatorów wykorzystujących L-asparaginę była ściśle zależna od aktywności bakterii proteolitycznych. Amonifikatory wykorzystujące kwas moczowy oraz bakterie rozkładające chitynę stwierdzono jedynie w glebach użyźnianych odchodami ptaków morskich (pingwiny, petrele olbrzymie). Znaczne ilości bakterii nitryfikacyjnych stwierdzono w niższych poziomach badanych profili gleb ornitogennych (tabele I). Wyniki te wskazują na znaczną aktywność nitryfikacji w głębszych partiach badanych gleb. Bakterie wiążące wolny azot wyizolowano z próbek gleb mineralnych pokrytych roślinnością oraz z ubogich torfów (tabela IV). Ponadto obecność bakterii przetrwalnikujących stwierdzono jedynie w glebach ornitogennych oraz w próbce nr 41, którą pobrano w pobliżu śmietniska Stacji Antarktycznej im. H. Arctowskiego.

7. References

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