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Anna KRZYSZOWSKA

Department of Ecological Bioenergetics,
Institute of Ecology, Polish Academy of Sciences,
Dziekanów Leśny, 05-092 Łomianki

Chemistry of the freshwater of the Fugleberget drainage basin

ABSTRACT: Studies of the chemical composition of surface freshwaters of the Fugleberget drainage basin, Spitsbergen, were performed in the summer of 1979. It was found that activity of birds (little auk) is the main factor differentiating the chemical properties of waters of the drainage basin. The birds faeces cause the enrichment of waters with nutrients, fertilizing the environment. There is a dependence of the concentration of determined water chemistry parameters on the distance from the bird colony.

Key words: Arctic, Spitsbergen, nutrient transport, role of birds in the ecosystem

1. Introduction

Colonies of marine animals, e.g. birds, can be a source of nutrients in the simple Arctic ecosystems. There are known numerous examples of the enrichment of the environment by birds (Russel 1940, Gillham 1956, Golovkin and Pozbniakova 1965, Heywood 1967, Norderhaug 1970, Allen and Kramer 1972, Galkina 1974, Grobbelaar 1975, 1978, Smith 1977, 1978). The enrichment of the environment is caused by birds which supply large amounts of nutrients and of organic matter in the form of their faeces. In the Arctic area, where soil is in the initial stage of the development, the nutrients are dispersed by water. The aim of the present paper is to study the nutrient transportation by temporary flowing waters in the Fugleberget drainage basin (Hornsund Fiord, SW Spitsbergen).

2. Terrain description and methods

The Ariekammen-Fugleberget drainage basin, located by Isbjörnhamna Bay in Hornsund Fiord (SW Spitsbergen) was chosen for studies. The boundaries of this drainage basin are made by the ridge of Ariekammen-Fugleberget in the north, the coastal embankment in the south, and by a sea terrace with rocks in the east and west. The area of the terrain studied is 1,5 km^2. This drainage basin can be divided into two parts: the western one with richer tundra and with a developed hydrographic cover (the Fuglebekken river, a small lake and streams), and the eastern one — which is rocky with scarce islands of vegetation. The plant consists mainly of mosses, lichens and wascular plants (Srodoń 1958, Nowak 1965, Kuc 1968 a, b). There are about 18 bird species in this region (Ferens 1958, Jakubiec 1975), with the little auk — Plautus alle (1) most numerous, forming colonies on Ariekammen and Fugleberget, among the other places. This colony has roughly about 100 thousand birds (Stępniewicz, private communication).

Three profiles, directed SW-NE, differing by their distance from the little auk colony, were established in the area studied (Fig. 1). Stations for water sampling were established along these profiles. Profile $C_1 — C_4$ (with four stations) was the closest to the colony, about 25 m from it, profile $B_1 — B_3$ (with three stations) was at a distance of about 350 m, profile $A_1 — A_5$ (5 stations) was at a distance of about 500 m.

The water analyses were made at the Polish Polar Station at Hornsund. Water samples were collected in a synchronous way from all stations along the established profiles. The studies were performed during the period of the high level of surface waters (25 September 1979), during the low flow, with partially dried out flowing waters (8 August 1979) and at the time of below zero temperatures near the ground, after the birds' departure. The number of stations was decreasing with time, as some of them dried out.

The following quantities were determined in water samples on the day of sample collection: temperature, pH, conductivity, alkalinity, hardness, calcium, chlorides, phosphoranes, nitrate nitrogen. Temperature was measured by a thermometer with an accuracy of 0.2°C. Conductivity was determined with a N 571 type battery conductometer (Merazet, Poznań, Poland) and recalculated to the summary concetration of dissolving ions mineralization), pH was determined colorimetrically, alkalinity, calcium and chlorides were determined by standard methods (Hermanowicz et al., 1976). Orthophosphates were determined by the colorometric molibdenian method, nitrate nitrogen — by the colorimetric method with phenoldisulphonic acid (Hermanowicz et al. 1976). These determinations were made on a 10 spectrocolorimeter (Zeiss DDR) and in Nessler cylinders. The flow was measured by determining the time of filling up of a vessel with known volume.

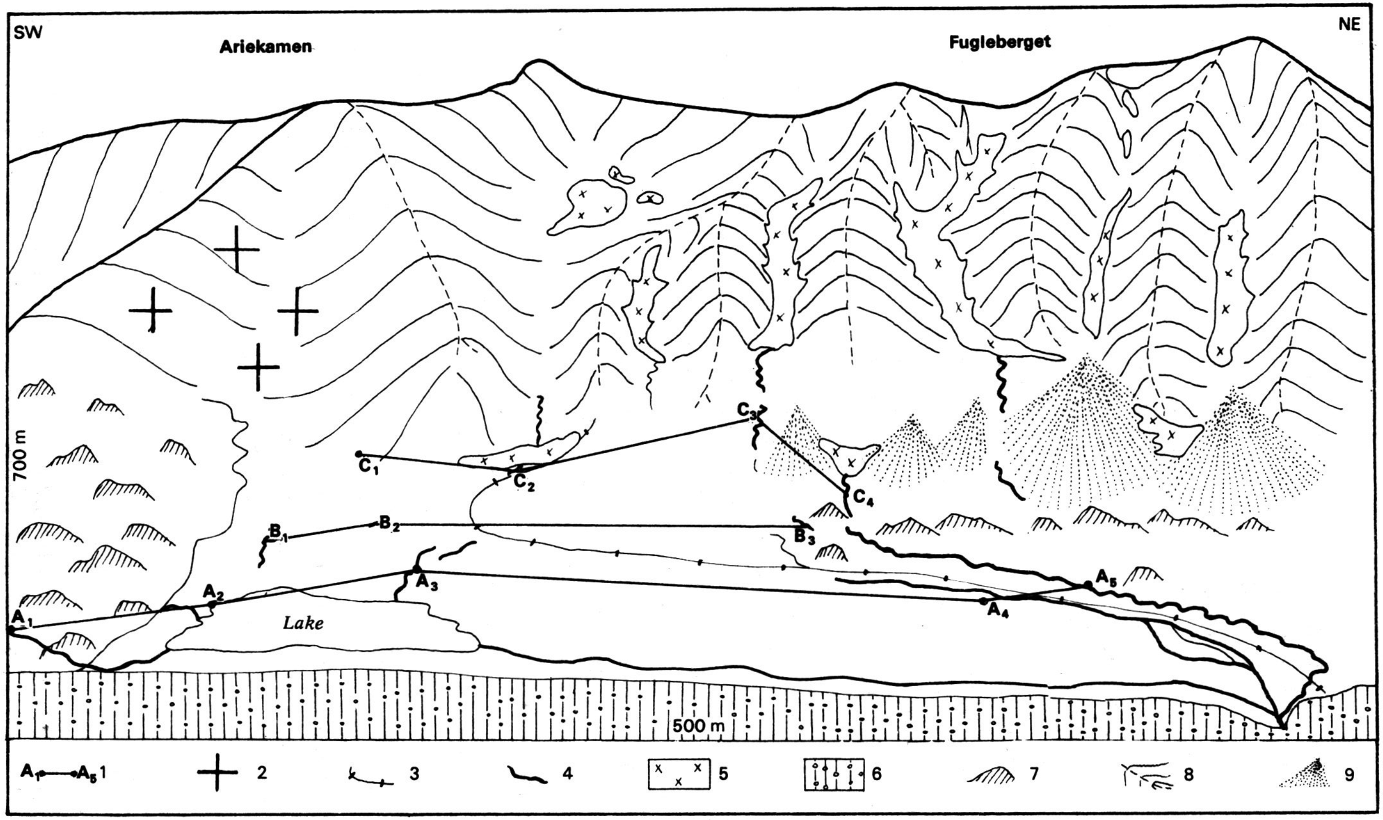

Fig. 1 Fugleberget drainage basin.
1. cross-sektions 2. colonies of birds 3. boundary between the part of "rocky" and the part of "fortile" 4. streams 5. iceand snow 6. watersity ridge 7. rocky 8. ridge of the mountain 9. screes

3. Results

The results of analyses are presented in Table I. The flow of streams was low and varied from 0.05 to $5 l s^{-1}$ (the Fuglebekken river). The small lake near the coastal embankment has a permanent outflow and its water level does not change much, with the exception of the initial period of snow thawing. The water temperature varied on the day of sampling from 4.0 to 5°C in July, 2.0—8,2°C in August and 0.8—3,7°C in September. The highest temperature of 11.5°C was recorded in the small lake waters on 25 July, 1979, while water occuring among the mosses had 5.5°C. The waters studied can be characterised on the basis of the results obtained as neutral, with pH of 6.6—8.0, soft and very soft -0.50 — $1.75 \text{ mval} \cdot l^{-1}$, with low chloride content -0.57 $-5.25 \text{ mg} \cdot l^{-1}$ (Table 1). Nitrate nitrogen varied from O to $6.8 \text{ mg} \cdot l^{-1}$. The maximum phosphate content was **0.31 mg·l^{-1}**. Larger concentrations of nitrate nitrogen and of phosphates occured in the western rather than in the eastern part of the area studied (compare A_1, A_2, A_3, A_4 from the west part with A_5 from the east part, and B_1, B_2 from the west part with B_3 from the east part, and C_1, C_2 from the west part with C_3, C_4 from the east part). The only exception is a higher content of nitrate nitrogen at station C_4, which suggests a local bird influence also in the east part.

There is also a visible difference of concentration of dissolving ions (mineralization) for sampling stations in the west and east parts. It is distinct for profile B_1—B_3, i.e. $88.56 \text{ mg} \cdot l^{-1}$ for station B_1, $74.45 \text{ mg} \cdot l^{-1}$ for B_2 (the west part), while for B_3 (the east part) it is $65.66 \text{ mg} \cdot l^{-1}$. For comparison, waters near Guliksen inhabited by colonies of little auk, some 30 km west of Ariekammen, were studied, where the phosphate concentrations were up to $13 \text{ mg} \cdot l^{-1}$, of nitrate nitrogen — up to $7.2 \text{ mg} \cdot l^{-1}$, and mineralization — up to $130.23 \text{ mg} \cdot l^{-1}$. An increase in the concentrations of the parameters determined was observed with time at some sampling stations (Table I), e.g. for A_1, A_3, A_4 and A_5. An increase in the nitrate nitrogen concentration with time is not so clear as that in mineralization. Thus, mineralization is a better parameter than nitrate anitrogen concentration for the description of the phenomenon, as it depends more on time and varies less.

4. Discussion

The results of analyses obtained confirm assigning the waters studied to the HCO_3^- class, Ca^{+2} and group type III according to the Alekin's classification (Rakusa-Suszczewski 1963), or to waters of the HCO_3 — Ca^{+2} — Cl^- type, according to the classification of Ščukariev-Priklonski

Table I

Results of chemical water analyses of profiles A_1 — A_5, B_1 — B_3, C_1 — C_4

Profile	Points	Date	Temp. °C	pH	Mineraliza-tion	PO_4 mg.l^{-1}	N_{NO_3} mg.l^{-1}	Cl^- mg.l^{-1}	Alkali-nity mg.l^{-1}	Hard-ness mval l^{-1}	Ca^{+2} mg.l
A_1 — A_5	A_1	25.07	4	6.8	57.07	n.d	1.35	1.70	0.50	0.88	16.03
		8.08	3.4	7.2	78.09	n.d	1.56	3.55	1.00	1.50	23.65
		3.09	0.8	7.6	94.26	0.09	2.50	3.55	1.20	1.98	28.06
	A_2	25.07	11.5	8.0	71.30	n.d	1.40	3.84	1.15	1.00	16.03
		8.08	8.2	8.0	79.00	n.d	1.88	5.25	1.35	1.86	23.25
		3.09	3.7	8.0	93.02	n.d	1.88	5.25	1.35	1.86	32.06
	A_3	25.07	2.5	7.0	68.91	n.d	0.01	1.56	1.30	1.20	22.04
		8.08	8.0	7.6	73.75	n.d	0.52	3.55	1.75	1.52	24.85
		3.09	2.2	7.0	79.38	n.d	0.36	3.55	1.20	1.82	24.85
	A_4	25.07	9.2	7.0	56.28	n.d	0.10	2.48	1.18	1.30	22.44
		8.08	7.6	7.4	71.19	n.d	0.20	3.55	1.20	1.40	22.04
	A_5	25.07	7.4	7.4	67.22	n.d	n.d	2.30	1.30	1.22	22.04
		8.08	6.8	7.6	73.00	n.d	n.d	3.55	1.40	1.58	30.86
B_1 — B_3	B_1	25.07	3.0	6.8	88.56	0.10	4.80	4.80	1.15	1.26	22.44
	B_2	25.07	2.5	7.0	74.45	0.31	2.60	1.92	1.32	0.80	14.03
	B_3	25.07	5.5	7.0	65.66	n.d	0.13	0.57	1.25	1.14	21.24
C_1 — C_4	C_1	25.07	4.0	6.6	103.18	0.10	6.80	3.55	1.05	1.94	25.25
		8.08	2.0	6.8	98.94	0.10	4.80	4.90	0.90	1.78	26.85
	C_2	25.07	0.0	6.6	22.79	n.d	n.d	1.20	0.35	0.50	8.81
		8.08	0.0	6.6	24.18	n.d	n.d	1.30	0.37	0.53	9.62
	C_3	25.07	7.2	7.2	47.33	n.d	0.08	1.42	0.52	0.80	15.63
	C_4	25.07	5.5	6.6	27.17	n.d	0.25	0.92	0.30	0.52	4.41

n.d — not dedected

(Bieroński 1975). The results of analyses showed that the main factor influencing the differentiation of the nutrient concentrations is the presence of bird colonies. The bird faeces are the main source of nitrate nitrogen and of phosphates in the surface waters, and this is confirmed by analyses of water from other places of the Arctic zone close to the bird colonies (Table II). An increase in the nutrient concentrations in waters and in soils, causing the development of tundra, results from the life activities of birds (Grobbelaar 1975, 1978, Smith 1977, 1978). There are higher concentrations of nutrients in the west part of the drainage basin with a richer tundra cover below the slopes with a bird colony than in the eastern part of the drainage basin. Waters in the direct neighbourhood of this colony have higher concentrations of nutrients. However, in some cases the nutrient concentration in waters by the colony can be lower, which results, e.g., from the shorter time of leaching and decomposition of bird faeces, as confirmed by the studies of Golovkin and Pozbniakova (1965).

Table II

Nutrients in surface waters near birds' colonies (polar zone)

Localities	Nitrients		Approximate number of birds	Authors
	Nitrogen mg.l^{-1}	Phosphorus mg.l^{-1}		
Murman Sea — Dvorova Bay	17—45 N_{NO_3}	14—78 PO_4	tens of thousands of gulls and other sea birds	Golovkin, Pozbniakova 1965
Marion Island lakes (sub-antarctic zone)	14—21 N_{NO_3}	2—4 P_{total}	tens of thousands penguins, albatrosses, petrels, gulls	Grobbelaar 1975
Signy Island lakes (South Orkney)	0.01 N_{NO_3}	0.072 PO_4	a few thousand sea birds	Heywood 1967
Ariekammen-Fugleberget drainage basin (SW Spitsbergen)	1.26—6.80 N_{NO_3}	0.31 PO_4	about one houndred thousand little auk	

The differentiation of the nutrient content in the waters studied depends on numerous factors, such as e.g. the distance from the bird colony, the quantity and dynamics of water causing the leaching of faeces, on the plant cover, on the soil dynamics, on the depth at which permafrost occurs. The differentiation of the nutrient concentrations also results from, among other things, changing activity of birds (e.g. in the period of hatching of the young, during the birds' migrations). Golovkin and Pozbniakova (1965) found that the nutrient content increases 4 to 111 times after young birds leave their nests. Apart from that, values of the parameters determined show an increasing tendency with drying out of water bodies and decreasing temperature. This is related to a larger concentration of nutrients and to smaller nutrient uptake by plants. In the case of Fugleberget drainage basin the differentiation of the chemical composition of water related to the distance from the sea is not so distinct as in the case of e.g. Marion Island (Grobbelaar 1978). The Ariekammen-Fugleberget catchment area is an example of a cumulation of material supplied by birds, which causes richer vegetation in the direct neighbourhood of the the bird colony than in the case of cliff colonies, where nutrients flow down to the sea (Nordehaug 1970). The influence of birds (little auk) is the main factor differentiating the chemical properties of surface waters within the drainage basin.

5. Резюме

В течение летнего сезона 1979 проводились исследования химизма поверхностных вод водосборного бассейна Ариекаммен-Фуглебергет на Шпицбергене. На основании результатов анализов было установлено, что исследуемые воды нейтральны, слабо минерализированы, мягки и очень мягки, с лишь небольшим содержанием хлористых анионов, с концентрацией фосфатов от 0 до 0.31 мг/л и нитратного азота от 0 до 6.8 мг/л (таблица I). Жизненная деятельность птиц, обитающих склон Ариекаммен, является главным фактором, дифференцирующим химические свойства поверхностных вод в пределах водосборного бассейна, поскольку гуано — это источник нитратного азота и фосфатов в водах изучаемого бассейна. Это подтверждают также результаты анализов из некоторых мест полярной зоны вблизи птичьих колоний (таблица II). В западной части бассейна, которая находится внизу на склоне с птичьими колониями, где растительный покров богаче, концентрации биогенов в воде выше чем в восточной части.

6. Streszczenie

Badania nad chemizmem wód powierzchniowych przeprowadzono w zlewni Ariekammen--Fugleberget, na Spitsbergenie w okresie lata 1979 r. Na podstawie wyników analiz stwierdzono, że badane wody są obojętne, słabo zmineralizowane, miękkie, i bardzo miękkie, o niewielkiej zawartości jonu chlorkowego, stężeniu fosforanów od 0 do 0.31 mg/l i azotu azotanowego od 0 do 6.8 mg/l^{-1} (tabela I). Działalność życiowa ptaków (traczyk lodowy) zasiedlających zbocze Ariekamen jest głównym czynnikiem różnicującym własności chemiczne wód powierzchniowych w obrębie zlewni. Odchody ptasie są źródłem azotu azotanowego i fosforanów w wodach zlewni Ariekammen-Fugleberget co potwierdzają również wyniki analiz wód z niektórych miejsc strefy polarnej w pobliżu kolonii ptasich (tabela II). W części zachodniej zlewni znajdującej się pod zboczem z kolonią ptasią i z bogatszą pokrywą roślinną, stężenia biogenów w wodzie są większe niż w części wschodniej.