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CHEMICAL PROPERTIES OF FRESHWATER ENVIRONMENTS AT THE ADMIRALTY BAY REGION (WEST ANTARCTICA)

WARUNKI CHEMICZNE LĄDOWYCH SIEDLISK WODNYCH W REJONIE ZATOKI ADMIRALICJI (ZACHODNIA ANTARKTYKA)

INTRODUCTION

On the western shore of Admiralty Bay freshwater environments are infrequent and mostly small. The surface waters there are only found in the streams, small ponds and mires. Biological properties, especially animal diversity, chemical and physical features of these environments vary locally from site to site (Janiec 1992). A great year round variation of nutrient concentration was also observed (Juchnowicz-Bierbasz 1999).

A study was undertaken to characterize chemical properties of aquatic environments of the coastal ecosystems at the Admiralty Bay area.

STUDY SITES, MATERIAL AND METHODS

Investigations were performed at the western shore of Admiralty Bay (King George Island), including an area stretching from Italian Valley through Pt. Thomas to Demay Pt. (Fig. 1) during austral summer 1987/ 1988. In order to evaluate the total variation in the chemistry of freshwater environments, various types of surface water were sampled, i.e. from moraine ponds and near-shore ponds, seasonal streams and permanent streams, flood waters and mires (moss tundra). The field study was carried out in January 1988. For details of analytical methods see Kawecka *et al.* (1998).

Water stands and their chemical parameters were ordinated using Principal Components Analysis (PCA). The data were ln-transformed before analysis. All statistical calculations were performed using the package Statistica v. 5.0.

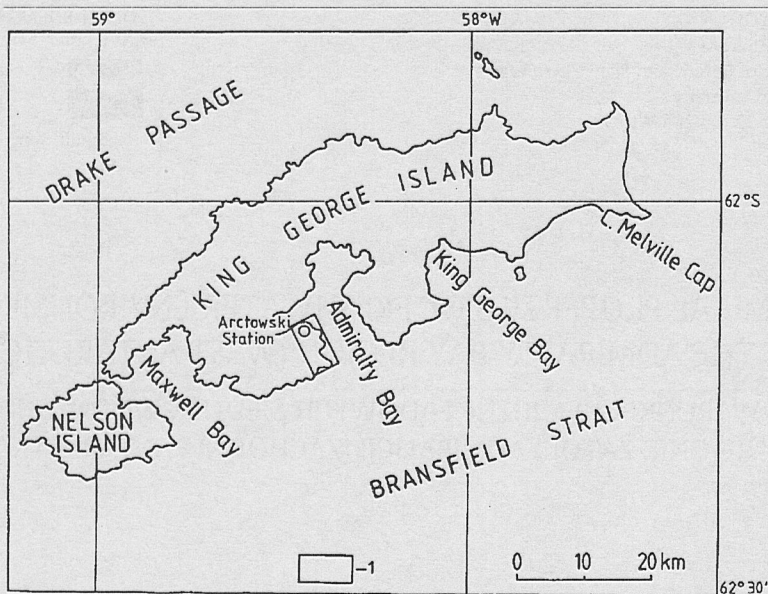


Fig. 1. Map of the King George Island showing study area - 1

RESULTS

Analysis of overall trends in water chemistry

Two groups of chemical parameters which together account for almost 80 % of the total variance observed in water were identified by principal component analysis (Table 1, Fig. 2). The first group consists of conductivity (Con) and cations significantly correlated ($p < 0.05$) with it: Na ($r = 0.97$), Mg ($r = 0.96$), K ($r = 0.95$) and Ca ($r = 0.73$). These parameters have high positive loadings with the first principal component (PC1). The second group includes ammonium, nitrate+nitrite, phosphate and pH. However anions of N and P have high positive loadings, whereas pH has a negative loading and its value is lower than that of the remaining ones.

Ecological interpretation of the two principal components is as follows. The first component is in effect a measure of total metallic cations content, which is represented by conductivity, having the highest loading on this component (Table 1). In addition, PC1 reflects those elements that are likely to be derived mainly from sea spray, i.e. Na and Mg. Both cations have loadings on the first component of the same order as this of conductivity. The second component is overall a measure of N and P content, these elements which are likely to be of mainly terrestrial origin.

Table 1. Principal component analysis of chemical parameters of terrestrial water sites at the Admiralty Bay region (ln-transformed data)

Variable	PC1	PC2
ln pH	0.049	-0.726
ln Conductivity	0.974	0.078
ln Na	0.962	-0.145
ln Mg	0.928	0.231
ln Ca	0.884	0.217
ln K	0.835	0.319
ln NH ₄	0.084	0.818
ln NO ₃ + NO ₂	0.182	0.863
ln PO ₄	0.241	0.804
Eigen value	4.809	2.234
Percent of the total variance	53.42	25.82
Cumulative percent of the total variance	53.42	79.25

SPATIAL VARIATION IN WATER CHEMISTRY

The PCA ordination of terrestrial water stands shows a clear spatial pattern (Fig. 3). Stands with lowest conductivity, Na, Mg, Ca and K values are grouped on the left end of the first axis; at the right end are stands that have the highest values of these parameters. Stands on the negative side of the second axis have low NO₃ + NO₂, NH₄ and PO₄ concentrations, while on the positive side, there are stands with high content of these nutrients. The stands can be grouped into five

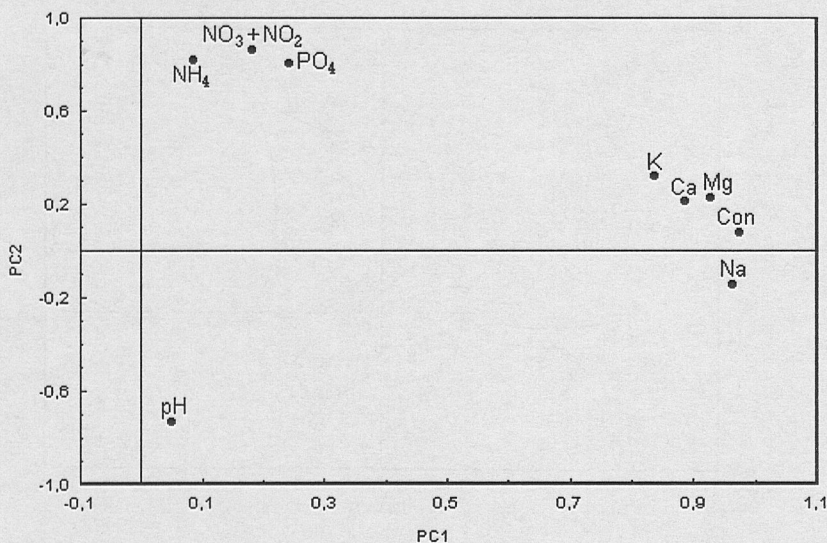


Fig. 2. Ordination diagram of chemical parameters in terrestrial water sites at the Admiralty Bay area, in relation to the first (PC1) and second (PC2) principal component

types (PC types A–E on Fig. 3) which form fairly well distinct clusters on the ordination diagram. Terrestrial water sites and their distribution in each of the PC types are presented in Table 2. These types differ clearly in water chemistry (Table 3).

Table 2. Terrestrial water sites and their distribution in each of the PC types

Terrestrial water sites	Number of water stands in PC type				
	PC type A	PC type B	PC type C	PC type D	PC type E
Peaty moss carpet					8
Initial moss carpet		9	4		1
Streams		9			5
Runnels	3	8	2		
Glacier streams	1				
Moraine ponds		4			
Near-shore ponds			5		1
Brackish ponds				2	

Waters of PC type A have the lowest conductivity values, as well as cation and anion concentrations of all stands, and their pH is near neutral. They are mainly the melting waters collected from glacier and snow banks. The second group, PC type B, consists of stands mostly situated in an inland area further from the shore and animal colonies. Their waters have a slightly basic pH, and values for conductivity, anions and cations higher than type A. Water stands in PC type C have both conductivity values and metallic cation concentrations nearly twice those of type B and a mean pH of about 8.40. They are situated along lowland coastal areas close to Arctowski Station. PC type D consists of a small group of two water stands of

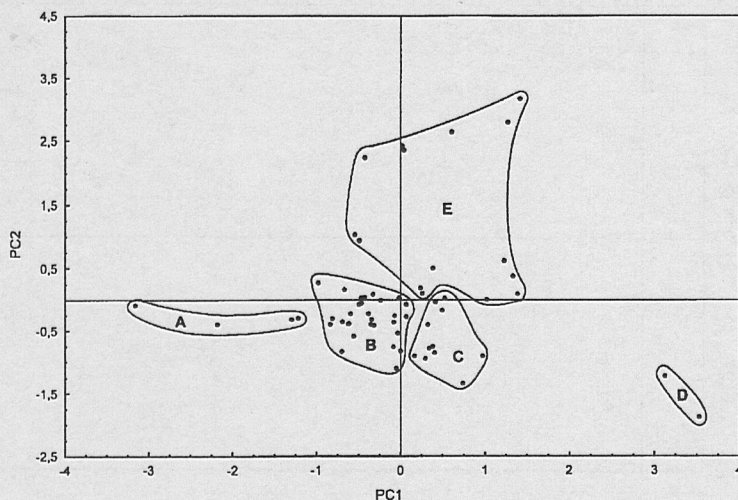


Fig. 3. Ordination diagram of 62 terrestrial water stands at the Admiralty Bay area, in relation to the first (PC1) and second (PC2) principal component. Solid lines delimit water types (A–E)

brackish ponds. These waters have the highest pH, conductivity, sodium, magnesium, calcium and potassium values. The last group, PC type E is characterised by the highest nutrient (nitrates+nitrites, ammonium and phosphates) values and the lowest pH. Waters of this group occur in situations subject to direct or indirect influence by sea-depending birds and mammals.

Table 3. Mean values (\pm SD) of chemical parameters for terrestrial waters at the Admiralty Bay region arranged in five types as delimited by principal component analysis

	PC type A		PC type B		PC type C		PC type D		PC type E	
n	4		30		11		2		15	
pH	7.10	(0.23)	7.34	(0.39)	8.39	(0.99)	8.65	(0.07)	6.44	(1.24)
Conductivity ($\mu\text{S cm}^{-1}$)	34	(19)	99	(31)	214	(75)	2700	(141)	314	(193)
Na (mg l^{-1})	4.9	(3.0)	13.9	(3.7)	29.4	(10.8)	352.8	(101.8)	25.2	(14.0)
Mg (mg l^{-1})	0.21	(0.17)	1.29	(0.58)	2.26	(0.92)	47.99	(15.39)	5.62	(5.62)
K (mg l^{-1})	0.24	(0.07)	0.42	(0.13)	1.03	(0.88)	23.46	(6.64)	3.74	(3.38)
Ca (mg l^{-1})	0.51	(0.48)	2.68	(1.11)	5.80	(2.72)	25.39	(8.51)	9.62	(9.03)
NH ₄ (mg l^{-1})	0.000	(0.000)	0.002	(0.005)	0.014	(0.016)	0.000	(0.000)	2.410	(6.275)
NO ₃ + NO ₂ (mg l^{-1})	0.055	(0.067)	0.613	(0.587)	0.575	(0.831)	0.009	(0.000)	40.92	(70.14)
PO ₄ (mg l^{-1})	0.052	(0.034)	0.113	(0.146)	0.267	(0.350)	0.217	(0.279)	2.516	(3.907)

DISCUSSION AND CONCLUSIONS

The results presented here demonstrate a great spatial variability of aquatic environments in the coastal ecosystems at the Admiralty Bay area. The chemical composition of surface waters in this region depends mainly on the proximity to the sea and the activity of animals. The substantially higher content of nutrients found in the waters from type E, in comparison to the other types, indicates that the most important N and P sources for the Admiralty Bay freshwater ecosystems are seabird and seal colonies. This mainly refers to ammonium ions, which are almost absent in water environments situated further from the animal colonies, i.e. water types A–D. The higher concentrations of nitrates and phosphates, as compared with ammonium, found in waters of recently referred types, suggest other sources for these anions. Nitrate-N and phosphate-P may enter surface waters from atmospheric deposition (sea spray and precipitation) and from weathering of volcanic rocks (phosphates). However, as compared to the main source of biogens supplied by animals, this form of N and P input is negligible. Interesting results emerge from comparison of Ca, Mg and K concentrations in two water types, i.e. E and C, which are located in the same proximity to the sea. The higher concentrations of calcium, magnesium and potassium (but not of sodium) found in water type E suggest that the presence of animals can affect not only the level of N and P (Myrcha, Pietr, Tatur 1985), but also other elements in water, as described in Tatur and Myrcha (1983).

Terrestrial waters are originally neutral or slightly basic (A and B types). Along the lowland nearshore zone these waters are strongly influenced by the sea. This effect is indicated by the higher reaction of water in types C and D, since the pH of sea water in this region has a basic reaction (pH = 8.4) (Rakusa-Suszczewski 1993). This increase in pH is paralleled by an increase in content of metallic cations, mainly Na and Mg, and to a lesser extent Ca and K. The maritime origin of sodium and magnesium is indicated by ionic dominance, i.e. Na > Mg > Ca > K, which is similar to that found for sea water (Smith 1985). Thus, the marine environment of Admiralty Bay is an important source of metallic cations for coastal freshwater sites. These ions are deposited on land mostly by sea spray (Heywood et al. 1980). Another sources of elements for the Antarctic freshwater environments are geochemical processes such as rock weathering. When waters are influenced mainly by such processes, the order of Mg and Ca is reversed and ionic dominance is following Na > Ca > Mg > K (Smith 1985). In the present study, the fairly similar ranking of these ions was found in waters of type B. It seems that in freshwater habitats placed on higher terraces and relatively far from the sea and animal colonies, the main sources of cations are local edaphic processes.

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STRESZCZENIE

Praca przedstawia zróżnicowanie właściwości chemicznych wód powierzchniowych na obszarze przybrzeżnej tundry zachodniego brzegu Zatoki Admiralicji (King George Island), na obszarze od Włoskiej Doliny poprzez Point Thomas do Demay Point.

Badania prowadzono w styczniu 1988. Pobierano próbki wody z różnych siedlisk lądowych: nadbrzeżnych i słonawych zbiorników morenowych, cieków lądowych i na lodowcach, strumieni oraz mszarników. Wyniki analiz chemicznych oraz stanowiska wód opracowano metodą analizy głównych składowych (PCA).

Wyróżniono dwie grupy zmiennych chemicznych, pochodzących z odmiennych źródeł, które związane są z przestrzennym zróżnicowaniem siedlisk lądowych. Do jednej należy przewodnictwo właściwe K, Ca, Na i Mg, dwa ostatnie kationy mogą być głównie morskiego pochodzenia. Do drugiej grupy należą pH oraz biogeny ($\text{NO}_3 + \text{NO}_2$, NH_4 i PO_4), których główne źródło znajduje się na lądzie.

W wyniku porządkowania stanowisk wyróżniono 5 typów wód powierzchniowych, o różnym składzie chemicznym (tab. 3), zależnym od odległości do morza oraz do miejsc skupień zwierząt lądowych. Te ostatnie są praktycznie jedynym źródłem biogenów N i P dla siedlisk słodkowodnych. Dotyczy to zwłaszcza kationów NH_4 . Aniony NO_3 i PO_4 mogą dodatkowo dopływać z atmosfery lub z wietrzenia podłoża skalnego. Są to jednak ilości znacznie mniejsze w porównaniu do głównego, zwierzęcego źródła biogenów. Obecność zwierząt wpływa nie tylko na poziom w wodzie N i P, lecz również innych makroelementów. Wody siedlisk lądowych mają pierwotnie odczyn obojętny lub lekko zasadowy. W strefie brzegowej zaznacza się wyraźny wpływ morza, co jest widoczne we wzroście pH i zawartości kationów metalicznych, zwłaszcza Na i Mg. Lądowe procesy edaficzne mogą być innym ważnym źródłem kationów zasadowych dla siedlisk słodkowodnych, zwłaszcza położonych na wyższych terasach dalej od morza oraz z dala od miejsc bytowania zwierząt.