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Polychlorinated biphenyls in the tissues of Antarctic marine migratory birds and penguins from the breeding colony on King George Island (South Shetland Islands)

ABSTRACT: Contents of PCBs was investigated using the gas chromatography method in the tissue of four Antarctic migratory birds: *Oceanites oceanicus, Larus dominicanus, Catharacta skua* and *Sterna vittata*, and the three penguin species: *Pygoscelis adeliae, P. papua* and *P. antarctica*. Samples were collected at King George Island in February 1978 and, for comparison, in March 1983. The highest PCBs content was recorded in the adipose tissue of *O. oceanicus* and *C. skua* (15.7 and 1.2 ppm). Differences in the content of these compounds in the tissue of various penguin species in 1978 was observed. The mean cumulation level of PCBs in the adipose tissue of penguins was higher in 1983 than in 1978. Differences in the level of PCBs contents in the tissue of migratory birds were related to their winter migrations to areas polluted to various degress with PCBs remains. A tendency to the increase of the contamination of penguin tissues with PCBs was observed. This tendency was related to the increase of vhe pollution of the Antarctic environment with these compounds.

Key words: Antarctica, South Shetland Islands, PCBs contents, penguins, migratory birds.

1. Introduction

Polychlorinated biphenyls (PCBs) in samples of biological material were first isolated and identified in late sixties (Jensen 1966). Their occurrence in Antarctic ecosystem was recorded for the first time in the seventies. They were discovered in Antarctic snow and glaciers (Peel 1975, Riesebrough et al. 1976). At present, they are common in the atmosphere and hydrosphere of Antarctica (Tanabe, Hidaka and Tatsukawa 1983).

There is scarce literature on the cumulation of PCBs in Antarctic seabirds, but among the investigated bird species the highest contents of these compounds were always recorded in the migratory species (Riesebrough and Carmignani 1972, Norheim, Sømme and Holt 1982, Schneider, Steinhagen-Schneider and Drescher 1985). Penguins were studied sporadically. Publications informing about PCBs contents in the penguin tissues are based on low numbers of samples and are usually preliminary ones (Norheim, Sømme and Holt 1982, Schneider, Steinhagen--Schneider and Drescher 1985). The study by Riesebrough et al. (1976) is a more comprehensive one, dealing with eggs of three pygoscelid species from the breeding colony on the Antarctic Peninsula.

Materials for the present paper were collected during the IInd and VIIth Polish Antarctic Expedition to the H. Arctowski Station (King George Island) in 1978 and 1983. The aim of the present work was to collect data which would allow to determine the influence of winter dispersion of the investigated species to the areas of potentially different degree of PCBs pollution upon the cumulation of these compounds in their tissues. Moreover we aimed at the determination of changes in the contamination of bird tissues by PCBs in the same breeding colonies caused by the continuous atmospheric transport of chloroorganic pollutants in the Antarctic region.

2. Material and methods

Investigated birds inhabited the neighbourhood of the Polish Antarctic Station at King George Island (62°09′45″S, 58°27′45″W). Materials for this work were collected in two periods: at the end of February 1978 and at the beginning of March 1983 (penguins only). In both cases the penguins studied belonged to the same breeding colonies. Tissues of *Pygoscelis antarctica* (Forster), *P. papua* (Forster), *P. adeliae* (Hombron et Jacquinot), *Sterna vittata* Gmelin, *Larus dominicanus* Lichtenstein, *Catharacta skua* Brum and *Oceanites oceanicus* (Kuhl) were studied. In each case only mature birds were considered. Whole livers and hypodermic adipose tissue samples of about 1 g each in the case of *O. oceanicus* and about 10 g each in the case of the other birds were collected for analysis. The samples were wrapped in aluminium foil washed in redistilled acetone and frozen at −20°C. Then, they were put into glass vessels washed in acetone and kept at the same temperature. The Holden and Marsden (1969) method was used for preparing the samples for

Table 1

PCBs content (ppm — wet weight) in Antarctic migratory birds and penguins of the breeding colonies on the King George Island in 1978. Mean values, standard deviation and variability range (in brackets) are given

Species	Number of samples	Tissue		Range of winter dispersion
		subcutaneous fat	liver	
Pygoscelis adeliae	10	0,72 ± 0,27 (0,23 – 2,10)	0,29 ± 0,06 (0,03 – 1,60)	Remaining within the Antarctic Convergence
Pygoscelis papua	10	0,15 ± 0,08 (0,04 – 0,23)	0,07 ± 0,02 (0,01 – 0,13)	Remaining within the Antarctic Convergence
Pygoscelis antarctica	10	0,16 ± 0,14 (0,02 – 0,39)	0,06 ± 0,03[*] (0,00 – 0,28)	Remaining within the Antarctic Convergence
Larus dominicanus	10	0,53 ± 0,18 (0,16 – 1,40)	0,11 ± 0,12 (0,07 – 0,25)	Remaining in the Southern Hemisphere
Sterna vittata	10	0,48 ± 0,19 (0,14 – 1,60)	0,21 ± 0,24 (0,05 – 1,30)	Remaining in the Southern Hemisphere
Catharacta skua	8	1,20 ± 0,16 (0,63 – 3,90)	0,42 ± 0,14 (0,08 – 0,68)	Reaching the tropical regions of the Northern Hemisphere
Oceanites oceanicus	10	15,70 ± 2,20 (8,40 – 23,10)	1,80 ± 0,16 (0,96 – 2,50)	Reaching the tropical and temperate regions of the Northern Hemisphere

[*] PCBs recorded in 6 specimens only

determination of PCBs using gas chromatography. The chromatographic analysis was carried out at the Department of Toxicology of the Institute of Hygiene in Warsaw. The PYE Unicam 104 chromatograph with the ECD Ni-63 detector was used. Glass columns (4 mm in diameter, 5 feet long) filled with 1.5% OV 17+1.95% OV 210 on the 80/100 mesh WHP chromosorb were used. The ECD temperature was 280 C. Argon was the carrier gas, its flow was 60 $ml \cdot min^{-1}$.

The PCBs contents were determined by comparing the chromatograms from samples with standard PCBs chromatograms: Clophen A30, Clophen A50 and Clophen A60.

3. Results

The PCBs contents in samples from tissues of birds collected in 1978 and the approximate range of their winter migrations are presented in tab. 1. The highest PCBs content in the liver and subcutaneous adipose tissue was recorded in *O. oceanicus*. Differences (by an order of magnitude) between the mean contents of these compounds in the tissues of this and other investigated species were statistically significant at $p = 0.001$ (t-test). A higher level of PCBs contents was recorded also in the tissues of C. skua in comparison with other five bird species.

The mean level of PCBs contents in the tissues of the remaining species was of the same order. Nevertheless the differences between the mean PCBs contents in the tissues of *P. papua* and *P. antarctica* (the lowest content level) and of *P. adeliae, L. dominicanus* and *S. vittata* were statistically significant ($p = 0.001$).

In contrast to the material from 1978 in the adipose tissue of penguins studied in 1983 the mean PCBs contents in the investigated

Table 2

Comparison of PCBs contents (ppm — wet weight) in the penguin adipose tissue of the nesting colonies of the King George Island in 1978 and 1983. Mean values, standard deviations and variability ranges (in brackets) are given

Species	Number of samples	1978	Number of samples	1983
Pygoscelis adeliae	10	0.72 ± 0.27 (0.23 – 2.10)	15	0.36 ± 0.16 (0.12 – 0.80)
Pygoscelis antarctica	10	0.16 ± 0.14 (0.02 – 0.39)	15	0.42 ± 0.04 (0.38 – 0.48)
Pygoscelis papua	10	0.15 ± 0.08 (0.04 – 0.23)	15	0.48 ± 0.10 (0.28 – 0.74)

pygoscelid species were very similar, and differences between species in this respect were statistically insignificant. A comparison of PCBs contents in the tissue of the same species in 1978 and 1983 showed a much lower level of these compounds in the latter year in *P. adeliae* and a threefold increase in the level of these compounds in other species in 1983 comparing with 1978 (Tab. 2). These differences were statistically significant at $p = 0.001$.

4. Discussion

A comparison of the present results with literature data can be sometimes imperfect due to the differences in methodology. Reisebrough and Carmignani (1972) have determined the level of PCBs in lipids extracted from the whole body of *O. oceanicus*. This is a method rarely used in bird studies and thus the data obtained this way may be only roughly compared with those concerning the adipose tissue alone. Values for the adipose tissue of birds from King George Island were close only to those obtained by the above authors for birds from Cape Halet (11.0 ppm). In contrast the data obtained by Riesebrough and Carmignani (1972) for birds from Ansvers Island (185.3 ppm) were many times higher than those reported in the present paper.

Comparable methods were used by Norheim, Sømme and Holt (1982). These authors gave results of the determination of PCBs levels in the adipose tissue of two subspecies of *C. skua* which were collected in 1977 and 1979 in the neighbourhood of Norwegian Antarctic Station. The level of PCBs in the adipose tissue of *C. skua macckormicki* (4.1 ppm) was higher than that obtained for *C. skua* from King George Island. On the other hand, PCBs contents in the liver of this subspecies and of *C. skua lonnbergi* (0.35 and 0.48 pp., respectively) were similar to those reported in the present paper. The level of PCBs in the adipose tissue in *P. antarctica* recorded by Norheim, Sømme and Holt (1982) was of the same order of magnitude as that obtained for this species on King George Island in 1978. In the livers of *P. antarctica* these authors did not record any PCBs. It seems however that this was a result of the assumed method sensivity (the level of PCBs detection at 0.1 ppm) and not a result of the complete absence of these compounds in the tissue.

Schneider, Steinhagen-Schneider and Drescher (1985) investigated the region of the Weddell Sea and found in the adipose tissue of *C. skua* and *P. adeliae* PCBs contents amounting to 3.648 and 0.776 ppm (wet weight), respectively. In the case of *C. skua* these were values three times higher than those obtained for this species on King George Island.

In *P. adeliae* the results were almost identical with the analogous material from King George Island in 1978.

Data for single bird specimens of various species are given by Figge, Hoerschelmann and Polzhofer (1976). For *C. skua* and *P. papua* of the Falklands region they obtained PCBs values 3.0 ppm and 0.7 ppm (adipose tissue) and 3.0 ppm and 0.2 ppm (livers), respectively, whereas in the liver of *L. dominicanus* the amount of PCBs was 0.1 ppm. Except for *L. dominicanus* these values are higher than those recorded for two other species from King George Island.

Differences in the levels of PCBs contents obtained for birds from King George Island are related to the ranges of their winter migrations and, probably, their different diets. It was recorded that the areas in which they spend winter, i.e. food types obtained there, determine to a large extent the contents of chlorinated hydrocarbons in their bodies (Riesebrough and Carmignani 1972, Conroy and French 1974, Łukowski 1983). As it was stated by Dorst (1967), Ashmole (1971) and Watson (1975) only *O. oceanicus* and *C. skua* leave the Southern Hemisphere for winter. *O. oceanicus* was observed during Antarctic winter at the coasts of North America, Western Europe, Africa and Japan, while *C. skua* in the tropical zone (California, India, Japan). The migrations of *L. dominicanus* and *S. vittata* are less distant and they remain at the southern coasts of South America and Australia. In contrast, penguins usually stay for winter at the edge of Antarctic ice cover and the distance to which they penetrate the Antarctic area varies. As it was stated by Simpson (1976) *P. antarctica* and *P. papua* are less vagile species than *P. adeliae*, for which South Shetlands are the northern limit of its occurrence.

The present data indicated that birds migrating into the areas of Northern Hemisphere (*O. oceanicus* and *C. skua*), into regions commonly considered as highly polluted with PCBs, displayed the highest level of the cumulation of these compounds in the tissues. The other species wintering in the Southern Hemisphere displayed, irrespectively of differences in their diets, clearly lower PCBs cumulation levels. These levels were variable, but all of them were of the same order. Such results indicate a much lower level of pollution with these compounds in the Southern Hemisphere than in the Northern one and generally lower pollution of the Antarctic environment with the PCBs. This is supported also by the studies carried out in the vicinity of the Japanese Syowa Station by Tanabe, Hidaka and Tatsukawa (1983) and by Hidaka et al. (1984).

A different food chain, particularly in *L. dominicanus*, which mostly fed on garbage from the Arctowski Station, would explain why this species should cumulate more residues of chlorinated hydrocarbons in their body than penguins — according to the biomagnification principle. The present results supported this statement but only in case of two penguin species, i.e. *P. papua* and *P. antarctica*. In 1978 *P. adeliae* had, particularly in their adipose tissue, a clearly highest level of PCBs contents among all tested birds wintering in the Southern Hemisphere. This level was nearly five times higher than those in other penguin species. The period of the stay in the breeding areas and food consumed there probably should not cause differences of PCBs contents in the tissue of various penguin species. It seems however that these differences appeared in the course of winter dispersion of penguins although the lack of precise data on their winter migrations does not allow this problem to be more extensively discussed in this respect. May be, the clearly higher level of PCBs cumulation in the tissues of *P. adeliae* in 1978 is related to their possible long lasting winter feeding on a krill population of a relatively high level of chlorinated hydrocarbons contents. The phenomenon of a considerable variability in the level of these compounds in krill from various regions of the South Atlantic was observed by Łukowski (1978).

Undoubtedly, the northern limit of the winter penguin migrations is restricted to the ice field occurrence, which, in turn, depends upon various climatic conditions in a given year. Consequently, it may vary from year to year and the content of chlorinated hydrocarbons may accordingly vary from year to year, because the farther to the north the penguins advance, the closer they are to the areas more strongly polluted with these compounds. A lower variability in results of PCBs values in the adipose tissue of pygoscelid penguins investigated in 1983 would indicate that the food of all three species in the course of the recent period (including winter) was polluted to a similar degree with these compounds.

Note that the mean accumulation level calculated for all penguin species in 1983 was higher than in 1978. This would suggest an increase in amounts and decrease in variability of PCBs in Antarctic environment. In the case of PCBs this would seem to be evident because their production and use are not restricted in most countries of the world.

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6. Streszczenie

W rejonie Polskiej Stacji Antarktycznej im. H. Arctowskiego na Wyspie King George (Szetlandy Południowe) pobrano w 1978 r. próby tkanek 4 gatunków migrujących ptaków morskich: *Oceanites oceanicus, Sterna vittata, Larus dominicanus* i *Catharacta skua* oraz 3 gatunków pingwinów: *Pygoscelis adeliae, P. antarctica* i *P. papua*. W r. 1983 ponownie zebrano próby tkanek tych gatunków pingwinów z analogicznych kolonii lęgowych. Metodą chromatografii gazowej oznaczono w nich zawartość PCBs (Tab. I i II). Najwyższy poziom zawartości tych związków stwierdzono w tkankach *O. oceanicus* i *C. skua*. Różnice w porównaniu z pozostałymi gatunkami okazały się istotne statystycznie na poziomie $p = 0.001$ (test t). Zawartość PCBs w tkankach pingwinów z r. 1978 okazała się najwyższa u *P. adeliae*. Różnica między tym, a pozostałymi gatunkami była statystycznie istotne ($p = 0.001$). Istotną statystycznie różnicę stwierdzono również w przypadku porównania zawartości PCBs w tkance tłuszczowej pingwinów z 1983 r. i z 1978 r. ($p = 0.001$).

Uzyskane wyniki porównano i przedyskutowano z danymi z literatury. Różnice w zawartości PCBs w tkankach ptaków migrujących powiązano z różnym zasięgiem ich wędrówek zimowych wykazując, że gatunki penetrujące w tym okresie wysoko skażone tereny Półkuli Północnej mają zdecydowanie wyższą zawartość PCBs w tkankach, w porównaniu z ptakami, które nie opuszczają Półkuli Południowej. Przedyskutowano również możliwość różnicowania się poziomu zawartości PCBs w tkankach pingwinów w okresie zimy, tłumacząc istniejące różnice możliwością żerowania w skupieniach kryla o różnym stopniu skażenia tymi związkami. Stwierdzono, że wyrównana i wyższa średnia zawartość PCBs w tkankach pingwinów z 1983 r. w porównaniu z 1978 r. jest odpowiedzią na wyrównanie się i wzrost poziomu skażenia PCBs atmosfery i hydrosfery Antarktyki.