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DDT residues in the tissues and eggs of three species of penguins from breeding colonies at Admiralty Bay (King George Island, South Shetland Islands)*)

ABSTRACT: Eggs and samples of the fat (blubber), muscles, and liver from three species of penguins: *Pygoscelis adeliae, P. antarctica* and *P. papua* were collected on King George Island in 1978. *DDT* residues were determined in the samples with the gas chromatography method. In the tissues *pp'DDE* and traces of *pp'DDT* were found, in the eggs merely *pp'DDE*. The highest *DDT* content (wet weight) was recorded in the fat of penguins, the lowest in the eggs. The differences between species in the mean values of the content of *DDT* residues in the tissues and eggs are not statistically significant. An increase in the level of *pp'DDE* concentration in the tissues and eggs of penguins was observed, as compared with earlier studies of other authors, as well as a tendency toward dippearance of the active form, i.e. *pp'DDT*, in the samples.

Key words: Antarctic, penguins, *DDT* content

1. Introduction

Accumulation of *DDT* residues in the bodies of the non-migrant species of Antarctic birds was observed already in the latter part of the sixties (Georg and Frear 1966, Sladen et al. 1966, Tatton and Ruzicka 1967). The subsequent years confirmed this fact and brought information about the increase of the content of these compounds in the animal tissues (Riesebrough and Carmignani 1972, Riesebrough 1974).

At first, the presence of chlorinated hydrocarbons in the tissues of Antarctic animals was associated with activities of the Antarctic Scientific stations and vessels. It was suggested that this may be the cause of local pollution (Sladen, Menzie and Reichel 1966). At present, transfer of pollutants *via* the atmosphere is considered to be the main source of conta-

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mination of the Antarctic (Riesebrough 1974). This statement was confirmed by other studies, demonstrating the presence of *DDT* in the snow from the inland regions of the Antarctic Continent (Peele 1975) and in krill from various regions of the Antarctic waters (Łukowski 1978).

A relatively most detailed information about the chlorinated hydrocarbons content in the tissues of Antarctic animals was given in respect of penguins: *Pygoscelis adeliae* and *P. antarctica* (George and Frear 1966, Sladen, Menzie and Reichel 1966, Tatton and Ruzicka 1967, Riesebrough and Carmignani 1972, Riesebrough (in preparation).

All the earlier studies giving information about the level of *DDT* and its metabolites concentration in the tissues of penguins were published in the sixties. At that time all over the world biocides containing *DDT* were used extensively. There is an interval of about 10 years between the findings presented in this study and the ulterior information about *DDT* content in the tissues of penguins and of a few years in the case of the eggs of these birds.

The materials for this study were collected at the time when in many countries of the world *DDT* had been already for several years withdrawn from general use. Thus, on the basis of the obtained results, it is possible to make a preliminary evaluation of the changes that have occurred during the last few years in the level of the *DDT* residues concentration in the tissues and eggs of the penguins.

2. Materials and methods

The tissues and eggs of the following species of penguins: *Pygoscelis adeliae* (Hombron et Jacquinnot), *Pygoscelis antarctica* (Forster) and *Pygoscelis papua* (Forster) were examined thoroughly. All the tested penguins and their eggs were taken from the breeding colonies located in the proximity of the Arctowski Station at Admiralty Bay. The samples of the penguin tissues were collected in February and eggs in October 1978. (Number of the tested samples is given in Table I). Samples of fat (blubber, adipose tissue) — about 10 g, slices of pectoral muscles — 100 g, and whole liver were cut off for analyses. All the samples were wrapped up in aluminium tinfoil, previously washed with redistilled acetone, and frozen at the temperature of −20 C. They were stored at this temperature for about a month, until the time of the extraction of pesticides. The preparation of samples from the tissue materials for the gas chromatography determinations was made after Thompson (1972).

Acetone and n-hexane extraction of pesticides from homogenized eggs was made immediately after collection. Then, the samples were purified in chromatographic column filled with florisil and anhydrous Na_2SO_4.

All the extracts from the tissues and from the eggs were stored in glass ampoules at the temperature of −20 C.

Table I

DDT residues content in the tissues and eggs of penguins from breeding colonies on King George Island (mean arithmetical values, standard errors and variability ranges are given)

Species	Tissue (wet weigth)	*N*	*pp'DDE*+ trace of *pp'DDT* (*ppm*)
Pygoscelis adeliae	liver	10	0.147± 0.172 0 ÷ 0.544
	pectoral muscle	10	0.161± 0.127 0 ÷ 0.375
	adipose tissue	10	0.548± 0.314 0.057 ÷ 0.889
	eggs	20	0.039± 0.042 trace ÷ 0.093
Pygoscelis antarctica	liver	10	0.091± 0.249 0 ÷ 0.184
	pectoral muscle	10	0.022± 0.020 0.001 ÷ 0.056
	adipose tissue	10	0.340± 0.238 0.069 ÷ 0.817
	eggs	20	0.057± 0.091 trace ÷ 0.093
Pygoscelis papua	liver	10	0.062± 0.068 0.006 ÷ 0.253
	pectoral muscle	10	0.051± 0.046 0.007 ÷ 0.172
	adipose tissue	10	0.364± 0.155 0.101 ÷ 0.552
	eggs	20	0.033± 0.047 trace ÷ 0.089

All the samples used for determination of the pesticides content were prepared at the Arctowski Station laboratory.

For determinations a Pye Unicam (Series 104) gas chromatograph was used with an ECD Ni-63 detector. Gas columns (5 feet in length, 4 mm in diameter) filled with: 1.5 OV17/1.95 OV 210 on W AW DMCS 80/100-mesh chromosorb were utilized. Carrier gas: argon. The presence of *pp'DDT*, *pp'DDD* and *pp'DDE* in the samples was found.

3. Results

DDT residues were found in almost all of the analysed samples (Table I). They were present in the fat of all three species of penguins, in the muscles of *P. antarctica* and *P. papua* and in 90% of the muscle samples from *P. adeliae*. The residues of this compound were found also in all the samples

from the liver of *P. papua*, in 90% of samples from *P. adeliae*, and in 80% of samples from *P. antarctica*. All tested eggs contained the residues of this compound.

The occurrence of the most durable metabolite: *pp'DDE* and traces of the active form of *pp'DDT* was stated in all the analysed tissues of penguins. Quantities smaller than 1 *ppb* were regarded as traces. In the eggs only *pp'DDE* was found.

In all the cases the content of *DDT* residues was lower than 1 *ppm*.

The highest concentration of pesticides was recorded in the fat of penguins, the lowest in their eggs. The mean level of pesticides concentration in the tissues and liver was similar within one species.

The differences between the mean arithmetical values calculated for the tissues and eggs of different species were not statistically significant (Student *T* test).

4. Discussion

The values of the total *DDT* content in the fat of Adelie penguins, given by Riesebrough (1974), excepting one case, are slightly lower, than the actual values (Table II). It is also characteristic that in the samples of the

Table II

pp'DDE and *pp'DDT* content (*ppm*) in the fat of penguins (mean arithmetical values and variability ranges are given)

Locality, date of measurements	*N*	*pp'—DDT*	*pp'—DDE*	Reference
McMurdo, summer of 1964—1965	5	All 0.01	All 0.01	George and Frear (1966)
McMurdo, summer of 1964—1965	1	0.13	0.01	George and Frear (1966)
McMurdo, summer of 1964—1965	1	0.16	0.01	George and Frear (1966)
McMurdo, summer of 1964—1965	1	0.18	0.01	George and Frear (1966)
McMurdo, summer of 1964—1965	1	0.02	0.01	George and Frear (1966)
McMurdo, February 1964	4	0.023 (0.000—0.069)	0.052 (0.019—0.083)	Sladen et al. (1966)
Hallett, January 1966	7	0.005 (0.005—0.010)	0.051 (0.030—0.095)	Brewerton (1969)
McMurdo, January 1967	7	0.036 (0.015—0.065)	0.293 (0.065—0.640)	Brewerton (1969)
King George Island summer of 1978—1979	10	trace	0.548 (0.057—0.889)	author's data Łukowski (1983)

sixties the presence of the active form, i.e. *pp'DDT* was always noted in quantities exceeding or slightly lower than the values of *pp'DDE* content (Sladen, Menzie and Reichel 1966, George and Frear 1967). In the materials of 1978 merely traces of *pp'DDT* were found, whereas *pp'DDE* was a decidedly predominant form.

Tatton and Ruzicka (1967) give information about *pp'DDE* and *pp'DDT* content in the fat of four species of Antarctic penguins. The mean level of these compounds concentration was respectively 0.032 *ppm* and 0.008 *ppm*. Thus, those values are markedly lower than the actual ones.

The information about *DDT* and its metabolites content in other tissues than fat is also inadequate. Sladen, Menzie and Reichel (1966) give the value 0.028 *ppm* for *pp'DDE* concentration in the liver of Adelie penguins and George and Frear (1967) — 0.01 *ppm* for the liver tissue and an analogous value for the muscle tissues. All those results are lower than the actual ones.

There are no data in the literature about the *DDT* content in the tissues of *P. papua* penguins.

Even such fragmentary comparative data show that the increase in the *DDT* residues content occurred in the tissues of all the examined species of penguins. This statement seems to be justified, the more so as there are no significant differences in the level of *pp'DDE* content in the tissues of various species of penguins tested in 1978.

The earlier studies concerning the level of *DDT* content in the eggs of penguins from the Antarctic Continent and adjacent islands are scarce and deal with a small quantity of eggs and only two species of penguins: *P. adeliae* — 10 eggs (Riesebrough and Carmignani 1972) and *P. antarctica* — 3 eggs (Tatton and Ruzicka 1967). In both studies the content of *DDT* residues in the eggs was reduced to lipid basis units, whereas the *DDT* content in the eggs collected in 1978 was reduced to wet weight units. Riesebrough (in preparation) declares that the mean content of lipids in the eggs of penguins from the Antarctic Peninsula region makes up about 10%. On the basis of that information the present results may be tentatively reduced to lipid basis. The comparison of the reduced data with the results of other authors (Table III) shows that, with exception of one case (one egg), the level of *DDT* residues content in eggs collected in 1978 is markedly higher than in the earlier data. Moreover, in the eggs tested earlier *pp'DDT* was always found in quantities not much diverging from the level of the *pp'DDE* content. In the eggs collected on King George Island the *pp'DDT* form was not found at all.

Thus, this situation is analogous to that in the case of the pesticides content in fatty tissue, where an increase in *pp'DDE* accumulation and a tendency toward disappearance of the active form — *pp'DDT* was observed.

In seems that lack or only traces of the active form of *DDT* in the present material may be associated with the fact that now for several years

Table III

pp'DDT and *pp'DDE* content (*ppm*) in the eggs of penguins after various authors. Values reduced to lipid basis units

Species	Location	*N*	*pp'DDE*	*pp'DDT*	References
Pygoscelis adeliae	Cape Hallett	3	0.046 (0.006 ÷ 0.095)	0.029 (0.005 ÷ 0.065)	Riesebrough and Cormignani (1972)
Pygoscelis adeliae	Anvers Island	2	0.084 ÷ 4.740	0.048 ÷ 0.400	Riesebrough and Cormignani (1972)
Pygoscelis adeliae	Cape Crozier	5	0.095	0.033	Riesebrough and Cormignani (1972)
Pygoscelis adeliae	King George	20	0.420	0.000	Łukowski (1982)
Pygoscelis antarctica	Signy Island	3	0.021 0.014 ÷ 0.032	0.008 0.005 ÷ 0.012	Tatton and Ruzicka (1967)
Pygoscelis antarctica	King George	20	0.910	0.000	Łukowski (1983)
Pygoscelis papua	King George	20	0.470	0.000	Łukowski (1983)

the use of *DDT* has been considerably restricted all over the world. This compound undergoes continuously metabolic changes in the world ecosystem to the forms most durable in the environment, i.e. to the *pp'DDE* form. At the same time, the circulation of *DDT* residues in the biosphere caused by exceptional stability of the chemical bonds of this compound is a well-known phenomenon. This situation should lead some time later to equalization of the *DDT* residues (mainly *pp'DDE*) concentration in the atmosphere and consequently equalization of the concentration of these compounds in the precipitations as well in the areas contaminated in the past, as in the areas where *DDT* was never used purposely. Equalization of *DDT* concentrations is followed by a rise of the level of *pp'DDE* concentration in the precipitations in the unpolluted areas, inclusive the Antarctic regions, and consequently resulting in an increase in the contamination of these regions and of the animals living there.

The earlier investigations (Łukowski 1978) seem to corroborate the appearance of a tendency toward an increase in the pollution of the Antarctic region. The results of the determinations of *DDT* residues in krill from the North Atlantic, caught along the coasts of North America, thereby in the regions with a potentially higher degree of pollution, show the values approximate to the data obtained for krill caught in the Antarctic waters of the South Atlantic.

5. Резюме

В феврале и октябре 1978 г. было собрано в гнездовых колониях по 10 особей пингвинов: *Pygoscelis adeliae*, *P. antarctica* и *P. papua*, а также по 20 яиц (из 10 гнезд) каждого из этих видов. В жире, мышцах, печени и яйцах определялось содержание остатков *DDT* (таблица I). Результаты исследования жира пингвинов Адели сравнивались с соответствующими данными других авторов (таблица II). Оказалось, что за последнее 10-летие повысилось содержание остатков *DDT* (*pp' DDE*) и почти полностью исчезло *pp' DDT* (в тканье пингвинов Адели). Литературные данные доказуют, что наблюдается также тенденция к повышению уровня *pp' DDE* в тканях антарктических и ослинных пингвинов. В яйцах пингвинов также установлено повышенное количество *pp' DDE* и отсутствие формы *pp' DDT* в пробах, собранных в 1978 г. (таблица III). Рост содержания *pp' DDE* в тканях и яйцах, а также тенденция к изчезанию активной формы автор считаем связанным со значительным ограничением употребления *DDT* в мире, с процессами его разложения до найболее стабильных форм т.е. *pp' DDE* и круговоротом *DDT* в биосфере. В результате этого круговорота возникает тенденция к выравниванию содержания остатков *DDT* в атмосфере земного шара и росту его концентрации в осанках и тканях животных, населяющих территории, где *DDT* никогда не применялся непосредственно — в том и на антарктических территориях.

6. Streszczenie

W lutym i październiku 1978 roku zebrano w koloniach lęgowych na wyspie Króla Jerzego po 10 sztuk pingwinów: *Pygoscelis adeliae, P. antarctica* i *P. papua* oraz po 20 jaj (z 10 gniazd) każdego z tych gatunków. W tłuszczu, mięśniach, wątrobie i jajach oznaczono zawartość pozostałości *DDT* (tabela I). Uzyskane dla tłuszczu pingwinów Adeli wyniki porównano z danymi innych autorów (tabela II). Stwierdzono, że w ostatnim 10-leciu nastąpił wzrost zawartości pozostałości *DDT* (*pp'DDE*) i prawie całkowity zanik *pp'DDT* (w tej tkance pingwinów Adeli). Z nielicznych informacji wynika, że istnieje również tendencja do wzrostu poziomu *pp'DDE* w tkankach pingwinów antarktycznych i pingwinów papua. W jajach pingwinów również stwierdzono wzrost zawartości *pp'DDE* i zanik formy *pp'DDT* w próbach zebranych w 1978 roku (tabela III). Wzrost zawartości *pp'DDE* w tkankach i jajach oraz tendencję do zaniku formy aktywnej powiązano w pracy ze znacznym ograniczeniem stosowania *DDT* na świecie, z procesami jego rozkładu do form najtrwalszych tj. *pp'DDE* i krążeniem pozostałości *DDT* w biosferze. W wyniku tego krążenia występuje tendencja do wyrównywania się stężeń pozostałości *DDT* w atmosferze naszego globu i wzrostu stężeń w opadach i tkankach zwierząt zamieszkujących tereny, na których nigdy nie stosowano *DDT* celowo — w tym i na terenach antarktycznych.

7. References

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