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Radioactivity exploration from the Arctic to the Antarctic.
Part 3. The SWEDARP expedition Oct 1988 – April 1989

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"Snowhill" painted on board M/S Stena Arctica by the artist Lars Lerin, who followed and documented the SWEDARP expedition. (copy by permission of Lars Lerin)

Abstract

The Swedish Antarctic Research Expedition named "***SWEDARP***" was performed during October 1988 through April 1989. The aim of our project was to study the radioactivity in air and water from Gothenburg to the Antarctic.

Between Gothenburg and the Equator, the average activity concentration of ^{7}Be in air was 4.3 ± 0.7 mBq/m^{3}. The activity concentration of ^{7}Be in the South Atlantic down to Antarctica varied between 1.3 and 1.7 with an average of 1.5 ± 0.8 mBq/m^{3}.

The average activity concentration of ^{210}Pb in air during autumn 1988 on the route Gothenburg-Montevideo was about 290±270 μBq/m^{3} and on the return in spring 1989 it was about 230±140 μBq/m^{3}. At the Equator, the average activity concentration of ^{210}Pb in November 1988 was about 630±170 and in April 1989 about 260±210 μBq/m^{3}. In the South Atlantic down to Antarctica during February-March 1989, the activity concentration of ^{210}Pb varied between 11 and 58 μBq/m^{3}.

The average activity concentration of ^{210}Po in air during the route Gothenburg- Montevideo in 1988 was about 63±58, and on the return, it was about 60±44 μBq/m^{3}. At the Equator, the average activity concentration in Nov 1988 was about 132±45, and in April 1989 about 70±60 μBq/m^{3}. The activity concentration of ^{210}Po in the South Atlantic down to Antarctica during February-March 1989 varied between 6 and 14 μBq/m^{3}.

The inventory (Bq.m^{-2}) of various deposited ratio nuclides, measured in moss, lichen, soil and lake sediments was: 280 ±110 for ^{210}Pb (excess); 155 ± 95 for ^{137}Cs, 4.6 ± 2.6 for $^{239+240}$Pu, 1.6 ± 1.0 for ^{241}Am and, 0.95± 0.5 for ^{238}Pu.

^{137}Cs activity concentration (Bq.m^{-3}) in surface waters samples along the route of the SWEDARP expedition was about 3 Bq.m^{-3} above 20 °N , decreased to about 2 Bq.m^{-3} between 20 °N and 40 °S where it decrease to about 1 Bq.m^{-3} , and at 55 °S (e) there is a further decrease to about 0.3 Bq.m^{-3}. Radio-Caesium, which originates from atmospheric nuclear weapons tests carried out in the late 1950's and the early 1960's shows a long residence time in surface waters of the North and South Atlantic Oceans with half-time, corrected for physical decay estimated to be more than bout 100 years. Concentration factor for ^{137}Cs estimated to 15000 for fish in the Antarctic is much higher than the value of 500 given by The IAEA 1985. Concentration factors for MacroAlgea/Water, was found to be about 1800 in the Antarctic compared to 100 the Arctic.

The $^{239+240}$Pu activity concentrations in the surface water was about 8 mBq.m^{-3} in the latitude band 5°-25 °N , about 3 mBq.m^{-3} in the latitude band 25-5 °N; and about 1,5 mBq.m^{-3} in the latitude band 0 °S-60 °S. Plutonlum-238 activity was measured in a few water samples from the southern hemisphere with activity ratio of ^{238}Pu to $^{239+240}$Pu in the range of 0.14-0.22. Plutonium isotopes $^{239+240}$Pu from atmospheric nuclear weapons tests has a low half-life of 7-8 years due to the higher affinity to sinking particles for Pu than Cs. In the southern hemisphere, ^{238}Pu was found as the result of the 1964 burn-up of a satellite in the atmosphere over the Mozambique Channel.

The Average activity concentrations (Bq/kg$_{dw,}$) of ^{137}Cs are in flesh of seals 2.5, penguins 0.2 and, fish 2.5 in liver of seals 0.6 and penguins 0.7 and in kidneys of seals 0.5. The Average activity concentrations (Bq/kg$_{dw}$) of ^{210}Po are in flesh of seals 8, penguins 4 and, fish 7, in liver of seals 110 and penguins 43 and, fish 5, and in kidneys of seals 91 and of penguins 43. The Average activity concentrations (Bq/kg$_{dw,}$) of ^{210}Pb are in flesh of seals 0,3, penguins 0,2, and fish 0.6, in liver of seals 4 and penguins 1 and, fish 1, and in kidneys of seals 1 and of penguins 1. The Average activity concentration of ^{137}Cs in samples of Krill is about 1.7 Bq/kg$_{dw}$ of ^{210}Po and ^{210}Pb are in samples of Amphipods, 87 and 1.4 Bq/kg$_{dw}$ respectively.

Radio-Caesium, which originates from atmospheric nuclear weapons tests carried out in the late 1950's and the early 1960's shows a long residence time in surface waters of the North and South Atlantic Oceans with half-time, corrected for physical decay estimated to be more than bout 100 years.

Plutonium isotopes $^{239+240}$Pu from atmospheric nuclear weapons tests has a low half-life of 7-8 years due to the higher affinity to sinking particles for Pu than Cs. In the southern hemisphere, ^{238}Pu was found as the result of the 1964 burn-up of a satellite in the atmosphere over the Mozambique Channel.

A. Route of the SWEDARP expedition

The Swedish Antarctic Research Expedition named "***SWEDARP***" was performed during October 1988 through April 1989 organized by the Swedish Polar Research program. The ship M/S Stena Arctica (**Figure 3-1**), was used as research platform, with air sampling device and laboratory container loaded on board in Gothenburg.

Figure 3-1
The first M/S Stena Arctica under Stena Bulk, loading in the harbour at Gothenburg for the SWEDARP expedition.
Photo: Kjell-Åke Carlsson

The route of the SWEDARP expedition is displayed in **Figure 3-2.**

We started in Gothenburg (67.4°N 12°E) with the first destination Montevideo (34.8°S 56.2°W). From Montevideo, we continued to the Swedish permanent base "*Svea*" at the North shelf of Antarctica. After unloading supply and equipment for the continental research group at "Svea", the ship continued to the Argentinean base "*Marambio"* (**Figure 3-3**).

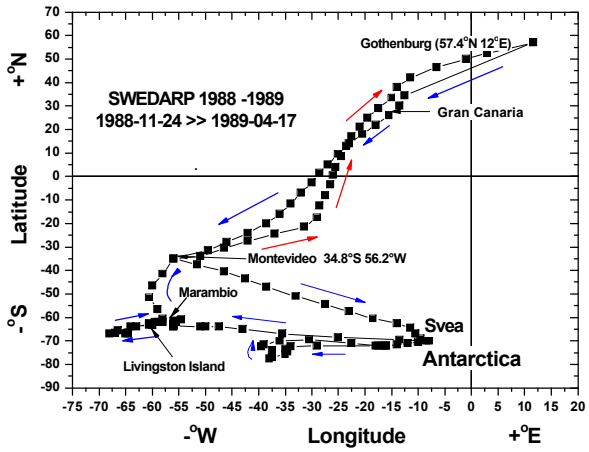

Figure 3-2
Route of the SWEDARP expedition 1988 -1989. The black square dots indicate the locations of air sampling.

Figure 3-3
The expedition approaching the Argentine research station "Esperanza base" at 63°24′ S, 56°59′ W. *Photo: Kjell-Åke Carlsson*

The expedition members were allowed to visit the Esperanza base with the remains of the stone-hut on "*Paulet Island*" where Captain C.A. Larsen stayed, after his vessel "Antarctic" sank in 1903.

Figure 3- 4
During the Antarctic winter 1903-04, Gunnar Andersson, Duse and Grundén survived in this stone-hut, where prayer and supplication of faith and hope embedded in their souls, until the corvette Uruguay came to rescue them. Hope Bay, Antarctica, Argentina 1905. Photo: *Kjell-Åke Carlsson*

B. Measurements of ^{210}Pb, ^{210}Po as well as ^{7}Be in surface air.

During the SWEDARP expedition to the Antarctica, surface air samples of ^{210}Pb, ^{210}Po as well as ^{7}Be were collected with a so-called "Andersen" air sampling device installed on board the ship M/S Stena Arctica. Air volumes of about 1 500 m^3 were collected at each occasion on membrane filters (size 0.25×0.25 m) at a flow rate of 100 m^3h^{-1}. The sampler had previously

been involved in an inter-calibration project of air samplers (Vintersved, 1994). During the Arctic Ocean expedition in 1991, the Andersen sampler was compared with a FOA transportable reference high volume air sampler (Microsorban filter, 0.56x0.56 m^2, 1 100 m^3h^{-1}). The samplers were placed close together on deck of the cruise vessel. The ^{7}Be results for the Anderson sampler were normalized to that of the FOA sampler. FOA nowadays FOI, is a Swedish research institute in the areas of defence and security.

The time between collection and analysis of the filters was maximum 2 months. Filters were whenever possible sent to Sweden by mail from Montevideo or Marambio Base in Antarctica or by personnel leaving the expedition. The filters were measured back home in Lund, for ^{7}Be by gamma spectrometry using a high performance Germanium detector (HpGe Canberra). After ^{210}Po and ^{210}Pb were measured by radiochemical procedure after adding ^{209}Po as radiochemical yield determinant and the samples were wet-ashed by using a mixture of concentrated nitric acid and hydrochloric acid. Polonium was spontaneously deposited on nickel discs, and the activity of ^{209}Po and ^{210}Po was measured by alpha spectrometry using surface ion implanted silicon detectors. The radiochemical yield was about (70-80 %).
Remaining traces of polonium were removed by anion exchange. The solution was then kept for about 8-12 months, to allow in-growth of ^{210}Po from ^{210}Pb. New ^{209}Po yield determinant was added again, and ^{209}Po and ^{210}Po was deposited on nickel discs and measured by alpha spectrometry.

The activity of ingrown ^{210}Po was calculated, with corrections for build-up from ^{210}Pb from sampling to analysis. Decay correction for the time elapsed between plating and measurement of ^{210}Po was done as well. Finally, after all appropriate corrections for radioactive decay were done, the activity concentrations of ^{210}Po and ^{210}Pb in air at sampling time were obtained.

Figure 3-5
Sampling of radioactivity in air and water around Antarctica.
Photo: *Kjell-Åke Carlsson*

In **Figure 3-6** are given the results from the measurements of ^{7}Be activity concentrations as well as of ^{210}Pb, and ^{210}Po in the surface air, recorded during the routes between Gothenburg 57°43'N 11°59'E - Montevideo 34°50'S 56°11'W and return. In **Table 3-1** are given the average activity concentrations of ^{7}Be (mBq.m^{-3}). ^{210}Pb, and ^{210}Po (μBq.m^{-3}) in the surface for various

segments of the route Gothenburg 57°43'N 11°59'E - Montevideo 34°50'S 56°11'W – Antarctica and return.

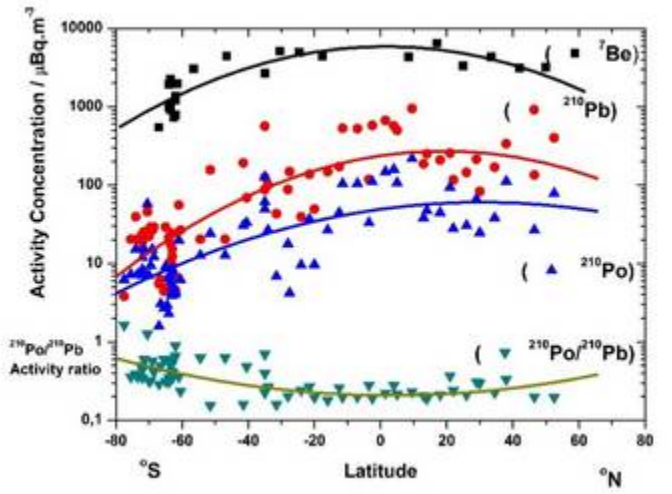

Figure 3-6
Activity concentrations of ^{7}Be as well as of ^{210}Pb, and ^{210}Po in the surface air as recorded on the routes Gothenburg 57°43'N 11°59'E - Montevideo 34°50'S 56°11'W and return.
The curves are 2nd degree polynomial fittings.

Table 3-1
Average activity concentrations of ^{7}Be (mBq.m^{-3}), ^{210}Pb, and ^{210}Po (µBq.m^{-3}) in the surface air on various segments on the route Gothenburg 57°43'N 11°59'E - Montevideo 34°50'S 56°11'W – Antarctica and return.

Time	Latitude N(+)/S(-)	Longitude W(-)/E(+)	Number of samples	^{7}Be mBq/m^3		^{210}Pb µBq/m^3		^{210}Po µBq/m^3	
				Ave.	SD	Ave.	SD	Ave.	SD
1988									
1124>1130	34.5 > 14	- 12.5 > - 56	6			163	61	36	9
1201>1205	9.5 > - 11.5	- 25 > - 56	6			626	169	132	45
1124>1212	34 > - 35	- 12.5 > - 56	5			288	268	63	58
1213>1227	- 35 > - 70	- 56 > - 8.5	15			45	45	21	17
1989									
0101>0205	- 72 > - 70	- 16 > - 8	15			22	9	9	3
0211 >0318	- 64 > - 60.5	-50 > - 58	33	1,3	0,6	15	13	6	4
0319>0324	- 56.5 > - 35	- 59> - 56	6	3,4	0,9	305	227	61	58
0206>0324	- 70 > - 35	- 13.5 > - 56	39	1,7	1,0	58	126	14	27
0401>0407	12.5 > - 13	- 28.5 > - 23.5	7	4,3	0,3	262	207	69	60
0325>0417	- 35 > N 52	- 56 > 3	24	4,3	1,1	232	140	60	44

In **Table 3-2** are given the results of average activity ratios of ^{7}Be /^{210}Pb , and ^{7}Be / ^{210}Po in the surface air on the routes Gothenburg 57°43'N 11°59'E - Montevideo 34°50'S 56°11'W - Antarctica and return.

Table 3-2
Average activity ratios (±SD) of $^{7}Be/^{210}Pb$, and $^{7}Be/^{210}Po$ at various route sections recorded during the SWEDARP expedition 1989.

Time	Latitude N(+)/S(-)	Longitude W(-)/E(+)	Number of samples	^{7}Be mBq/m^3 Ave.	SD	^{210}Pb µBq/m^3 Ave.	SD	^{210}Po µBq/m^3 Ave.	SD
1988									
1124>1130	34.5 > 14	- 12.5 > - 56	6			163	61	36	9
1201>1205	9.5 > - 11.5	- 25 > - 56	6			626	169	132	45
1124>1212	34 > - 35	- 12.5 > - 56	5			288	268	63	58
1213>1227	- 35 > - 70	- 56 > - 8.5	15			45	45	21	17
1989									
0101>0205	- 72 > - 70	- 16 > - 8	15			22	9	9	3
0211 >0318	- 64 > - 60.5	-50 > - 58	33	1,3	0,6	15	13	6	4
0319>0324	- 56.5 > - 35	- 59> - 56	6	3,4	0,9	305	227	61	58
0206>0324	- 70 > - 35	- 13.5 > - 56	39	1,7	1,0	58	126	14	27
0401>0407	12.5 > - 13	- 28.5 > - 23.5	7	4,3	0,3	262	207	69	60
0325>0417	- 35 > N 52	- 56 > 3	24	4,3	1,1	232	140	60	44

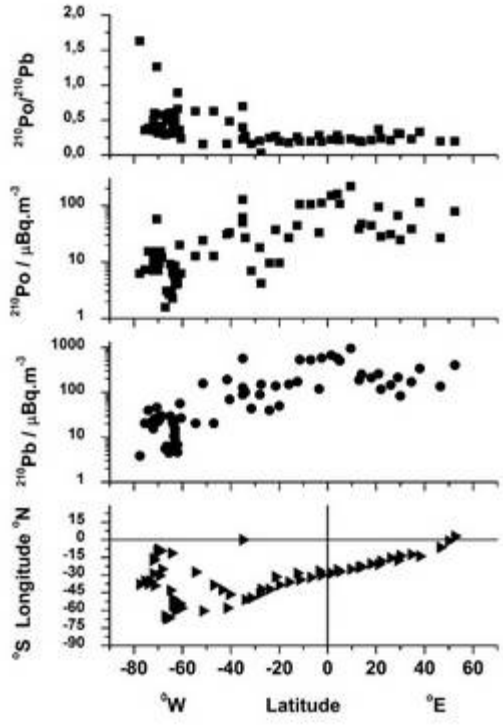

Figure 3-7 Activity concentrations of ^{210}Pb, and ^{210}Po and the $^{210}Po/^{210}Pb$-activity ratio in the surface air as recorded on the routes Gothenburg 57°43'N 11°59'E - Montevideo 34°50'S 56°11'W and return.

The activity concentration of ^{7}Be in the South Atlantic down to Antarctica varied between 1.3 and 1.7 with an average of 1.5 ± 0.8 mBq/m^3. At the Equator and up to Gothenburg the average activity concentration of ^{7}Be was 4.3 ± 0.7 mBq/m^3.

The activity concentration of ^{210}Pb in the South Atlantic down to Antarctica during February-March 1989 varied between 11 and 58 μBq/m^3. At the Equator, the average activity concentration of ^{210}Pb in November 1988 was about 630±170 and in April 1989 about 260±210 μBq/m^3. The average activity concentration of ^{210}Pb during the route Gothenburg- Montevideo in 1988 was about 290±270 μBq/m^3 and on the return Montevideo-Gothenburg it was about 230±140 μBq/m^3.

The activity concentration of ^{210}Po in the South Atlantic down to Antarctica during February-March 1989 varied between 6 and 14 μBq/m^3. At the Equator the average activity concentration in Nov 1988 was about 132±45, and in April 1989 about 70±60 μBq/m^3. The average activity concentration of ^{210}Po during the route Gothenburg- Montevideo in 1988 was about 63±58, and on the return Montevideo-Gothenburg it was about 60±44 μBq/m^3.

C Deposition of ^{210}Pb, ^{137}Cs, $^{239+240}$Pu, ^{238}Pu, and ^{241}Am in the Antarctic Peninsula Area

During the SWEDARP expedition samples of lichens (identified as being close to *Alectoria nigricans*), various types of moss, grass (*Dechampsia Antarctica* and *Colobamtimus*) and soil, all with a known area (between 1/16 and 1/ 4 m^2), were collected on the South Shetland Islands (Livingston Island, King George Island, Deception Island and Horseshoe Island).

Figure 3-8

Moss carpets at Livingston Island 62°38´ S, 60°30´W.

Photo: *Bertil Persson*

^{210}Pb, ^{137}Cs, $^{239+240}$Pu, ^{238}Pu and ^{241}Am were analysed in lichen, moss, grass and soil samples, as well as in lake sediments from the South Shetland Islands, the Antarctic, in order to evaluate the flux and deposition of these elements (Roos et al., 1994). Average inventories of the analysed radionuclides in samples collected 1988, are given in Table 3-3.

Table 3-3 Average inventories of the analysed radionuclides in samples collected 1988 in Antarctica

Radionuclide	Inventory Bq.m^{-2}	Samples
^{210}Pb (excess)	280 ± 110	(n=15)
^{137}Cs	155 ± 95	(n =19)
$^{239+240}$Pu	4.6 ± 2.6	(n =19)
^{241}Am	1.6 ± 1.0	(n =19)
^{238}Pu.	0.95 ± 0.5	(n =19)

From the maximum value of unsupported ^{210}Pb the annual deposition of ^{210}Pb, is estimated to be 18 ± 5 Bq m^{-2}. The ratios $^{239+240}$Pu and ^{241}Am /$^{239+240}$Pu are 0.21 ± 0.04 and 0.35 ± 0.08 respectively, which agree well with expected values in this area. A significant difference in ^{137}Cs /$^{239+240}$Pu activity ratios was observed between lichens and moss, grass and soil which may be an effect of submerging and melt water. From one of three lakes studied it is possible to perform ^{210}Pb dating with reasonably accuracy showing an average annual sedimentation rate in this lake was about 45 g.m^{-2}.a^{-1}.

As shown in **Table 3-4**, there is a strong correlations were between the deposition of the natural radionuclide ^{210}Pb, and the artificial radionuclides ^{137}Cs, $^{239+240}$Pu, ^{238}Pu and ^{241}Am.

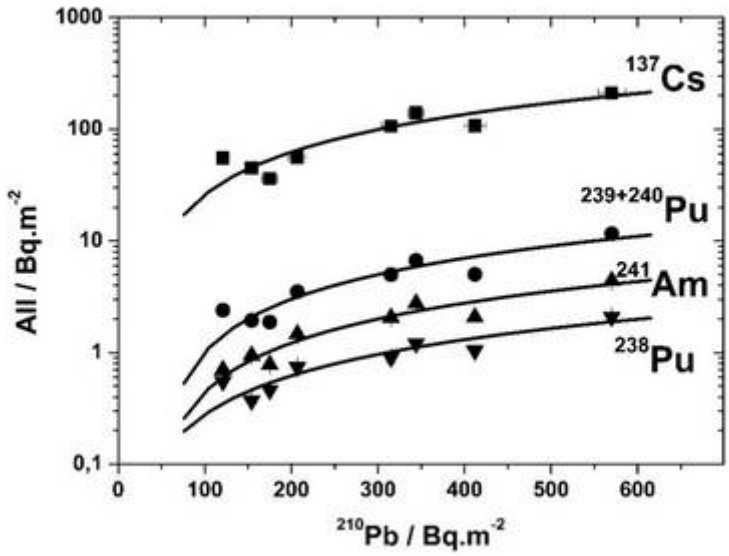

Figure 3-9
The correlations between the deposition of the natural radionuclide ^{210}Pb, and the artificial radio-nuclides ^{137}Cs, $^{239+240}$Pu, ^{238}Pu and ^{241}Am.

Due to the wide spread in the values of the deposition level of the artificial radionuclides, the results are displayed in a logline diagram **Figure 3-9**.

Table 3-4
Linear regression coefficients k=Y/X between the deposition X of the natural radionuclide ^{210}Pb, and the deposition Y of artificial radionuclides ^{137}Cs, $^{239+240}$Pu, ^{238}Pu and ^{241}Am and corresponding coefficients of variation R.

Radionuclides	k	SD	R
^{137}Cs	0.34	0.02	0.94
$^{239+240}$Pu	0.017	0.001	0.94
^{241}Am	0.0068	0.0005	0.95
^{238}Pu	0.0032	0.0002	0.94

D Measurements of various Caesium and Plutonium isotopes in water.

Radio Caesium (^{134}Cs, ^{137}Cs) and Plutonium (^{238}Pu, $^{239+240}$Pu) was measured in water samples collected along the route 73 °N to 72 °S. The sampling volume in the Antarctic was often about 1400 l (Holm et al., 1991).

D1 Caesium 137

The result of ^{137}Cs activity concentration (Bq.m^{-3}) in surface waters samples along the route of the SWEDARP expedition from the North (73 °N) and South Atlantic (to 72 °S) are displayed in

Figure 3-10
Interior of the water laboratory container on board, where seawater samples of 100-200 1 were collected in two special precipitation vessels placed to the right. One for precipitation ^{137}Cs and another for trans-uranium elements. Cartridge-filters (Millipore CWSS 012C3) are placed in the holders on the wall to the left.

Photo: *Kjell-Åke Carlsson*

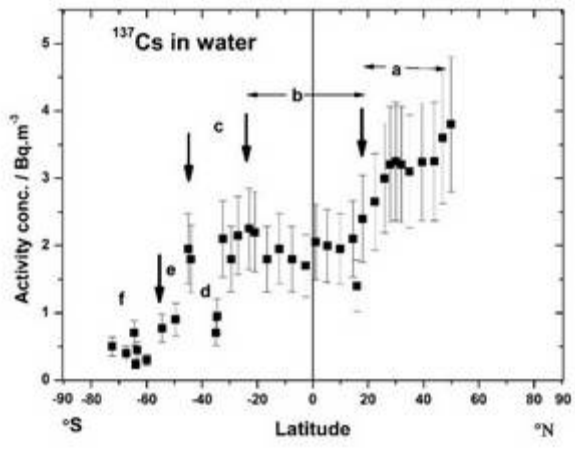

Figure 3-11.
^{137}Cs activity concentration (Bq.m^{-3}) in surface waters from the North and South Atlantic. All data corrected for physical decay to February 1989.

Following separate regions in **Figure 3-11** can be distinguished in the result of ^{137}Cs activity concentration (Bq.m^{-3}) in surface waters samples along the route of the SWEDARP expedition from the North (73 °N) and South Atlantic (to 72 °S):

a. above 20 °N where the activity concentration are about 3 Bq.m^{-3},
b. between 20 °N and 30 °S where the activity concentration decrease from 3 to about 2 Bq.m^{-3}
c. between 30 - 45 °S where the activity concentration are fluctuating about 2 Bq.m^{-3}
d. at 40 °S the activity concentrations decrease to about 1 Bq.m^{-3} , when entering the South Sea current and
e. between 55 - 45 °S where the activity concentration are fluctuating between 1 -2 Bq.m^{-3}
f. below the circumpolar Antarctic water at 55 °S (e) there is a decrease to about 0.3 Bq.m^{-3}, which are accompanied, by decreases in water temperature.

D2 Caesium 134

In 1986 large amounts of ^{134}Cs was released in the Chernobyl accident. The ^{134}Cs/^{137}Cs-activity ratio in samples of Atlantic surface water ln April/May 1986 was about 0.47 and was estimated to be about 0.17 in 1989. This ratio is significantly lower than that in the effluents from European nuclear fuel reprocessing plants, ^{134}Cs was only found at few locations north of 35°N, the most southerly latitude we would expect any impact of the release from Chernobyl accident. It is, however, most probably that the ^{134}Cs recorded is derived from European reprocessing plants rather than from the Chernobyl accident.

D3 Plutonium 239+240.

The results for $^{239+240}$Pu from the SWEDARP expedition are displayed the **Figure 3-12**. The long physical half -life of the plutonium isotopes $^{239+240}$Pu makes it unnecessary to correct for physical decay between 1973 and 1989. The plutonium activity concentrations in the surface water are about 8 mBq.m^{-3} in the latitude band 5°-25 °N, about 3 mBq.m^{-3} in the latitude band 25-5 °N, and about 1,5 mBq.m^{-3} in the latitude band 0 °S-60 °S. Slightly higher values were

measured around the Antarctic Peninsula. As a comparison we can mention that based on the Swedish Ymer-80 expedition in 1980 the $^{239+240}$Pu activity concentrations were about 11-15 mBq.m^{-3} from in the Norwegian Sea and the Barents and Greenland Seas between 55 to 82 °N.

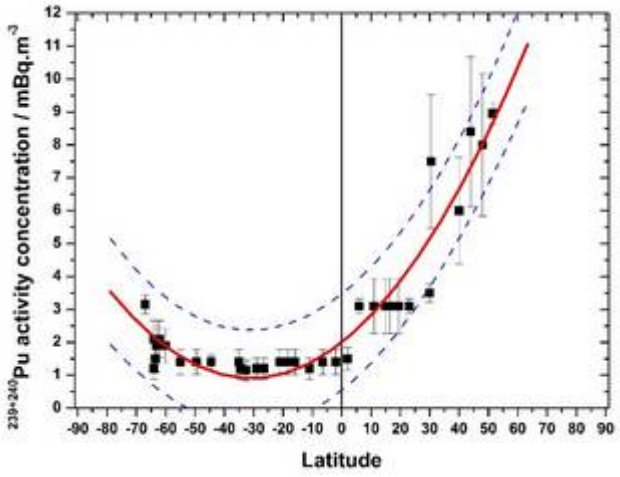

Figure 3-12.
Activity concentration (mBq.m^{-3}) of $^{239+240}$Pu in surface waters from the North and South Atlantic. Polynomial Regression for Data **R^2(COD) = 0.91**:
$Y = 2.0 + 0.07 \times X + 0.0011 \times X^2$

D4. Plutonium 238

In the southern hemisphere, ^{238}Pu originates mainly from a satellite (SNAP-9A containing 1 kg of Pu metal) that in 1964 re-entered the atmosphere and burned up at high altitude over the Mozambique Channel. This event significantly increased both the environmental levels of ^{238}Pu in addition to the activity ratio to $^{239+240}$Pu (which is typically 0.025 in fallout from Nuclear weapons tests), especially in the southern hemisphere.

During the SWEDARP expedition, Plutonlum-238 activity was measured in a few water samples from the southern hemisphere- The activity ratio of ^{238}Pu to $^{239+240}$Pu was ranging from 0.14-0.22. In macro algae from the Antarctic Peninsula we found an activity ratio of ^{238}Pu to $^{239+240}$Pu of 0.27±0.03 (n = 6, 1. S.E.), and in terrestrial samples (carpets of mosses and lichens) from the Antarctic Peninsula area an activity ratio of 0.24±0.02 (n =24, 1 S.E.).

E Measurements of various Radionuclides in Biota.

E1 Radionuclides in Marine animals

The activity concentration of ^{137}Cs, ^{210}Po and ^{210}Pb was analyzed in samples of various species of seals, penguins and fish are displayed in Figures 3-13,14,15 for flesh, liver and kidney.
To the right in these Figures are also given data for Amphipods and Krill. The horizontal bars in the figures 3-13,14,15 represent the average activity concentration of the radionuclide in question.

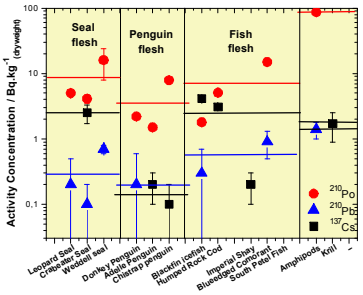

Figure 3-13.
The activity concentration of ^{137}Cs, ^{210}Po and ^{210}Pb in flesh-samples of seals, penguins and fish. To the right data for Amphipods and Krill.

The Average activity concentration of ^{137}Cs, ^{210}Po and ^{210}Pb was analyzed in samples of various species of seals, penguins and fish are for flesh , liver and kidney as well as Amphipods and Krill are given in Table 3-5.

The pattern of average concentration is very similar for seals and fish. For penguins, however, the similar pattern as amphipods do indicate that also these animals might also be an important part of their diet.

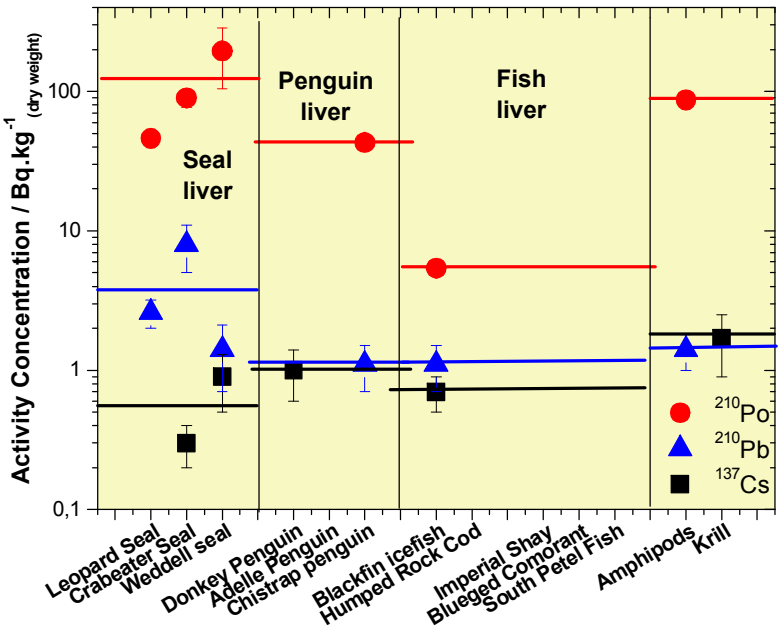

Figure 3-14.
The activity concentration of ^{137}Cs, ^{210}Po and ^{210}Pb in liver-samples of seals, penguins and fish. To the right data for Amphipods and Krill.

The pattern of average concentration in liver do indicate that Amphipods is an important part of fish diet.

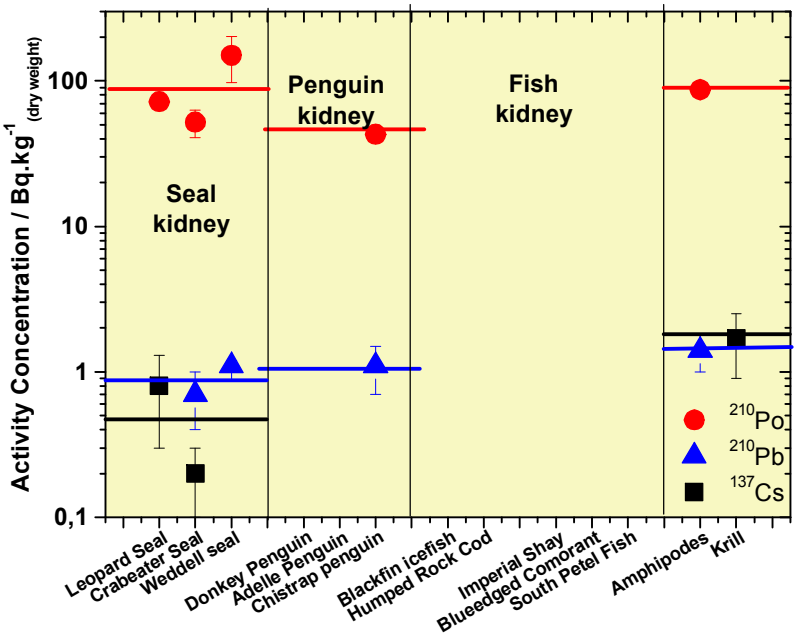

Figure 3-15.
The activity concentration of ^{137}Cs, ^{210}Po and ^{210}Pb in kidney-samples of seals, penguins and fish. To the right data for Amphipods and Krill.

Table 3-6
The average activity concentration (Bq per kg dry weight) of ^{137}Cs, ^{210}Po and ^{210}Pb in flesh , liver and kidney samples of various species of seals, penguins and fish, as well as in Amphipods and Krill.

	^{137}Cs		^{210}Po		^{210}Pb	
	Bq/kg $_{Dw}$	SE	Bq/kg $_{Dw}$	SE	Bq/kg $_{Dw}$	SE
Flesh						
Seal	2.5	±0.8	8	±4	0.3	±0.2
Penguins	0.2	±0.1	4	±2	0.2	±0.4
Fish	2.5	±0.1	6.9	±0.3	0.6	±0.4
Liver						
Seal	0.6	±0.3	110	±44	4	±2
Penguins	0.7	±0.2	43	±2	1.1	±0.4
Fish			5.4	±0.3	1.1	±0.4
Kidney						
Seal	0.5	±0.3	91	±30	0.9	±0.2
Penguins			43	±2	1.1	±0.4
Amphipodes			87	±3	1.4	±0.4
Krill	1.7	±0.8				

The concentration factor for ^{137}Cs of 15000 estimated for fish in the Antarctic is much higher than the value of 500 given by the IAEA 1985 (IAEA, 1985).

E2 Macro Algae

The activity concentration of ^{238}Pu, $^{239+240}$Pu, ^{241}Am, ^{137}Cs, ^{210}Po and ^{210}Pb was analyzed in 10 samples of Macro Algae collected during the SEDARP expedition in the Antarctic. The results are displayed in **Figure 3-16**. Generally the activity concentrations in macro algae relatively to the fallout levels are higher in the Antarctic, with a value of 3500 compared to 110 in the Arctic.

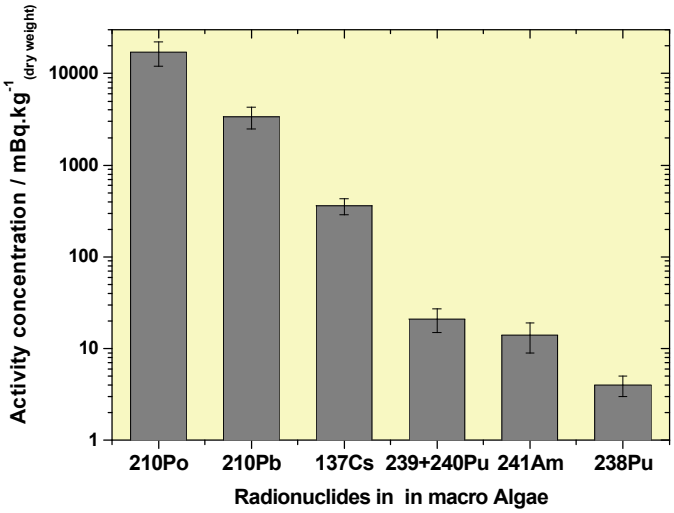

Figure 3-16.
The average activity concentration of ^{238}Pu, $^{239+240}$Pu, ^{241}Am, ^{137}Cs, ^{210}Po and ^{210}Pb in 10 samples of Macro algae collected during the SWEDARP expedition in the Antarctic.

Concentration factors Algea/Water of the radionuclides displayed in **Figure 3-16** was found to be much higher than in the Arctic (Holm et al., 1983). In macro algea we derive a concentration factor for the two regions to 150 and 1800 respectively.

F. Conclusions

Radio-caesium, which originates from atmospheric nuclear weapons tests carried out in the late 1950's and the early 1960's shows a long residence time in surface waters of the North and South Atlantic Oceans. The half-time, corrected for physical decay, is estimated to be more than bout 100 years. In open sea-water radio-caesium can be regarded as a conservative tracer for evaluating oceanographic processes. In dose commitment estimates for radiological assessment, only physical decay has to be taken into account.

Plutonium isotopes $^{239+240}$Pu from atmospheric nuclear weapons tests has a half-life of 7-8 years. In 1989 the average of $^{239+240}$Pu/^{137}Cs - activity ratio in 37 samples of Atlantic surface waters was $(3.3\pm 0.7)\cdot 10^{-3}$ compared to $12\cdot 10^{-3}$ in fresh fallout from nuclear weapons tests. The activity ratio shows a minimum at latitudes 30-40 °S. The lower value is due to the higher affinity to sinking particles for Pu. In the southern hemisphere, ^{238}Pu could be found as the result of the 1964 burn-up of a satellite in the atmosphere over the Mozambique Channel.

The Average activity concentrations ($Bq/kg_{dw,}$) of ^{137}Cs are in flesh of seals 2.5, penguins 0.2 and, fish 2.5 in liver of seals 0.6 and penguins 0.7 and in kidneys of seals 0.5. The Average activity concentrations ($Bq/kg_{dw,}$) of ^{210}Po are: in flesh of seals 8, penguins 4 and, fish 7 in liver of seals 110 and penquins 43 and, fish 5, and in kidneys of seals 91 and of penguins 43. The Average activity concentrations ($Bq/kg_{dw,}$) of ^{210}Pb are in flesh of seals 0,3, penguins 0,2, and fish 0.6, in liver of seals 4 and penquins 1 and, fish 1, and in kidneys of seals 1 and of penguins 1. The Average activity concentration of ^{137}Cs in samples of Krill is about 1.7 Bq/kg_{dw} of ^{210}Po and ^{210}Pb are in samples of Amphipods, 87 and 1.4 Bq/kg_{dw} respectively.

The concentration factor for ^{137}Cs of 15000 estimated for fish in the Antarctic is much higher than the value of 500 given by The IAEA 1985. Concentration factors Algea/Water was found to be about 1800 in the Antarctic compared to 100 the Arctic.

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