Radioactive contamination at dumping sites for nuclear waste in the Kara Sea

Results from the Russian-Norwegian 1993 expedition to the Kara Sea

Joint Russian – Norwegian Expert Group
for Investigation of Radioactive Contamination
in the Northern Areas

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PREFACE

The present report summarizes the results obtained from the joint Russian-Norwegian expedition to the dump sites for radioactive waste in the Tsivolky Bay, the Stepovogo Bay and in the Novaya Zemlya Trough undertaken in September-October 1993 on board R/V "Victor Buynitsky" of the Federal Service of Russia for Hydrometeorology and Environmental Monitoring. The report has been prepared by a working group headed by Per Strand, Norwegian Radiation Protection Authority, and Alexander I. Nikitin, SPA "Typhoon", the Federal Service of Russia for Hydrometeorology and Environmental Monitoring. The members of the working group were:

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The expedition leaders were Lars Føyn, Institute of Marine Research, Norway and Alexander I. Nikitin, SPA "Typhoon" of Roshydromet, Russia. The analytical results were provided by the following institutions:

SPA "Typhoon", Russia
Norwegian Radiation Protection Authority, Norway
Agricultural University of Norway, Norway
Institute for Energy Technology, Norway
IAEA/Marine Environmental Laboratory, Monaco

The Russian Navy specialists G.N. Amiev, S.V. Malevanniy, S.N. Larichev presented results of their measurements in the Stepovogo Bay and provided one soil and bottom sediment sample from this bay area for radionuclide analysis.

Sven P. Nielsen, Risø Research Centre, has been working with the development of the model and contributed to the text of Chapter 7.2.

Iolanda Osvath, IAEA/MEL, has contributed with advices and useful comments to this report.

1. INTRODUCTION

In 1992, a Russian-Norwegian expert group for the investigation of radioactive contamination in the northern areas was established under the joint Russian-Norwegian Commision for Cooperation in the Environmental Sector. The expert group is led by the Ministry of Environmental Protection of the Russian Federation and the Norwegian Ministry of Environment. The expert group was formed as a result of allegations claiming that the former Soviet Union had dumped radioactive waste in the Barents and Kara Seas.

The main task of the expert group include gathering information about the handling, storage and discharge/dumping of radioactive material in the northern areas, field investigations in the Barents and Kara Seas and assessments of the possible effects on human beings and the environment of the radioactive contamination from dumping of radioactive waste and other sources.

In addition to the investigations of dumping of radioactive waste in the Barents and Kara Seas, the expert group has initiated a joint project on past and potential releases and transport of radionuclides to the Arctic seas from the Chelyabinsk region, and a joint field work was carried out during summer 1994.

As part of the work of the expert group a joint Russian-Norwegian expedition to the Barents and Kara Sea was carried out in 1992, giving information about the general level of contamination especially in the Kara Sea. The results of this investigation were published in 1993 (JRNC, 1993). A summary is given in chapter 4.

In 1993, Russian authorities provided information about the dumping of radioactive waste through the publication of a White Book based on the report of a Russian governmental commission (White Book no. 3, 1993). The report confirmed that a total of 17 nuclear reactors from submarines and the icebreaker "Lenin" had been dumped in the Kara Sea. Some of these reactors still contain spent nuclear fuel. In addition, several thousand containers with low- and intermediate level wastes and some liquid waste had been dumped in the northern areas.

The work of the Russian-Norwegian expert group is important to several international organizations. Information on the progress of the work to the consultative meetings of the London Convention 1972 (LC72) was provided by Norway and the Russian Federation in 1992 and 1993. Norway and the Russian Federation are also cooperating with IAEA in the scientific programme "International Arctic Seas Assessments Project" (IASAP). The objectives of IASAP are to assess the risks associated with the dumping of radioactive waste, and to examine possible remedial actions.

In September-October 1993 the second joint Russian-Norwegian expedition to the Kara Sea was carried out. The purpose of this joint expedition was to investigate the main

dumping sites in the Kara Sea, i.e. the areas where spent nuclear fuel has been dumped. Investigations were carried out in the Tsivolky Bay, the Stepovogo Bay and in an area in the open Kara Sea, as shown in Figure 1.1. The present report gives the results of the investigations of the 1993 expedition.

A joint expedition to the Abrosimov Bay, where a major part of the radioactive waste has been dumped, were carried out in August-September 1994. The results from this expedition will be available in 1995.

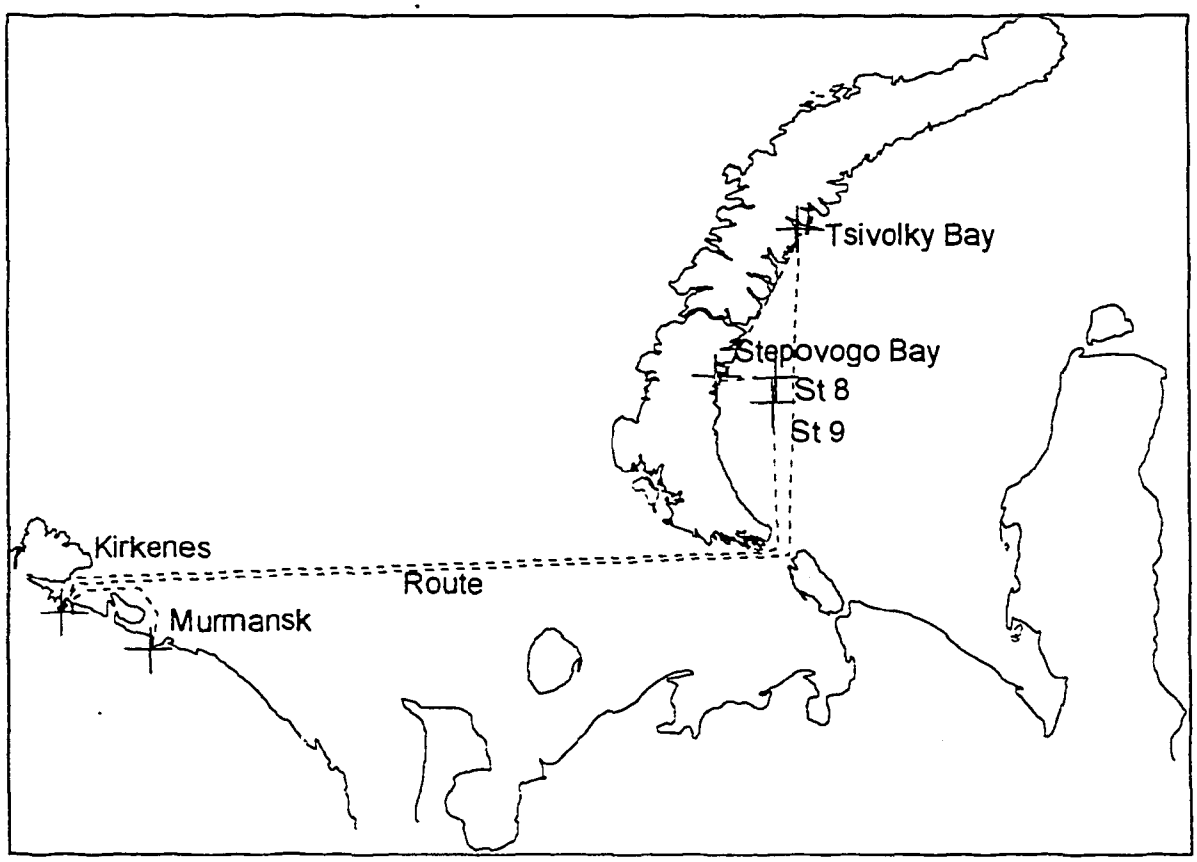

Figure 1.1) Route and sampling areas of the 1993 joint Russian-Norwegian Kara Sea Expedition

2. PRESENT AND POTENTIAL SOURCES CONTRIBUTING TO RADIOACTIVE CONTAMINATION OF THE BARENTS AND KARA SEAS

The major sources contributing to the present level of artificially produced radionuclides in the Barents and Kara Seas are:

- Fallout from nuclear weapons testing (atmospheric, underwater, underground).
- River transport of radionuclides originating from global fallout, or from releases from nuclear installations.
- Marine transport of radionuclides discharged from European reprocessing plants.
- Marine transport of fallout from the Chernobyl accident.

In addition, a contribution from direct discharge of liquid radioactive wastes and leakage of radionuclides from dumped solid radioactive wastes may play a role, especially in the near-field areas.

The river and marine transport to the Arctic Seas have declined since 1950-1960ies and 1980ies, respectively. Additional contribution from rivers may occur from flooding events, while the installation of THORP at Sellafield may contribute to an increase of mobile nuclides (e. g. ^{99}Tc). Leakage from dumped solid wastes is expected to increase as corrosion proceeds.

Additional contributions may arise in the future due to accidental releases associated with:

- nuclear installations, especially the Kola reactors
- handling and storage especially of spent fuel and high activity waste (onboard ships, coastal areas, catchment areas of Ob and Yenisey).
- devices driven by nuclear reactors (submarines and other military vessels, icebreakers, satellites, etc.).
- light houses containing up to 13 PBq ^{90}Sr
- military activities (e. g. nuclear installations, handling, storage, and transportation of nuclear weapons)

2.1 Nuclear weapons tests

Totally 522 atmospheric nuclear weapons tests have been carried out, of these 87 took place at Novaya Zemlya. The major deposition of global fallout occurred during 1955-66. However, the integrated deposition was at its lowest in the polar regions (UNSCEAR, 1982). Still, global fallout is the major source contributing to an overall background contamination level of radionuclides in the Arctic region. At present, the total integrated deposition on ground surfaces at the latitude of the Novaya Zemlya is estimated (tab.

3.1) to be about 1.5 GBq/km^2 (40 mCi/km^2) for ^{137}Cs and about 1.0 GBq/km^2 (27 mCi/km^2) for ^{90}Sr (Boltneva, 1977), i. e. similar to levels for ^{137}Cs reported for northern Sweden (2.2-2.6 GBq/km^2 (60-70 mCi/km^2)) and Finland (2.2 GBq/km^2 (60 mCi/km^2)) during 1964-1969. In Table 2.1 the total deposition of ^{137}Cs and ^{90}Sr in the Barents and Kara Seas for the period 1945-1992 due to atmospheric fallout is estimated (JRNC, 1993).

Global fallout is also transferred to the Arctic Seas by rivers having large catchment areas, by run-off from land, and by sea currents from the Atlantic Ocean. In addition to exchange of waters, redistribution may also occur due to transport of sediments especially in shallow waters and estuaries.

3 Underwater (1955, 1957, 1961) and 45 underground detonations (1961-1990) have been carried out at Novaya Zemlya. The 3 underwater detonations are assumed to have a short-term impact on waters and a longterm impact on sediments. The elevated activity of Pu-isotopes observed in a sediment sample collected outside the Kara Gate in 1992, may be attributed to this source (JRNC, 1993). Even though the 45 underground nuclear tests performed are supposed to have no significant impact on the level of contamination, local effects cannot be excluded.

2.2 River transport

The river transport of radionuclides is attributed to run-off from drainage areas contaminated from global fallout, discharges from nuclear installations and accidental releases. For Yenisey, the main source is previous releases from nuclear installations at Krasnoyarsk. For Ob, the main sources originate from the tributary river systems Techa-Iset-Tobol- Irtysh (discharges from Mayak since 1948, Kyshtym accident 1957, airborne release from Lake Karachay in 1967), Karabolka - Sinara - Iset - Tobol - Irtysh (Kyshtym accident 1957) and from Romashka - Tom rivers (discharges and accidental releases from Siberian Chemical Plant, Tomsk - 7)

It is, however, difficult to estimate the total input of radionuclides to the Arctic seas with river waters especially prior to 1961. The data in open literature are inconsistent, e. g. a) the discharges to the Techa River during 1946-1949 amounted to 102 PBq (2.75 MCi) of beta emitting radionuclides, of which the fraction of ^{90}Sr is about 11.6 % or 11.1 PBq (300 kCi) (Degteva et al,1992), b) discharges of ^{90}Sr to the Techa is estimated to be about 315 TBq (8.5 kCi) (IAEA, 1993), or c) about 630 TBq (17 kCi) of ^{90}Sr was discharged with the Techa river and the Iset river during 1949-1952 (Pasockov,1993). Thus, more precise estimates of the total amount of ^{90}Sr and ^{137}Cs transported to the Arctic seas is needed, and valuable information is expected from the ongoing Joint Russian - Norwegian collaboration on the contamination of radionuclides from the Mayak nuclear installation and the potential impact on the Kara Sea.

Based on the observations carried out by Roshydromet organizations during 1961-1989 (Vakulovsky, 1993) about 1.1 PBq (30 kCi) ^{90}Sr and probably 0.1 PBq ^{137}Cs have been transported to the Kara Sea by the major rivers Ob and Yenisey, while about 0.2 PBq (5 kCi) ^{90}Sr and probably 0.02 PBq (3 kCi) ^{137}Cs have been transported over the same period to the Barents Sea by the rivers Pechora, Onega and Severnaya Dvina (Table 2.1).

2.3 Marine transport from European reprocessing facilities

The two nuclear reprocessing plants at Sellafield (formerly Windscale, UK), discharging since 1952 into the Irish Sea, and La Hague, France, discharging since 1966 into the English Channel, are the main sources of fission products transported along the Norwegian coast to the Arctic Seas. From Sellafield, the principal source with respect to quantities discharged, the transit time to the Barents and Kara Seas is estimated to be 4-6 years. The maximum releases occurring during 1974-1978 were detected in the Barents and Kara Seas (Vakulovsky, Nikitin and Chumichev, 1988), in the White Sea (Vakulovsky et al, 1988) and in the Arctic Ocean (Nikitin, 1991) in the early 1980ies. At that time the concentration of ^{137}Cs in the southern Barents Sea was 30 Bq/m^3 a factor of 5 to 6 higher than the level detected previously due to global fallout. The discharges from Sellafield and La Hague have decreased significantly since then and the level observed in the Kara Sea in 1992 was at its lowest since 1961 (JRNC, 1993).

According to a recent assessment (Kershaw and Baxter, 1993) 41 PBq ^{137}Cs and 6.2 PBq ^{90}Sr have been discharged into the Irish Sea up to 1992. Up to 1985 0.9 PBq ^{137}Cs and 0.8 PBq ^{90}Sr have been discharged into the English Channel. Assuming that about 20 % of ^{137}Cs and 30 % of ^{90}Sr discharged from Sellafield are transported to the Barents Sea, and at least 2% of the North Cape branch waters enter the Kara Sea (Timofeev, 1960; Suhovej, 1986)., the integrated input to the Barents Sea should be 8.2 PBq ^{137}Cs and 1.8 PBq ^{90}Sr and similarly 0.16 PBq ^{137}Cs and 0.03 PBq ^{90}Sr to the Kara Sea.

2.4 Marine transport of fallout from the Chernobyl accident

About 100 PBq ^{137}Cs were released during the Chernobyl accident in April 1986. The former Soviet Union as well as most parts of Europe, especially Central Scandinavia and the Baltic Sea were affected by the fallout. In the polar region of Scandinavia, however, the fallout levels were similar to the present level of global fallout (e. g. 1-2 kBq/m^2 in Norway). The direct deposition in the Kara Sea area is, therefore, assumed to be minor. However, marine transport from the the Baltic Sea (Chernobyl fallout), North Sea and probably run-off from Chernobyl contaminated area in Central Norway into the Norwegian Sea has contributed to the concentration of ^{134}Cs in the Kara Sea as observed in 1992 (JRNC, 1993).

2.5 Discharges of liquid radioactive waste

According to (White Book no.3, 1993), about 0.45 PBq of liquid radioactive wastes (LRW) have been discharged directly into the sea water within five dedicated areas of the Barents Sea. In the Kara Sea, approximately 0.32 PBq of LWR was discharged from the icebreaker "Lenin" in 1975.

2.6 Disposal of solid radioactive waste

According to (White Book No.3, 1993), totally 6 submarine reactors containing spent fuel, part of the spent fuel from one of the reactors of the icebreaker "Lenin" and 11 reactors without fuel have been disposed in three bays at the east coast of Novaya Zemlya and in the dedicated area of the open Kara Sea within the Novaya Zemlya Trough. In the White Book, the maximum total activity was estimated to be 85 PBq (2.3 MCi) for the fuelled reactors and about 3.7 PBq (0.1 MCi) for the empty reactors at the time of disposal. For most of the fuelled reactors furfural-based material has been used as protection barriers. In addition, low and intermediate-level solid radioactive wastes (SRW) resulting from operation of vessel with nuclear reactors, were placed in metal containers and disposed within the dedicated areas. In addition SRW objects were dumped separately or within specialized barges. Totally 574 TBq (15.5 kCi) of SRW were dumped in the Kara Sea, while 1.5 TBq (40 Ci) were dumped in the Barents Sea.

Leakage from the dumped reactors is a potential source of future radioactive contamination of the Kara Sea. The release of radionuclides from sealed reactors is a longterm process and will be dependent on the kinetics of the corrosion processes under the prevailing climate conditions, the quality and quantity of the protection barriers, as well as the physico-chemical forms of the radionuclides.

<u>The sunken nuclear submarine "Komsomolets"</u>
The nuclear installation and warheads onboard the sunken nuclear submarine "Komsomolets" at 1658 m depth close to Bear Island (1989) represents a potential source of contamination. It has been estimated that the reactor contains about 1.55 PBq (42 kCi) of ^{90}Sr and 2 PBq (55 kCi) of ^{137}Cs, and that the nuclear warheads contains approximately 16 TBq (430 Ci) plutonium. Mobile radionuclides released from "Komsomolets" are expected to mix slowly with the huge water masses of the deeper part of the Norwegian Sea and will probably reach biological active layers of the southern part of the Atlantic Ocean in some hundred years. By that time, the activity of ^{90}Sr and ^{137}Cs will be considerably reduced due to radioactive decay.

Table 2.1 Estimated integrated input of ^{137}Cs and ^{90}Sr to the Barents and Kara Seas

Sources	Barents Sea		Kara Sea	
	^{137}Cs (PBq)	^{90}Sr (PBq)	^{137}Cs (PBq)	^{90}Sr (PBq)
Global fallout	2.1	1.5	1.4	1.0
Chernobyl fallout 1)	1-5		0.02-0.10	
River transport				
1949-52, Ob 2), 3)			0.06	0.6 (11.1
1961-89 Pechora,Onega, Severnaya Dvina 4)	0.02	2.0		
1961-89 Ob, Yenisey 4)			0.11	1.1
Marine transport 5)				
1956-92 Sellafield 4)	8.2	1.8	0.16	0.03
1966-85 La Hague 4)	0.18	0.22	0.004	0.004
Waste disposal 6)				
Reactors			Total 85 + 3.7	
SRW	Total 0.001		Total 0.6	
LRW	Total 0.45		Total 0.32	

1) Aarkrog, 1993 (assuming 2 % of the Barents sea leg to the Kara Sea)
2) Pasockow, 1993
3) Degteva et al, 1992
4) Vakulovsky et al, 1993
5) Kershaw and Baxter, 1993
6) White Book no.3, 1993 (Numbers refer to maximum activitites at time of disposal)

3. DUMPING OF NUCLEAR WASTE IN THE BARENTS AND KARA SEAS

General characteristics of the radioactive wastes dumped in the Kara and Barents Seas are presented in the White Book (White Book no.3, 1993).

In Figure 3.1 the locations of the major radioactive waste sites and disposal areas in the West Arctic region of Russia, as used by the former USSR for discharge of liquid waste and dumping of solid radioactive wastes are given (White Book no. 3, 1993).

The total activity of liquid radioactive wastes discharged into the northern seas of Russia is reported to be about 0.8 PBq. About 450 TBq were discharged in the Barents Sea, 315 TBq in the Kara Sea, 3.7 TBq in the White Sea. The discharges of liquid radioactive wastes in the Kara and White Seas had the character of single operations, but in the Barents Sea the discharges were carried out during several years.

Low and intermediate level solid radioactive wastes were dumped in the special chosen areas in the Kara Sea (the bays of Novaya Zemlya and in the Novaya Zemlya Trough). As a rule, solid radioactive wastes were enclosed in metal containers. Large pieces of solid radioactive wastes were disposed separately or within specially designated ships. Summary data on low and intermediate level solid radioactive waste dumped in the Kara and Barents Seas are presented in Table 3.1.

A characteristic feature of the former USSR dumping of radioactive waste was the dumping of objects containing spent nuclear fuel. The data on such objects are summarized in Table 3.2. According to the official information, six reactors with nuclear fuel and one shielding assembly from the nuclear icebreaker "Lenin" with part of the spent nuclear fuel, have been dumped in the bays of Novaya Zemlya and in the Novaya Zemlya Trough. Moreover, in the bays of Novaya Zemlya and in the Kara Sea, 10 reactors without spent nuclear fuel were dumped. Information about these objects are summarized in Table 3.3. These estimates given by Russian experts for the activities in the dumped objects refer to the maximum possible total activity at the time of disposal. As an illustration, these maximum estimated activities dumped in different dumping areas are presented in Figure 3.2.

A proper estimation of radionuclide composition requires detailed knowledge about the fuel and the burnup. Based on information given in the "White Book" estimations of the individual radionuclide activity in the dumped reactors with spent fuel as well as without spent fuel have been performed by several scientists. Most concern has been put on the radionuclide composition in the dumped reactors of icebreaker "Lenin" (Tsivolky Bay) and of the sunken submarine no. 601 in the Stepovogo Bay with reactors with spent nuclear fuel.

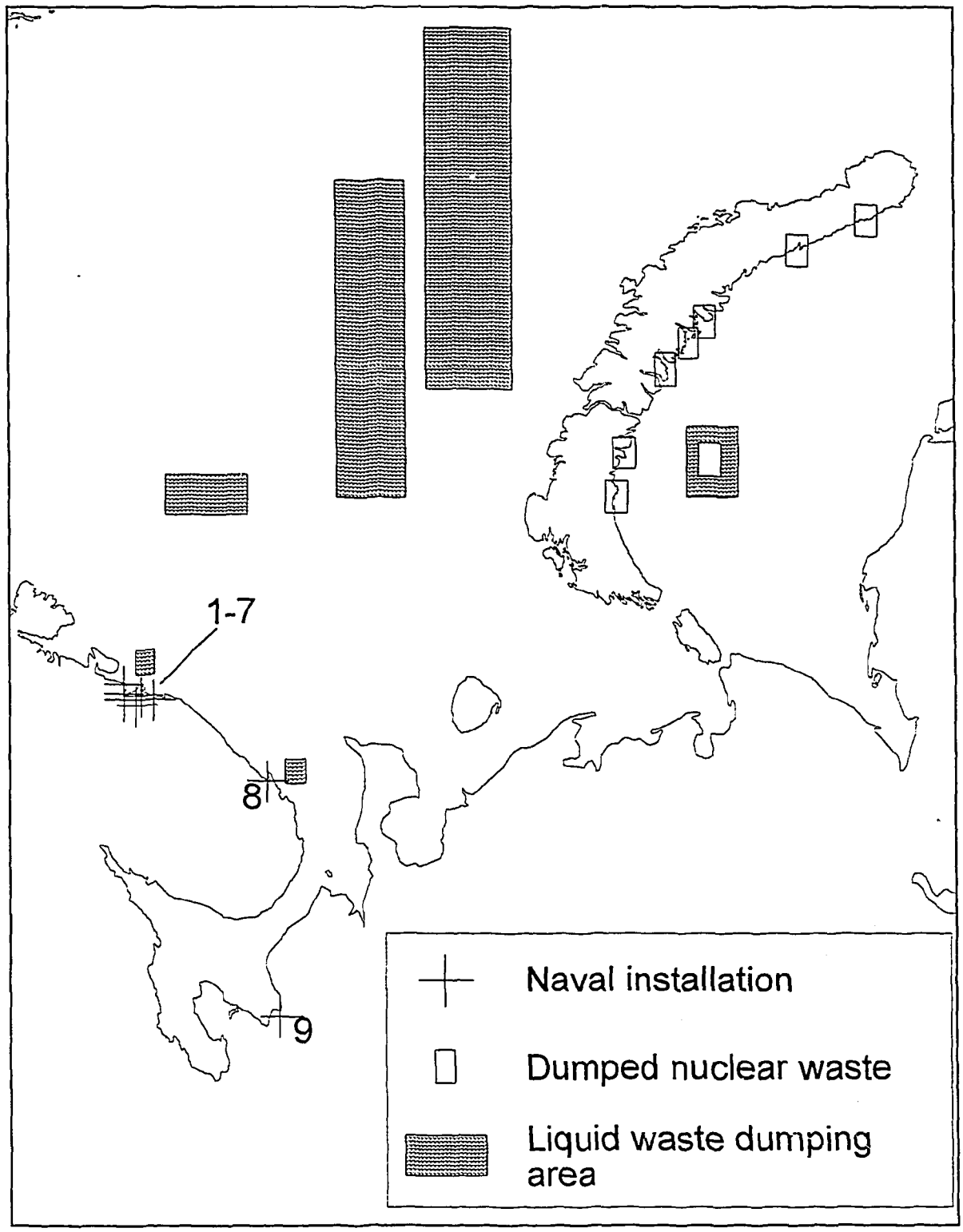

Figure 3.1 Main sources of radioactive waste in North West Russia and dumping areas in the Barents and Kara Seas (White book no. 3)
The numbers indicate various naval installations for nuclear powered vessels

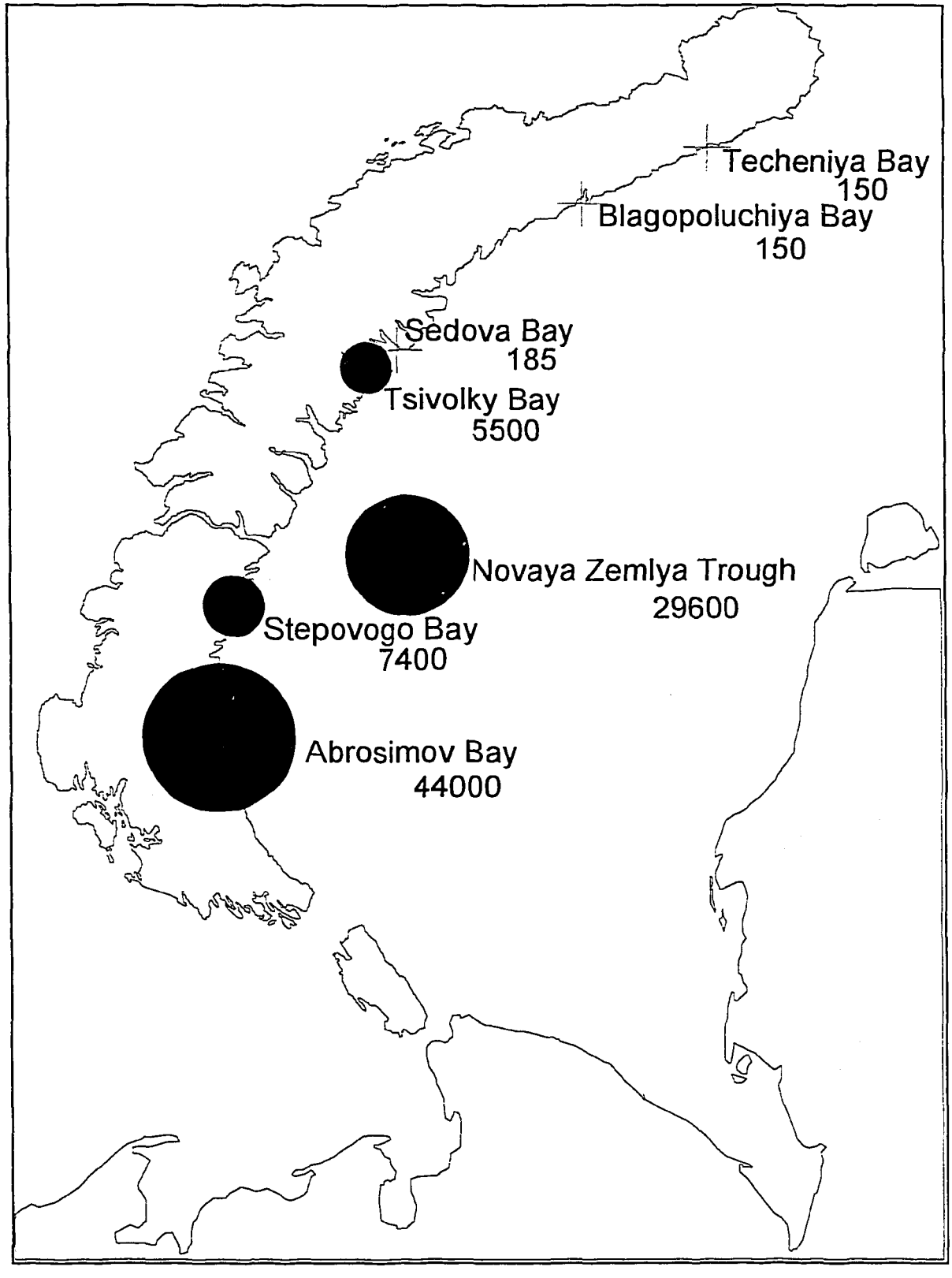

Figure 3.2) Estimates of the maximum total activity in solid waste at the time of dumping for the different dumping areas in the Kara Sea. All numbers are in TBq. (Whitebook no.3, 1993)

3.1 Reactors of the icebreaker "Lenin"

Scientists from the Russian research center "Kurchatov Institute" have performed calculations on the inventory of the reactors of the icebreaker "Lenin" (Sivintsev, 1993). The reactor compartment dumped in Tsivolky Bay contains three reactor pressure vessels without fuel and a special container loaded with part of the spent fuel from reactor no. 2.

The reactor compartment was dumped in August 1967 at the depth of 40-50 m directly from the icebreaker "Lenin" through the bottom part of its hull. Before dumping the spent fuel had been removed from the reactors, primary circuit, dried out and hermetically sealed. The most radioactive inner parts of reactor vessels had been covered by a protective barrier based on furfural.

As a consequence of an accident in February 1965, only 34 fuel elements could be removed from the damaged reactor no.2. The remaining 125 fuel elements were removed from the reactor vessel together with the screening assembly. That part of the damaged spent fuel was inserted in cylindrical stainless steel-concrete-stainless steel container with inner and outer diameter of about 1 m and 2 m, respectively. The container was filled with furfural, and stored on land for about two years.Before dumping this container was transferred from land and put on the top of the reactor compartment being dumped in the Tsivolky Bay.

Based on estimates made by specialists from the "Kurchatov Institute" Center on the activity of individual radionuclides in the dumped reactor compartment on the time of dumping and at present are given in Table 3.4 and 3.5 respectively.

At the time of dumping (1967) the activities in the reactor compartment could be attributed to:

Fission products	470.4 kCi (17.4 PBq)
Activation products	65.8 kCi (2.4 PBq)
Actinides	7.3 kCi (0.27 PBq)
Total	540 kCi (20 PBq)

At present (1993), the activities in the dumped reactor compartment has decreased with a factor of about 10:

Fission products	50.9 kCi (1.88 PBq)
Activation products	6.3 kCi (0.23 PBq)
Actinides	2.3 kCi (0.09 PBq)
Total	59.5 kCi (2.2 PBq)

As seen from Table 3.5, the dominating fission products are now ^{137}Cs and ^{90}Sr, while dominating actinides are ^{241}Pu and ^{239}Pu. Among neutron activation products the activity of ^{63}Ni is at present much higher than ^{60}Co.

The estimates on radionuclide inventories performed by Mount et al.(1993) differ from the estimates of the "Kurchatov Institute" by one order of magnitude. This is due to nonrealistic values of the average full power of the reactor and the effective time of the reactor operation (burnup).

3.2 Nuclear submarine dumped in the Stepovogo Bay

Estimations on the inventory of radionuclides in the reactors of the nuclear submarine dumped in the Stepovogo Bay have been performed by scientists from the Russian Institute of Physics and Power Engineering (Yefimov et al., 1994).

In 1968, there was an accident on one of the reactors of nuclear submarine having a lead-bismuth coolant system (No. 601). In 1981 this submarine was dumped in Stepovogo Bay. The nuclear installation was conserved and prepared prior to dumping. The following barriers prevents sea water from entering the spent fuel of submarine no. 601:

- Submarine hull
- Bitumen in the reactor compartment
- Steel construction of the reactor and primary circuit
- Furfural in the primary circuit
- Lead - bismuth around core
- Cladding of fuel elements
- Fuel matrix

In the Tables 3.6-3.9 estimations of the activities of individual radionuclides performed by E.I. Yefimov et al (1994) for the submarine No. 601 at the time of dumping and at the end of 1993 are presented.

For comparison, earlier estimates made by Mount et al (1993) are also presented. As in the case of icebreaker "Lenin", the activities of fission products were overestimated by Mount.

The total activity of the nuclear power installation of submarine No. 601 at the time of dumping was about 740 TBq (20 kCi), which is an order of magnitude lower than the first official information given (White Book no. 3, 1993).

Table 3.1 Summary data on low- and intermediate-level solid radioactive waste dumped in the Kara and Barents Seas (White Book no.3, 1993).
C - Containers, LO - Large Objects, V - Vessels

Area (See Fig.3.1)	Activity		Number of Dumping operations	Years	Remarks
	Ci	TBq			
1	3320	123	22	1967-1991	3174+? C, 9 LO, 8 V
2	3410	126	8	1982-1984	1108 C, 104 LO
3	2027	75	8	1968-1983	472+? C, 4 LO, 1V
4	2684	99	8	1964-1978	1600+? C, 6 LO, 1V
5	1280	47	5	1968-1975	5 LO
6	661	25	7	1966-1981	8+? C, 7 LO, 4 V
7	235	8	1	1972	1 LO
8	1845	68	3	1982-1988	146+? C, 18 LO, 1 V
Off Kolguyev Island	40	1.5	1	1978	1 V
Chernaya Bay (Novaya Zemlya)	300	11	1	1991	1 LO
Barents Sea	>100	>4	1	?	Barge with solid RW in welded hold
Total	~16000	~590	65		6508+? C , 155 LO, 17 V

Table 3.2. Objects with spent nuclear fuel dumped in the Northern Seas (White Book no.3, 1993) NS = Nuclear submarine, SNF = Spent nuclear fuel.

Object	Coordinates year	Depth, meters	Max. Total Activity PBq (kCi)*	Radionuclide content	Description of protective barriers
Compartment of NS No. 285 with two reactors, one containing SNF in place (see also Table 3.4)	71°56'2"N, 55°18'5" E, Abrosimov Inlet.1965	20	30 (800)	Fission products	Stock reactor compartment and interior structures filled with furfurol mixture
Compartment with two reactors containing SNF from NS No.901	71°56'2"N 55°18'9" E, Abrosimov Inlet. 1967	20	15 (400)	Fission products	Same
Shielding asembly of reactor from OK-150 unit of nuclear icebreaker Lenin with residual SNF (60% of fuel complement based on UO_2)	74°22' 1" N. 58°42'2" E, Tsivolka Inlet-1967	49	3.7 (100)	137Cs (-50kCi),90-Sr(-50 kCi), 238Pu, 241Am, 244Cm (-2kCi)	SNF residue bound by furfurol-based mixture, shielding placed in reinforced concrete container and metal shell
Reactor from NS No-421 with SNF	72°40' N, 58° 10' E, Novaya Zemlya Depression, 1972	300	30 (800)	Fission products	Metal container with lead shell dumped along with barge
NS No.601 with two reactors containg SNF	72°31'15" N, 55° 30' 15" E, Stepovoy Inlet.1981	50	7.4 (200)	Fission products	Stock reactor compartment and interior structures filled with furfurol mixture
Total: 5 objects with 7 reactors containing SNF	1965-1981		85 (2300)		

*) Estimates refer to time of dumping

Table 3.3. Objects without spent nuclear fuel dumped in Northern Seas, 1965-1968.

Object	Coordinates Year	Depth, meters	Total Activity	Radionuclide Content	Description of Protective Barriers
Reactor of NS No.285 (See Table 3.3)	71°56'2" N. 55°18'5" E, Abrosimov Inlet. 1965	20	Requires special analysis	Unclear	Stock reactor compartment structures
Reactor compartment (two reactors) from NS No.254	71°55'13" N, 55°32'32" E. Ambrosimov Inlet.1965	20	Requires special analysis	Unclear	Stock reactor compartment structures
Reactor compartment (two reactors) from NS No.260	71°56'2" N', 55°18'5" E, Abrosimov Inlet. 1966	20	Requires special analysis	Unclear	Stock reactor compartment structures
OK-150 nuclear power plant from icebreaker Lenin, comprising three reactors with primary loop pipelines and watertight stock equipment	74°26'4" N, 58° 37'3" E, Tsivolka Inlet. 1967	50	2 PBq (50 kCi)	Mainly ^{60}Co	Biological shielding unit (B-300 steel, concrete)
Two reactors from NS No. 538	73°59' N, 66°18' E, Techenjye Inlet. 1988	35-40	Requires special analysis	Unclear	Metal container with lead shell
Total: 5 objects with 10 reactors without SNF	1965-1988	20-40	Requires special analysis (possibly up to 4 PBq (100 kCi) at time of dumping)		

Table 3.4
Activity of radionuclides in the reactor compartment from the icebreaker "Lenin" at the time of dumping (1967) (Sivintsev, 1993).

Radionuclide	Activity		
	Ci	Bq	%
Fission products			
Ce-144	1.339×10^{5}	4.954×10^{15}	28.5
Pr-144	1.339×10^{5}	4.954×10^{15}	28.5
Pm-147	6.052×10^{4}	2.239×10^{15}	12.8
Cs-137	2.484×10^{4}	9.191×10^{14}	5.3
Ba-137m	2.350×10^{4}	8.695×10^{14}	5.0
Sr-90	2.296×10^{4}	8.495×10^{14}	5.0
Y-90	2.98×10^{4}	8.503×10^{14}	5.0
Ru-106	1.944×10^{4}	7.193×10^{14}	4.2
Rh-106	1.944×10^{4}	7.193×10^{14}	4.2
Kr-85	2.732×10^{3}	1.011×10^{14}	0.6
Nb-95	2.526×10^{3}	9.346×10^{13}	0.5
Cs-134	1.852×10^{3}	6.852×10^{13}	0.4
Sb-125	1.749×10^{3}	6.471×10^{13}	0.2
H-3	1.080×10^{2}	3.994×10^{12}	0.02
Tc-99	3.630×10	1.343×10^{11}	0.0008
Subtotal	4.704×10^{8}	1.741×10^{16}	100.0
Activation products			
Co-60	4.470×10^{4}	1.650×10^{15}	88.1
Ni-63	6.030×10^{3}	2.230×10^{14}	11.9
Subtotal	5.073×10^{4}	1.873×10^{15}	100.0
Actinides			
Pu-241	6.993×10^{3}	2.587×10^{14}	96.2
Pu-239	1.365×10^{2}	5.050×10^{12}	1.9
Pu-240	6.122×10^{1}	2.256×10^{12}	1.0
Pu-238	3.544×10^{1}	1.310×10^{12}	0.5
Am-241	2.484×10^{1}	9.190×10^{11}	0.3
Subtotal	7.265×10^{3}	2.688×10^{14}	100.0

Table 3.5. Activity of radionuclides in the dumped reactor compartment from the icebreaker "Lenin" at present (1993) (Sivintsev, 1993).

Radionuclide	Activity		
	Ci	Bq	%
Fission products			
Cs-137	1.331×10^{4}	4.925×10^{14}	26.14
Ba-137m	1.259×10^{4}	4.658×10^{14}	24.73
Sr-90	1.208×10^{4}	4.470×10^{14}	23.73
Y-90	1.208×10^{4}	4.470×10^{14}	23.73
Kr-85	4.768×10^{2}	1.764×10^{13}	0.94
Sm-151	2.969×10^{2}	1.099×10^{13}	0.583
Pm147	$4.8.27 \times 10^{1}$	1.786×10^{12}	0.0095
H-3	2.371×10^{1}	8.773×10^{11}	0.047
Tc-99	3.629×10^{0}	1.343×10^{11}	0.007
Sb-125	2.034×10^{0}	7.526×10^{10}	0.004
Subtotal	5.091×10^{4}	1.884×10^{15}	100.0
Activation products			
Co-60	1.300×10^{3}	4.810×10^{13}	20.6
Ni-63	5.000×10^{3}	1.850×10^{14}	79.4
Subtotal	6.300×10^{3}	2.330×10^{14}	100.0
Actinides			
Pu-241	1.908×10^{3}	7.060×10^{13}	82.1
Am-241	1.891×10^{2}	7.000×10^{12}	8.1
Pu-239	1.363×10^{2}	5.040×10^{12}	5.9
Pu-240	6.105×10^{1}	2.260×10^{12}	2.6
Pu-238	2.856×10^{1}	1.060×10^{12}	1.2
Subtotal	2.325×10^{3}	8.601×10^{13}	100.0

Table 3.6. Activity of radionuclides in the reactors from the nuclear submarine no. 601 at the time of dumping and at present (Yefimov et al, 1994).

Nuclide	Half - life Years	Activity, Bq		
		1981, time of dumping	end 1993	1993, estimation of Mount et al,(1993)
Kr-85	10.72	1.6×10^{13}	7.0×10^{12}	
Sr-90	28.6	1.6×10^{14}	1.18×10^{14}	(1.19-1,24)x10^{15}
Tc-99	2.15×10^{5}	3.1×10^{10}	3.1×10^{10}	3.3×10^{11}
Cd-113m	13.7	2.35×10^{10}	1.23×10^{10}	
Sb-125	2.73	1.6×10^{12}	5.85×10^{10}	(2.6-3.3) x 10^{11}
I-129	1.57×10^{7}	6.5×10^{7}	6.5×10^{7}	(3.7-7.4) x 10^{8}
Cs-134	2.06	2.22×10^{11}	3.8×10^{9}	(0.74-2.2)x 10^{11}
Cs-135	3.0×10^{6}	3.23×10^{9}	3.23×10^{9}	
Cs-137	0.17	1.74×10^{14}	1.3×10^{14}	1.31×10^{15}
Pm-147	2.62	2.88×10^{13}	1.2×10^{12}	(0.83-1.35) x 10^{13}
Sm-151	90	4.10×10^{12}	3.7×10^{12}	(1.73-3-2) x 10^{13}
Eu-152	13.33	1.2×10^{14}	6.4×10^{13}	
Eu-154	8.8	3.6×10^{13}	1.4×10^{13}	4.9×10^{12}
Eu-155	4.96	5.9×10^{11}	1.11×10^{11}	(1.54-1.88) x 10^{12}
H-3	12.33	1.0×10^{14}	5.0×10^{13}	

Table 3.7 Activity of minor actinides in reactor cores from nuclear submarine no. 601 (Yefimov et al, 1994).

Nuclide	Physical Half - life, years	Activity, Bq		
		1981, time of dumping	end 1993	1993, estimation of Mount et al (1993)
Np-237	2.14×10^{6}	9.42×10^{7}	9.42×10^{7}	
Pu-238	87.74×10^{6}	9.27×10^{9}	8.56×11^{9}	$(3.3\text{-}45.5) \times 10^{11}$
Pu-239	2.41×10^{4}	3.40×10^{11}	3.40×10^{11}	$(2.04\text{-}10.7) \times 10^{12}$
Pu-240	6570	6.5×10^{9}	6.50×10^{9}	
Pu-241	14.35	5.1×10^{10}	2.76×10^{10}	$(2.9\text{-}130) \times 10^{12}$
Am-241	432	1.4×10^{9}	2.13×10^{9}	
Am-242	141	4.9×10^{4}	4.62×10^{4}	$(2.22\text{-}102) \times 10^{11}$
Am-243	7380	1.32×10^{3}	1.32×10^{3}	
Cm-242	0.446	4.1×10^{4}	3.9×10^{4}	
Cm-243	28.5	2.80×10^{2}	2.1×10^{2}	
Cm-244	181	$1{,}65 \times 10^{4}$	1.0×10^{4}	

Table 3.8. Activity of the main long lived radionuclides in reactor components from nuclear submarine no. 601 (Yefimov et al, 1994).

Nuclide	Physical Half - life, years	Activity, Bq		
		1981, time of dumping	end 1993	1993, estimation of Mount et al. (1993)
Co-60	5.27	4.84×10^{12}	1.0×10^{12}	4.0×10^{13}
Ni-59	7.5×10^{4}	1.0×10^{9}	1.0×10^{9}	3.5×10^{12}
Ni-63	100.1	1.7×10^{12}	1.5×10^{12}	3.13×10^{14}

Table 3.9 Activity of main long - lived radionuclides in lead - bismuth coolant, nuclear submarine no.601 (Yefimov et al, 1993).

Nuclide	Half - life, years	Activity, Bq	
		1981, time of dumping	end 1993
Co-60	5.27	6.8×10^{9}	1.4×10^{9}
Ni-63	100.1	1.1×10^{11}	1.0×10^{11}
Bi-207	32.2	3.9×10^{10}	3.0×10^{10}
Bi-208	3.66×10^{5}	1.4×10^{10}	1.4×10^{10}
Bi-210	3.0×10^{6}	3.0×10^{9}	3.0×10^{9}

4. SUMMARY OF THE RESULTS FROM THE 1992 RUSSIAN- NORWEGIAN EXPEDITION TO THE BARENTS AND KARA SEAS

The expedition in 1992 was performed in order to characterize the present radioactive contamination in the area. The expedition took place during August 14 - September 10, 1992 with the research vessel "Viktor Buynitsky". The participants included Russian and Norwegian scientists as well as a representative from the International Atomic Energy Agency, as observer.

Water samples, sediments and biota were collected at 2 stations in the Barents Sea and 11 stations in the Kara Sea. The results from the 1992 expedition were published by the Russian-Norwegian Expert Group in 1993 (JRNC, 1993).

A summary of the results of the concentrations of ^{137}Cs, ^{90}Sr, ^{238}Pu, $^{239,240}Pu$, ^{241}Pu, ^{241}Am and ^{99}Tc in sea water are given in Table 4.1 and the geographical distributions of ^{137}Cs and ^{90}Sr in surface water are illustrated in Figure 4.1. The area of the circles is proportional to the activity levels of the radionuclide in the surface sea water.

The distribution of ^{137}Cs and ^{99}Tc demonstrated a concentration gradient with highest values in high salinity waters at the Kara Gate and along the east coast of Novaya Zemlya, while lower values were found in the low salinity water originating from the estuary of the river Ob. For ^{90}Sr, the concentration gradient reflected a contribution from river transport.

Some difference were observed in the vertical distribution of ^{137}Cs and ^{90}Sr in the low salinity waters outside the estuaries of rivers Ob and Yenisey. The surface waters were enriched in ^{90}Sr compared to ^{137}Cs, while at all other stations ^{137}Cs concentration was higher than ^{90}Sr at all depths. Especially at stations along the east coast of Novaya Zemlya, higher concentrations of ^{137}Cs were observed in the saline bottom water, than in the surface water.

The activity ratios between the different radionuclides were utilized for estimating the contribution from different sources to the contamination of the Kara Sea. The ratio of $^{134}Cs/^{137}Cs$ in sea water was relatively constant (in the range 0.019-0.034), and systematic geographical variations can not be seen. The known sources of ^{134}Cs are the discharges from Sellafield reprocessing plant and Chernobyl fallout. Assuming that the ratio of $^{134}Cs/^{137}Cs$ in the Sellafield discharges was 0.08 (1980-85) (UNSCEAR, 1988) at the time of discharge, and taken the 5-6 year transport time and the low discharges after the mid 1980's into account, the ^{134}Cs contribution from Sellafield would be negligible in 1992. In August 1992, the $^{134}Cs/^{137}Cs$ ratio in the Chernobyl fallout was 0.074. This implies that if Chernobyl is the only source of ^{134}Cs, approximately up to 30 % of the ^{137}Cs in the surface water in the Kara Sea would originate from the Chernobyl accident.

Table 4.1 Concentration of ^{137}Cs, ^{90}Sr, ^{99}Tc, ^{129}I, ^{238}Pu, $^{239,240}Pu$ and ^{241}Am, in the sea water samples from different stations and different depths (1992).

Station no	Depth meter	Salinity	Water temp.	^{137}Cs	^{90}Sr	^{99}Tc	^{129}I	^{238}Pu	$^{239,240}Pu$	^{241}Am
		0/00	^{0}C	Bq/m^3	Bq/m^3	mBq/m 3	mBq/m 3	mBq/m 3	mBq/m^3	mBq/m^3
1	0	33.0		8.1	3.8	197	2.6	0.3	4.0	0.6
	28			11.2	3.6					
	70			6.3	3.8			n.d	6.8	
	170			12.6	5.6			0.1	7.4	0.9
2	0			5.3	3.7			0.2	3.5	n.d
	80			7.6	3.7			0.6	5.4	1.2
	190			10.8	3.8			n.d	8.6	n.d
3	0	28.3	2	6.2	3.5	156	2	n.d.	3.5	n.d
	80	27.6	-1	10.5	4.7			0.5	7.3	0.9
	323	27.5	-2	20.4	6.4			1.4	16.0	1.8
4	0	15.2	4	5.5	11.4			n.d	4.4	0.8
	70	27.6	-1	12.1	5.3			0.8	7.3	2.6
	250	27.5	-2	18.3	6.0			0,7	10.5	n.d
5	0	8.6	3	3.8	8.3	64	1.2	0.3	7.7	1.5
	7	9.3	3	3.7	12.1			0.8		
	85	34.0	-1	10.1	4.5			n.d	7.9	
	120	34.3	-1	10.7	4.8				n.d	0.5
6	0	10.1	3	3.3	6.7	63	1.2	n.d	4.3	0.5
	16	29.6	1	11.0	5.1			n.d	9.2	0.9
7	0	21.6	3	7.7	5.5	172	1.9	0.1	1.8	
	75	34.3	-1	11.9	4.0			n.d	5.3	n.d
	170	34.5	-1	9.8	4.5			n.d	7.2	
8	0	30.3	4	6.5	4.3			n.d	2.8	n.d
	70	34.4	-1	9.3	4.0			n.d	6.0	n.d
	124	34.4	-1	8.8	3.9			n.d	6.8	
9	0	20.5	3	7.6	6.3	135	1.8	n.d	3.0	0.5
	10	30.5	3	10.0	5.7			n.d	3.1	n.d
	20	34.1	-1	12.7	3.8			n.d	8.9	0.7
10	0	30.9	3	7.2	3.1	150	1.8	0.3	2.5	n.d
	50	34.1	-2	10.4	3.0			0.2	3.8	n.d
	115	34.5	-2	8.6	3.5			n.d	6.2	
11	0	30.8	4	7.3	3.8	155	1.8	0.2	3.1	n.d
	40	34.0	-1	7.7	3.3					1.2
	87	34.5	-1	7.8	3.6			0.4	5.4	n.d
12	0	31.1	7	7.4	3.6	157		n.d	2.0	n.d
	35	33.8	4	6.5	3.3			0.1	5.2	
	85	34.5	-1	6.1	3.3			n.d	7.4	0.2
13	0	33.9		5.1	4.2	144		0.2	7.5	0.7
	100			4.4	3.6				11.5	0.2

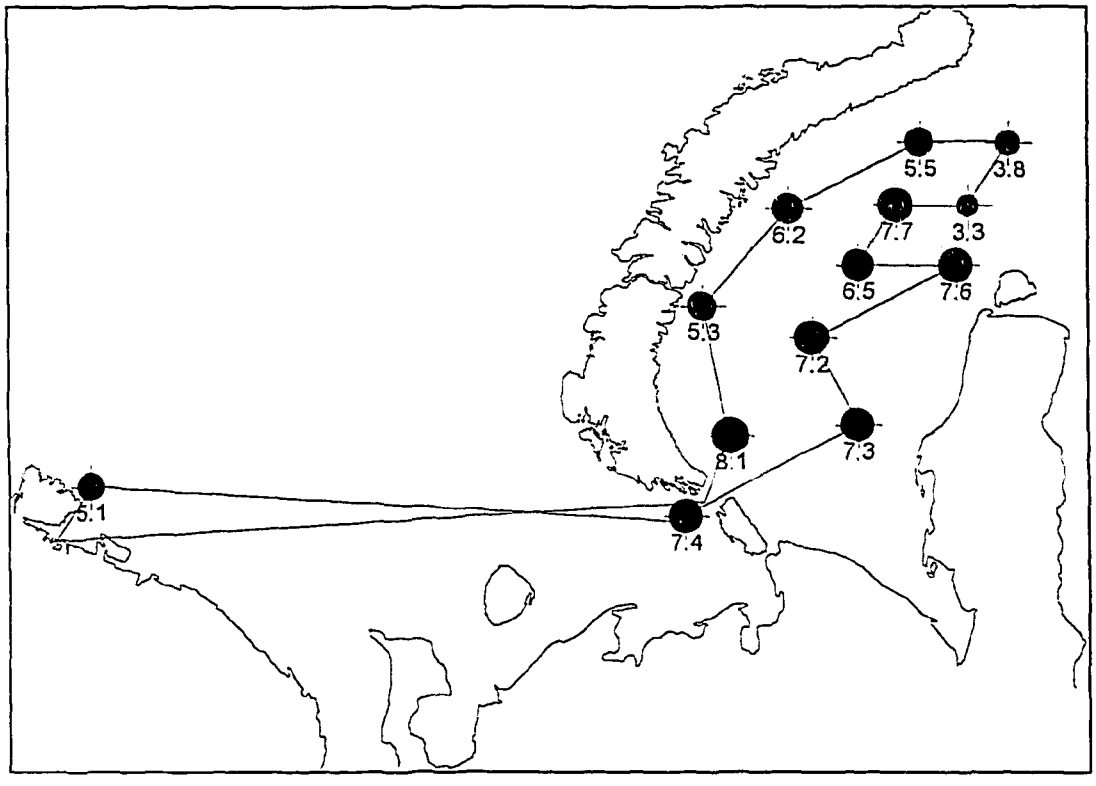

Figure 4.1a) Concentrations of ^{137}Cs in surface water (Bq/m^3) (JRNC, 1993)

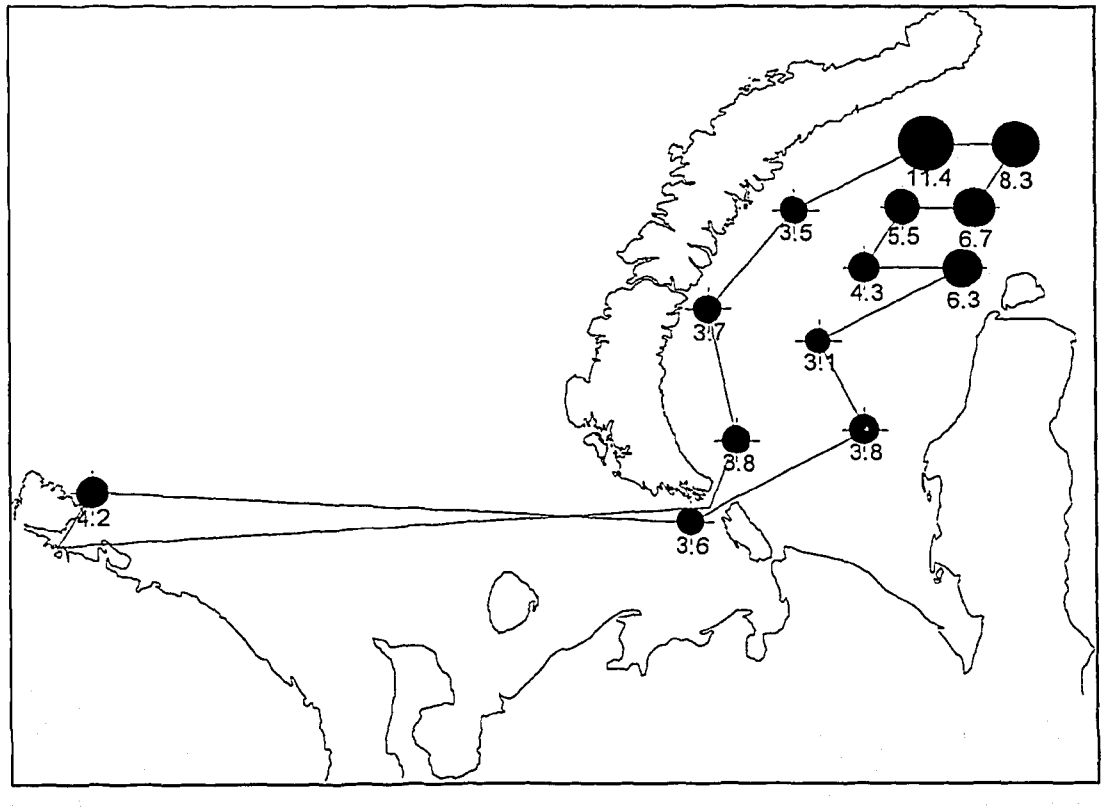

Figure 4.1b) Concentrations of ^{90}Sr in surface water (Bq/m^3) (JRNC, 1993)

The geographical distribution of the $^{90}Sr/^{137}Cs$ ratio varied in the Kara Sea. The high value of the $^{90}Sr/^{137}Cs$ ratio in the north east Kara Sea strongly correlates with low salinity, which indicate the importance of the river input of ^{90}Sr.

The total activity of ^{137}Cs and ^{239}Pu in sediments 0-10 cm from all stations is shown in Figure 4.2. It is seen that sediments close to the Kara Gate station have higher activity levels, especially for plutonium, than the stations in the Kara Sea. The source of this additional activity may be underwater nuclear explosions.

During the last 30 years several expeditions to the Arctic seas have included the measurements of radionuclides in their analytical program. In the Kara Sea, however, relatively few results are available from previous investigations. The highest concentration of ^{90}Sr was observed during the atmospheric weapons testing (Vakulovsky et al, 1993). The concentration has decreased with time, reaching a level of 3-11 Bq/m^3 for surface waters as found in the 1992 expedition.

The present results, and the comparison with data from previous investigations allow the following main conclusions to be drawn:

At present the level of concentration of radionuclides in the Barents and Kara Seas is low and can be attributed to global fallout, releases from the Sellafield reprocessing plant, contribution from the rivers Ob and Yenisey and Chernobyl fallout. However at one location (the Kara Gate outside the Kara Sea), sediments were one order of magnitude higher in plutonium than at the other stations in the Kara Sea.

The radiological impact on man and the environment as a result of the levels of radioactive contamination observed in 1992 is extremely low.

The observed levels of radioactive contamination are lower or similar compared to other marine systems. The levels of radioactive contamination in the Kara Sea are for example lower than present levels in the Baltic Sea, the Black Sea, the North Sea and the Irish Sea.

Comparison with the results from previous investigations shows that the present level of radioactive contamination in the Kara Sea are lower than the levels reported from all earlier investigations during the period 1963-1992.

The results of this investigation show that, in 1992, the influence of the dumped radioactive wastes on the general level of radioactive contamination in the Kara Sea was insignificant. However, local effects in the vicinity of the dumping sites could not be excluded, as these areas had not yet been investigated.

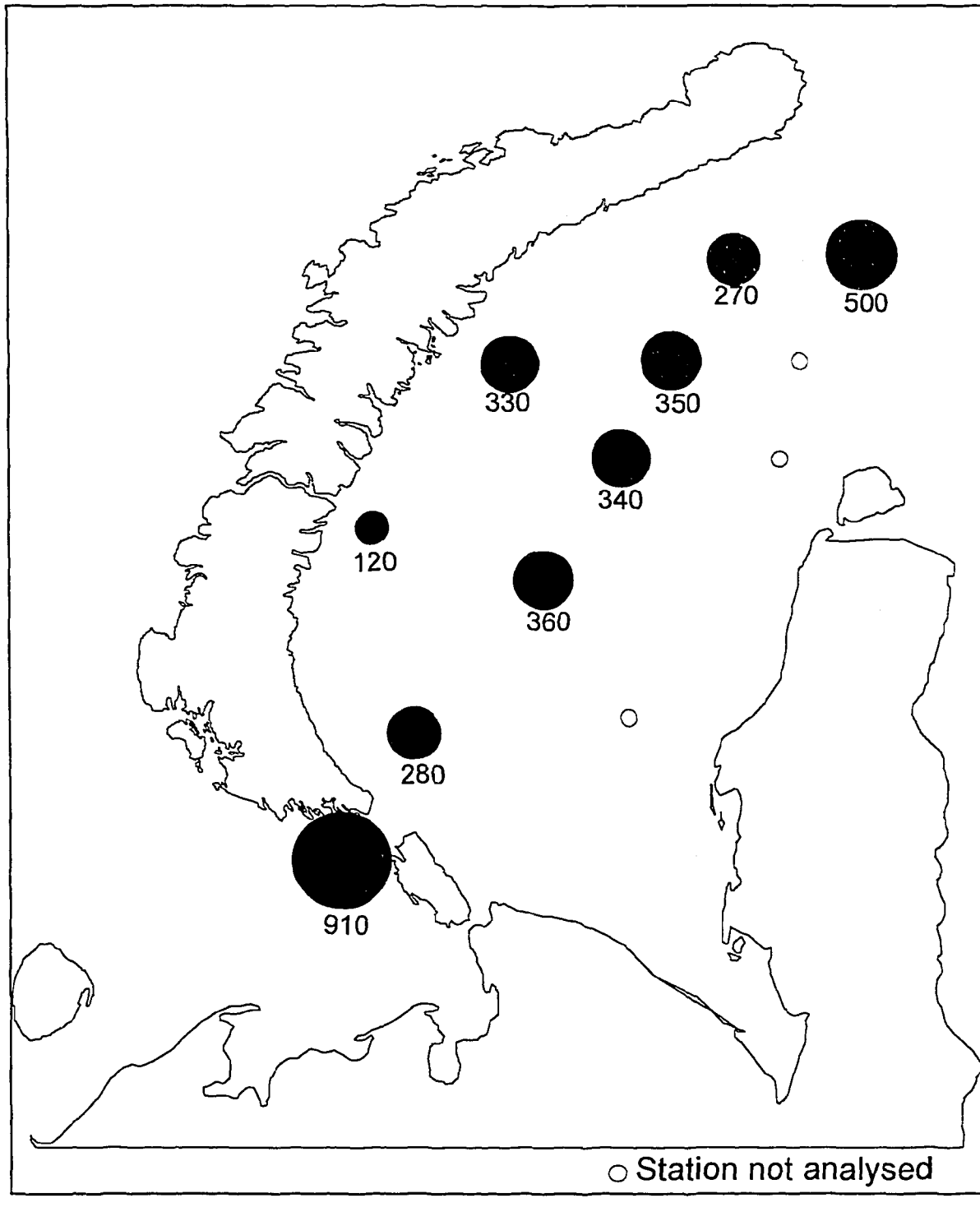

Figure 4.2a) The amounts of ^{137}Cs (Bq/m^2) in the upper 10 cm of sediments in the Kara Sea (JRNC 93)

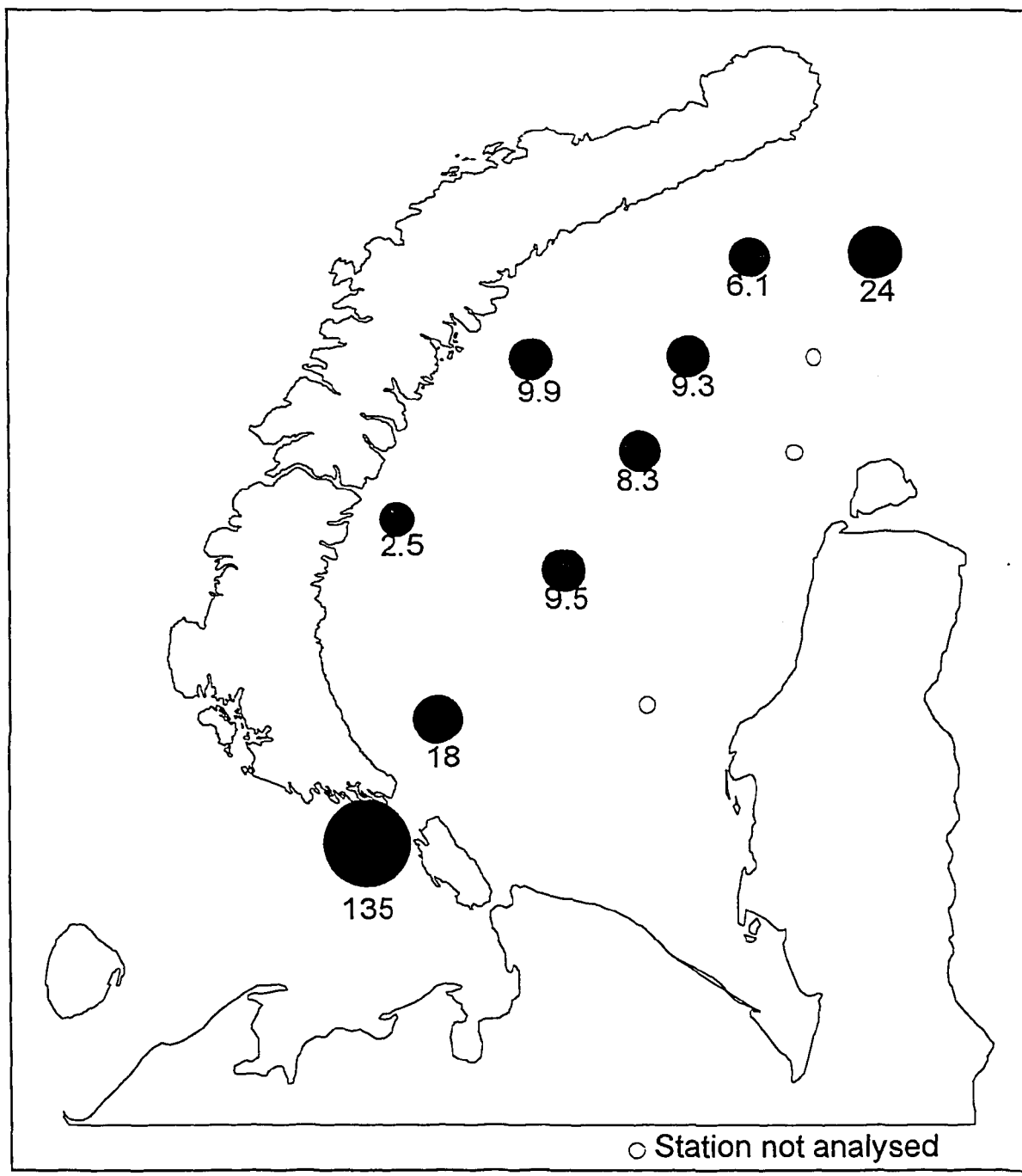

Figure 4.2b) The amounts of $^{239,240}Pu$ (mBq/m^2) in the upper 10cm layer of sediments in the Kara Sea (JRNC, 93)

5. UNDERWATER MEASUREMENTS AND TECHNICAL INSPECTIONS

5.1 Hydrographical parameters at the dumping sites

During the 1993 cruise nine hydrological sets of measurements were performed to determine temperature, salinity and sigma T, using a Gytre mini-CTD (Gytre, 1991) fixed to the hydrography wire of the ship. Of these, four measurements were performed in the Tsivolky Bay, three in the Stepovogo Bay and two in the open part of the Kara Sea, i.e. the Novaya Zemlya Trough.

5.1.1 The Tsivolky Bay

The vertical profiles of temperature and salinity at the stations 1 - 4 show the presence of two well-defined water masses. The first one consists of the surface water of the bay. This layer is formed due to the inflow of fresh water (rivers and glaciers). The temperature is 3-5 ^{0}C on the surface (fig. 5.1). The vertical temperature profiles were characterised by an increase in the upper part of the thermocline. The salinity of this water mass changes from 14-15 ‰ on the surface to 18-19 ‰ at the lower boundary.

The second water mass layer consists of Kara Sea water located from the thermocline to the bottom. The temperature was about 1 ^{0}C near the thermocline and -1.5 ^{0}C near the bottom. The salinity ranged within 33.5 - 34.0 ‰ and 34.4 - 34.8 ‰, respectively.

5.1.2 The Stepovogo Bay

The vertical profiles for the Stepovogo Bay were somewhat different from those in the Tsivolky Bay (fig. 5.2). At the stations 5 and 7 the depth was not more than 40 m and no clear temperature gradients were found. The salinity decreased gradually from 17-20 ‰ on the surface to 25-28 ‰ near the bottom. The water at these stations was characterised by desalination of the Kara Sea water with fresh water flowing from the Novaya Zemlya.

At station 6, having a somewhat greater depth, the vertical distribution of temperature and salinity was more similar to that in the Tsivolky Bay. The desalinated water was observed down to the depth of 25 m, the temperature in the layer varied within 3.7 to 2.7 ^{0}C and the salinity from 20.0 to 27.0 ‰. The thermocline was 6-7 m and located at 25-31 m depth. The temperature in the near-bottom layer varied within -1.0 and -1.7 ^{0}C and the salinity between 34.0 and 34.8 ‰.

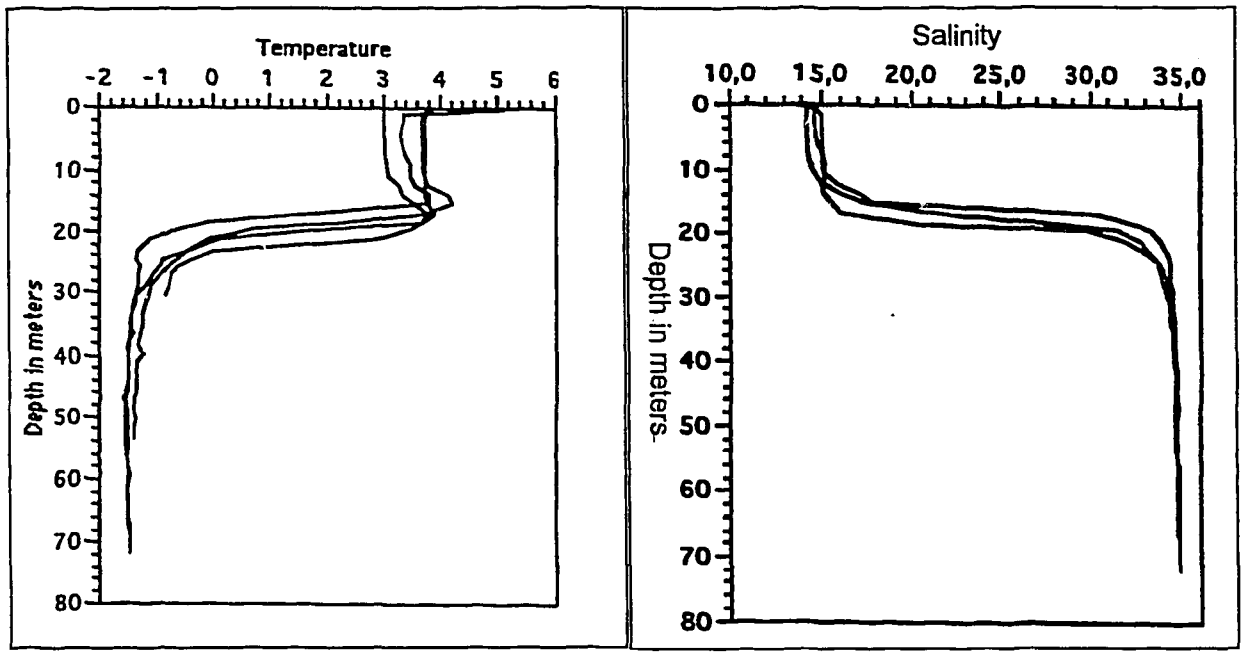

Figure 5.1 Temperature and salinity profiles from the Tsivolky Bay

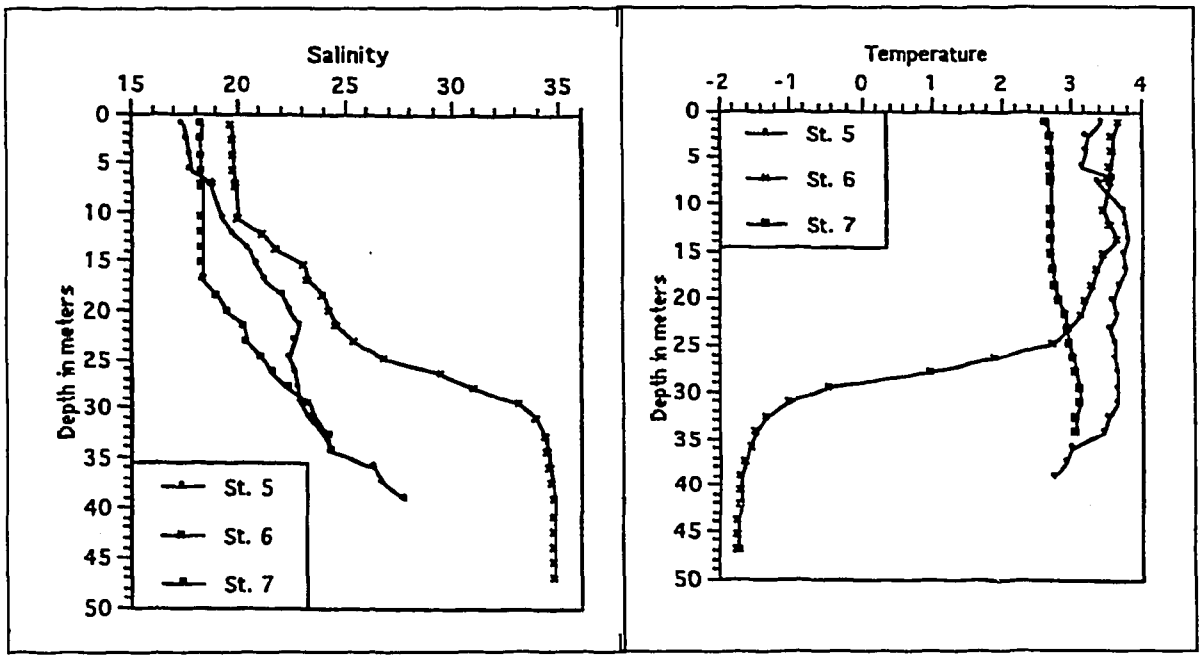

Figure 5.2 Temperature and salinity profiles from the Stepovogo Bay

5.1.3 The dumping site in the Novaya Zemlya Trough

In the trough stretching along the eastern coast of the Novaya Zemlya (stations 8 and 9), the water was studied down to 360 m depths (fig. 5.3). The two vertical profiles of temperature and salinity indicate the presence of four water mass layers. The upper layer of 0-20 m was relatively warm and desalinated (about 32 ‰) because of the influence of fresh water originating from the Ob and Yenisey rivers. The water temperature of this layer was found to be within 2.1 - 2.5 °C. In the layer between 20 and 80 m the Kara Sea water masses with temperature as low as -1.75 °C were dominant. There was a certain increase in the temperature in the layer within 80-240 m, reaching maximum temperature of -1.43 °C. This water mass is, most probably, the deep cold waters from the Central Atlantic Basin. Below this water mass, another decrease of temperature was observed, practically close to the freezing point (the minimum was -1.86 °C). This water mass is formed during the winter time as a result of ice formation and is characterized by very low temperature and high salinity. Due to the high density, it descends to the near-bottom layers and can build up in troughs.

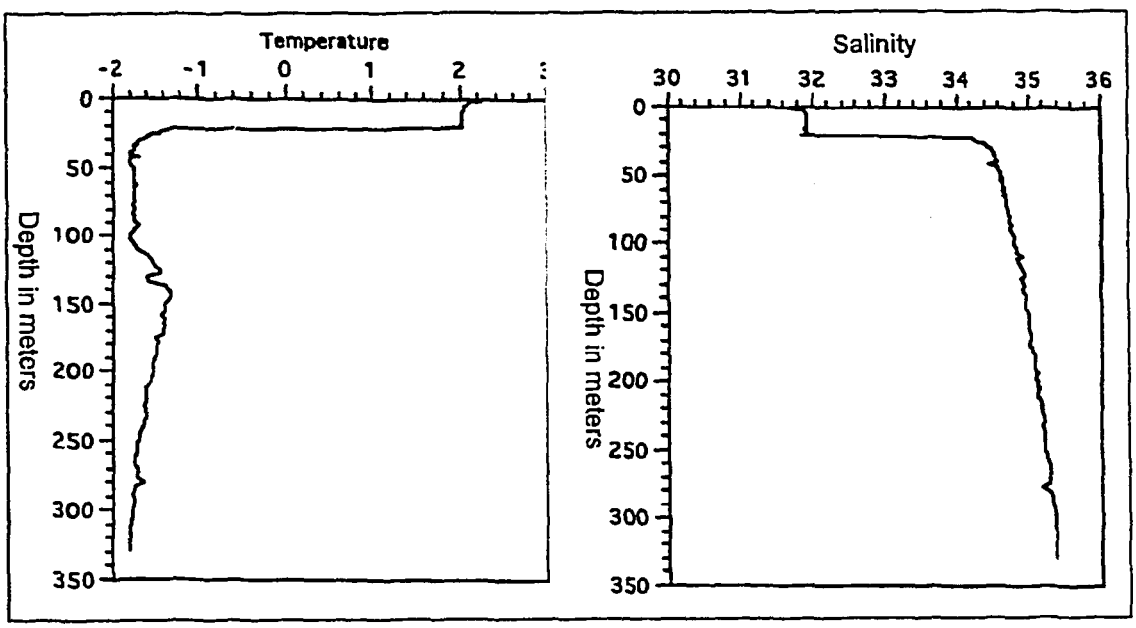

Figure 5.3) Temperature and salinity profiles from the open Kara Sea

5.2 Inspection of dumped objects using side scanning sonar and underwater camera

In order to find the main dumped objects, a grid of course lines was made, covering the positions described in White Book No. 3. A high-frequency side scanning sonar was then deployed and towed after the ship following the grid with a speed of 2 - 3 knots (Føyn and Nikitin, 1993). When a relevant object was recognized on the sonar screen, a buoy for marking its exact position was dropped from the ship. Sonar screen pictures from the Tsivolky Bay are shown in Figure 5.4.

The area was surveyed by several sonar searches in order to confirm the findings of the objects on the bottom. The best defined objects were then chosen for closer investigations by the use of the remote operated vehicle (ROV). The ROV was equipped with a high frequency sonar, a video camera, and sediment and water sampling devices. It was also equipped with radiation detectors.

The two largest localised objects were a cargo vessel in the Tsivolky Bay and a submarine in the Stepovogo Bay. The turbidity of the water in the Tsivolky Bay was a considerable hindrance to the video camera search. The visibility in front of the ROV was about one meter, only (Føyn and Nikitin, 1993). Nevertheless, it was possible to obtain useful close-up pictures of the cargo vessel, as shown in Figure 5.5. In the Stepovogo Bay, the turbidity was less than in the Tsivolky Bay, but the visibility was still too low to allow pictures of the entire submarine to be taken. Figure 5.6 illustrates details from parts of the submarine.

The degree of corrosion of the studied objects is difficult to judge from the video pictures because the objects were heavily covered by algae and crustaceans.

5.3 Underwater radiation measurements with submersible detectors

The expedition was equipped with different types of submersible detectors to be used in the investigations of the dumped radioactive waste objects (Føyn and Nikitin, 1993).

The Norwegian team brought one 3" x 3" NaI(Tl) gamma detector and one BF_3 neutron detector mounted on the ROV connected via separate cables to a multichannel analyser and PC system on board. The Russian team brought a submersible 80 x 400 mm NaI(Tl) detector enclosed in a steel capsule and connected to multichannel analysers on board. The IAEA crew member brought a submersible spectrometrical system consisting of a HPGe and a 4" x 6" NaI(Tl) gamma detector, multichannel analysers and a PC system.

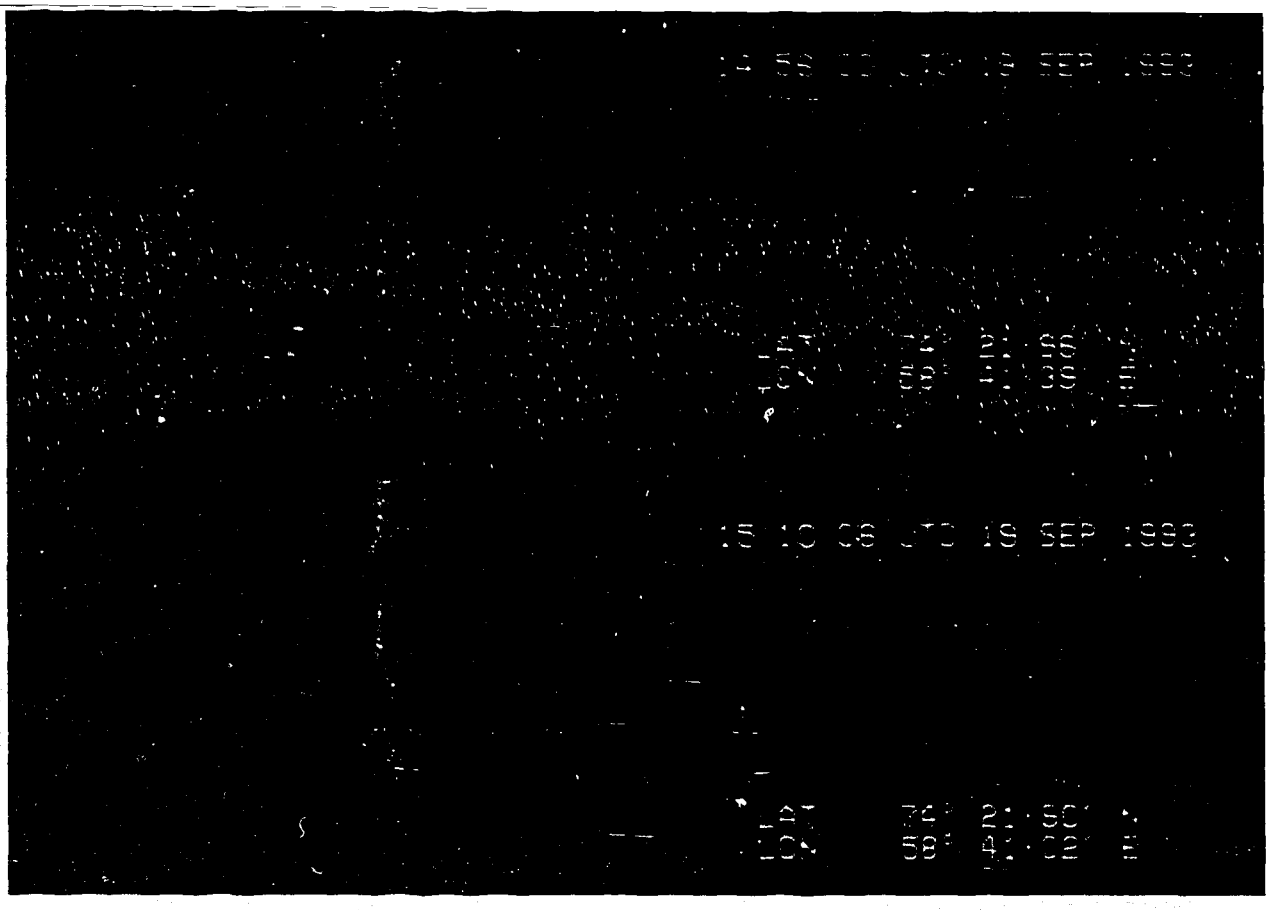

Figure 5.4a Pictures taken in the Tsivolky Bay using side scanning sonar. Various dumped objects are shown.

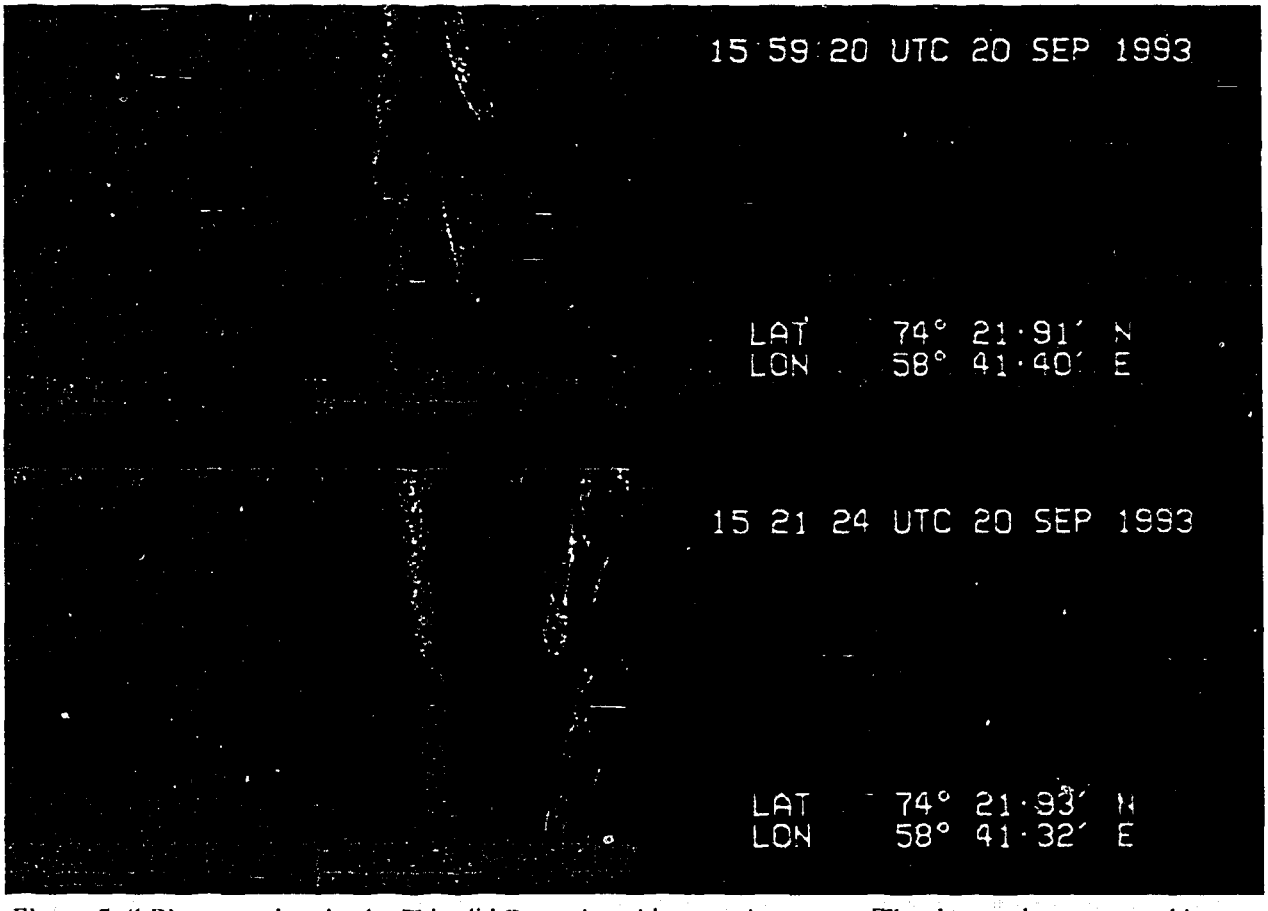

Figure 5.4b Pictures taken in the Tsivolki Bay using side scanning sonar. The dumped cargo vessel is shown.

Figure 5.5 Pictures taken using the video camera on the ROV. The four pictures are from various parts of a large cargo vessel dumped in the Tsivolky Bay.

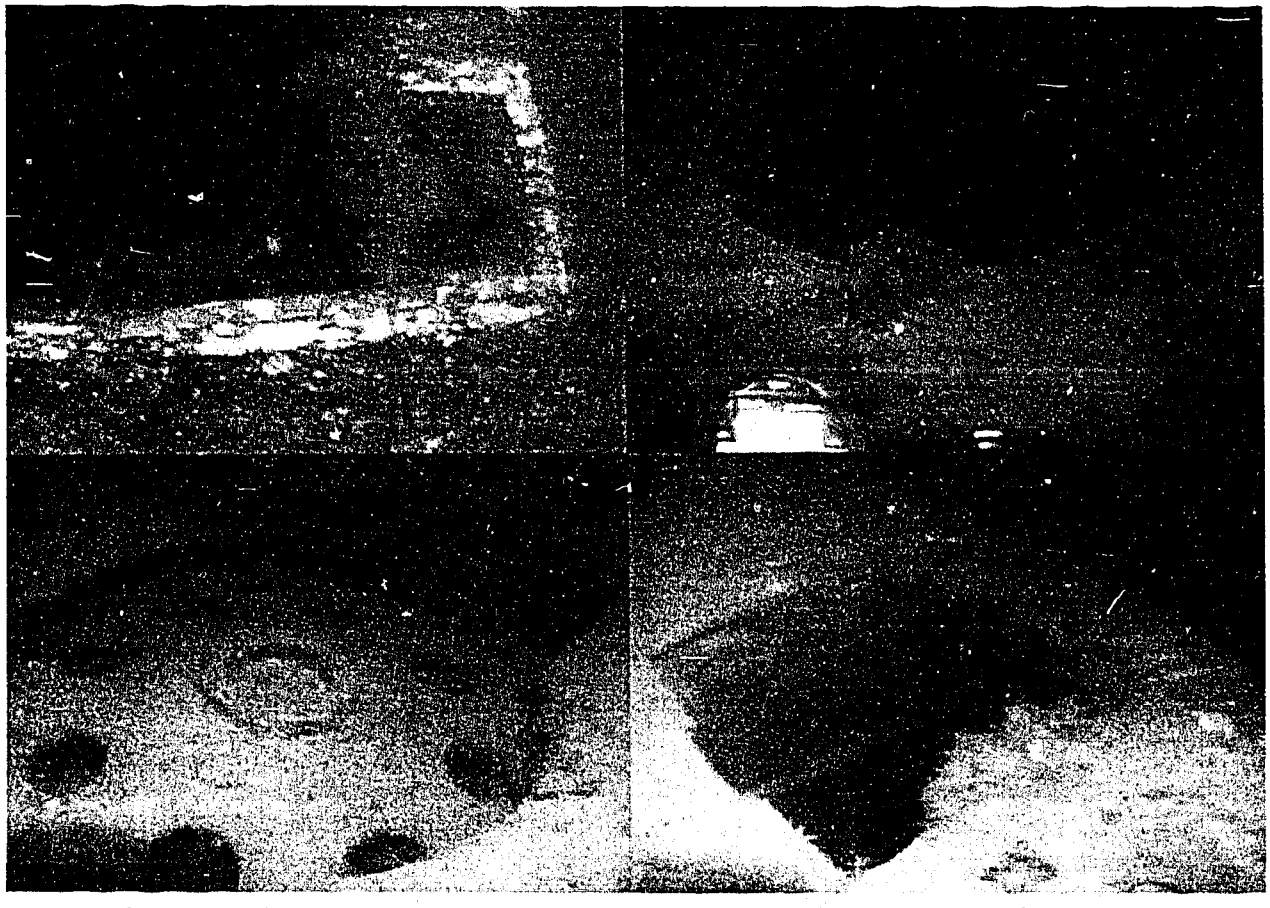

Figure 5.6 Pictures taken using the video camera on the ROV. The four pictures are from various parts of the dumped submarine in the Stepovogo Bay.

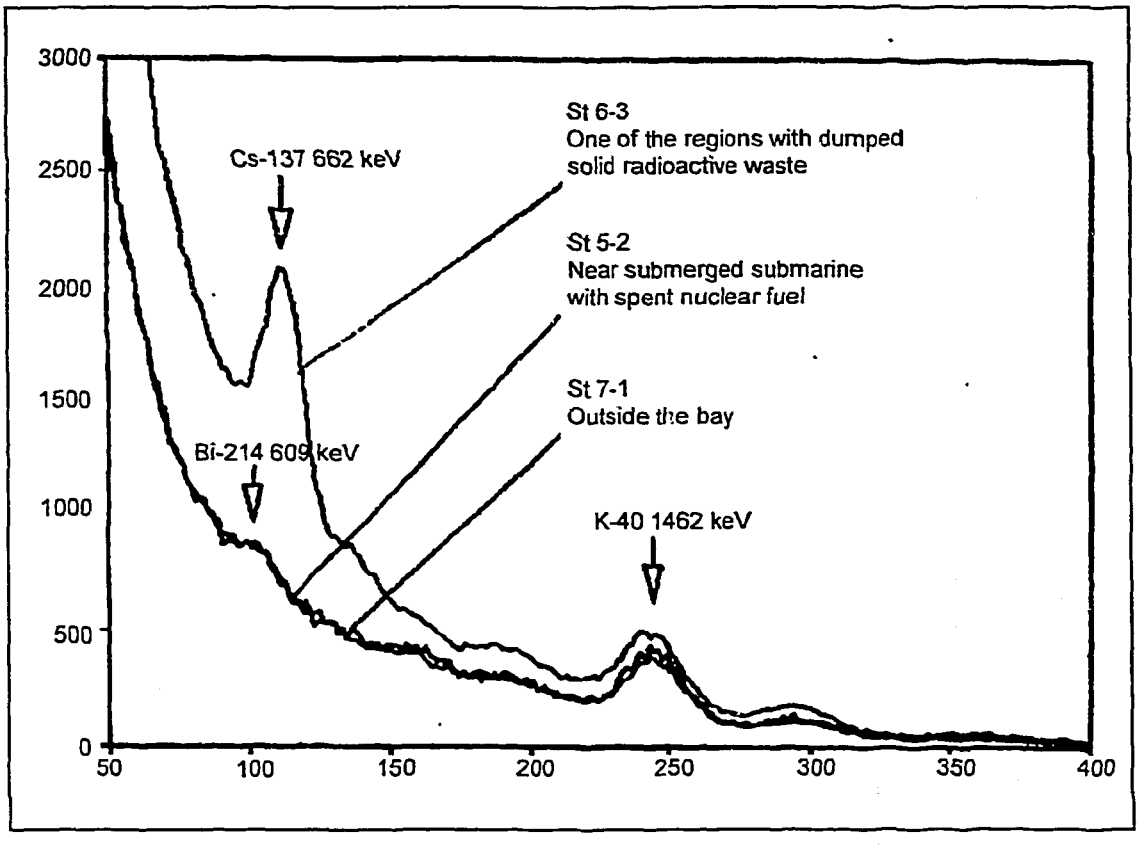

Figure 5.7) Gamma spektrum of bottom sediments form the Stepovogo bay recorded with an underwater NaI detector

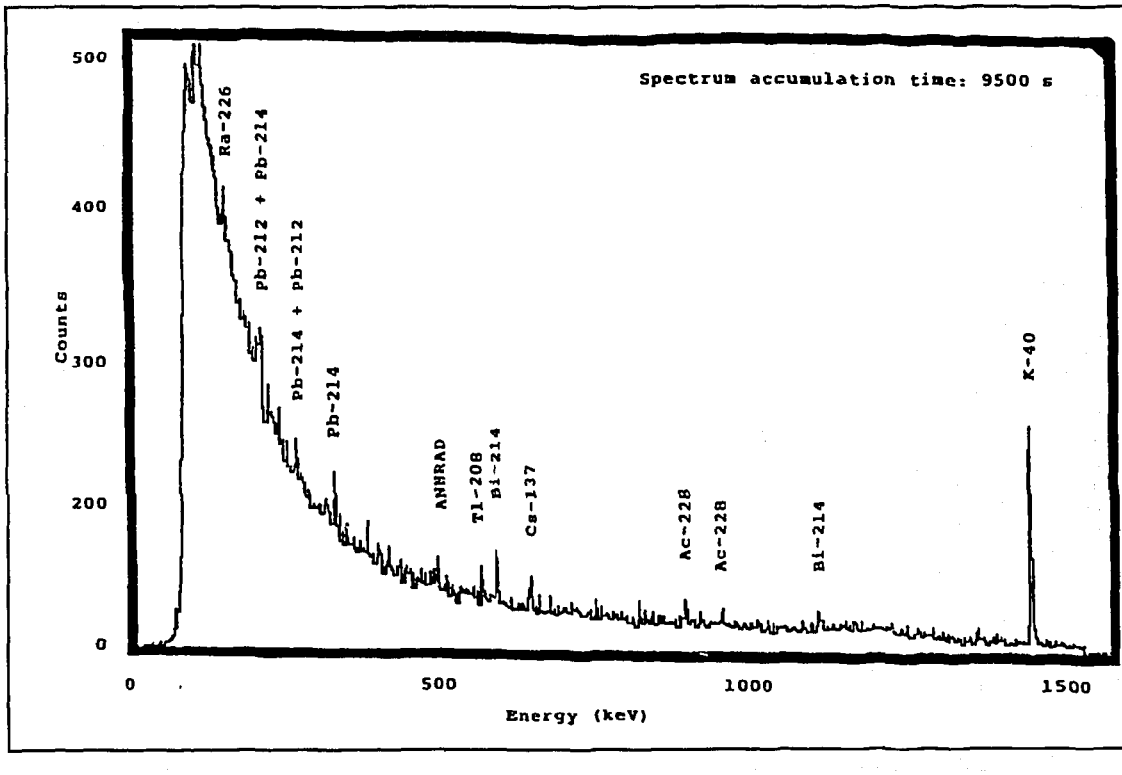

Figure 5.8) High resolution gamma spectrum recorded with germanium detector on sediments at station 5-2 in the Stepovogo Bay.

With this equipment, the expedition was able to detect radiation from some of the observed objects and from local radioactive contamination of bottom sediments close to dumped objects. Examples of gamma spectra are given in the Figures 5.7 and 5.8. ^{137}Cs was the only artificial radionuclide detected from under-water positions. The measurements were useful for selecting locations for sediment sampling.

6. CONCENTRATION OF RADIONUCLIDES IN WATER, SEDIMENTS AND BIOTA AT THE DUMPING SITES.

6.1 Sampling and preconcentration techniques

During the expedition samples of water, sediments and biota were collected as described in the cruise report (Føyn and Nikitin, 1993).

Normally, water samples were collected at three different depths: surface, intermediate layer and near bottom water. In shallow waters, however, only surface and bottom water samples were collected. Surface water was collected by using two electric pumps (a Russian pump of type "Malish", and a Norwegian system based on a "Gardena" pump) submerged into the water just below the surface. Water from the deeper layers was pumped through a hose with an inner diameter of 1.8 cm. The sampling depth was determined by the use of a Scannamar depth recorder.

The water volumes collected at each station are given in the cruise report (Føyn and Nikitin, 1993). A comparison of the Russian and Norwegian flowmeters have shown a difference of 5 %, which has been considered satisfactory (JRNC, 1993).

Handling of water (Norway)

At each site and at each depth, water was pumped trough a 1μm polypropylene filter to 3 storage tanks (3 x 1000 litres) placed on deck, and water samples were distributed by "Gardena" pumps to various precipitation tanks and to a filtration system.

For determination of ^{137}Cs and ^{134}Cs, water was pumped directly into a filtration system consisting of three consecutive cartridges, firstly suspended matter > 1μm was removed, and then two Cs-sorbents (fibres coated with $Cu_2Fe(CN)_6$) were applied. A flowmeter mounted at the outlet of the third cartridge registered the filtered water volume. The filtered water quantity depended on time available.

For Pu-isotopes, the water sample (200 l) was transferred into precipitation tanks, adjusted to pH 2 by adding 200 ml conc. HCl, and $^{242}Pu/^{243}Am$-tracer was added for chemical recovery. Then, 16 g $FeSO_4\ 7H_2O$ and 200 g $Na_2S_2O_5$ were added and after 1 hour stirring, the water was adjusted to pH 9.5 by addition of 0.5 M NaOH. The resulting Fe-hydroxide precipitate was left for at least 10 hrs, thereafter the supernatant was siphoned off and the precipitated slurry (transuranic elements co-precipitated with $Fe(OH)_3$) transferred to a 10 l polyethylene container for further radiochemical separation in the laboratory.

For ^{90}Sr, water samples (100 l) were transferred to polyethylene containers. One litre conc. HCl and stable Sr-carrier were added and the sample was spiked with ^{85}Sr tracer. The containers were transported to laboratory for further radiochemical separation.

Handling of the water (Russia)

The water was initially pumped through a blue band filter for removing suspended matter and then through a Cs sorbent (fibres coated with $Cu_2Fe(CN)_6$) for collecting Cs-isotopes.

For Pu-isotopes, the filtered water samples were acidified by HCl to pH 2, and ^{242}Pu tracer and 200 g sodium sulfite per 100 l of water were added. The sample was stirred periodically for 12 hrs prior to the addition of a $FeCl_3$ solution (1 g Fe^{3+} per 100 l sample) and the sample was then stirred periodically for 2-3 hrs. After thoroughly mixing, a NaOH-solution was added stepwise until pH reached 8.5-9.5. The sample was left for 12-24 hrs to obtain a complete clear supernate. The supernate was decanted, the precipitate was filtered and the filter was collected for further radiochemical separation in laboratory.

For ^{90}Sr, samples of filtered water (10 l) were collected in separate plastic bottles and 120g Na_2CO_3 was added. After dissolution of Na_2CO_3, the bottle was left for 24-48 hrs. Then, the mixed Sr-, Ca-, Mg-carbonate precipitate was filtered using a Büchner funnel, and 200 cm^3 deionised water was used for washing. The filtered precipitate was then transferred to plastic bags. Filtered sea water samples (0.25 l) were correspondingly collected for analysis of stable strontium.

Sediment sampling

Sediment was sampled by means of a Smøgen boxcorer with an inner area of 30 x 30 cm and a Russian modified Petersen grab. Sediment core profiles were subsampled by slowly inserting plastic tubes into the sediment contained in the boxcorer. Thus, vertical profiles and additional sub-samples of the upper surface sediment were collected for every boxcorer shot.

Most of the core profiles were frozen after collection and transported to laboratory for sectioning. After a slight defrosting, some of the sediment cores were sliced into 1 cm (0-10 cm) and 2 cm (remaining core) sections and transferred to plastic containers. After the collection of profiles, the surface layer (0-2 cm) was collected in the boxcorer with a spatula. About two thirds of the boxcorer surface layer, corresponding to about 100 cm^2, was sampled in this manner.

Biota samples

Traps and a triangular bottom dredge were used for collecting biota. The traps, with a bait of mackerel, were deployed in the bays from a small rubber dingy and in the open sea from the research vessel. Brittle stars collected from deep water were deep frozen and stored.

Only two fish were caught in the vincinity of station 2; one *Boreagus saida* (polar cod) and one *Liparis fabricii* (polar snailfish).

Seaweed, mainly *Fucus evanescens, Laminaria digitata and Laminaria saccharina*, was collected by dredging at 4 - 8 meters depth at the stations 1 and 2 in the Tsivolky Bay (salinity 14 - 15 ‰) and at the stations 5 and 6 in the Stepovogo Bay (salinity 17 - 20 ‰).

6.2 Analytical procedures and methods of analysis

Analysis of gamma emitters

Filters and sorbents were dried at 105 ^{0}C and ashed at 450 ^{0}C prior to measurements. The surface sediment samples and sectioned core samples were freezedried and homogenized prior to gamma measurements. Biological samples were dried at 105 ^{0}C prior to measurements.

All samples were subjected to gamma spectrometry using various high resolution HPGe or Ge(Li)-detectors (resolution in the range of 1.7-2.0 keV, efficiencies in the range of 10-55 %). The counting times varied from one to several days.

Analysis of beta emitters

The prepared water samples were transferred into precipitation tanks (Norway). While stirring, 500 g $(COOH)_2$ dissolved in hot deionised water was added. Then 1.5 l NH_4OH was added and the pH was adjusted to 4.0 by using dilute NH_4OH. At the AUN laboratory, the oxalate precipitate was then left for 12 hrs. Oxalate precipitate from 100 l water and aqua regia extracts from sediments (Sr-carrier and ^{85}Sr spike added) were subjected to ^{90}Sr-analysis using liquid-liquid extraction of ^{90}Y and Cerenkov radiation from ^{90}Y was determined by low level liquid scintillation counting (Bjørnstad et al, 1992). Chemical yields were determined by complexometric titration (toluene containing 5% HDEHP, backextracted into 3M HNO_3)

Analysis of ^{90}Sr at the IFE laboratory was performed similar to the Russian method described below. First, ^{85}Sr spike and Sr-carrier was added to the samples. Then the carbonate precipitate from 50 litres of water and the solution after acid leaching of sediments were subjected to further radiochemical separation.

The counting samples of yttrium oxide were measured by low background anticoincidence beta counters (Risø type, background 15 pulses/hour, efficiency 55%) The chemical yields were determined by ^{85}Sr spike and titration with EDTA.

Carbonate precipitate from 10-20 l water and solution after acid treatment of sediment were subjected to ^{90}Sr-analysis (Russia). Radionuclides interferring with the ^{90}Sr determination, were removed by precipitation and separation of hydroxides, barium chromate, carbonates and an additional precipitation of iron hydroxide. The measurements were based on the daughter nuclide ^{90}Y after ingrowth to equilibrium and separation of ^{90}Y after the addition of stable yttrium carrier. The counting samples of yttrium oxide were

measured by a low background beta counter (background of 15 pulses/hour, efficiency 36 %). The chemical yield was determinded from stable Sr using flame photometry (Vakulovsky and Silantev, 1969; Chumichev, 1972).

Analysis of alpha emitters

The precipitate from 200 l water samples and aqua regia extracts from sediments (10 g) were subjected to alpha analysis (Norway). Pu and Am were separated (^{242}Pu and ^{243}Am spike added) by extraction with a 10 % TIOA/xylene solution, then Pu was backextracted from the organic phase into 8N HCl, and separated by ion exchange chromatography. After electrodeposition on stainless steel discs, Pu and Am were measured by semiconductor silicon detectors (Chen et al, 1991).

The precipitate from 100-200 l water samples and the solution after decomposition of sediments (not more than 10 g) by a mixture of acids were subjected to ^{239,240}Pu analysis (Russia). Interferring components were removed by anion-exchange chromatography. Counting samples were prepared by electroplating onto stainless steel discs. Measurement of alpha radiation was perfomed by Ortec detectors S70A 450 R type (Pavlotskaya et al., 1984; Tishkova et al., 1987; Lovett et al., 1990).

6.3 Results and discussion of the analytical data

The analytical results obtained for different radiouclides in water, sediments and biota from all sampling sites are given in Annex B.

Concentrations of radionuclides in sea water

Based on results from the involved laboratories, the concentrations of ^{137}Cs, ^{90}Sr, ^{238}Pu, $^{239,240}Pu$ and ^{241}Am in sea water are summarized in Table 6.1. The activity ratios are given in Table 6.2.

The concentration of ^{137}Cs varied within the range 4.5 - 32 Bq/m^3. The highest levels were observed in the near bottom waters from the inner part of the Stepovogo Bay, station 6 (26-32 Bq/m^3). Excluding these samples, the concentrations of ^{137}Cs varied within the range of 4.5 - 14 Bq/m^3. In general, the concentration of ^{137}Cs increased with depth, and was at its highest in the near bottom waters. The activity ratio $^{134}Cs/^{137}Cs$ varied within 0.007 - 0.032.

The concentration of ^{90}Sr was in the range 3 - 25 Bq/m^3. The highest levels of ^{90}Sr were also observed in the near bottom water samples from the inner part of the Stepovogo Bay (25 Bq/m^3). Excluding these samples, the maximum concentration was 5.7 Bq/m^3. In the Tsivolky Bay, the ^{90}Sr concentration was highest in the surface waters.

The mean activity ratio for $^{90}Sr/^{137}Cs$ was 0.9 $\pm$ 0.3 for surface water and 0.5 $\pm$ 0.2 for near bottom waters. In general, the activity ratio decreased with depths at all sites investigated.

The concentration of $^{239,240}Pu$ varied within 1.9 - 26.0 mBq/m^3. In general, the activity level increased with depths, while no site specific differences were observed. Cross flow membrane filtration at near bottom water indicated that the colloidal fraction was small. The concentration of ^{238}Pu was above the detection limit at station 4 only (0.9 mBq/m^3).

Both the results of plutonium and cesium analysis might be influenced by the fact that at some sampling stations small sediment particles came hrough the 1μm filter. When ashing some of the Cs-filters, the ash weight of the filter was up to a factor 2 greater than the average ashed filter.

Twelve sea water samples have been subjected to ^{241}Am analysis. Concentrations within 1.5 - 7.7 mBq/m^3 were obtained in 4 samples (station 5,6 and 7) while the nuclide was not detected im the remaining 8 samples.

Table 6.1
Mean concentration of ^{137}Cs, ^{134}Cs, ^{90}Sr, $^{239,240}Pu$ and ^{241}Am in sea water samples from different stations and different depths, based on Russian and Norwegian measurements.

Station no.	Depth (m)	^{137}Cs Bq/m^3	^{134}Cs Bq/m^3	^{90}Sr Bq/m^3	$^{239,240}Pu$ mBq/m^3	^{241}Am mBq/m^3
1	0	5.0 ±0.2	0.12 ±0.02	5.0 ±1.3	4.0 ±2	
	43	11.6 ±0.3	0.27 ±0.05	3.4 ±0.7		
	55	6.9 ±0.1		4.1 ±1.0	5.7 ± 0.7	
2	0	5.1 ±0.2	0.14 ±0.03	5.4 ±1.4	4.5 ±0.7	
	28	8.2 ±0.3		4.0 ±1,1	7.0 ±2	
3	0	4.5 ±0.1	0.14 ±0.04	5.7 ±1,1	9.8 ±1	
	40	6.1 ±0.1	0.21 ±0.06	3.5 ±0,7	26 ±2	
	70	10.0 ±0.2	0.23 ±0.07	3.5 ±0,7	8.1 ±0.9	
4	0	4.9 ±0.1	0.16 ±0.04	4.8 ±0,9	5.4 ±0.8	
	40	6.1 ±0.1	0.16 ±0.02	3.4 ±0.7	8.9 ±2	
	72	9.5 ±0.3		3.6 ±0.7	5.8 ±0.4	< 1.2
5	0	5.2 ±0.1	0.14 ±0.02	4.9 ±1.0	2.3 ±0.4	< 3
	25	8.2 ±0.4	0.21 ±0.02	4.0 ±0.2	2.3 ±1	7.7 ± 0.8
	6	6.3 ±0.1		4.7 ±0.7		
6	0	5.8 ±0.3	0.13 ±0.00	5.2 ±1.0	1.9 ±0.4	2.0 ± 0.4
	40	31.9 ±1.3	0.21 ±0.01	24.6 ±1.4	6.0 ±0.8	< 1.2
	45	26.5 ±0.5		24.3 ±4.0		
7	0	5.1 ±0.3	0.12 ±0.12	5.5 ±0.8	2.9 ±0.4	< 1.2
	39	6.9 ±0.3	0.16 ±0.00	4.2 ±0.7	18 ±2*)	5.3 ±0.8*)
8	0	5.7 ±1.0	0.12 ±0.01	3.1 ±0.1	3.8 ±0.6	< 1.2
	140	7.1 ±0.3		2.9 ±0.6	5.3 ±0.6	< 1.2
	360	7.4 ±0.4		2.8 ±0.6	7.0 ±1	< 1.2
9	0	5.2 ±0.2	0.08 ±0.02	2.6 ±0.6	2.6 ±0.5	< 1.2
	140	8.6 ±0.4	0.23 ±0.05	3.3 ±0.7	6.1 ±0.6	< 1.2
	340	13.5 ±0.6	0.32 ±0.19	2.9 ±0.6	12 ±1	< 1.2

*) sediment in sample

Table 6.2

Activity ratios of some of the radionuclides in sea water. The ratios are based on mean values for the radionuclides, except for the ratio $^{134}Cs/^{137}Cs$.

Station no.	Depth (m)	$^{134}Cs/^{137}Cs$	$^{90}Sr/^{137}Cs$	$^{239,240}Pu/^{90}Sr$ (x 10^{-3})	$^{239,240}Pu/^{137}Cs$ (x 10^{-3})
1	0	0.020 ±0.003	1.0 ±0.2	0.85 ±0.40	0.67 ±0.3
	43	0.024 ±0.004	0.3 ±0.01	0.15 ± 0.05	0.43 ±0.007
	55		0.6 ±0.10		
2	0	0.026 ±0.005	1.1 ±0.2	0.94 ±0.2	0.84 ±0.1
	28		0.5 ±0.09	1.9 ±0.5	0.73 ±0.2
3	0	0.032 ±0.009	1.3 ±0.2	1.7 ±0.2	2.2 ±0.3
	40	0.025 ±0.007	0.6 ±0.10	8.5 ±0.8	3.1 ±0.2
	70	0.023 ±0.007	0.3 ±0.07	2.5 ±0.3	0.81 ±0.1
4	0	0.028 ±0.007	1.0 ±0.2	1.1 ±0.2	0.94 ±0.1
	42	0.019 ±0.002	0.6 ±0.11	2.9 ±0.7	1.1 ±0.3
	72		0.4 ±0.06	1.9 ±0.2	0.41 ±0.03
5	0	0.023 ±0.004	0.9 ±0.2	0.6 ±0.1	0.37 ±0.07
	25	0.026 ±0.003	0.5 ±0.4	0.6 ±0.1	0.29 ±0.06
	30		0.8 ±0.1		
6	0	0.020 ±0.001	0.9 ±0.2	0.37 ±0.08	0.29 ±0.06
	40	0.0067 ±0.0004	0.77 ±0.03	0.23 ±0.03	0.19 ±0.03
	45		0.9 ±0.2		
7	0	0.019 ±0.018	1.08 ±0.05	0.45 ±0.06	0.46 ±0.07
	39	0.021 ±0.001	0.6 ±0.12	0.39 ±0.04	2.4 ±0.2
8	0	0.018 ±0.001	0.5 ±0.09	1.2 ±0.2	0.57 ±0.09
	140		0.4 ±0.08	2.0 ±0.2	0.62 ±0.07
	360		0.4 ±0.08	2.7 ±0.4	0.92 ±0.1
9	0	0.014 ±0.004	0.5 ±0.12	0.96 ±0.2	0.46 ±0.09
	140	0.026 ±0.006	0.4 ±0.08	1.9 ±0.2	0.70 ±0.07
	340	0.025 ±0.015	0.22 ±0.04	4.5 ±0.5	0.94 ±0.09

Concentrations of radionuclides in sediment profiles

The ^{137}Cs concentrations were highest at station 6 (Stepovogo Bay); with maximum 100-200 Bq/kg in the upper layers (down to 3-4 cm), while concentrations in the range 5-25 Bq/kg were found at the other sites. In general, ^{137}Cs was enriched in the upper 5 cm sediment layer and decreased with depth. The concentration of ^{134}Cs was below the detection limit in the sediment profiles.

The ^{90}Sr concentrations were in the range 0.2-4.2 Bq/kg. The highest concentrations were observed at station 6. The concentration of ^{90}Sr in sediments decreased relatively smoothly with the depth of the profile.

^{60}Co was observed at station 1 and 6 only, with the highest concentrations in the upper sediment layers at station 6 (2.5-19 Bq/kg).

The $^{239,240}Pu$ concentrations were in the range 0.03-0.94 Bq/kg, with the highest values observed at station 6 (Stepovogo Bay) and station 8 (Novaya Zemlya Trough). The concentration level was similar to that observed in sediment samples from the open Kara Sea collected during the 1992 expedition (higher levels observed at stations 1-92 and 5-92). In general, the upper 4-5 cm sediment layer was enriched with $^{239,240}Pu$, and the concentration decreased with depth.

Surface sediments

Traces of ^{134}Cs were observed at stations 1, 4, 5 and 6, while ^{60}Co was observed at stations 1, 4, 5, 6 and 9, probably due to analysis of larger samples than for the profiles. The levels of ^{238}Pu and $^{239,240}Pu$ are very low. At station 6 (Stepovogo Bay) the ^{137}Cs concentration was within 200-300 Bq/kg, while the maximum concentration at station 5 was 200 Bq/kg. Otherwise, concentrations of ^{137}Cs within 3-30 Bq/kg were found. ^{152}Eu and ^{154}Eu are also observed in the one sample collected with the ROV sampler close to the hull of the dumped nuclear submarine in the Stepovogo Bay (station 5).

Analyses of biota

The concentrations of ^{137}Cs, and ^{90}Sr in fish (*Boreogadus saida* (polar cod), *Liparis fabricii* (polar snailfish) are given in Table 6.3. The concentrations of Pu were below the detection limit (< 1 mBq/kg fresh weight).

The uptake of radionuclides in seaweed depends on several factors like salinity and temperature conditions. As the climatic conditions and salinity are similar in the two bays, the results can be compared.

Table 6.3
Concentration of ^{137}Cs, ^{90}Sr and $^{239,240}Pu$ in fish, fresh weight (muscle + bone)

Species	^{137}Cs (Bq/kg)	^{90}Sr (Bq/kg)
Boreagus saida (polar cod)	5 ± 1	2.9 ± 0.2
Liparis fabricii (polar snailfish)	9 ± 1	2.1 ± 0.2

The concentration of ^{137}Cs varied within 1.1 to 8.1 Bq/kg d.w. (Tab. 6.4). The ^{137}Cs concentration in Fucus samples from Stepovogo was higher than those from Tsivolky. However, the only sample of Laminaria from Stepovogo showed lower ^{137}Cs concentration than most of the about 20 Laminaria samples from Tsivolky.

^{60}Co was observed in two samples collected at station 1 (Fucus 1.5 Bq/kg d.w.) and station 5 (Fucus 1.1 Bq/kg d.w.), however very close to the detection limit. Slightly higher $^{239,240}Pu$ concentrations were found in samples from the Stepovogo Bay compared to the samples from the Tsivolky Bay (0.4 Bq/kg and 0.06 Bq/kg, respectively).

The seaweed may reflect the actual concentrations in the sea water of anthropogenic radionuclides if present in a retainable form. The concentration factors for seaweed depend on the biological species, and the concentration factor for Fucus vesiculosus/sea water (Bq/kg d.w. per Bq/litre) in the Skagerak/North Sea area the factor is 100-200 times higher for ^{60}Co than for ^{137}Cs (Aarkrog, 1985). The concentration factors for arctic climatic conditions are, however, not known.

From this one cannot conclude that the detected ^{60}Co and ^{137}Cs in the seaweed is due to the dumped materials. It may as well reflect the other sources of radioactive contamination mentioned in chapter 2.

Table 6.4 Concentrations of ^{137}Cs, ^{60}Co and $^{239,240}Pu$ in seaweed (Bq/kg d.w.)

Station	Species	^{137}Cs (Bq/kg)	^{60}Co (Bq/kg)	^{90}Sr (Bq/kg)	$^{239,240}Pu$ (mBq/kg)
St1(3)	Fucus Evanescenes	1.7 ±0.4	1,5 ±0,3		
St1(2)	Fucus Evanescenes	< 2.2	< 2,6		
St1(2)	Fucus Evanescenes	1.6 ±0.4	< 1,0		
St1(4)	Fucus Evanescens	2.7 ±0.4	< 0,9		
St1(2)	Laminaria Digitata	5.1 ±0.5	< 1,5		
St1(3)	Laminaria Digitata	2.8 ±0.3	< 1,1		
St2(1)a	Laminaria Digitata	< 2.4	< 3,1		
St2(2)a	Laminaria Digitata	4.1 ±0.6	< 2.1		
St2(2)b	Laminaria Digitata	< 1.7	< 1.7		
St2, mix	Laminaria Digitata	2.4 ±0.3	< 1.1		
St2, mix	Laminaria Digitata	2.7 ±0.2	< 0.6		
St2(1)c	Laminaria Digitata Laminaria Saccharina	4.0 ±1.1	4.6 ±1.2		
St1(2)	Laminaria Digitata leaves some Saccharina	2.7 ±0.5	< 0.9		
St1(2)a	Laminaria Digitata leaves some Saccharina	< 1.6	< 2.0		
St1(3)	Laminaria Digitata leaves, some Saccharina	6.8 ±0.5	< 1.7	2.4 ± 0.2	63 ± 7
St1(3)	Laminaria Digitata lower stem some Saccharina	8.1 ±0.7	< 2.0	2.1 ± 0.2	40 ± 20
St1(4)	Laminaria Digitata stem	6.2 ±0.6	< 1.8		
St1(3)	Laminaria Digitata stems, some Saccharina	4.3 ±0.3	< 1.2	3.2 ± 0.2	64 ± 9
St1(4)	Laminaria Digitata, Laminaria Saccharina	2.8 ±0.3	< 0.8	5.4 ± 0.3	58 ± 9
St2(1)b	Laminaria Saccharina	< 2.2	< 2.7		
St2(2)a	Laminaria Saccharina	1.1 ±0.3	< 0.9		
St5(1)	Fucus Evanescens	3.4 ±0.2	1.1 ±0.3	3.9 ± 0.3	400 ± 20
St6(1)	Fucus Evanescens	4.1 ±0.3	< 0.9	3.5 ± 0.2	440 ± 50
St5(1)	Laminaria Digitata	2.5 ±0.4	< 1.3		

6.3.1. The Tsivolky Bay

The sampling sites are shown in Figure 6.1. The sites cover the area where the "Lenin" reactors and the spent fuel from one of the reactors have been dumped. Furthermore, a large cargo vessel was identified by sonar and inspected by underwater camera (station 1).

The found concentrations of ^{137}Cs and ^{90}Sr in sea water are summarized in Table 6.5. In addition, results from the open Kara Sea obtained during the 1992 expedition are included. As seen from the table, concentration levels in the inner as well as the in outer Tsivolky Bay were similar to those observed in the open Kara Sea.

Table 6.5
Concentrations of ^{137}Cs and ^{90}Sr in sea water from the Tsivolky Bay (Bq/m^3)

Station		^{137}Cs	^{90}Sr
1 Inner area	Surface	4-6	4-6
	Bottom	7-11	3-4
2 Inner area	Surface	5	4-6
	Bottom	6-10	4
3 Inlet	Surface	4-5	6
	Bottom	10	3-4
4 Outer area	Surface	4-6	5
	Bottom	5-14	4
Kara Sea, 1992	Surface	3-8	3-12
	Bottom	4-18	3-6

The vertical distributions of ^{137}Cs in sediment profiles from Tsivolky Bay are illustrated in Figures 6.2 a) - 6.2 d). The distribution of ^{137}Cs was similar to that observed in sediment from the open Kara Sea, 1992, being enriched in the upper sediment layer and decreasing in concentration with depth. In the Tsivolky Bay, the ^{137}Cs concentration was within 4-30 Bq/kg d.w. in the surface sediment layer, while concentrations within 2-33 Bq/kg d.w. were observed in the open Kara Sea (1992).

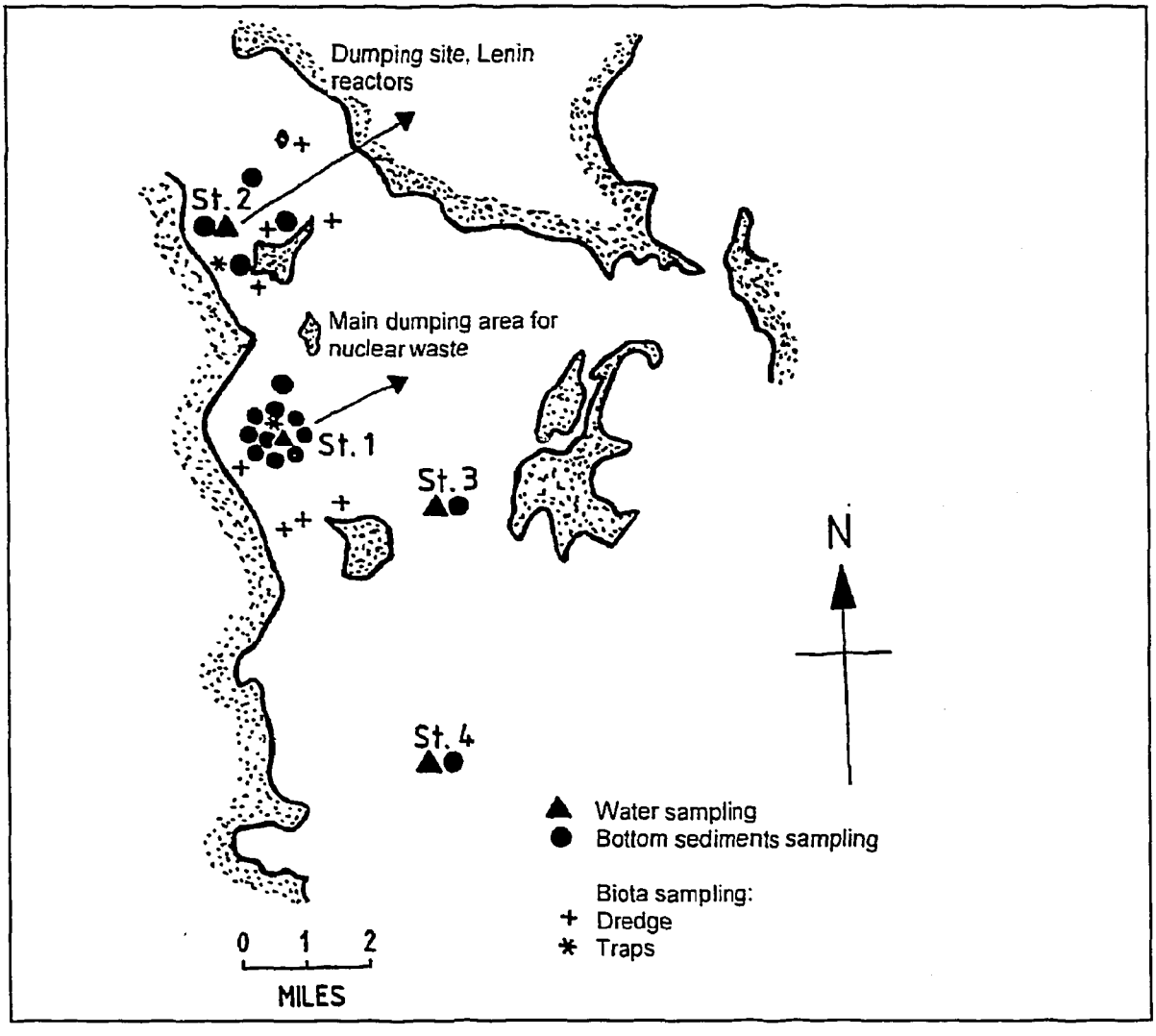

Figure 6.1 Sampling stations and the dumping sites in the Tsivolky Bay

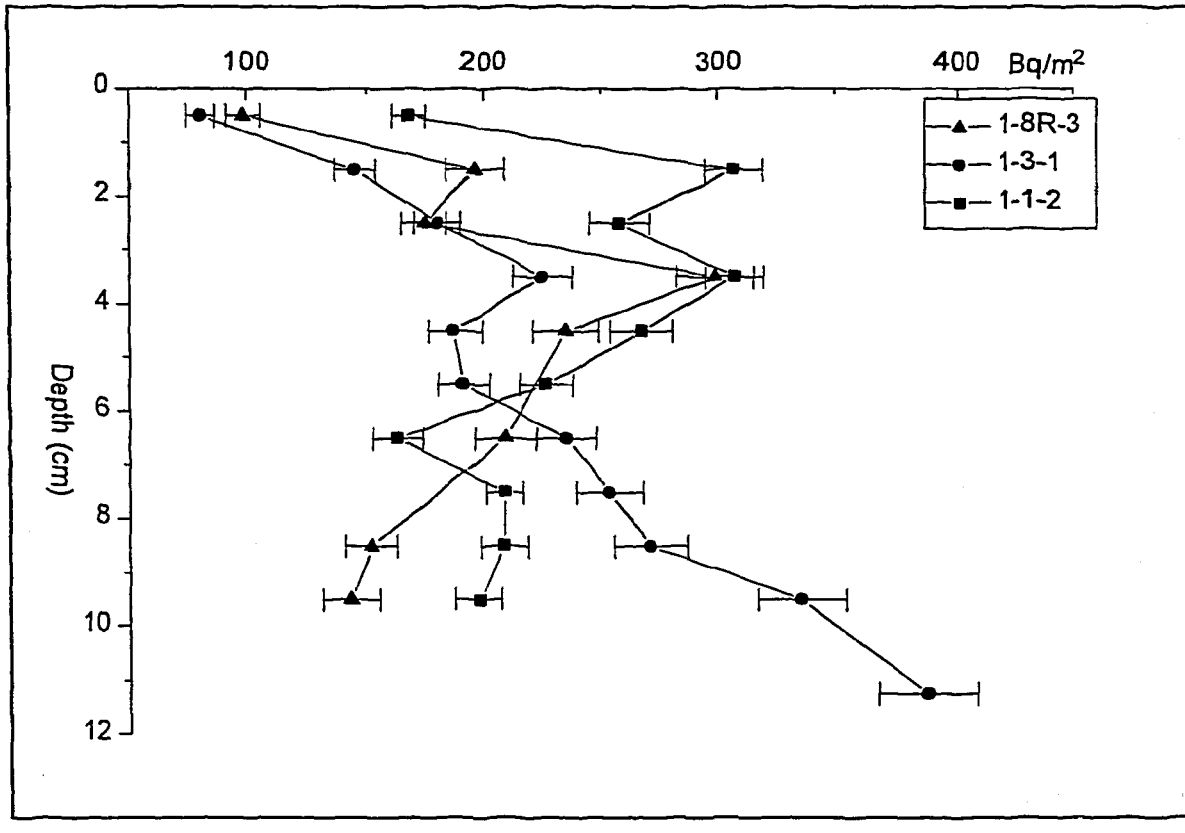

Figure 6.2 a) ^{137}Cs in sediment profiles from the Tsivolky Bay, Station 1

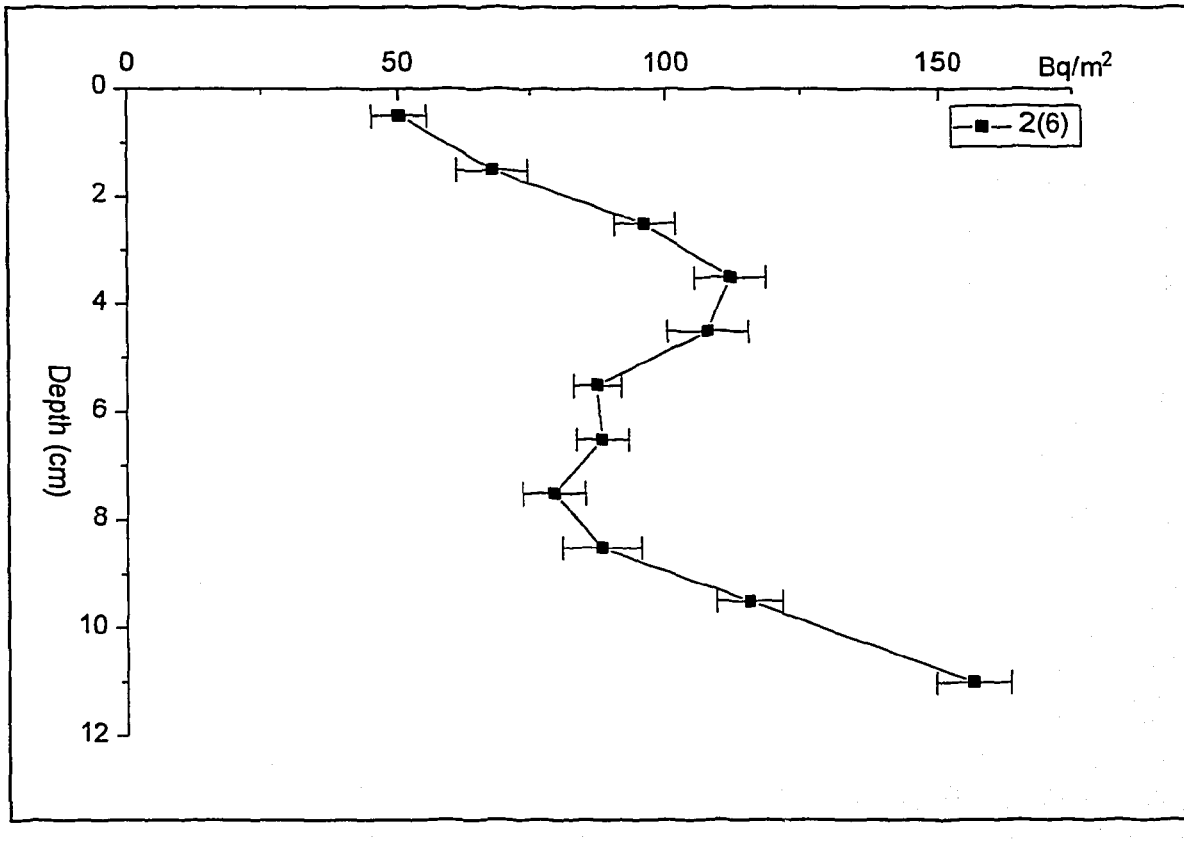

Figure 6.2 b) ^{137}Cs in sediment profile from the Tsivolky Bay, Station 2

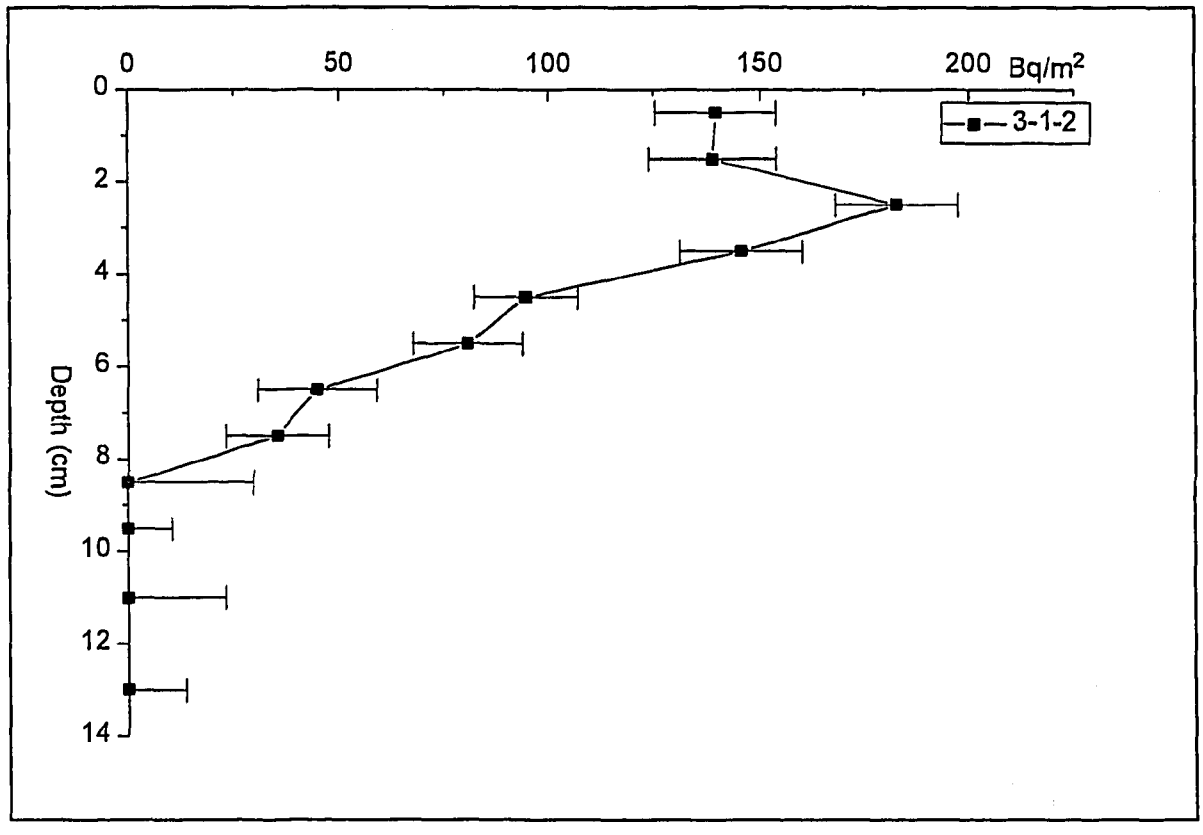

Figure 6.2 c) ^{137}Cs in sediment profile from the Tsivolky Bay, Station 3

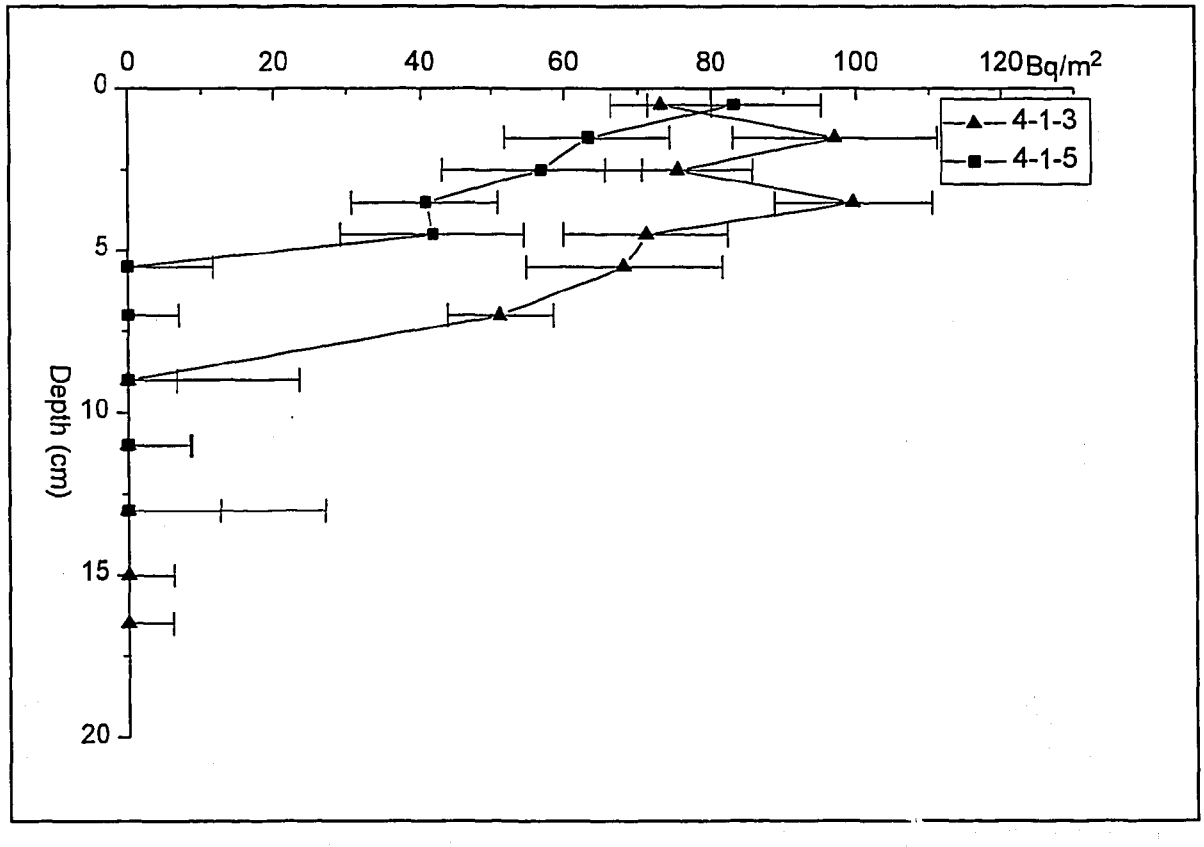

Figure 6.2 d) ^{137}Cs in sediment profiles from outside the Tsivolky Bay, Station 4

Measurements of ^{210}Pb in one sediment core collected at station 1 were performed by MEL/IAEA. The sediment appeared to be mixed, as the concentration of ^{210}Pb was uniform throughout the profile. Thus, it was not possible to estimate the sedimentation rate.

The most striking feature in the Tsivolky Bay was the presence of ^{60}Co in the upper 4-5 cm layer (up to 19 Bq/kg d.w.) Due to the relatively short halflife of the nuclide, ^{60}Co may originate from the dumped nuclear waste. However, a contribution from underground nuclear tests in the Novaya Zemlya region cannot be excluded.

6.3.2 The Stepovogo Bay

The location of the sampling sites are given in Figure 6.3. In the area a nuclear submarine containing two reactors with spent nuclear fuel has been dumped. The submarine was located by means of sonar, ROV and inspected by underwater camera.

The concentrations of ^{137}Cs in surface and near-bottom waters of the Stepovogo Bay are given in Table 6.6. The concentration of ^{137}Cs in the surface waters varied within 4-6 Bq/m^3. The level was quite similar to the concentration in the surface waters of the open Kara Sea (3-8 Bq/m^3) reported from the 1992 expedition.

The concentration of ^{137}Cs (30 Bq/m^3) in the near bottom waters of the bay was, however, significantly higher than in the surface water at station 6, situated in the interior of the bay. In the outer part of the bay (station 5 near the dumped nuclear submarine) and at the bay inlet (station 7), the ^{137}Cs concentration levels in the near bottom water were only slightly higher than in the surface waters. The increased level in the near bottom waters at station 6 can be explained by leakage from dumped radioactive waste, from desorption from contaminated sediments and/or from run-off from Novaya Zemlya.

Table 6.6
Concentrations of ^{137}Cs and ^{90}Sr in sea water from the Stepovogo Bay (Bq/m^3).

Station		^{137}Cs	^{90}Sr
5	Surface	5-6	4-6
	Bottom	6-8	4-5
6	Surface	5-7	5-6
	Bottom	22-32	24-26
7	Surface	4-6	5-7
	Bottom	6-8	4-5

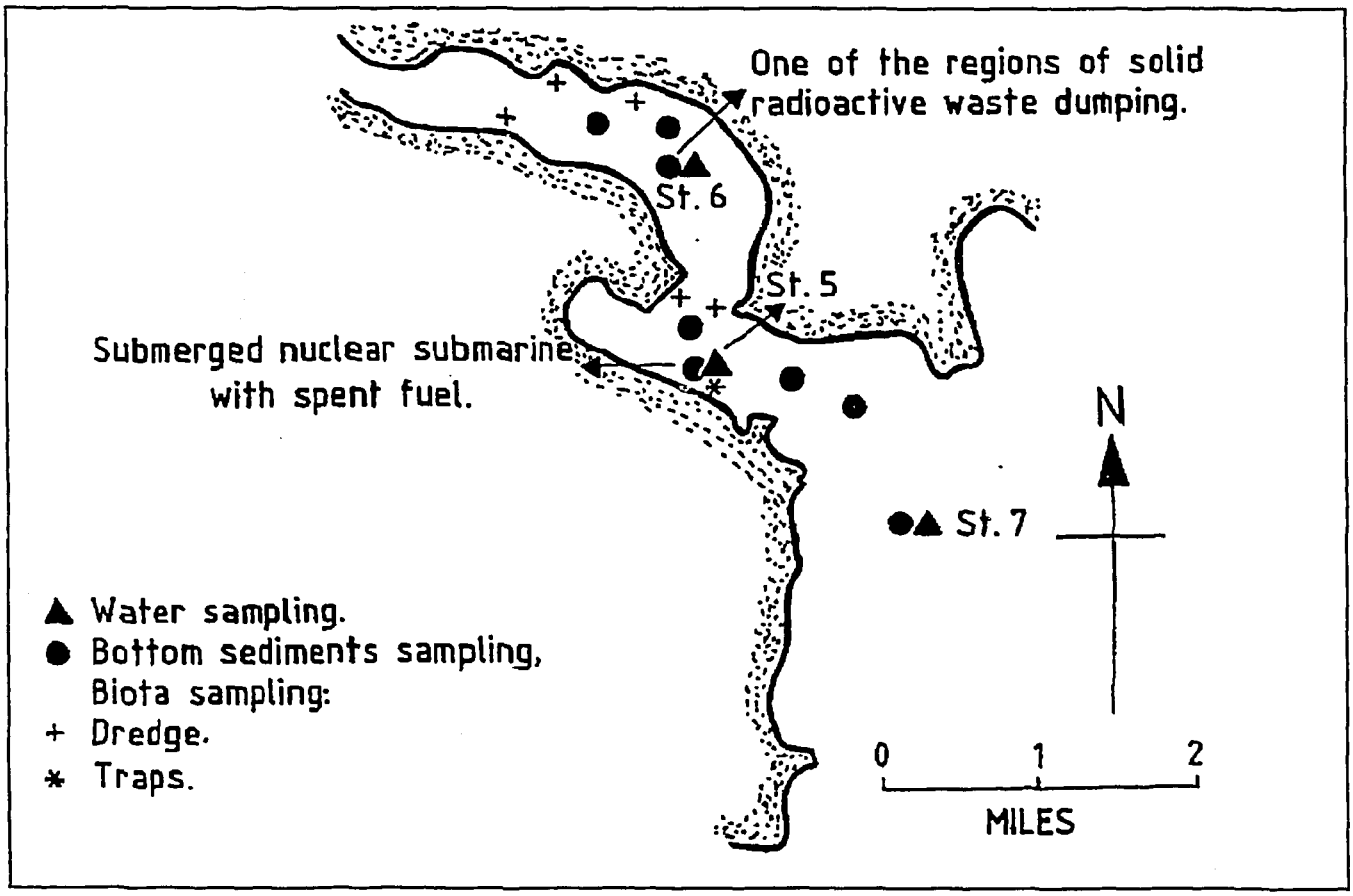

Figure 6.3) Sampling stations and dumping areas in the Stepovogo Bay

The vertical distributions of ^{137}Cs in sediment profiles are shown in Figure 6.4 a) - 6.4 b). In the outer part of the bay and at the inlet of the bay the concentration level (10-20 Bq/kg d.w.) was similar to that observed in the open Kara sea in 1992 (10-27 Bq/kg d.w.). Based on measurements of ^{210}Pb in sediment profiles, the sedimentation rate at station 6 has been estimated to be 1.3 mm/year (Figure 6.5).

In one sediment sample collected with the ROV sampler close to the hull of the dumped nuclear submarine, the concentration of ^{137}Cs was more than one order of magnitude higher (203 Bq/kg) than in all other sediment samples collected at station 5. In this sample ^{152}Eu and ^{154}Eu were also identified (34 ± 1 Bq/kg and 22 ± 1 Bq/kg, respectively). According to the estimated inventory of fission products in the submarine reactors, these nuclides were expected to be among the dominating gamma emitters at the end of 1993. Although the ratio $^{152}Eu/^{154}Eu$ was lower in the sediment sample than expected from the estimates given in Table 3.6, the overall agreement in the radionuclide composition strongly suggests that the enhanced activity originates from the reactors of the dumped nuclear submarine.

In the interior of the bay, where the water exchange with the external part of the bay may be reduced due to a shallow threshold, much higher deposition ^{137}Cs was observed (about 100-200 Bq/kg d.w.). In addition to increased concentration of ^{137}Cs, ^{60}Co was also identified in the bottom sediments. The increased levels of ^{137}Cs and the presence of ^{60}Co in sediments from the interior part of the bay may be due to run-off of radionuclides from Novaya Zemlya or leaching of radionuclides from the dumped solid radioactive wastes. Unfortunately, collection of soil samples along the coast was not permitted during the expedition. However, one soil sample from the area was collected during the Russian Navy expedition in 1993 and analysed by scientists from the Navy and SPA "Typhoon". The concentration of ^{60}Co in the upper 10 cm layer of soil appeared to be lower than the detection limit (<0.9 Bq/kg for the 0-5 cm soil layer, <0.5 Bq/kg for the 5-10 cm layer). As ^{60}Co could not be identified in the sample, the source of ^{60}Co can hardly be attributed to run-off. Even though the results are based on one soil sample from Stepovogo Bay shore, one may assume that the increased contamination levels of ^{137}Cs and ^{60}Co in the inner part of the Stepovogo bay most likely are due to leaching from the dumped solid radioactive wastes. To confirm this conclusion, further investigations of radioactive contamination of the coastal areas of Novaya Zemlya should be undertaken.

The concentration levels of ^{90}Sr in the surface waters (3-6 Bq/m^3) were similar to that in waters from the western and southern parts of the Kara Sea (3-4 Bq/m^3) observed in 1992. The concentration was relatively uniform throughout the water column at station 5 and 7. At station 6 in the interior of the bay, however, the concentration of ^{90}Sr in the near bottom water increased with a factor of about five (25 Bq/m^3). ^{90}Sr was also

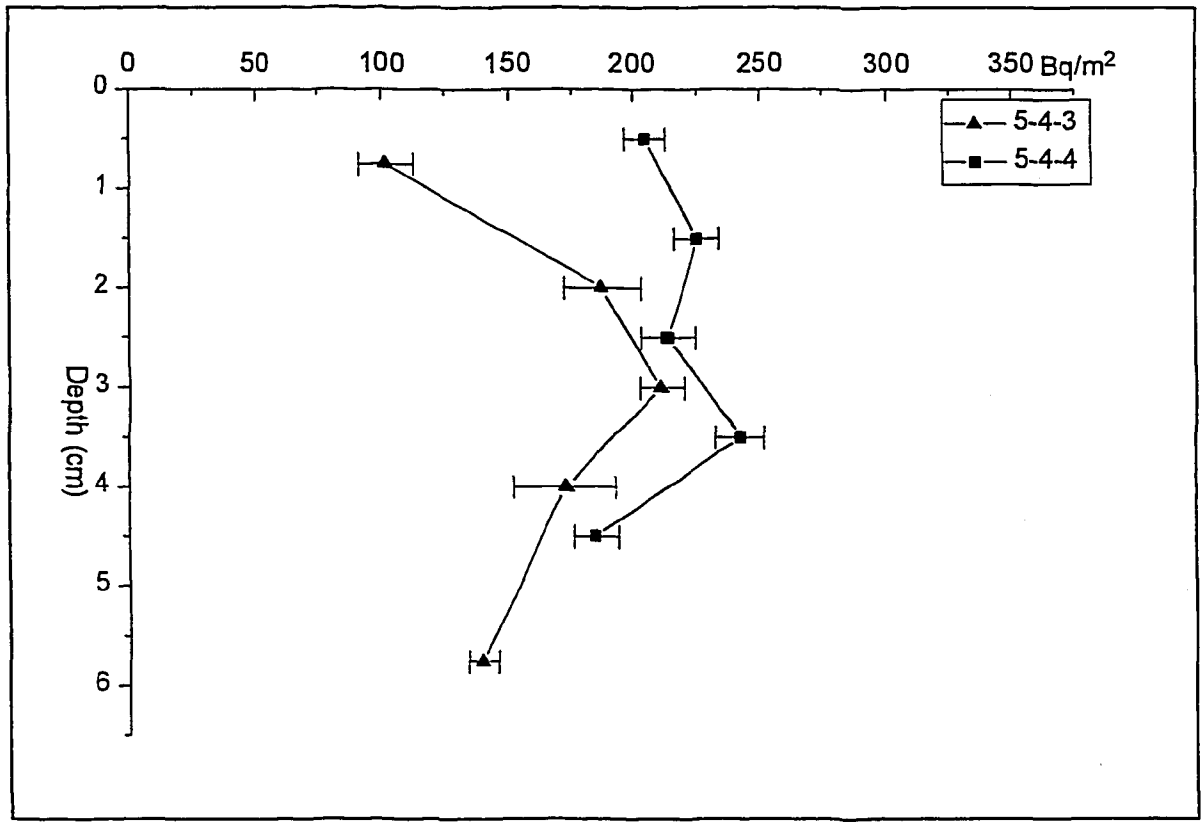

Figure 6.4 a) ^{137}Cs in sediment profiles from the Stepovogo Bay, Station 5

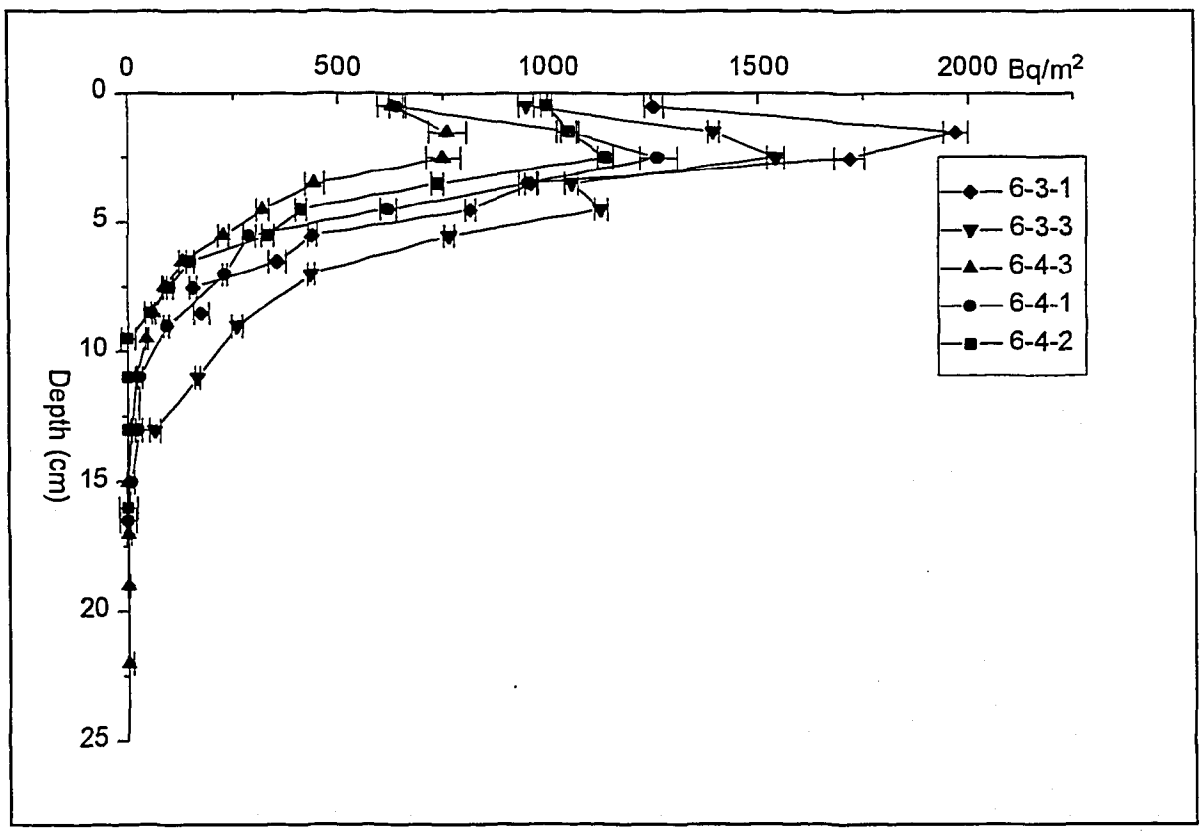

Figure 6.4 b) ^{137}Cs in sediment profiles from the Stepovogo Bay, Station 6

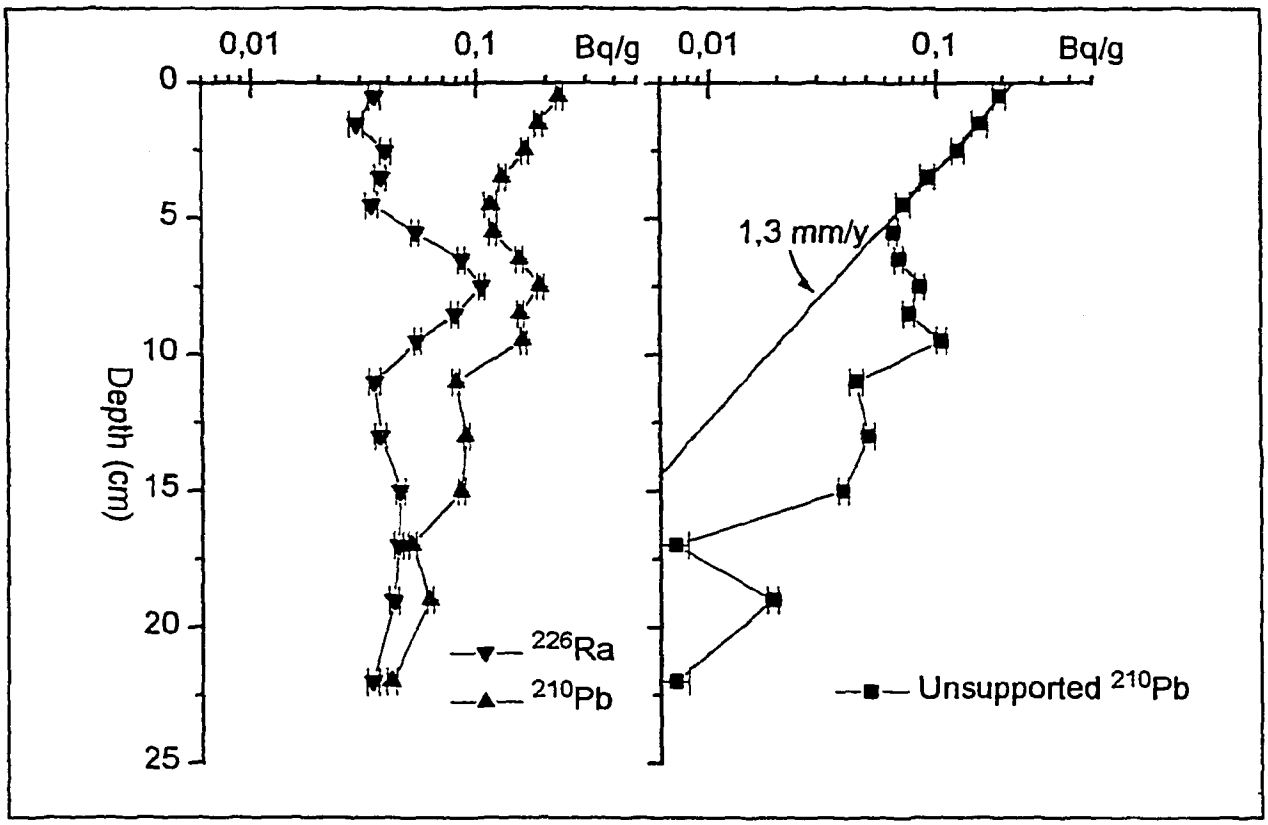

Figure 6.5) The amount of unsupported ^{210}Pb is used for calculation of the sedimentation rate. The data shown are from sample 6-4-3 from the Stepovogo Bay and shows a sedimentation rate of 1.3mm/y for the upper 5 cm.

identified in sediments, especially at station 6 (Fig. 6.4). The source of ^{90}Sr can hardly be explained by global fallout or run-off from land, as ^{90}Sr is rather mobile in waters, and is usually showing low retention in soils and sediments. The level of ^{90}Sr in the near bottom water at station 6 originates, therefore, most likely from leaching from dumped radioactive waste.

The concentrations of $^{239,240}Pu$ in surface and near bottom waters were within the range 2-6 mBq/m^3. This level is somewhat lower than observed in 1992 in the open Kara Sea (2-16 mBq/m^3). The vertical distribution was relatively uniform. Based on these results, the presence of $^{239,240}Pu$ cannot be attributed to leaching from the dumped radioactive waste.

6.3.3 The Novaya Zemlya Trough

The locations of the two sampling sites (stations 8,9) are given in Figure 6.6. No dumped objects could be identified in the area. The concentrations of ^{137}Cs and ^{90}Sr in sea water are given in Table 6.7. The concentration levels were similar to those observed in the open Kara Sea, 1992.

In the surface sediment layer (0-2 cm) the concentrations of ^{137}Cs were within 7-30 Bq/kg d.w. while the concentration range 2 - 33 Bq/kg d.w. was found in 1992.

Based on the limited number of samples from the Novaya Zemlya Trough, no indication of leakage from dumped radioactive waste can be seen.

Table 6.7
Concentrations of ^{137}Cs and ^{90}Sr in sea water at the Novaya Zemlya Trough, Bq/m^3

Station		^{137}Cs	^{90}Sr
8	Surface	5-7	3
	Bottom	7-8	3
9	Surface	4-6	3
	Bottom	13-14	3
Kara Sea, 1992	Surface	3-8	3-12
	Bottom	4-18	3-6

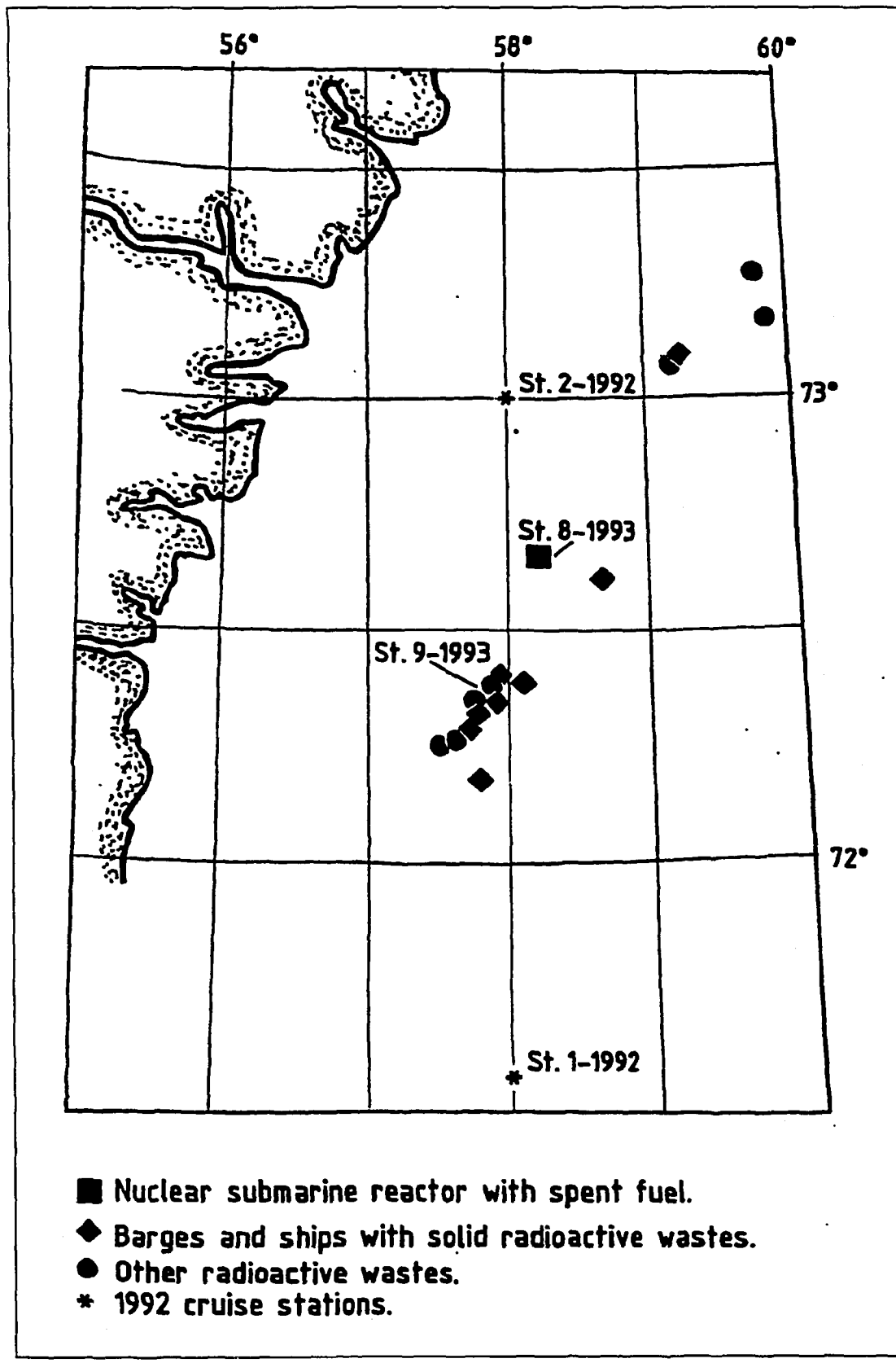

Figure 6.6) Map of the sampling stations and dumping areas in the open Kara Sea

7. ASSESSEMENT OF DOSES

Based on information on the actual levels of radionuclides in the Kara Sea ecosystem, various sources contributing to the present levels, and potential sources, especially dumped radioactive solid waste (inventories, leaching, release rates, etc.), the major goal of the Joint Russian-Norwegian collaboration is to assess short and long term consequences for the environment and man. Work on dose assessment is performed within the Russian-Norwegian expert group as well as within IASAP. So far, the assessments are only preliminary and work is still needed in relation to model development and site specific relevant input parameters. The processes associated with transport and biological uptake are taking place under extreme climatic conditions. Furthermore, the site specific biodiversity influencing pathway transfer must be taken into consideration, as well as local dietary habits.

Two approaches to assessing potential doses to man have been applied. The first one (chapter 7.1) is based on present radioactive contamination in the Kara and Barents Seas and doses to critical groups are calculated. The second approach (chapter 7.2) is based on two scenarios where dumped radioactive waste in the Kara and Barents Seas will be available in a soluble form either instanttaneously or during a period of 100 years.

7.1 Doses and risk assessement based on present radioactive contamination of the Barents and Kara Seas

To assess radioactive contamination of aquatic ecosystems, dynamic models of the radionuclide biogenic migration have been developed (Kryshev and Sazykina, 1993A) A special feature of these models is the combination of radionuclide migration and accumulation processes with the ecosystem biomass dynamics equations (Kryshev and Sazykina, 1986). The models can describe the processes of radionuclide migration with allowance made for various factors, such as temperature, the concentration of a stable analogue of the radioisotope and biogenic elements, and accumulation of radionuclides from water through food chains.

Analysis of the radionuclide concentrations in various compartments of the marine ecosystem was performed on the basis of observational data and model calculations. Table 7.1 presents the average and maximum concentrations of ^{137}Cs and ^{90}Sr in the sea water during 1961-1990. The concentrations have, however, declined since the early 1980's. Estimated concentration factors in some marine biota species are given in Table 7.2 (Kryshev and Sazykina, 1993C).

Table 7.1. The average concentration of radionuclides in sea water (1961-1990), Bq/m^3.

Radionuclide	Barents Sea			Kara Sea		
	Average	Standard deviation	Maximum*	Average	Standard deviation	Maximum*
^{137}Cs	17	6	34	27	12	60
^{90}Sr	12	4	24	20	9	40

* The maximum values correspond to the maximum activities in 1963 due to radioactive fallout resulting from atmospheric nuclear weapon tests.

Table 7.2.
Estimated radionuclide concentration factors in different biota (compartments) of the ecosystem of the Arctic seas (Bq/kg fresh weight per Bq/kg sea water).

Component of the ecosystem	^{137}Cs	^{90}Sr
Algae	50 $\pm$ 20	5 $\pm$ 2
Zooplankton	30 $\pm$ 20	2 $\pm$ 1
Mollusks	30 $\pm$ 20	10 $\pm$ 4
Crustaceans	30 $\pm$ 20	2 $\pm$ 1
Fish (flesh)	200 $\pm$ 90	10$\pm$ 6
Water fowl	100 $\pm$ 50	80 $\pm$ 40

When assessing dose and radiation risk to man, the following pathways of radiation exposure were considered: consumption of fish, crustaceans and water fowl, and external radiation from water and coastal soil. The risk coefficients chosen were those given in publication 60 from the ICRP.

The exposure doses to man were assessed on the basis of experimental and calculated concentrations of ^{137}Cs and ^{90}Sr in various compartments of the marine ecosystem (Kryshev and Sazykina, 1986; Woodhead, 1979). Assuming consumption of 20 and 100 kg/year, respectively of fish from the Barents Sea, the corresponding doses are illustrated in Figure 7.1. 20 kg fish/year refer to

average consumption while 100 kg fish/year should be considered as a relevant intake for a critical group of the population i.e. fishermen and their families. Based on actual sea water concentrations during 1961-1990, two dose maxima are observed, which are associated with maximum in global fallout (early 1960ies) and maximum in the Sellafield contribution (early 1980ies).

Assuming similar consumption of fish from the Kara Sea, the annual risk resulting from the radioactive contamination (1961-90) is estimated (Table 7.3). According to these estimates the risk should not exceed 8×10^{-7}, which is more than one order of magnitude lower than the risk from an effective dose of 1 mSv, i.e. the annual dose limit for the public based on the recommendations from ICRP. The uncertainties in the estimates remain, however, to be assessed.

Table 7.3.The estimated annual risk resulting from radioactive contamination (^{137}Cs and ^{90}Sr) of the Arctic seas (1961-1992).

Component of risk	Barents Sea	Kara Sea
Consumption of fish	$(0.8\text{-}4.0)\times10^{-7}$	$(1.3\text{-}6.5)\times10^{-7}$
Consumption of crustacea and mollusks	$(1.0\text{-}2.0)\times10^{-9}$	$(1.5\text{-}3.0)\times10^{-9}$
Consumption of water fowl	$(5\text{-}10)\times10^{-9}$	$(8\text{-}16)\times10^{-8}$

7.2 A preliminary assesment of potential collective doses from dumped radioactive waste

In the ongoing work to estimate future potential doses from dumped radioactive waste, and assess the long term consequences to man and the environment, a model which takes into account different release scenarios, transport processes, sedimentation, uptake in different marine species, and consumption of these species by man, is being developed. This work is performed by Risø National Laboratory in collaboration with NRPA and Institute of Marine Research, Norway.

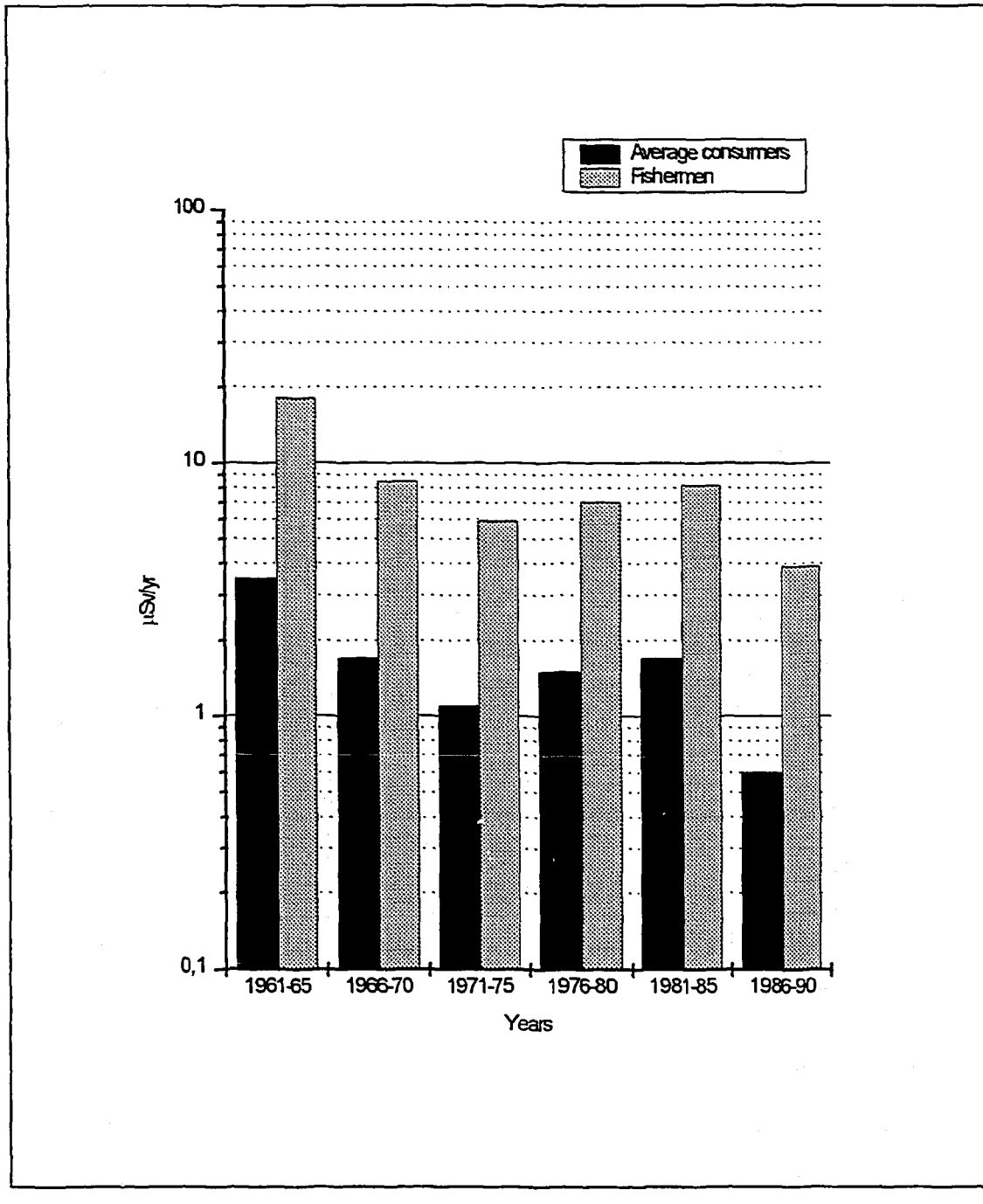

Figure 7.1) Dose rate dynamics for two groups of consumers of fish from the Barents Sea

7.2.1 Box structure of the model

The present model is a combination of two models: 1) the adjusted version (Nielsen, 1994A) of a regional box model used for radiological assessments in North-West European costal waters (NRPB, CEA and CIEMAT,1992) and 2) a larger box model covering the Arctic Ocean and the North Atlantic (Chartier, 1993). The resulting model structure and water fluxes were selected taking into account expert information based on experimental data from the Barents Sea (Ådlandsvik, 1993). Part of the box model for the Arctic Ocean and the box structure are illustrated in the Figures 7.2 and 7.3.

7.2.2 Main correlations

The present model uses first order differential equations to describe the transfer of radionuclides between the boxes. The equations are of the form:

$$\frac{dA_i}{dt}=\sum_{j=1}^{n} k_{ji}A_j-\sum_{j=1}^{n} k_{ij}A_i-k_iA_i+Q_i,$$

where A_i and A_j are activities (Bq) at time t in boxes i and j, k_{ij} and k_{ji} are rates of transfer (y^{-1}) between boxes i and j ($k_{ii}=0$ for all i), k_i is an effective rate of transfer of activity (y^{-1}) from box i taking into account loss of material from the compartment without transfer to another, Q_i is a continuous source of input into box i (Bq y^{-1}) and n is the number of boxes in the system.

Instantaneous uniform mixing within each box is assumed. The rates of transfer k_{ij} are related to the volume exchange R_{ij} (km^3 y^{-1}) according to:

$$R_{ij}=k_{ij}\cdot V_i,$$

where V_i is the volume of water represented by box i.

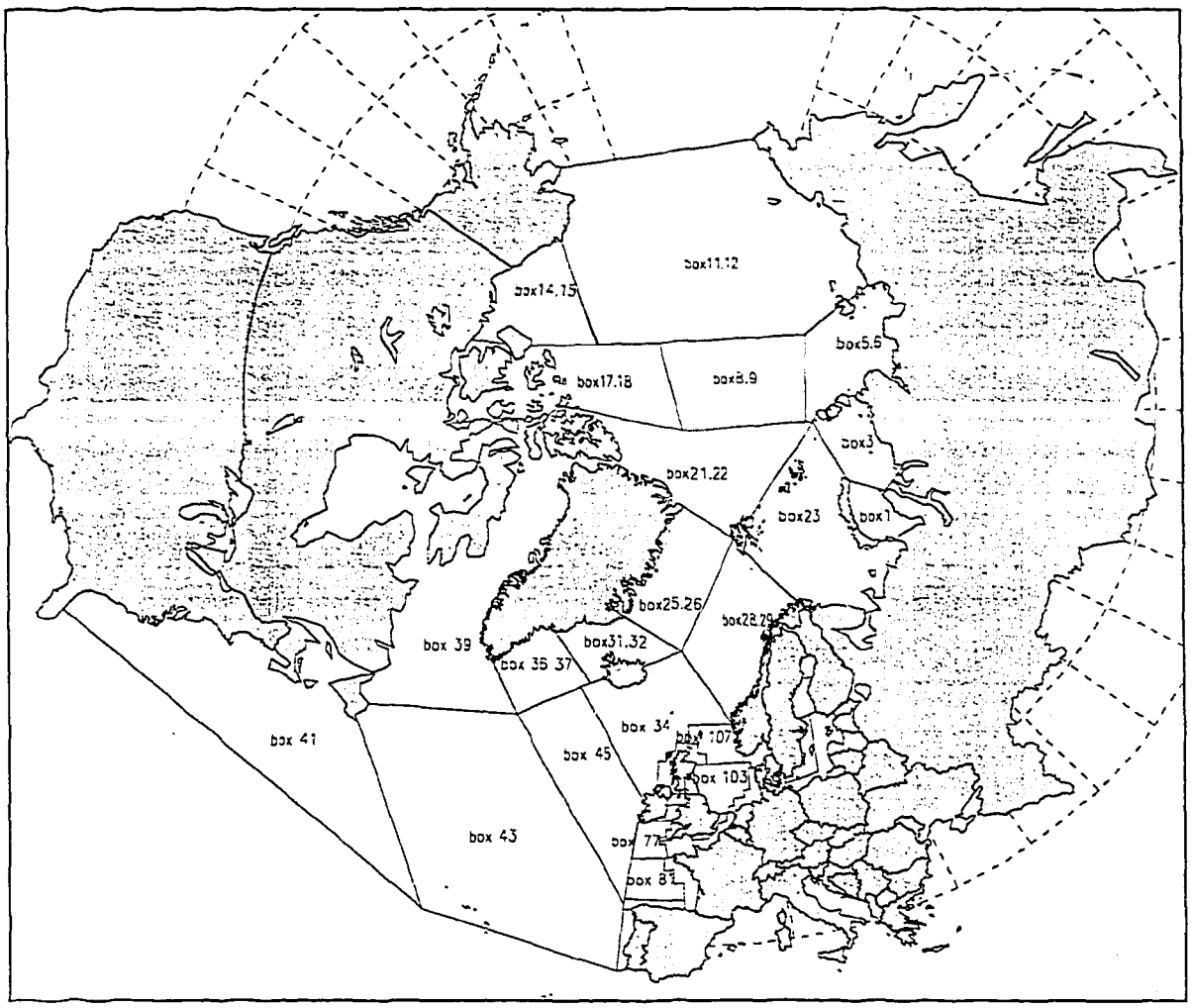

Figure 7.2) Map of the box structure in the northern areas

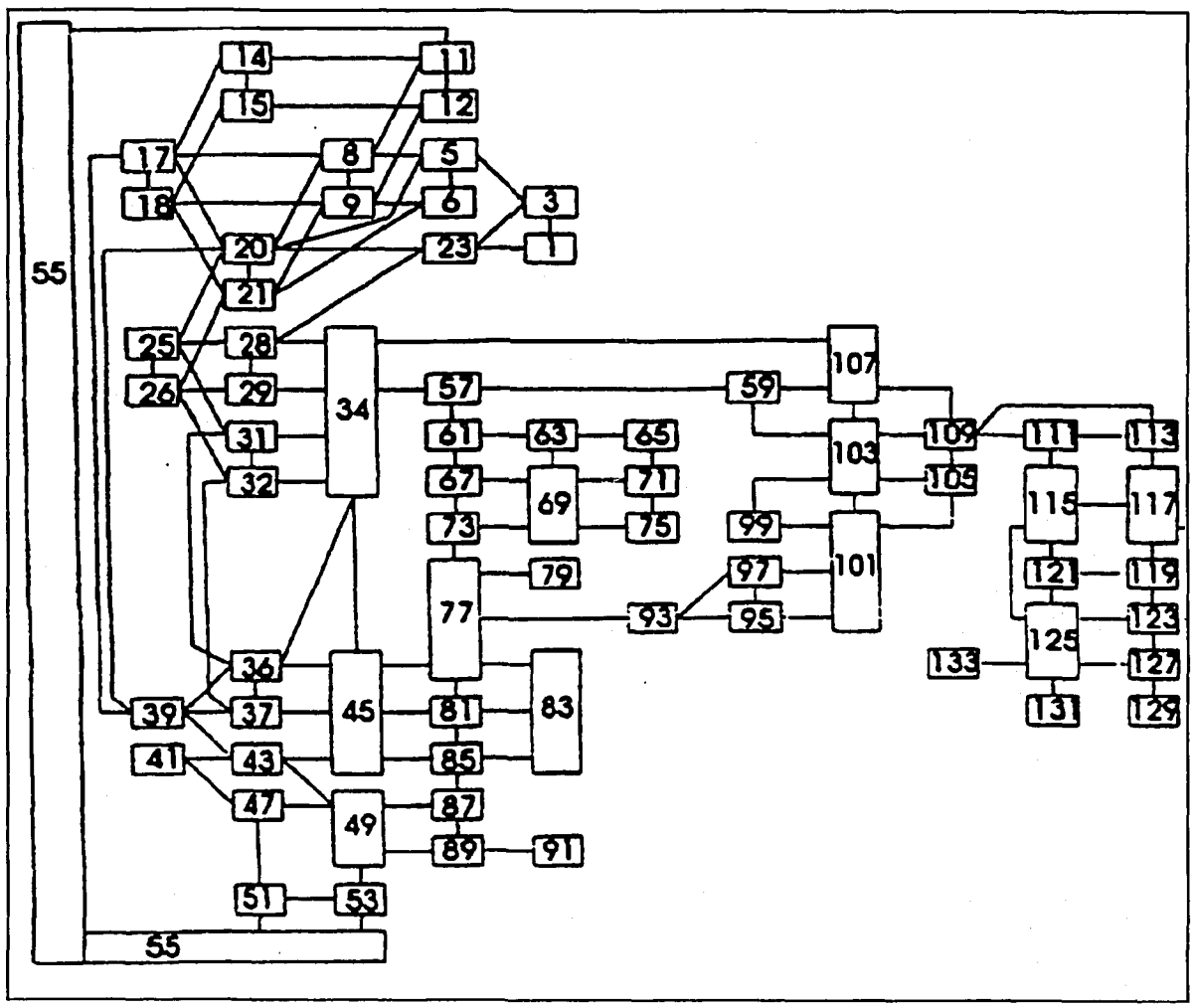

Figure 7.3) Structure of the box model used in the dose assessment

At any given time the activity in the water column is partitioned between the water phase and suspended sediment material. The fraction of activity F_w in the water column is described in the form:

$$F_w = \frac{1}{1 + K_d \cdot SSL},$$

where K_d is the sediment concentration factor ($m^3\ t^{-1}$) and SSL is the suspended sediment load ($t\ m^{-3}$).

The model also includes radioactive decay of nuclides in all boxes, the activity transfer to sediments, the transfer between surface sediment layer and bottom boundary layer by diffusion and bioturbation, and the removal of activity from the top surface sediment to the lower sediment layers due to burial processes.

7.2.3 Basic data terms

In 1993, the first official information about the dumped material in the Kara and Barents Seas was given, (White Book no. 3, 1993), and during the last year, more complete information about parts of the dumped material (Chapter 3) has been given. However this information is not complete, and more detailed knowledge about the dumped radioactive waste (inventory etc.) is necessary. This has been specially addressed by the IASAP Project.

The present model assumes that the liquid and solid nuclear waste contains the radionuclides ^{137}Cs, ^{60}Co, ^{90}Sr and ^{3}H only, and that they occur in equal amounts of activity at the time of dumping or discharge. It has also been assumed that radioactivity in the spent nuclear fuel is dominated by ^{137}Cs and ^{90}Sr, but the presence of ^{239}Pu and ^{241}Am have also been taken into account. It has been assumed, according to the box structure, that discharges can occur into either box no.1 (the Western Kara Sea) or box no.23 (the Barents Sea).

So far, the values of suspended sediment loads, sedimentation rates, diffusion coefficients, and bioturbation are taken from the regional model (NRPB, CEA and CIAMAT, 1992) and from IAEA (IAEA, 1985). Concentration factors for

fish, crustaceans and mollusks and data for the edible fractions of marine produce to the human diet from the Marina study (CEC, 1990) and from NRPB report (NRPB, 1991) are used. Based on site specific information, however, these variables/parameters may be adjusted.

7.2.4 Model reliability

The reliability of the model is tested by comparison with observed data and with other models. The 3D World Ocean Model, which was used to derive the structure and water fluxes for the present model, has been used to calculate the dispersion of a number of tracers with simulated steady-state circulation and compared with *in situ* data. The agreement was satisfying and the limited discrepancies were explained (Chartier, 1993), so this model according to expert review (Ådlandsvik, 1993) is considered useful for the calculation of long range dispersion of conservative and semi-conservative tracers.

The regional box model, which covers the North-West European coastal areas and forms part of the present model, was used for a comparison with observed concentrations of radionuclides in sea water (Nielsen, 1994A). The radionuclides were ^{137}Cs, ^{99}Tc and ^{125}Sb discharged from two European reprocessing plants Sellafield and La Hague. An analysis of the predicted-to-observed sea water concentrations indicated agreement within 10% (Nielsen, 1994A). The ^{125}Sb data has not been used for model adjustments, but these data support the general conclusions in sea water. However, no model validation is performed for the Kara Sea, and documented site-specific information, i.e. sea currents is still to be implemented.

7.2.5 Dose estimates - the need for site specific information

For the solid radioactive waste two basic scenarios are considered. The first scenario assumes instant release of all radionuclides in soluble form at the time of dumping, as for liquid waste. In the second scenario, it is assumed that the solid waste will be released over a period of one hundred years. It should be noted that recent Russian studies indicate possible releases from sunken nuclear vessels over periods ranging from 10 to 1000 years (Platovskih, 1992; Dodzhdnikov, 1993; Sivintsev, 1993).

Preliminary estimates indicate that the collective dose will be small for both scenarios. Incomplete information about potential sources of radioactive

contamination, however, limits the possibility of estimating the potential total dose. Furthermore, due to the extreme climatic conditions in the Kara Sea i.e. icecovered about 11 months/year, water temperature close to 0^0 C or below during summer, low salinity water surface layers, the biodiversity is probably different from that of the Barents Sea. These conditions will influence transport processes and kinetics, biological uptake and pathways i.e. critical parameters for estimating dose to man. In addition, information on the harvesting of marine products as well as dietary intake and local dietary habits should be considered.

The Joint Russian-Norwegian expedition in 1994 is assumed to provide more data relevant for the assessment work.

8. SUMMARY AND CONCLUSIONS

During the 1993 Joint Russian-Norwegian Expedition to the Kara Sea, three dumping sites for nuclear waste were investigated: The Tsivolky Bay, the Stepovogo bay and an area in the open Kara Sea (The Novaya Zemlya Trough).

Dumped waste was localized and inspected in the Tsivolky Bay and in the Stepovogo Bay using side scanning sonar and underwater camera. In the Stepovogo Bay, the dumped nuclear submarine no. 601, containing spent nuclear fuel, was localized. Samples of waters, sediments and biota were collected at 9 stations and later analysed for several radionuclides (gammaemitters, ^{90}Sr, ^{238}Pu, $^{239,240}Pu$ and ^{241}Am).

The analyses of the samples allow the following conclusions to be drawn:

1. Elevated levels of ^{137}Cs and ^{90}Sr and presence of ^{60}Co were observed in the inner part of the Stepovogo Bay, and in one sample collected close to the hull of the dumped nuclear submarine in the Stepovogo Bay. ^{60}Co was also observed in the Tsivolky Bay. This radioactive contamination most likely originates from the dumped radioactive material. It may be due to leaching from the waste.

2. The enhanced levels of contamination caused by dumped nuclear waste are still low and restricted to small areas. Thus, radiation doses from the existing contamination would be negligible. Radioactive contamination outside these areas is similar to the activity levels in the open Kara Sea.

9. RECOMMENDATIONS

1. Further information about the dumped radioactive waste should be obtained, especially a description of the inventory and physical characteristics of all the dumped reactors containing spent nuclear fuel. This could be achieved through the work of the source term group in the International Arctic Seas Assessment Programme (IASAP).

   This information should, together with the results of the joint Russian-Norwegian investigation at the dump sites, be used in the ongoing work on the assessment of the potential consequences of the dumping of nuclear waste in the Kara Sea.

2. A joint Russian-Norwegian programme for monitoring of the Kara Sea including the dump sites should be established. The aim of the programme should be to monitor changes in the radioactive contamination in the dumping areas due to leaching of radionuclides.

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ANNEX A

Participants on the 1993 Russian - Norwegian expedition to the Kara Sea, August - September 1993

Alexander Nikitin, Vladimir Chumichev, Alexander Kobanov, Nikolai Pegoev
SPA "Typhoon", Obninsk, Kaluga region

Alexey Namiatov, Vasili Bessonov, Alexander Yakushkov
Murmansk Area Department for Hydrometeorological and Environmental Monitoring, Murmansk

Nikolai Kurganov, Navy Medical Department, Moskva
Vladimir Evseev, Navy, Researh Department, Moskva

Trygve Bjerk, Institute for Energy Technology, Kjeller

Lars Føyn, Vidar Saue, Trond Sangolt
Institute of Marine Research (IMR), Bergen

Bjørn Lind, Norwegian Radiation Protection Authority, Oslo

Georg Østby, Isotope Laboratory, NLH, Ås

K.H. Johansen, Norwegian Broadcasting Cooperation, Oslo

Hans J. Kellerman, German Fisheries Reseach Institute, Hamburg

Iolanda Osvath, IAEA - MEL, Monaco

ANNEX B

Comparison of Russian and Norwegian data

B.1 Comparison of results for radionuclides in sea water

The data may reflect differences in the collected water sample (same depth, but different volumes), different filtering systems as well as different measurement equipment. The analytical results for ^{137}Cs and ^{90}Sr in sea water obtained by Russia (Typhoon) and Norway (NRPA, AUN, IFE) are compared in Figures B.1 and B.2, respectively. For ^{137}Cs, the agreement in the results are acceptable, even though some outliers are evident. For ^{90}Sr the overall agreement is good.

B.2 Intercomparison measurements of the radionuclides in sea water.

IAEA/MEL organized an intercomparison exercise for the measurement of ^{137}Cs, ^{90}Sr and $^{239,240}Pu$ in sea water. Onboard the ship, about 3000 l seawater (station 5, Stepovogo Bay, 25 m depth) was homogenized as good as possible. A limited volume was filtered through the Norwegian, respectively the Russian system, and subsamples were distributed to the participants. A complete report will be prepared by IAEA/MEL. The results are given in Table B.1. Good agreement between individual results was obtained for ^{137}Cs and ^{90}Sr. In the case of $^{239,240}Pu$ one reported result appears to be an outlier, while good agreement is obtained for the remaining individual results.

The outlier was analysed by IFE. The laboratory received the sample as an iron hydroxide slurry prepared onboard and already containing Pu and Am tracers for estimation of chemical recovery. There is no evidence for Pu contamination at the laboratory during the analysis. The resulting alfa spetrum has well defined and clean peaks.

There may be several explanations for the high value found, e.g.

- The homogenization of the 3000 litre feed sample has not been good enough.

- The actual sub sample has not been filtered well enough.
- The actual sub sample has been added less ^{242}Pu tracer than reference value.

Table B.1

Results of intercomparison exercise for sea water from station 5 (Stepovogo Bay)

Laboratory	^{137}Cs (Bq/m^3)	^{90}Sr (Bq/m^3)	$^{239,240}Pu$ (mBq/m^3)
1. IAEA-MEL/N	8.1 $\pm$ 0.6	4.1 $\pm$ 0.2	1.9 $\pm$ 0.2
2. IAEA-MEL/R	8.9 $\pm$ 0.6	4.5 $\pm$ 0.2	1.9 $\pm$ 0.2
3. IFE	-	3.7 $\pm$ 0.2	11.4 $\pm$ 1.2
4. AUN	-	4.0 $\pm$ 0.1	-
5. NRPA	8.0 $\pm$ 0.3	-	2.3 $\pm$ 0.5
6. "Typhoon"	8.3 $\pm$ 0.3	4.7 $\pm$ 0.7	-

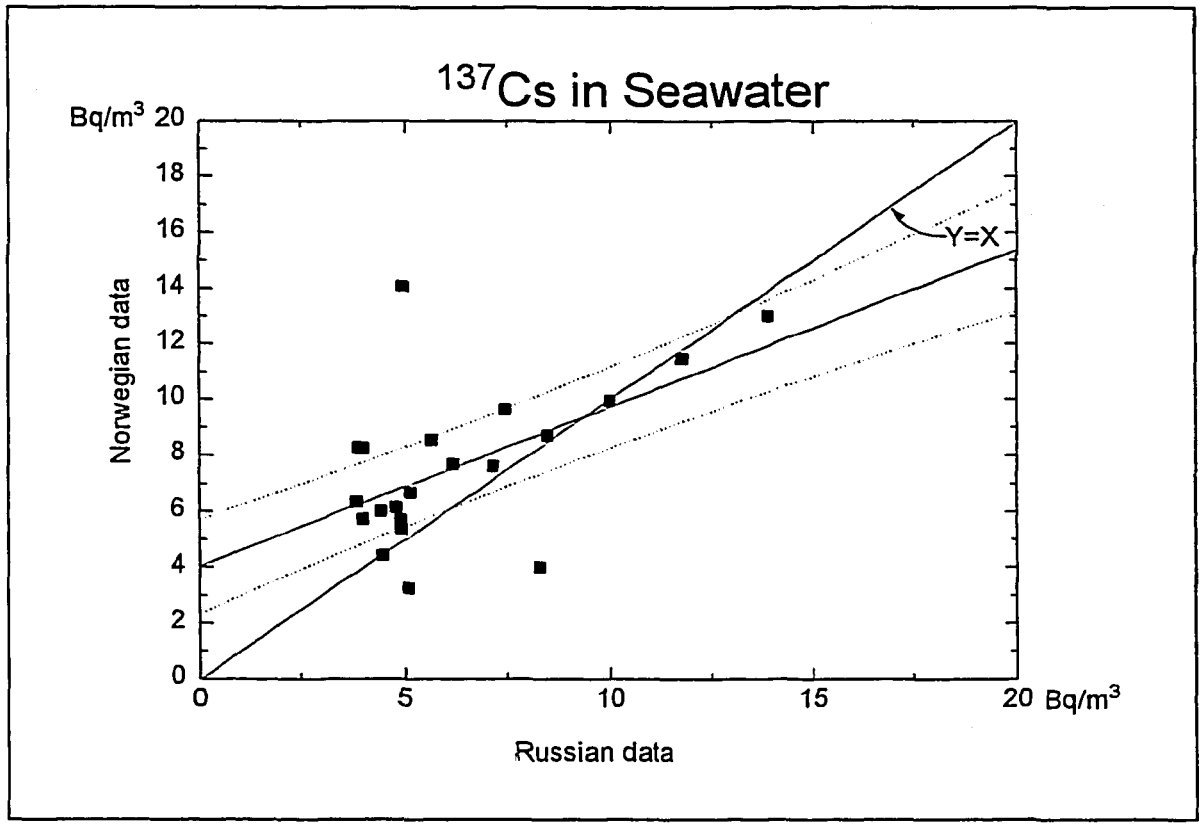

Figure B1 ^{137}Cs in seawater analysed by Russian and Norwegian institutions

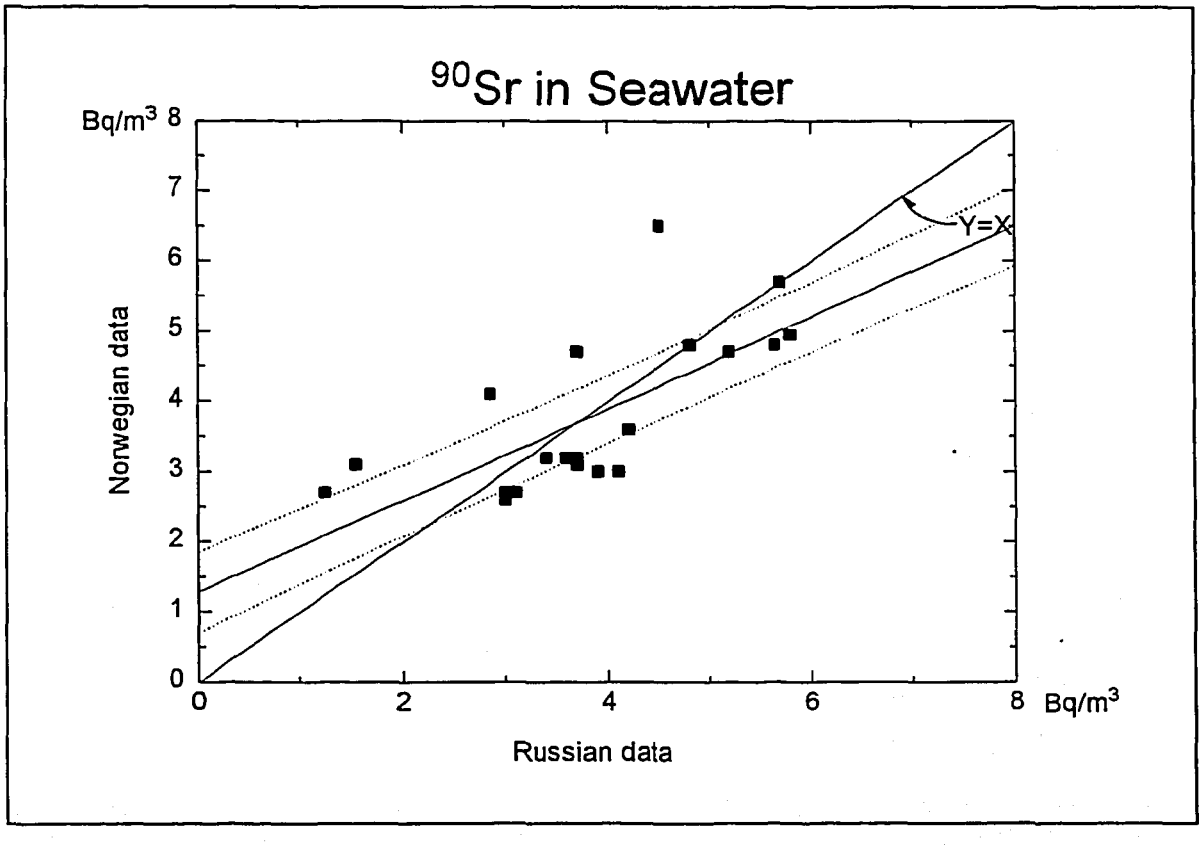

Figure B2 ^{90}Sr in seawater analysed by Russian and Norwegian institutions

ANNEX C

RESULTS OF RADIONUCLIDE ANALYSIS

ANNEX C

Sediment samples from the 1993 Kara Sea Expedition

St no.	Measured by	Depth (cm)	Sample identity	Tot. weight (kg)	Cs-137	Cs-134	Sr-90	Co-60	Pu-238	Pu-239,240	Am-241
1	NO	0-1	St1-1-2	0,08893	14,8 ±0,6		0,8 ±0,20	0,9 ±0,2	n.d	0,47 ±0,09	0,13 ±0,02
	NO	1-2		0,11406	21,1 ±0,8		0,6 ±0,20	3,9 ±0,4			
	NO	2-3		0,10658	19,0 ±1,0		0,5 ±0,20	3,4 ±0,3			
	NO	3-4		0,11359	21,2 ±0,9		0,8 ±0,20	1,4 ±0,2	n.d	0,51 ±0,09	
	NO	4-5		0,12357	17,0 ±0,9		0,5 ±0,20	2,0 ±0,2	n.d	0,39 ±0,03	
	NO	5-6		0,12435	14,3 ±0,7		0,6 ±0,20	2,1 ±0,2			
	NO	6-7		0,11725	10,9 ±0,7		0,3 ±0,20	0,8 ±0,2			
	NO	7-8		0,12502	13,1 ±0,5		0,3 ±0,20	0,6 ±0,2			
	NO	8-9		0,12630	13,0 ±0,7		0,4 ±0,20	2,8 ±0,2			
	NO	9-10		0,12645	12,3 ±0,6		0,4 ±0,20	1,2 ±0,2			
1	IA	0-1	St1-3-1(20)	0,06860	9,2 ±0,7	< 1,2		< 1,5			
	IA	1-2		0,07370	15,5 ±0,9	< 1,1		< 1,2			
	IA	2-3		0,07950	17,8 ±1,0	< 0,7		< 0,8			
	IA	3-4		0,09060	19,5 ±1,1	< 1,1		< 1,4			
	IA	4-5		0,06970	21,1 ±1,3	< 1,3		< 1,8			
	IA	5-6		0,06590	22,8 ±1,3	< 1,3		1,5 ±0,3			
	IA	6-7		0,07510	24,6 ±1,3	< 1,0		1,5 ±0,2			
	IA	7-8		0,07570	26,3 ±1,5	< 1,2		< 1,4			
	IA	8-9		0,08160	26,1 ±1,5	< 1,4		< 1,9			
	IA	9-10		0,09170	28,7 ±1,6	< 1,1		< 1,7			
	IA	10-12,5		0,18230	33,4 ±1,8	< 1,1		< 1,4			
1	IA	0-1	St1-8R-3	0,05940	13,0 ±0,9	< 1,3		< 1,7			
	IA	1-2		0,08810	17,5 ±1,1	< 1,0		1,4 ±0,3			
	IA	2-3		0,06430	21,3 ±1,2	< 1,3		2,2 ±0,4			
	IA	3-4		0,09770	24,0 ±1,3	< 0,9		1,4 ±0,4			
	IA	4-5		0,08390	22,0 ±1,3	< 1,3		2,2 ±0,5			
	IA	5-6		0,09480	20,9 ±1,2	< 1,1		< 1,2			
	IA	6-7		0,10590	15,5 ±1,0	< 1,4		1,5 ±0,5			
	IA	7-8		0,07990	12,6 ±0,8	< 1,2		< 1,4			
	IA	8-9		0,11940	10,0 ±0,7	< 1,4		< 1,7			
	IA	9-10		0,15660	7,2 ±0,6	< 1,2		< 1,6			

ANNEX C

Sediment samples from the 1993 Kara Sea Expedition

St no.	Measured by	Depth (cm)	Sample identity	Tot. weight (kg)	Cs-137	Cs-134	Sr-90	Co-60	Pu-238	Pu-239,240	Am-241
2	NO	0-1	St2 (6)	0,09959	4,0 ±0,4		0,4 ±0,20		n.d	0,03 ±0,01	0,06 ±0,01
	NO	1-2		0,09815	5,4 ±0,5		0,2 ±0,20		n.d	0,07 ±0,02	n.d
	NO	2-3		0,10376	7,3 ±0,4		< 0,2				
	NO	3-4		0,10470	8,4 ±0,5		< 0,2		n.d	0,09 ±0,01	
	NO	4-5		0,11851	7,1 ±0,5					0,10 ±0,04	
	NO	5-6		0,11638	5,9 ±0,3					0,08 ±0,02	
	NO	6-7		0,12641	5,5 ±0,3					0,07 ±0,03	
	NO	7-8		0,11293	5,5 ±0,4						
	NO	8-9		0,11714	5,9 ±0,5						
	NO	9-10		0,11968	7,6 ±0,4						
	NO	10-12		0,22981	10,7 ±0,5						
3	NO	0-1	St3-1-2	0,07968	13,8 ±1,4	< 1,1	1,0 ±0,10	< 1,7	n.d	0,26 ±0,03	
	NO	1-2		0,08517	12,8 ±1,4	< 4,1	1,0 ±0,20	< 2,9	n.d	0,35 ±0,03	
	NO	2-3		0,08856	16,2 ±1,3	< 3,3	1,1 ±0,20	< 2,3	n.d	0,37 ±0,03	
	NO	3-4		0,08798	13,0 ±1,3	< 3,3	1,0 ±0,10	< 2,6	n.d	0,06 ±0,01	
	NO	4-5		0,09901	7,5 ±1,0	< 3,2	2,6 ±0,20	< 2,5	n.d	0,22 ±0,02	
	NO	5-6		0,10391	6,1 ±1,0	< 2,9		< 1,9			
	NO	6-7		0,10002	3,5 ±1,1	< 3,6		< 3,3			
	NO	7-8		0,09526	2,9 ±1,0	< 2,8		< 2,4			
	NO	8-9		0,10118	< 2,3	< 3,6		< 3,2			
	NO	9-10		0,08210	< 2,0	< 2,7		< 1,9			
	NO	10-12		0,21315	< 1,7	< 2,8		< 1,6			
	NO	12-14		0,16567	< 1,3	< 2,5		< 1,7			
4	RU	0-1	St4-1-1 H=158m	0,04658	14,4 ±2,5	< 2,7		< 2,0			
	RU	1-2		0,07306	17,8 ±1,5	< 1,7		< 1,2			
	RU	2-3		0,07209	14,2 ±2,3	< 2,8		< 2,3			
	RU	3-4		0,07485	7,8 ±1,4	< 1,5		< 1,2			
	RU	4-5		0,07184	7,0 ±1,3	< 3,9		< 1,0			
	RU	5-6		0,07100	4,0 ±0,7	< 0,8		< 0,8			
	RU	6-8		0,20156	2,5 ±0,7	< 0,8		< 0,6			
	RU	8-10		0,19973	1,2 ±0,4	< 2,1		< 0,4			
	RU	10-12		0,20046	1,3 ±0,4	< 2,2		< 0,5			
	RU	12-14		0,20506	< 0,9	< 0,6		< 0,9			
	RU	14-15.5		0,14825	< 1,0	< 1,3		< 1,0			

ANNEX C

Sediment samples from the 1993 Kara Sea Expedition

St no.	Measured by	Depth (cm)	Sample identity	Tot. weight (kg)	Cs-137	Cs-134	Sr-90	Co-60	Pu-238	Pu-239,240	Am-241
4	RU	0-1	St4-1-3 H=158m	0,07778	8,4 ±1,2	< 1,3		< 1,0			
	RU	1-2		0,08000	6,2 ±1,1	< 1,2		< 0,9			
	RU	2-3		0,08256	5,4 ±1,3	< 2,9		< 1,1			
	RU	3-4		0,07999	4,0 ±1,0	< 3,8		< 1,1			
	RU	4-5		0,09930	3,3 ±1,0	< 2,1		< 0,7			
	RU	5-6		0,09090	< 1,0	< 1,1		< 0,9			
	RU	6-8		0,18464	< 0,6	< 2,8		< 0,5			
	RU	8-10		0,15385	< 0,7	< 3,3		< 0,6			
	RU	10-12		0,19410	< 0,7	< 3,2		< 0,6			
	RU	12-14		0,20992	< 0,5	< 1,9		< 0,5			
4	RU	0-1	St4-1-5 H=158m	0,05989	9,6 ±0,9	< 1,1		< 0,7			
	RU	1-2		0,06517	11,7 ±1,7	< 1,8		< 1,4			
	RU	2-3		0,05651	10,5 ±1,4	< 1,2		< 1,0			
	RU	3-4		0,07108	11,0 ±1,2	< 1,0		< 0,8			
	RU	4-5		0,07345	7,6 ±1,2	< 1,5		< 1,2			
	RU	5-6		0,07537	7,1 ±1,4	< 1,4		< 1,1			
	RU	6-8		0,14380	5,6 ±0,8	< 2,3		< 0,7			
	RU	8-10		0,17413	< 2,1	< 2,0		< 0,5			
	RU	10-12		0,16679	< 0,8	< 2,4		< 0,7			
	RU	12-14		0,18495	< 2,3	< 2,6		< 0,5			
	RU	14-16		0,16522	< 0,6	< 2,6		< 0,6			
	RU	16-17		0,16243	< 0,6	< 0,7		< 0,5			
4	NO	0-1	St4-1-6(32)	0,08752	12,8 ±0,8	< 2,4	0,7 ±0,08	< 2,4	2,9E-02 ±0,01	0,29 ±0,03	
	NO	1-2		0,11582	10,3 ±0,9	< 2,6	0,4 ±0,07	< 1,9	n.d	0,33 ±0,05	
	NO	2-3		0,08256	10,6 ±0,9	< 2,6	0,4 ±0,07	< 2,7	n.d	0,31 ±0,04	
	NO	3-4		0,07595	7,7 ±1,1	< 3,7	0,3 ±0,15	< 2,6	n.d	0,36 ±0,03	
	NO	4-5		0,07681	4,6 ±0,6	< 2,1	0,3 ±0,04	< 1,5	n.d	0,37 ±0,04	
	NO	5-6		0,08615	3,5 ±0,6	< 1,8		< 1,8			
	NO	6-7		0,08836	3,0 ±1,0	< 3,6		< 2,4			
	NO	7-8		0,09674	< 1,6	< 2,9		< 2,4			
	NO	8-9		0,10490	2,8 ±0,6	< 2,5		< 1,7			
	NO	9-10		0,11422	2,2 ±0,8	< 2,9		< 2,0			
	NO	10-12		0,19280	< 0,9	< 1,9		< 1,1			
	NO	12-14		0,18189	< 0,8	< 1,7		< 1,6			
	NO	14-16		0,07766	2,1 ±0,9	< 2,4		< 1,8			

ANNEX C

Sediment samples from the 1993 Kara Sea Expedition

St no.	Measured by	Depth (cm)	Sample identity	Tot. weight (kg)	Cs-137	Cs-134	Sr-90	Co-60	Pu-238	Pu-239,240	Am-241
5	NO	0-1	St5-4-4	0,12604	12,8 ±0,5		0,4 ±0,20		n.d	0,37 ±0,06	0,07 ±0,01
	NO	1-2		0,09810	18,0 ±0,7		0,6 ±0,30		1,2E-01 ±4E-2	0,37 ±0,06	0,08 ±0,02
	NO	2-3		0,11057	15,2 ±0,8		0,7 ±0,30		8,3E-02 ±3E-2	0,34 ±0,07	0,11 ±0,02
	NO	3-4		*0,12259*	*15,5 ±0,6*		*0,9 ±0,20*		*1,3E-02 ±8E-3*	*0,30 ±0,03*	*0,06 ±0,03*
	NO	4-5		0,11615	12,5 ±0,6		2,2 ±0,30		n.d	0,34 ±0,05	n.d
	RU	0-1.5	St5-4-3(34) H=42m	0,12740	9,4 ±1,0	< 1,0		< 0,8			
	RU	1.5-2.5		0,10154	14,5 ±1,2	< 1,2		< 1,0			
	RU	2.5-3.5		0,13574	12,2 ±0,5	< 2,4		< 0,4			
	RU	3.5-4.5		0,09090	14,9 ±1,8	< 1,8		< 1,4			
	RU	4.5-7.0		0,24100	11,4 ±0,5	< 1,9		< 0,4			
6	NO	0-1	St6-4-2	0,07096	110,2 ±1,4	< 2,8	2,0 ±0,30	5,1 ±0,9	3,0E-02 ±1E-2	0,73 ±0,05	
	NO	1-2		0,07671	107,1 ±1,9	< 4,3	2,4 ±0,30	6,9 ±1,3	5,4E-02 ±1E-2	0,82 ±0,06	
	NO	2-3		0,09275	96,4 ±1,5	< 2,9	2,5 ±0,20	3,4 ±0,7	4,2E-02 ±1E-2	0,81 ±0,07	
	NO	3-4		0,09449	61,0 ±1,2	< 2,6	1,3 ±0,10	< 1,8	n.d	0,33 ±0,04	
	NO	4-5		0,10044	32,1 ±1,1	< 1,5	1,3 ±0,30	< 3,8	n.d	0,10 ±0,01	
	NO	5-6		0,09990	26,2 ±1,2	< 1,8		< 2,6			
	NO	6-7		0,09967	11,6 ±0,7	< 3,2		< 1,8			
	NO	7-8		0,09345	8,2 ±0,9	< 2,0		< 2,3			
	NO	8-9		0,10994	3,8 ±0,9	< 2,6		< 2,1			
	NO	9-10		0,09788	< 1,5	< 2,5		< 1,7			
	NO	10-12		0,18141	< 1,5	< 1,0		< 2,0			
	NO	12-14		0,17573	< 2,3	< 3,1		< 2,3			
	NO	14-18		0,11578	< 1,5	< 2,8		< 1,7			
6	RU	0-1	St6-3-1	0,05662	174,0 ±3,0	< 1,6		3,5 ±1,2			
	RU	1-2		0,07885	196,0 ±3,0	< 1,2		9,5 ±1,3			
	RU	2-3		0,07199	187,0 ±4,0	< 2,8		18,8 ±1,9			
	RU	3-4		0,06430	117,0 ±2,0	< 2,1		3,2 ±0,8			
	RU	4-5		0,07835	81,4 ±1,3	< 0,8		3,2 ±0,7			
	RU	5-6		0,08072	42,8 ±1,0	< 0,7		< 0,6			
	RU	6-7		0,10664	26,2 ±1,4	< 1,1		< 1,0			
	RU	7-8		0,06310	19,2 ±1,2	< 2,6		< 0,7			
	RU	8-		0,14645	9,3 ±1,0	< 1,2		< 0,9			

St no.	Measured by	Depth (cm)	Sample identity	Tot. weight (kg)	Cs-137	Cs-134	Sr-90	Co-60	Pu-238	Pu-239,240	Am-241
6	RU	0-1	St6-3-3	0,03890	191,0 ±4,0	< 1,9	4,0 ±0,80	12,4 ±1,6		0,79 ±0,20	
	RU	1-2		0,05184	211,0 ±2,0	< 2,2	4,2 ±0,80	11,1 ±1,1		0,83 ±0,20	
	RU	2-3		0,06198	195,0 ±2,5	< 1,5	2,8 ±0,60	13,7 ±1,1		0,66 ±0,20	
	RU	3-4		0,06352	130,0 ±2,0	< 2,8	2,6 ±0,50	3,1 ±0,9			
	RU	4-5		0,09127	97,0 ±1,3	< 1,8	1,6 ±0,30	3,4 ±0,6			
	RU	5-6		0,08305	72,0 ±1,1	< 0,7	1,2 ±0,20	1,4 ±0,6			
	RU	6-8		0,15967	43,0 ±0,8	< 1,8	1,0 ±0,20	< 0,4		0,058 ±0,015	
	RU	8-10		0,15498	26,0 ±1,3	< 3,1	0,36 ±0,07	< 0,9			
	RU	10-12		0,16130	16,0 ±0,7	< 2,6	0,42 ±0,08	< 0,5			
	RU	12-14		0,16923	6,0 ±1,2	< 0,9	0,36 ±0,07	< 0,7		0,043 ±0,015	
6	RU	0-1	St6-4-1	0,04375	114,0 ±3,0	< 5,0		2,8 ±1,0			
	RU	1-2		0,07007	117,0 ±3,0	< 3,3		5,8 ±0,8			
	RU	2-3		0,08331	119,0 ±4,0	< 1,5		< 1,3			
	RU	3-4		0,08686	85,8 ±2,0	< 3,2		< 0,6			
	RU	4-5		0,10279	47,0 ±1,3	< 0,9		< 0,7			
	RU	5-6		0,06648	33,9 ±1,6	< 1,5		< 1,2			
	RU	6-8		0,15760	22,8 ±0,6	< 0,5		< 0,4			
	RU	8-10		0,16230	9,0 ±0,6	< 5,6		< 0,5			
	RU	10-12		0,14695	3,1 ±0,6	< 1,4		< 0,5			
	RU	12-14		0,15656	2,5 ±0,8	< 2,1		< 0,5			
	RU	14-16		*0,21235*	*0,7 ±0,4*	< *0,9*		< *0,3*			
	RU	16-17		0,10216	< 1,6	< 2,7		< 0,5			
6	IA	0-1	6-4-3(47)	0,04200	117,0 ±6,0	< 0,9		*5,3 ±0,3*	*5,9E-02 ±7E-3*	*0,76 ±0,08*	
	IA	1-2		*0,05720*	*104,0 ±6,0*	< 1,0		*3,7 ±0,3*	*6,4E-02 ±6E-3*	*0,93 ±0,07*	
	IA	2-3		0,06310	93,0 ±5,0	< 0,7		2,5 ±0,2	3,2E-02 ±6E-3	0,73 ±0,06	
	IA	3-4		0,05810	60,0 ±3,0	< 1,0		< 1,4	1,5E-02 ±3E-3	0,30 ±0,03	
	IA	4-5		0,06450	39,0 ±2,0	< 0,7		< 0,9	2,5E-02	0,12 ±0,02	
	IA	5-6		0,07350	24,0 ±1,3	< 0,8		< 0,9	1,2E-02	*0,05 ±0,01*	
	IA	6-7		0,06550	15,5 ±1,0	< 1,2		< 1,5	9,0E-03	0,016 ±0,008	
	IA	7-8		0,06190	11,2 ±0,7	< 0,8		< 1,0	1,2E-02	< 0,011	
	IA	8-9		0,05700	8,5 ±0,6	< 0,9		< 1,0	8,0E-03	< *0,009*	
	IA	9-10		0,06790	5,3 ±0,4	< 0,7		< 0,8			
	IA	10-12		0,12310	2,5 ±0,2	< 0,7		< 0,8			
	IA	12-14		0,12210	1,1 ±0,2	< 0,8		< 0,9			
	IA	14-16		0,08720	< 0,8	< 0,9		< 0,9			
	IA	16-18		0,10320	< 0,9	< 0,9		< 1,0			
	IA	18-20		0,09860	< 0,7	< 0,8		< 0,9			
	IA	20-24		0,23420	< 1,4	< 1,2		< 1,6			

ANNEX C

Sediment samples from the 1993 Kara Sea Expedition

St no.	Measured by	Depth (cm)	Sample identity	Tot. weight (kg)	Cs-137	Cs-134	Sr-90	Co-60	Pu-238	Pu-239,240	Am-241
8	RU	0-1	St8-1-1	0,03242	24,0 ±3,2	< 3,2		< 2,3			
	RU	1-2		0,03495	19,9 ±1,9	< 1,9		< 1,4			
	RU	2-3		0,04123	19,4 ±1,7	< 5,6		< 1,4			
	RU	3-4		0,03683	12,9 ±1,6	< 2,8		< 1,4			
	RU	4-5		0,04060	10,7 ±2,6	< 4,5		< 4,0			
	RU	5-6		0,05460	8,0 ±1,7	< 3,4					
	RU	6-8		0,10432	< 1,2	< 1,4					
	RU	8-10		0,09170	< 2,8	< 0,9					
	RU	10-12		0,19600	< 2,2	< 2,5					
	RU	12-13		0,07741	< 2,3	< 2,9					
8	RU	0-1	St8-1-4	0,04237	19,0 ±1,7	< 1,8		< 1,3			
	RU	1-2		0,04812	12,6 ±1,6	< 1,7		< 1,3			
	RU	2-3		0,03469	11,0 ±2,2	< 2,5		< 1,7			
	RU	3-4		0,03670	9,3 ±1,2	< 4,3		< 1,0			
	RU	4-5		0,04427	7,2 ±2,0	< 1,9		< 1,5			
	RU	5-6		0,04093	7,2 ±1,4	< 1,5		< 1,1			
	RU	6-8		0,09198	< 1,0	< 2,4		< 0,9			
	RU	8-10		0,07990	< 1,2	< 1,4		< 1,1			
	RU	10-12		0,08290	< 1,7	< 2,6		< 1,6			
	RU	12-14		0,12350	< 1,0	< 1,2		< 0,9			
	RU	14-15		0,02656	< 1,4	< 1,7		< 1,3			
8	RU	0-1	St8-1-6 H=378m	0,02016	24,0 ±5,6	< 7,3		< 6,7			
	RU	1-2		0,02701	22,5 ±2,0	< 3,1		< 1,6			
	RU	2-3		0,03215	23,5 ±3,7	< 5,6		< 4,3			
	RU	3-4		0,02825	15,8 ±1,9	< 2,1		< 1,5			
	RU	4-5		0,03784	14,6 ±3,4	< 5,5		< 4,7			
	RU	5-6		0,03774	11,8 ±2,6	< 3,9		< 3,3			
	RU	6-8		0,09072	< 2,6	< 3,2		< 3,1			
	RU	8-10		0,08217	< 2,7	< 3,0		< 2,9			
	RU	10-12		0,10143	< 2,6	< 3,3		< 3,0			
	RU	12-15		0,12036	< 2,0	< 2,6		< 2,2			

ANNEX C

Sediment samples from the 1993 Kara Sea Expedition

St no.	Measured by	Depth (cm)	Sample identity	Tot. weight (kg)	Cs-137	Cs-134	Sr-90	Co-60	Pu-238	Pu-239,240	Am-241
8	NO	0-1	St8-1-4	0,02540	20,0 ±1,0				4,8E-02 ±2E-2	0,94 ±0,08	0,32 ±0,04
	NO	1-2		0,03257	16,2 ±0,8				1,6E-02 ±1E-2	0,85 ±0,07	0,25 ±0,02
	NO	2-3		0,05989	9,0 ±0,8				n.d	0,42 ±0,06	0,07 ±0,03
	NO	3-4		0,05400	7,2 ±0,7				6,0E-03 ±5E-3	0,23 ±0,02	
	NO	4-5		0,03633	4,7 ±0,4				n.d	0,12 ±0,02	0,02 ±0,01
	NO	5-6		0,05238	3,5 ±0,4				n.d	0,11 ±0,01	
	NO	6-7		0,04369	2,2 ±0,4				n.d	0,06 ±0,01	
	NO	7-8		0,05429	2,7 ±0,7				n.d	0,04 ±0,01	
	NO	8-9		0,05835	1,5 ±0,3				n.d	0,07 ±0,01	
	NO	9-10		0,05982	3,5 ±0,4				n.d	0,12 ±0,02	
9	NO	0-1	St9-1-4	0,03549	16,0 ±1,4	< 4,2	0,8 ±0,15	< 3,2	n.d	0,32 ±0,04	
	NO	1-2		0,07862	12,4 ±0,7	< 2,3	0,4 ±0,06	< 1,7	n.d	0,38 ±0,05	
	NO	2-3		0,05307	5,6 ±0,8	< 2,5	0,5 ±0,12	< 1,7	n.d	0,11 ±0,02	
	NO	3-4		0,05341	6,8 ±0,9	< 3,4	0,4 ±0,06	< 3,0		0,21 ±0,04	
	NO	4-5		0,05413	4,0 ±0,7	< 2,9	0,2 ±0,05	< 2,0		0,11 ±0,03	
	NO	5-6		0,06758	< 2,8	< 3,6		< 3,0			
	NO	6-7		0,05968	1,4 ±0,6	< 2,5		< 2,0			
	NO	7-8		0,05978	1,6 ±0,7	< 3,2		< 2,2			
	NO	8-9		0,05623	< 1,5	< 2,9		< 2,0			
	NO	9-10		0,06336	< 3,0	< 4,0		< 2,3			
	NO	10-12		0,14142	< 1,2	< 1,9		< 1,5			
	NO	12-14		0,12826	< 1,2	< 2,6		< 1,6			
	NO	14-16		0,13932	< 1,5	< 1,9		< 1,4			
	NO	16-		0,02255	< 1,4	< 2,6		< 2,2			
9	RU	0-1	St9-1-3	0,02521	19,3 ±2,8	< 2,9		< 2,1			
	RU	1-2		0,02699	19,2 ±2,4	< 2,5		< 1,9			
	RU	2-3		0,03651	13,9 ±1,6	< 1,8		< 1,3			
	RU	3-4		0,04031	15,1 ±1,8	< 2,2		< 1,6			
	RU	4-5		0,04163	5,9 ±1,8	< 2,0		< 1,5			
	RU	5-6		0,04307	5,8 ±1,4	< 4,9		< 1,1			
	RU	6-8		0,08723	5,1 ±1,0	< 1,2		< 0,9			
	RU	8-10		0,09777	< 1,2	< 1,4		< 1,1			
	RU	10-12		0,09362	< 1,5	< 1,1		< 0,8			
	RU	12-14		0,09770	< 0,8	< 0,9		< 0,7			
	RU	14-16		0,10330	< 0,7	< 2,4		< 0,7			
	RU	16-18		0,08476	< 0,8	< 1,0		< 0,8			
	RU	18-20		0,09373	< 1,3	< 3,0		< 0,8			

Sediment samples from the 1993 Kara Sea Expedition

St no.	Measured by	Depth (cm)	Sample identity	Tot. weight (kg)	Cs-137	Cs-134	Sr-90	Co-60	Pu-238	Pu-239,240	Am-241
9	RU	0-1	St9-1-5	0,03549	29,2 ±4,0	< 5,8		< 5,1			
	RU	1-2		0,03271	27,2 ±4,0	< 5,5		< 5,1			
	RU	2-3		0,04190	21,8 ±3,0	< 3,8		< 3,5			
	RU	3-4		0,04447	17,7 ±1,4	< 3,7		< 1,2			
	RU	4-5		0,03718	14,5 ±2,6	< 5,0		< 4,3			
	RU	5-6		0,04870	15,8 ±2,8	< 4,3		< 3,5			
	RU	6-8		0,09500	8,7 ±1,3	< 2,8		< 2,6			
	RU	8-10		0,10085	< 2,4	< 2,8		< 2,7			
	RU	10-12		0,10941	< 2,2	< 2,8		< 2,6			
	RU	12-14		0,09732	< 2,5	< 3,1		< 2,7			
	RU	14-16		0,09970	< 2,4	< 2,7		< 2,6			
	RU	16-18		0,09879	< 2,0	< 2,5		< 2,2			
	RU	18-20		0,08446	< 2,4	< 2,9		< 2,6			
	RU	20-		0,24621	< 0,6	< 3,5		< 0,6			
9	RU	0-1	St9-1-1	0,02398	23,8 ±2,5	< 4,8		< 4,0			
	RU	1-2		0,03216	22,7 ±3,3	< 3,0		< 2,3			
	RU	2-3		0,02978	24,6 ±3,1	< 3,4		< 2,2			
	RU	3-4		0,03254	22,8 ±3,6	< 5,0		< 4,5			
	RU	4-5		0,04637	14,2 ±1,6	< 1,5		< 1,1			
	RU	5-6		0,03824	13,1 ±3,7	< 5,6		< 5,5			
	RU	6-8		0,08215	6,6 ±1,3	< 3,2		< 3,4			
	RU	8-10		0,08960	< 2,1	< 2,5		< 2,6			
	RU	10-12		0,09420	< 2,1	< 2,6		< 2,4			
	RU	12-14		0,09900	< 2,6	< 3,2		< 2,7			
	RU	14-19									

ANNEX C

Sediment samples from the 1993 Kara Sea Expedition

St no.	Measured by	Depth (cm)	Sample identity	Tot. weight (kg)	Cs-137	Cs-134	Sr-90	Co-60	Pu-238	Pu-239,240	Am-241
1	RU	SURF.	(1b)H=53m Rov	0,11502	19,8 ±1,3	< 1,3		< 1,0			
	RU	SURF.	H=43m Rov(b)	0,16171	15,3 ±1,0	< 1,8		< 1,0			
	RU	SURF.	2P-1 H=53m	0,32794	13,3 ±0,8	< 2,0		< 0,7			
	RU	SURF.	2P-3 H=53m	0,29608	14,9 ±0,4	< 2,3		2,0 ±0,3			
	RU	SURF.	1R-1 H=18m	0,26600	14,6 ±1,1	< 1,8		< 0,9			
	RU	SURF.	2R-1 H=28m	0,28510	9,1 ±0,7	< 3,2		< 0,5			
	RU	SURF.	3R-1 H=54m	0,24681	12,8 ±0,9	< 0,9		< 0,6			
	RU	SURF.	5R-1 H=36m	0,24507	30,9 ±1,1	< 0,7		< 0,5			
	RU	SURF.	6R-1 H=36m	0,23322	8,6 ±0,6	< 1,1		< 0,5			
	RU	SURF.	6R-1 H=37m	0,27995	21,4 ±1,0	< 0,9		< 0,7			
	RU	SURF.	7R-1 H=63m	0,28832	13,9 ±1,0	< 1,1		< 0,8			
	RU	SURF.	8R-1 H=43m	0,15172	16,6 ±1,2	< 1,0		< 0,9			
	RU	SURF.	St1-7-1 H=64m	0,15531	11,2 ±1,1	< 1,1		< 0,8			
1	NO	SURF.	St1-1r-2	0,27540	14,7 ±0,6	0,29 ±0,06		0,17 ±0,08			
	NO	SURF.	2n-2	0,27230	18,7 ±0,7			1,80 ±0,10			
	NO	SURF.	2R-2	0,26470	10,7 ±0,5	0,28 ±0,06					
	NO	SURF.	3R-2	0,26320	10,3 ±0,4	0,16 ±0,04		0,32 ±0,07			
	NO	SURF	5R-2	0,23070	13,4 ±0,5						
	NO	SURF	6R-2	0,26150	22,2 ±0,9			1,50 ±0,07			
	NO	SURF	7R-2	0,25470	10,7 ±0,4	0,15 ±0,04		1,00 ±0,08			
	NO	SURF	8R-2	0,13960	15,4 ±0,6			0,74 ±0,07			
1	IA	SURF	1-2R-4	0,22100	8,7 ±0,6	< 1,0		< 1,20			
2	NO	SURF.	nr2 (30m)	0,27950	3,7 ±0,2						
	RU	SURF.		0,24877	3,8 ±0,7	< 2,24		< 0,7			
	RU	SURF.		0,28963	3,1 ±0,5	< 0,64		< 0,5			
	RU	SURF.		0,30344	3,7 ±0,4	< 1,40		< 0,4			
	RU	SURF.		0,30343	4,8 ±0,7	< 0,84		< 0,4			
	RU	SURF.		0,29374	4,4 ±0,6	< 2,15		< 0,6			
3	NO	SURF.	St3-1-4	0,14090	13,9 ±0,6						
	NO	SURF.	St3-1-6		9,9 ±0,4						
	NO	SURF.	St3-1-2		13,3 ±0,5						
	NO	SURF.	St3-1-1 H=138m	0,14047	13,7 ±0,7	< 2,40					
	NO	SURF.	St3-1-3 H=113m	0,13710	14,3 ±1,1	< 3,70					
	NO	SURF.	St3-1-5 H=108m	0,13548	11,4 ±1,0	< 0,84					

St no.	Measured by	Depth (cm)	Sample identity	Tot. weight (kg)	Cs-137	Cs-134	Sr-90	Co-60	Pu-238	Pu-239,240	Am-241
4	RU	SURF.		0,14057	13,7	< 2,15		< 0,6			
	RU	SURF.		0,13710	14,3	< 2,40		< 0,9			
	RU	SURF.		0,13548	11,4	< 3,70		< 0,7			
	RU	SURF.	St4-1-1 H=158m	0,12371	15,2 ±1,2	< 1,22		< 1,0			
	RU	SURF	St4-1-3 H=158m	0,13820	12,8 ±0,9	< 0,93		< 0,7			
	RU	SURF.	St4-1-5 H=158m	0,16835	10,3 ±0,6	< 2,26		< 0,5			
	NO	SURF.	St4-1-2	0,13830	15,2 ±0,6	0,37 ±0,07		0,25 ±0,05			
	NO	SURF.	St4-1-4	0,13650	11,7 ±0,5						
	NO	SURF.	St4-1-6	0,17080	9,1 ±0,4			0,22 ±0,05			
5	IA	SURF.	5-1-3	0,21090	20,0 ±1,2	< 1,40		< 1,8			
	IA	SURF.	5-1-4	0,41970	20,4 ±1,2	< 1,3		< 1,6			
	IA	SURF.	5-2-3	0,35070	29,2 ±1,6	< 1,10		< 1,4			
5	NO	SURF.	St5-1-2	0,21770	6,7 ±0,3	0,17 ±0,04		0,29 ±0,05			
	NO	SURF.	St5-1-3 ROV	0,01830	203,0 ±8,0			1,2 ±0,2		8,0E-04	
	NO	SURF.	St5-4-6	0,17870	14,7 ±0,6	0,23 ±0,04				4,8E-04	
	NO	SURF.	ROV, subm.	0,00460	8,0 ±2,0						
	RU	SURF.	St5-1-1	0,16265	14,1 ±0,8	< 1,19		< 0,6			
	RU	SURF.	St5-1-1 H=30m	1,19000	11,0 ±0,3	< 1,58		< 0,2			
5	RU	SURF.	St5-1-1M H=30m	0,97500	9,9 ±0,4	< 1,89		< 0,3			
	RU	SURF.	St5-1-1 ROV	0,21908	15,5 ±0,5	< 0,40		< 0,3			
	RU	SURF.	St5-2-1 H=32m	1,72000	9,1 ±0,4	< 1,38		< 0,1			
	RU	SURF.	St5-3-1 H=32m	1,80500	7,5 ±0,5	< 0,97		< 0,3			
	RU	SURF.	St 5-4-1 H=42m	1,91500	8,7 ±0,3	< 1,76		< 0,2			
	RU	SURF.	St 5-4-5 H=42m	0,21915	9,7 ±0,6	< 1,42		< 0,3			
6	RU	SURF.	St6-1-1 H=45m	0,14130	90,2	< 2,41		3,4			
	RU	SURF.	St6-1-3 H=45m	0,16889	73,6	< 0,95		3,1			
	RU	SURF.	St6-2-1 H=41m	1,36000	34,3	< 2,06		1,6			
	RU	SURF.	St6-3-1 H=45m	0,14096	220,0	< 3,79		10,0			
	RU	SURF.	St6-3-3 H=45m	0,14026	214,0	< 1,92		9,0			
	RU	SURF.	St6-3-5 H=45m	0,12748	289,0	< 1,55		15,2			
	RU	SURF.	St6-4-1 H=57m	0,09870	101,0	< 2,57		4,6			
6	RU	SURF.	St7-1-1 H=30m	0,78500	8,9	< 1,64		< 0,5			
	RU	SURF.	St7-1-5 H=38m	1,51500	9,0	< 2,17		< 0,2			
	RU	SURF.	St7-1-5 H=38m	1,02500	7,4	< 1,00		< 0,2			

Sediment samples from the 1993 Kara Sea Expedition

St no.	Measured by	Depth (cm)	Sample identity	Tot. weight (kg)	Cs-137	Cs-134	Sr-90	Co-60	Pu-238	Pu-239,240	Am-241
6	NO		St6-1-2	0,13290	108,0 ±4,0	0,47 ±0,07		3,0 ±0,1			
	NO		St6-1-3	0,12490	190,0 ±8,0	0,41 ±0,05		10,2 ±0,3			
	NO		St6-3-4	0,13010	198,0 ±8,0	0,37 ±0,06		9,1 ±3,0			
	NO		St6-3-6	0,13790	233,0 ±9,0	0,41 ±0,04		12,3 ±0,4			
	NO		St6-4-2	0,10410	58,0 ±2,0	0,39 ±0,04		5,2 ±0,2			
	NO		St6 ROV	0,16350	67,0 ±3,0	0,32 ±0,05		1,9 ±0,1		5,6E-04	
7	IA		St7-1-7	0,48330	14,8 ±0,9	< 1,1		< 1,3			
8	RU	SURF.		0,01856	21,3 ±1,1	< 1,11		< 0,8			
	RU	SURF.		0,10079	12,3 ±0,8	< 0,84		< 0,6			
	RU	SURF.		0,08737	15,6 ±3,7	< 3,68		< 0,8			
	NO	SURF	St8-1-2	0,08290	18,4 ±0,8						
	NO	SURF	St8-1-4	0,08810	12,1 ±0,5						
	NO	SURF	St8-1-6	0,09180	15,4 ±0,6						
9	IA	SURF.	St9-1-9(b)	0,06910	22,4 ±1,2	< 0,5		< 1,0			
9	RU	SURF.		0,10150	14,5 ±1,5	< 1,66		< 1,4			
	RU	SURF.		0,07794	13,4 ±1,4	< 4,25		< 1,3			
	RU	SURF.		0,09379	18,0 ±1,9	< 1,26					
	NO	SURF	St9-1-2	0,06460	17,6 ±0,7			0,7 ±0,2			
	NO	SURF	St9-1-6	0,07700	21,5 ±0,9			0,6 ±0,1			
	NO	SURF	St9-1-8	0,07480	20,0 ±0,8			0,31 ±0,07			

St no.	Measured by	Depth (cm)	Cs-137	Cs-134	Sr-90	Co-60	Pu-238	Pu 239,240	Am 241
1	NO	0-1	168 ±7		9,1 ±2,3	10,2 ±2,0	n.d	5,3 ±1,02	1,5 ±0,20
	NO	1-2	306 ±12		8,7 ±2,9	56,5 ±5,1			
	NO	2-3	258 ±13		6,8 ±2,7	45,7 ±4,1			
	NO	3-4	307 ±12		11,6 ±2,9	20,1 ±2,7	n.d	7,4 ±1,23	
	NO	4-5	267 ±13		7,9 ±3,1	31,3 ±3,5	n.d	6,1 ±0,47	
	NO	5-6	226 ±11		9,5 ±3,2	32,6 ±3,6			
	NO	6-7	163 ±10		4,5 ±3,0	11,8 ±3,1			
	NO	7-8	209 ±8		4,8 ±3,2	8,9 ±2,5			
	NO	8-9	208 ±10		6,4 ±3,2	44,2 ±3,5			
	NO	9-10	198 ±10		6,4 ±3,2	19,3 ±2,9			
1	IA	0-1	80 ±6	< 10,5		< 13,1			
	IA	1-2	145 ±8	< 10,3		< 11,3			
	IA	2-3	180 ±10	< 7,1		< 8,1			
	IA	3-4	225 ±13	< 12,7		< 16,1			
	IA	4-5	187 ±12	< 11,5		< 16,0			
	IA	5-6	191 ±11	< 10,9		12,6 ±2,5			
	IA	6-7	235 ±12	< 9,6		14,3 ±1,9			
	IA	7-8	253 ±14	< 11,6		< 13,5			
	IA	8-9	271 ±16	< 14,5		< 19,7			
	IA	9-10	335 ±19	< 12,8		< 19,8			
	IA	10-12,5	775 ±42	< 25,5		< 32,5			
1	IA	0-1	98 ±7	< 9,8		< 12,9			
	IA	1-2	196 ±12	< 11,2		15,7 ±3,4			
	IA	2-3	174 ±10	< 10,6		18,0 ±3,3			
	IA	3-4	299 ±16	< 11,2		17,4 ±5,0			
	IA	4-5	235 ±14	< 13,9		23,5 ±5,3			
	IA	5-6	252 ±14	< 13,3		< 14,5			
	IA	6-7	209 ±13	< 18,9		20,2 ±6,7			
	IA	7-8	128 ±8	< 12,2		< 14,2			
	IA	8-9	152 ±11	< 21,3		< 25,8			
	IA	9-10	144 ±12	< 23,9		< 31,9			

St no.	Measured by	Depth (cm)	Cs-137	Cs-134	Sr-90	Co-60	Pu-238	Pu 239,240	Am 241
2	NO	0-1	50 ±5		5,1 ±2,5		n.d	0,4 ±0,14	0,7 ±0,18
	NO	1-2	68 ±7		2,5 ±2,5		n.d	0,8 ±0,24	n.d
	NO	2-3	96 ±6		< 2,6				
	NO	3-4	112 ±7		< 2,7		n.d	1,2 ±0,13	
	NO	4-5	108 ±8					1,5 ±0,62	
	NO	5-6	87 ±4					1,2 ±0,31	
	NO	6-7	88 ±5					1,1 ±0,43	
	NO	7-8	79 ±6						
	NO	8-9	88 ±7						
	NO	9-10	115 ±6						
	NO	10-12	313 ±15						
3	NO	0-1	139 ±14	< 11,2	10,1 ±1,0	< 17,2	n.d	2,6 ±0,30	
	NO	1-2	139 ±15	< 44,5	10,8 ±2,2	< 31,4	n.d	3,8 ±0,33	
	NO	2-3	183 ±15	< 37,2	12,4 ±2,3	< 25,9	n.d	4,2 ±0,34	
	NO	3-4	146 ±15	< 37,0	11,2 ±1,1	< 29,1	n.d	0,7 ±0,11	
	NO	4-5	95 ±12	< 40,3	32,8 ±2,5	< 31,5	n.d	2,7 ±0,25	
	NO	5-6	81 ±13	< 38,4		< 25,1			
	NO	6-7	45 ±14	< 45,8		< 42,0			
	NO	7-8	35 ±12	< 34,0		< 29,1			
	NO	8-9	< 30	< 46,4		< 41,2			
	NO	9-10	< 21	< 28,2		< 19,9			
	NO	10-12	< 46	< 76,0		< 43,4			
	NO	12-14	< 27	< 52,7		< 35,9			
4	RU	0-1	85 ±15	< 16,0		< 11,9			
	RU	1-2	166 ±14	< 15,5		< 11,2			
	RU	2-3	130 ±21	< 25,3		< 20,7			
	RU	3-4	74 ±13	< 14,3		< 11,4			
	RU	4-5	64 ±12	< 35,4		< 9,1			
	RU	5-6	36 ±6	< 7,0		< 6,8			
	RU	6-8	64 ±18	< 19,7		< 15,0			
	RU	8-10	31 ±10	< 52,9		< 9,2			
	RU	10-12	33 ±10	< 57,2		< 11,7			
	RU	12-14	< 23	< 15,4		< 23,0			
	RU	14-15,5	< 19	< 24,9		< 18,0			

St no.	Measured by	Depth (cm)	Cs-137	Cs-134	Sr-90	Co-60	Pu-238	Pu 239,240	Am 241
4	RU	0-1	83 ±12	< 12,9		< 9,9			
	RU	1-2	63 ±11	12,2		< 9,2			
	RU	2-3	57 ±14	< 30,5		< 11,6			
	RU	3-4	41 ±10	< 38,7		< 11,2			
	RU	4-5	42 ±13	< 26,6		< 8,9			
	RU	5-6	< 12	< 12,7		< 10,4			
	RU	6-8	< 14	< 65,8		< 11,8			
	RU	8-10	< 14	< 64,6		< 11,8			
	RU	10-12	< 17	< 79,1		< 14,8			
	RU	12-14	< 13	< 50,8		< 13,4			
4	RU	0-1	73 ±7	< 8,4		< 5,5			
	RU	1-2	97 ±14	< 14,9		< 11,6			
	RU	2-3	76 ±10	< 8,6		< 6,9			
	RU	3-4	100 ±11	< 9,1		< 7,2			
	RU	4-5	71 ±11	< 14,0		< 11,2			
	RU	5-6	68 ±13	< 13,4		< 10,6			
	RU	6-8	103 ±15	< 42,1		< 12,8			
	RU	8-10	< 47	< 44,3		< 10,2			
	RU	10-12	< 17	< 51,0		< 13,8			
	RU	12-14	< 54	< 61,2		< 11,5			
	RU	14-16	< 13	< 54,7		< 11,6			
	RU	16-17	< 12	< 14,5		< 11,2			
4	NO	0-1	143 ±9	< 26,7	7,8 ±0,9	< 26,7	0,3 ±0,11	3,2 ±0,33	
	NO	1-2	152 ±13	< 38,3	5,9 ±1,0	< 28,0	n.d	4,9 ±0,74	
	NO	2-3	111 ±9	< 27,3	4,2 ±0,7	< 28,4	n.d	3,3 ±0,42	
	NO	3-4	74 ±11	< 35,8	2,9 ±1,5	< 25,1	n.d	3,4 ±0,29	
	NO	4-5	45 ±6	< 20,5	2,9 ±0,4	< 14,7	n.d	3,6 ±0,39	
	NO	5-6	38 ±7	< 19,7		< 19,7			
	NO	6-7	34 ±11	< 40,5		< 27,0			
	NO	7-8	< 20	< 35,7		< 29,6			
	NO	8-9	37 ±8	< 33,4		< 22,7			
	NO	9-10	32 ±12	< 42,2		< 29,1			
	NO	10-12	< 22	< 46,6		< 27,0			
	NO	12-14	< 19	< 39,4		< 37,1			
	NO	14-16	21 ±9	< 23,7		< 17,8			

St no.	Measured by	Depth (cm)	Cs-137	Cs-134	Sr-90	Co-60	Pu-238	Pu 239,240	Am 241
5	NO	0-1	205 ±8		6,4 ±3,2		n.d	6,0 ±0,93	1,2 ±0,21
	NO	1-2	225 ±9		7,5 ±3,7		1,5 ±0,46	4,6 ±0,80	1,0 ±0,19
	NO	2-3	214 ±11		9,9 ±4,2		1,2 ±0,45	4,8 ±0,96	1,5 ±0,21
	NO	3-4	242 ±10		14,0 ±3,1		0,2 ±0,12	4,7 ±0,47	0,9 ±0,47
	NO	4-5	185 ±9		32,5 ±4,4		n.d	5,0 ±0,68	n.d
	RU	0-1.5	152 ±16	< 16,5		< 13,7			
	RU	1.5-2.5	187 ±16	< 15,9		< 13,1			
	RU	2.5-3.5	211 ±9	< 40,8		< 6,9			
	RU	3.5-4.5	172 ±21	< 21,3		< 16,3			
	RU	4.5-7.0	350 ±15	< 58,3		< 12,0			
6	NO	0-1	995 ±13	< 25,3	18,1 ±2,7	46,1 ±8,1	0,3 ±0,09	6,6 ±0,45	
	NO	1-2	1046 ±19	< 42,0	23,4 ±2,9	67,0 ±12,7	0,5 ±0,10	8,0 ±0,59	
	NO	2-3	1138 ±18	< 34,2	29,5 ±2,4	40,1 ±8,7	0,5 ±0,12	9,6 ±0,83	
	NO	3-4	734 ±14	< 31,3	15,6 ±1,2	< 21,7	n.d	3,9 ±0,48	
	NO	4-5	411 ±14	< 19,2	16,6 ±3,8	< 48,6	n.d	1,2 ±0,13	
	NO	5-6	333 ±15	< 22,9		< 33,1			
	NO	6-7	147 ±9	< 40,6		< 22,8			
	NO	7-8	97 ±11	< 23,8		< 27,4			
	NO	8-9	53 ±12	< 36,4		< 29,4			
	NO	9-10	< 19	< 31,2		< 21,2			
	NO	10-12	< 35	< 23,1		< 46,2			
	NO	12-14	< 51	< 69,4		< 51,5			
	NO	14-18	< 22	< 41,3		< 25,1			
6	RU	0-1	1254 ±22	< 11,5		25,2 ±8,7			
	RU	1-2	1968 ±30	< 12,0		95,4 ±13,1			
	RU	2-3	1714 ±37	< 25,7		172,3 ±17,4			
	RU	3-4	958 ±16	< 17,2		26,2 ±6,5			
	RU	4-5	812 ±13	< 7,7		31,9 ±7,0			
	RU	5-6	440 ±10	< 7,3		< 6,2			
	RU	6-7	356 ±19	< 14,9		< 13,2			
	RU	7-8	154 ±10	< 20,9		< 5,9			
	RU	8-	173 ±19	< 22,4		< 17,3			

St no.	Measured by	Depth (cm)	Cs-137	Cs-134	Sr-90	Co-60	Pu-238	Pu 239,240	Am 241
6	RU	0-1	946 ±20	< 9,4	19,0 ±4,0	61,4 ±7,9		3,7 ±0,99	
	RU	1-2	1393 ±13	< 14,5	26,0 ±5,3	73,3 ±7,3		5,1 ±1,32	
	RU	2-3	1539 ±20	< 11,8	20,0 ±4,7	108,1 ±8,7		4,7 ±1,58	
	RU	3-4	1051 ±16	< 22,6	19,0 ±4,0	25,1 ±7,3			
	RU	4-5	1127 ±15	< 20,9	17,0 ±3,5	39,5 ±7,0			
	RU	5-6	761 ±12	< 7,4	11,5 ±2,1	15,2 ±6,3			
	RU	6-8	874 ±16	< 36,6	19,0 ±4,1	< 8,5		1,1 ±0,30	
	RU	8-10	513 ±26	< 61,2	6,7 ±1,4	< 17,8			
	RU	10-12	329 ±14	< 53,4	8,1 ±1,6	< 9,9			
	RU	12-14	129 ±26	< 19,4	7,1 ±1,5	< 15,1		0,9 ±0,32	
6	RU	0-1	635 ±17	< 27,9		15,6 ±5,6			
	RU	1-2	1044 ±27	< 29,4		51,7 ±7,1			
	RU	2-3	1262 ±42	< 15,9		< 13,8			
	RU	3-4	949 ±22	< 35,4		< 6,6			
	RU	4-5	615 ±17	< 11,8		< 9,2			
	RU	5-6	287 ±15	< 12,7		< 10,2			
	RU	6-8	458 ±12	< 10,0		< 8,0			
	RU	8-10	186 ±12	< 115,7		< 10,3			
	RU	10-12	58 ±11	< 26,2		< 9,4			
	RU	12-14	50 ±16	< 41,9		< 10,0			
	RU	14-16	19 ±11	< 24,3		< 8,1			
	RU	16-17	< 21	< 35,1		< 6,5			
6	IA	0-1	626 ±32	< 4,8		28,3 ±1,6	0,3 ±0,04	4,1 ±0,32	
	IA	1-2	757 ±44	< 7,3		26,9 ±2,2	0,5 ±0,04	6,8 ±0,51	
	IA	2-3	747 ±40	< 5,6		20,1 ±1,6	0,3 ±0,05	5,9 ±0,48	
	IA	3-4	444 ±22	< 7,4		< 10,4	0,1 ±0,02	2,2 ±0,22	
	IA	4-5	320 ±16	< 5,7		< 7,4	0,2	1,0 ±0,16	
	IA	5-6	225 ±12	< 7,5		< 8,4	0,1	0,4 ±0,10	
	IA	6-7	129 ±8	< 10,0		< 12,5	0,1	0,1 ±0,07	
	IA	7-8	88 ±6	< 6,3		< 7,9	0,1	0,1	
	IA	8-9	62 ±4	< 6,5		< 7,3	0,1	0,1	
	IA	9-10	46 ±3	< 6,1		< 6,9			
	IA	10-12	39 ±3	< 11,0		< 12,5			
	IA	12-14	17 ±3	< 12,4		< 14,0			
	IA	14-16	< 9	< 10,0		< 10,0			
	IA	16-18	< 12	< 11,8		< 13,1			
	IA	18-20	< 9	< 10,0		< 11,3			
	IA	20-24	< 42	< 35,8		< 47,7			

St no.	Measured by	Depth (cm)	Cs-137	Cs-134	Sr-90	Co-60	Pu-238	Pu 239,240	Am 241
8	RU	0-1	99 ±13	< 13,2		< 9,5			
	RU	1-2	89 ±8	< 8,2		< 6,0			
	RU	2-3	102 ±9	< 29,4		< 7,3			
	RU	3-4	60 ±8	< 13,1		< 6,6			
	RU	4-5	55 ±13	< 23,3		< 20,7			
	RU	5-6	56 ±12	< 23,6					
	RU	6-8	< 16	< 18,6					
	RU	8-10	< 33	< 11,0					
	RU	10-12	< 55	< 62,4					
	RU	12-13	< 23	< 28,6					
8	RU	0-1	102 ±9	< 9,7		< 7,0			
	RU	1-2	77 ±10	< 10,4		< 8,0			
	RU	2-3	49 ±10	< 11,0		< 7,5			
	RU	3-4	43 ±6	< 20,1		< 4,4			
	RU	4-5	41 ±11	< 10,7		< 8,5			
	RU	5-6	38 ±7	< 7,8		< 5,7			
	RU	6-8	< 12	< 28,1		< 10,9			
	RU	8-10	< 12	< 14,2		< 11,2			
	RU	10-12	< 18	< 27,4		< 16,9			
	RU	12-14	< 16	< 18,9		< 13,5			
	RU	14-15	< 5	< 5,7		< 4,4			
8	RU	0-1	62 ±14	< 18,7		< 17,2			
	RU	1-2	77 ±7	< 10,7		< 5,5			
	RU	2-3	96 ±15	< 22,9		< 17,6			
	RU	3-4	57 ±7	< 7,6		< 5,4			
	RU	4-5	70 ±16	< 26,5		< 22,6			
	RU	5-6	57 ±12	< 18,7		< 15,9			
	RU	6-8	< 30	< 37,0		< 35,8			
	RU	8-10	< 28	< 31,4		< 30,3			
	RU	10-12	< 34	< 42,6		< 38,7			
	RU	12-15	< 31	< 39,8		< 33,7			

St no.	Measured by	Depth (cm)	Cs-137	Cs-134	Sr-90	Co-60	Pu-238	Pu 239,240	Am 241
8	NO	0-1	65 ±3				0,2 ±0,05	3,0 ±0,27	1,0 ±0,14
	NO	1-2	67 ±3				0,1 ±0,04	3,5 ±0,28	1,0 ±0,09
	NO	2-3	69 ±6				n.d	3,2 ±0,44	0,5 ±0,21
	NO	3-4	50 ±4				0,0 ±0,03	1,6 ±0,15	
	NO	4-5	22 ±2				n.d	0,6 ±0,09	0,1 ±0,04
	NO	5-6	23 ±2				n.d	0,7 ±0,09	
	NO	6-7	12 ±2				n.d	0,3 ±0,06	
	NO	7-8	19 ±4				n.d	0,3 ±0,04	
	NO	8-9	11 ±2				n.d	0,5 ±0,07	
	NO	9-10	27 ±3				n.d	0,9 ±0,11	
9	NO	0-1	72 ±6	< 19,0	3,6 ±0,7	< 14,5	n.d	1,4 ±0,18	
	NO	1-2	124 ±7	< 23,0	4,0 ±0,6	< 17,0	n.d	3,8 ±0,50	
	NO	2-3	38 ±5	< 16,9	3,4 ±0,8	< 11,5	n.d	0,7 ±0,14	
	NO	3-4	46 ±6	< 23,1	2,7 ±0,4	< 20,4		1,4 ±0,27	
	NO	4-5	28 ±5	< 20,0	1,4 ±0,3	< 13,8		0,8 ±0,21	
	NO	5-6	< 24	< 31,0		< 25,8			
	NO	6-7	11 ±5	< 19,0		< 15,2			
	NO	7-8	12 ±6	< 24,4		< 16,7			
	NO	8-9	< 11	< 20,8		< 14,3			
	NO	9-10	< 24	< 32,3		< 18,6			
	NO	10-12	< 22	< 34,2		< 27,0			
	NO	12-14	< 20	< 42,5		< 26,1			
	NO	14-16	< 27	< 33,7		< 24,8			
	NO	16-	< 4	< 7,5		< 6,3			
9	RU	0-1	62 ±9	< 9,3		< 6,7			
	RU	1-2	66 ±8	< 8,6		< 6,5			
	RU	2-3	65 ±7	< 8,4		< 6,0			
	RU	3-4	77 ±9	< 11,3		< 8,2			
	RU	4-5	31 ±10	< 10,6		< 8,0			
	RU	5-6	32 ±8	< 26,9		< 6,0			
	RU	6-8	57 ±11	< 13,3		< 9,6			
	RU	8-10	< 15	< 17,4		< 13,7			
	RU	10-12	< 18	< 13,1		< 9,9			
	RU	12-14	< 10	< 11,2		< 8,8			
	RU	14-16	< 9	< 31,6		< 8,8			
	RU	16-18	< 9	< 10,8		< 8,6			
	RU	18-20	< 16	< 35,8		< 9,5			

St no.	Measured by	Depth (cm)	Cs-137	Cs-134	Sr-90	Co-60	Pu-238	Pu 239,240	Am 241
9	RU	0-1	132 ±18	< 26,2		< 23,0			
	RU	1-2	113 ±17	< 22,9		< 14,6			
	RU	2-3	116 ±16	< 20,3		< 6,4			
	RU	3-4	100 ±8	< 20,9		< 24,3			
	RU	4-5	69 ±12	< 23,7		< 16,6			
	RU	5-6	98 ±17	< 26,7		< 16,1			
	RU	6-8	105 ±16	< 33,9		< 32,7			
	RU	8-10	< 31	< 36,0		< 33,4			
	RU	10-12	< 31	< 39,0		< 37,6			
	RU	12-14	< 31	< 38,4		< 32,2			
	RU	14-16	< 30	< 34,3		< 27,9			
	RU	16-18	< 25	< 31,4		< 32,7			
	RU	18-20	< 26	< 31,2		< 6,7			
	RU	20-	< 19	< 109,7		< 159,9			
9	RU	0-1	73 ±8	< 14,7		< 12,2			
	RU	1-2	93 ±14	< 12,3		< 9,4			
	RU	2-3	93 ±12	< 12,9		< 8,3			
	RU	3-4	94 ±15	< 20,7		< 18,6			
	RU	4-5	84 ±9	< 8,9		< 6,5			
	RU	5-6	64 ±18	< 27,3		< 26,8			
	RU	6-8	69 ±14	< 33,5		< 35,6			
	RU	8-10	< 24	< 28,5		< 29,7			
	RU	10-12	< 25	< 31,2		< 28,8			
	RU	12-14	< 33	< 40,3		< 34,0			
	RU	14-19							

St no.	Measured by	Depth (cm)	Cs-137	Cs-134	Sr-90	Co-60	Pu-238	Pu 239,240	Am 241
1	RU	SURF.	228 ±15	< 15,0		< 11,5			
	RU	SURF.	247 ±16	< 29,1		< 16,2			
	RU	SURF.	436 ±26	< 65,6		< 23,0			
	RU	SURF.	441 ±12	< 68,1		59,2 ±8,9			
	RU	SURF.	388 ±29	< 47,9		< 23,9			
	RU	SURF.	258 ±20	< 91,2		< 14,3			
	RU	SURF.	316 ±22	< 22,2		< 14,8			
	RU	SURF.	757 ±27	< 17,2		< 12,3			
	RU	SURF.	201 ±14	< 25,7		< 11,7			
	RU	SURF.	599 ±28	< 25,2		< 19,6			
	RU	SURF.	401 ±29	< 31,7		< 23,1			
	RU	SURF.	252 ±18	< 15,2		< 13,7			
	RU	SURF.	174 ±17	< 17,1		< 12,4			
1	NO	SURF.	405 ±17	8,0 ±1,7		4,7 ±2,2			
	NO	SURF.	509 ±19			49,0 ±2,7			
	NO	SURF.	283 ±13	7,4 ±1,6					
	NO	SURF.	271 ±11	4,2 ±1,1		8,4 ±1,8			
	NO	SURF	309 ±12						
	NO	SURF	581 ±24			39,2 ±1,8			
	NO	SURF	273 ±10	3,8 ±1,0		25,5 ±2,0			
	NO	SURF	215 ±8			10,3 ±1,0			
1	IA	SURF							
2	NO	SURF.	103 ±6						
	RU	SURF.	93 ±17	< 55,7		< 16,5			
	RU	SURF.	89 ±14	< 18,5		< 14,0			
	RU	SURF.	112 ±12	< 42,5		< 11,9			
	RU	SURF.	147 ±21	< 25,5		< 13,1			
	RU	SURF.	130 ±18	< 63,2		< 16,7			
3	NO	SURF.	196 ±8						
	NO	SURF.							
	NO	SURF.							
	NO	SURF.	192 ±10	< 33,7					
	NO	SURF.	196 ±15	< 50,7					
	NO	SURF.	154 ±14	< 11,4					

St no.	Measured by	Depth (cm)	Cs-137	Cs-134	Sr-90	Co-60	Pu-238	Pu 239,240	Am 241
4	RU	SURF.	193	< 30,2		< 8,4			
	RU	SURF.	196	< 32,9		< 12,3			
	RU	SURF.	154	< 50,1		< 9,1			
	RU	SURF.	188 ±15	< 15,1		< 12,1			
	RU	SURF	177 ±12	< 12,9		< 10,1			
	RU	SURF.	173 ±10	< 38,0		< 8,6			
	NO	SURF.	210 ±8	5,1 ±1,0		3,5 ±0,7			
	NO	SURF.	160 ±7						
	NO	SURF.	155 ±7			3,8 ±0,9			
5	IA	SURF.	422 ±25	< 29,5		< 38,0			
	IA	SURF.	856 ±50	< 54,6		< 67,2			
	IA	SURF.	1024 ±56	< 38,6		< 49,1			
5	NO	SURF.	145 ±6	3,7 ±0,9		6,3 ±1,1			
	NO	SURF.	371 ±15			2,2 ±0,4		0,0	
	NO	SURF.	263 ±11	4,1 ±0,7				0,0	
	NO	SURF.	4 ±1						
	RU	SURF.	229 ±13	< 19,4		< 10,1			
	RU	SURF.	1309 ±36	< 188,0		< 22,6			
5	RU	SURF.	961 ±39	< 184,3		< 25,4			
	RU	SURF.	340 ±11	< 8,8		< 6,6			
	RU	SURF.	1560 ±69	< 237,4		< 24,1			
	RU	SURF.	1350 ±90	< 175,1		< 54,2			
	RU	SURF.	1670 ±57	< 337,0		< 38,3			
	RU	SURF.	213 ±13	< 31,1		< 6,6			
6	RU	SURF.	1275	< 34,1		48,0			
	RU	SURF.	1243	< 16,0		52,2			
	RU	SURF.	4665	< 280,2		219,0			
	RU	SURF.	3101	< 53,4		140,5			
	RU	SURF.	3002	< 26,9		126,5			
	RU	SURF.	3684	< 19,8		193,8			
	RU	SURF.	997	< 25,4		45,4			
6	RU	SURF.	698	< 128,7		< 35,3			
	RU	SURF.	1365	< 328,8		< 31,7			
	RU	SURF.	760	< 102,5		< 18,9			

St no.	Measured by	Depth (cm)	Cs-137	Cs-134	Sr-90	Co-60	Pu-238	Pu 239,240	Am 241
6	NO		1435 ±53	6,2 ±0,9		39,9 ±1,3			
	NO		2373 ±100	5,1 ±0,6		127,4 ±3,7			
	NO		2576 ±104	4,8 ±0,8		118,4 ±39,0			
	NO		3213 ±124	5,7 ±0,6		169,6 ±5,5			
	NO		604 ±21	4,1 ±0,4		54,1 ±2,1			
	NO		1095 ±49	5,2 ±0,8		31,1 ±1,6		0,0	
7	IA		715 ±43	< 53,2		< 62,8			
8	RU	SURF.	40 ±2	< 2,1		< 1,5			
	RU	SURF.	124 ±8	< 8,5		< 6,1			
	RU	SURF.	136 ±32	< 32,2		< 6,7			
	NO	SURF	153 ±7						
	NO	SURF	107 ±4						
	NO	SURF	141 ±6						
9	IA	SURF.	155 ±8	< 3,5		< 6,9			
9	RU	SURF.	147 ±15	< 16,8		< 13,7			
	RU	SURF.	104 ±11	< 33,1		< 9,9			
	RU	SURF.	169 ±18	< 11,8					
	NO	SURF	114 ±5			4,52 ±1,3			
	NO	SURF	166 ±7			4,62 ±0,8			
	NO	SURF	150 ±6			2,32 ±0,5			

St no.	Measured by	Depth (cm)	Co-60/Cs-137	Pu239,240/Cs-137	Pu-238/Pu-239,40	Cs-134/Cs-137	Cs-137/Sr-90	Pu-239,40/Sr-90	Pu-239,40/Am-241
1	NO	0-1	0,061 ±0,012	3,1E-02 ±6E-3			1,9E+01 ±5E+0	5,8E-01 ±2E-1	3,6E+00 ±9E-1
	NO	1-2	0,184 ±0,018				3,5E+01 ±1E+1		
	NO	2-3	0,177 ±0,018				3,8E+01 ±2E+1		
	NO	3-4	0,066 ±0,009	2,4E-02 ±4E-3			2,7E+01 ±7E+0	6,4E-01 ±2E-1	
	NO	4-5	0,117 ±0,014	2,3E-02 ±2E-3			3,4E+01 ±1E+1	7,8E-01 ±3E-1	
	NO	5-6	0,144 ±0,018				2,4E+01 ±8E+0		
	NO	6-7	0,072 ±0,020				3,6E+01 ±2E+1		
	NO	7-8	0,043 ±0,012				4,4E+01 ±3E+1		
	NO	8-9	0,212 ±0,020				3,2E+01 ±2E+1		
	NO	9-10	0,098 ±0,015				3,1E+01 ±2E+1		
1	IA	0-1							
	IA	1-2							
	IA	2-3							
	IA	3-4							
	IA	4-5							
	IA	5-6	0,066 ±0,014						
	IA	6-7	0,061 ±0,009						
	IA	7-8							
	IA	8-9							
	IA	9-10							
	IA	10-12,5							
1	IA	0-1							
	IA	1-2	0,080 ±0,018						
	IA	2-3	0,103 ±0,020						
	IA	3-4	0,058 ±0,017						
	IA	4-5	0,100 ±0,023						
	IA	5-6							
	IA	6-7	0,097 ±0,033						
	IA	7-8							
	IA	8-9							
	IA	9-10							

St no.	Measured by	Depth (cm)	Co-60/Cs-137	Pu239,240/Cs-137	Pu-238/Pu-239,40	Cs-134/Cs-137	Cs-137/Sr-90	Pu-239,40/Sr-90	Pu-239,40/Am-241
2	NO	0-1		8,1E-03 ±3E-3			9,9E+00 ±5E+0	8,0E-02 ±5E-2	5,6E-01 ±2E-1
	NO	1-2		1,2E-02 ±4E-3			2,7E+01 ±3E+1	3,4E-01 ±3E-1	
	NO	2-3							
	NO	3-4		1,1E-02 ±1E-3					
	NO	4-5		1,4E-02 ±6E-3					
	NO	5-6		1,4E-02 ±4E-3					
	NO	6-7		1,3E-02 ±5E-3					
	NO	7-8							
	NO	8-9							
	NO	9-10							
	NO	10-12							
3	NO	0-1		1,9E-02 ±3E-3			1,4E+01 ±2E+0	2,6E-01 ±4E-2	
	NO	1-2		2,7E-02 ±4E-3			1,3E+01 ±3E+0	3,5E-01 ±8E-2	
	NO	2-3		2,3E-02 ±3E-3			1,5E+01 ±3E+0	3,4E-01 ±7E-2	
	NO	3-4		4,9E-03 ±9E-4			1,3E+01 ±2E+0	6,4E-02 ±1E-2	
	NO	4-5		2,9E-02 ±5E-3			2,9E+00 ±4E-1	8,3E-02 ±1E-2	
	NO	5-6							
	NO	6-7							
	NO	7-8							
	NO	8-9							
	NO	9-10							
	NO	10-12							
	NO	12-14							
4	RU	0-1							
	RU	1-2							
	RU	2-3							
	RU	3-4							
	RU	4-5							
	RU	5-6							
	RU	6-8							
	RU	8-10							
	RU	10-12							
	RU	12-14							
	RU	14-15,5							

St no.	Measured by	Depth (cm)	Co-60/Cs-137	Pu239,240/Cs-137	Pu-238/Pu-239,40	Cs-134/Cs-137	Cs-137/Sr-90	Pu-239,40/Sr-90	Pu-239,40/Am-241
4	RU	0-1							
	RU	1-2				1,9E-01			
	RU	2-3							
	RU	3-4							
	RU	4-5							
	RU	5-6							
	RU	6-8							
	RU	8-10							
	RU	10-12							
	RU	12-14							
4	RU	0-1							
	RU	1-2							
	RU	2-3							
	RU	3-4							
	RU	4-5							
	RU	5-6							
	RU	6-8							
	RU	8-10							
	RU	10-12							
	RU	12-14							
	RU	14-16							
	RU	16-17							
4	NO	0-1		2,3E-02 ±3E-3	1,0E-01 ±4E-2		1,8E+01 ±2E+0	4,1E-01 ±6E-2	
	NO	1-2		3,2E-02 ±6E-3			2,6E+01 ±5E+0	8,3E-01 ±2E-1	
	NO	2-3		2,9E-02 ±5E-3			2,7E+01 ±5E+0	7,8E-01 ±2E-1	
	NO	3-4		4,6E-02 ±8E-3			2,6E+01 ±1E+1	1,2E+00 ±6E-1	
	NO	4-5		8,1E-02 ±1E-2			1,5E+01 ±3E+0	1,2E+00 ±2E-1	
	NO	5-6							
	NO	6-7							
	NO	7-8							
	NO	8-9							
	NO	9-10							
	NO	10-12							
	NO	12-14							
	NO	14-16							

St no.	Measured by	Depth (cm)	Co-60/Cs-137	Pu239,240/Cs-137	Pu-238/Pu-239,40	Cs-134/Cs-137	Cs-137/Sr 90	Pu-239,40/Sr-90	Pu-239,40/Am-241
5	NO	0-1		2,9E-02 ±5E-3			3,2E+01 ±2E+1	9,3E-01 ±5E-1	5,1E+00 ±1E+0
	NO	1-2		2,1E-02 ±4E-3	3,3E-01 ±1E-1		3,0E+01 ±2E+1	6,2E-01 ±3E-1	1,5E+00 ±1E+0
	NO	2-3		2,3E-02 ±5E-3	2,4E-01 ±1E-1		2,2E+01 ±9E+0	4,9E-01 ±2E-1	3,3E+00 ±8E-1
	NO	3-4		2,0E-02 ±2E-3	4,3E-02 ±3E-2		1,7E+01 ±4E+0	3,4E-01 ±8E-2	5,4E+00 ±3E+0
	NO	4-5		2,7E-02 ±4E-3			5,7E+00 ±8E-1	1,5E-01 ±3E-2	
	RU	0-1.5							
	RU	1.5-2.5							
	RU	2.5-3.5							
	RU	3.5-4.5							
	RU	4.5-7.0							
6	NO	0-1	0,046 ±0,008	6,6E-03 ±5E-4	4,1E-02 ±1E-2		5,5E+01 ±8E+0	3,7E-01 ±6E-2	
	NO	1-2	0,064 ±0,012	7,6E-03 ±6E-4	6,6E-02 ±1E-2		4,5E+01 ±6E+0	3,4E-01 ±5E-2	
	NO	2-3	0,035 ±0,008	8,4E-03 ±7E-4	5,2E-02 ±1E-2		3,9E+01 ±3E+0	3,2E-01 ±4E-2	
	NO	3-4		5,4E-03 ±7E-4			4,7E+01 ±4E+0	2,5E-01 ±4E-2	
	NO	4-5		3,0E-03 ±3E-4			2,5E+01 ±6E+0	7,4E-02 ±2E-2	
	NO	5-6							
	NO	6-7							
	NO	7-8							
	NO	8-9							
	NO	9-10							
	NO	10-12							
	NO	12-14							
	NO	14-18							
6	RU	0-1	0,020 ±0,007						
	RU	1-2	0,048 ±0,007						
	RU	2-3	0,101 ±0,010						
	RU	3-4	0,027 ±0,007						
	RU	4-5	0,039 ±0,009						
	RU	5-6							
	RU	6-7							
	RU	7-8							
	RU	8-							

St no.	Measured by	Depth (cm)	Co-60/Cs-137	Pu239,240/Cs-137	Pu-238/Pu-239,40	Cs-134/Cs-137	Cs-137/Sr-90	Pu-239,40/Sr-90	Pu-239,40/Am-241
6	RU	0-1	0,065 ±0,008	4,1E-03 ±1E-3			4,8E+01 ±1E+1	2,0E-01 ±6E-2	
	RU	1-2	0,053 ±0,005	3,9E-03 ±9E-4			5,0E+01 ±1E+1	2,0E-01 ±6E-2	
	RU	2-3	0,070 ±0,006	3,4E-03 ±1E-3			7,0E+01 ±1E+1	2,4E-01 ±9E-2	
	RU	3-4	0,024 ±0,007				5,0E+01 ±1E+1		
	RU	4-5	0,035 ±0,006				6,1E+01 ±1E+1		
	RU	5-6	0,020 ±0,008				6,0E+01 ±1E+1		
	RU	6-8		1,3E-03 ±3E-4			4,3E+01 ±9E+0	5,8E-02 ±2E-2	
	RU	8-10					7,2E+01 ±1E+1		
	RU	10-12					3,8E+01 ±7E+0		
	RU	12-14		7,2E-03 ±3E-3			1,7E+01 ±5E+0	1,2E-01 ±5E-2	
6	RU	0-1	0,025 ±0,009						
	RU	1-2	0,050 ±0,007						
	RU	2-3							
	RU	3-4							
	RU	4-5							
	RU	5-6							
	RU	6-8							
	RU	8-10							
	RU	10-12							
	RU	12-14							
	RU	14-16							
	RU	16-17							
6	IA	0-1	0,045 ±0,003	6,5E-03 ±6E-4	7,8E-02 ±1E-2				
	IA	1-2	0,036 ±0,004	8,9E-03 ±8E-4	6,9E-02 ±8E-3				
	IA	2-3	0,027 ±0,003	7,8E-03 ±8E-4	4,4E-02 ±9E-3				
	IA	3-4		5,0E-03 ±6E-4	5,0E-02 ±1E-2				
	IA	4-5		3,1E-03 ±5E-4					
	IA	5-6		1,9E-03 ±5E-4					
	IA	6-7		1,0E-03 ±5E-4					
	IA	7-8							
	IA	8-9							
	IA	9-10							
	IA	10-12							
	IA	12-14							
	IA	14-16							
	IA	16-18							
	IA	18-20							
	IA	20-24							

St no.	Measured by	Depth (cm)	Co-60/Cs-137	Pu239,240/Cs-137	Pu-238/Pu-239,40	Cs-134/Cs-137	Cs-137/Sr-90	Pu-239,40/Sr-90	Pu-239,40/Am-241
8	RU	0-1							
	RU	1-2							
	RU	2-3							
	RU	3-4							
	RU	4-5							
	RU	5-6							
	RU	6-8							
	RU	8-10							
	RU	10-12							
	RU	12-13							
8	RU	0-1							
	RU	1-2							
	RU	2-3							
	RU	3-4							
	RU	4-5							
	RU	5-6							
	RU	6-8							
	RU	8-10							
	RU	10-12							
	RU	12-14							
	RU	14-15							
8	RU	0-1							
	RU	1-2							
	RU	2-3							
	RU	3-4							
	RU	4-5							
	RU	5-6							
	RU	6-8							
	RU	8-10							
	RU	10-12							
	RU	12-15							

St no.	Measured by	Depth (cm)	Co-60/Cs-137	Pu239,240/Cs-137	Pu-238/Pu-239,40	Cs-134/Cs-137	Cs-137/Sr-90	Pu-239,40/Sr-90	Pu-239,40/Am-241
8	NO	0-1		4,7E-02 ±5E-3	5,1E-02 ±2E-2				2,9E+00 ±5E-1
	NO	1-2		5,2E-02 ±5E-3	1,9E-02 ±1E-2				3,4E+00 ±4E-1
	NO	2-3		4,6E-02 ±8E-3					5,9E+00 ±2E+0
	NO	3-4		3,2E-02 ±4E-3	2,6E-02 ±2E-2				
	NO	4-5		2,6E-02 ±5E-3					8,1E+00 ±5E+0
	NO	5-6		3,1E-02 ±5E-3					
	NO	6-7		2,5E-02 ±6E-3					
	NO	7-8		1,4E-02 ±4E-3					
	NO	8-9		4,4E-02 ±1E-2					
	NO	9-10		3,4E-02 ±6E-3					
9	NO	0-1		2,0E-02 ±3E-3			2,0E+01 ±4E+0	4,0E-01 ±9E-2	
	NO	1-2		3,1E-02 ±4E-3			3,1E+01 ±5E+0	9,5E-01 ±2E-1	
	NO	2-3		1,9E-02 ±4E-3			1,1E+01 ±3E+0	2,1E-01 ±7E-2	
	NO	3-4		3,1E-02 ±7E-3			1,7E+01 ±3E+0	5,3E-01 ±1E-1	
	NO	4-5		2,9E-02 ±9E-3			2,0E+01 ±6E+0	5,7E-01 ±2E-1	
	NO	5-6							
	NO	6-7							
	NO	7-8							
	NO	8-9							
	NO	9-10							
	NO	10-12							
	NO	12-14							
	NO	14-16							
	NO	16-							
9	RU	0-1							
	RU	1-2							
	RU	2-3							
	RU	3-4							
	RU	4-5							
	RU	5-6							
	RU	6-8							
	RU	8-10							
	RU	10-12							
	RU	12-14							
	RU	14-16							
	RU	16-18							
	RU	18-20							

St no.	Measured by	Depth (cm)	Co-60/Cs-137	Pu239,240/Cs-137	Pu-238/Pu-239,40	Cs-134/Cs-137	Cs-137/Sr-90	Pu-239,40/Sr-90	Pu-239,40/Am-241
9	RU	0-1							
	RU	1-2							
	RU	2-3							
	RU	3-4							
	RU	4-5							
	RU	5-6							
	RU	6-8							
	RU	8-10							
	RU	10-12							
	RU	12-14							
	RU	14-16							
	RU	16-18							
	RU	18-20							
	RU	20-							
9	RU	0-1							
	RU	1-2							
	RU	2-3							
	RU	3-4							
	RU	4-5							
	RU	5-6							
	RU	6-8							
	RU	8-10							
	RU	10-12							
	RU	12-14							
	RU	14-19							

St no.	Measured by	Depth (cm)	Co-60/Cs-137	Pu239,240/Cs-137	Pu-238/Pu-239,40	Cs-134/Cs-137	Cs-137/Sr-90	Pu-239,40/Sr-90	Pu-239,40/Am-241
1	RU	SURF.							
	RU	SURF.							
	RU	SURF.							
	RU	SURF.	0,134 ±0,020						
	RU	SURF.							
	RU	SURF.							
	RU	SURF.							
	RU	SURF.							
	RU	SURF.							
	RU	SURF.							
	RU	SURF.							
	RU	SURF.							
	RU	SURF.							
1	NO	SURF.	0,012 ±0,005			2,0E-02 ±4E-3			
	NO	SURF.	0,096 ±0,006						
	NO	SURF.				2,6E-02 ±6E-3			
	NO	SURF.	0,031 ±0,007			1,6E-02 ±4E-3			
	NO	SURF							
	NO	SURF	0,068 ±0,004						
	NO	SURF	0,093 ±0,008			1,4E-02 ±4E-3			
	NO	SURF	0,048 ±0,005						
1	IA	SURF							
2	NO	SURF.							
	RU	SURF.							
	RU	SURF.							
	RU	SURF.							
	RU	SURF.							
	RU	SURF.							
3	NO	SURF.							
	NO	SURF.							
	NO	SURF.							
	NO	SURF.							
	NO	SURF.							
	NO	SURF.							

St no.	Measured by	Depth (cm)	Co-60/Cs-137	Pu239,240/Cs-137	Pu-238/Pu-239,40	Cs-134/Cs-137	Cs-137/Sr-90	Pu-239,40/Sr-90	Pu-239,40/Am-241
4	RU	SURF.							
	RU	SURF.							
	RU	SURF.							
	RU	SURF.							
	RU	SURF							
	RU	SURF.							
	NO	SURF.	0,016 ±0,003			2,4E-02 ±5E-3			
	NO	SURF.							
	NO	SURF.	0,024 ±0,006						
5	IA	SURF.							
	IA	SURF.							
	IA	SURF.							
5	NO	SURF.	0,043 ±0,008			2,5E-02 ±6E-3			
	NO	SURF.	0,006 ±0,001	3,9E-06					
	NO	SURF.		3,3E-05		1,6E-02 ±3E-3			
	NO	SURF.							
	RU	SURF.							
	RU	SURF.							
5	RU	SURF.							
	RU	SURF.							
	RU	SURF.							
	RU	SURF.							
	RU	SURF.							
	RU	SURF.							
6	RU	SURF.	0,038						
	RU	SURF.	0,042						
	RU	SURF.	0,047						
	RU	SURF.	0,045						
	RU	SURF.	0,042						
	RU	SURF.	0,053						
	RU	SURF.	0,046						
6	RU	SURF.							
	RU	SURF.							
	RU	SURF.							

St no.	Measured by	Depth (cm)	Co-60/Cs-137	Pu239,240/Cs-137	Pu-238/Pu-239,40	Cs-134/Cs-137	Cs-137/Sr-90	Pu-239,40/Sr-90	Pu-239,40/Am-241
6	NO		0,028 ±0,001			4,4E-03 ±7E-4			
	NO		0,054 ±0,003			2,2E-03 ±3E-4			
	NO		0,046 ±0,015			1,9E-03 ±3E-4			
	NO		0,053 ±0,003			1,8E-03 ±2E-4			
	NO		0,090 ±0,005			6,7E-03 ±7E-4			
	NO		0,028 ±0,002	8,3E-06		4,8E-03 ±8E-4			
7	IA								
8	RU	SURF.							
	RU	SURF.							
	RU	SURF.							
	NO	SURF							
	NO	SURF							
	NO	SURF							
9	IA	SURF.							
9	RU	SURF.							
	RU	SURF.							
	RU	SURF.							
	NO	SURF	0,040 ±0,011						
	NO	SURF	0,028 ±0,005						
	NO	SURF	0,016 ±0,004						

ANNEX C

Raw Data *All numbers in Bq/m³*

Watersamples form the 1993 Kara Sea expedition

St.	Sampling date	Depth	Cs-137	Cs-134	Sr-90	Pu-238	Pu-239,240	Am 241
1	17.09.93	0 RU	3,93 ±0,06		6,0 ±1,0			
		0 NO	6,00 ±0,05	0,12 ±0,02	4,7 ±0,3	n.d	4,0E-3 ±2E-3	
	20.09.93	0 RU	4,94 ±0,15		4,4 ±0,8			
		43 NO	11,46 ±0,19	0,27 ±0,05	3,2 ±0,1			
	17.09.93	43 RU	11,80 ±0,20		3,6 ±0,7			
	20.09.93	55 RU	6,89 ±0,12		4,2 ±0,7			
	21.09.93	55 RU			4,0 ±0,7			
(1)		55 NO					7,1E-3 ±1E-3	
(2)		56 NO					5,7E-3 ±7E-4	
(3)		57 NO					5,3E-3 ±6E-4	
(4)		58 NO					4,9E-3 ±8E-4	
	18.09.93	0 RU	5,00 ±0,12		5,3 ±1,0			
		0 NO	5,34 ±0,07	0,14 ±0,03	4,8 ±0,3	n.d	4,5E-3 ±7E-4	
	18.09.93	28 RU	5,83 ±0,15		4,4 ±0,8			
	18.09.93	28 RU	9,10 ±0,19		4,0 ±0,7			
		28 NO	9,63 ±0,12	n.d.	3,6 ±0,2	n.d	7,0E-3 ±2E-3	
3	22.09.93	0 RU	4,47 ±0,08		5,7 ±1,0			
		0 NO	4,43 ±0,08	0,14 ±0,04	5,7 ±0,4	n.d	9,8E-3 ±1E-3	
	22.09.93	40 RU	4,00 ±0,08		3,9 ±0,7			
		40 NO	8,26 ±0,12	0,21 ±0,06	3,0 ±0,2	n.d	2,6E-2 ±2E-3	
	22.09.93	70 RU	10,00 ±0,18		3,7 ±0,7			
		70 NO	9,94 ±0,12	0,23 ±0,07	3,2 ±0,2		8,1E-3 ±9E-4	
4		0 RU	4,00 ±0,09		4,8 ±0,9			
		0 NO	5,73 ±0,08	0,16 ±0,04	4,8 ±0,3	n.d	5,4E-3 ±8E-4	
		40 RU	3,90 ±0,06		3,7 ±0,7			
		40 NO	8,28 ±0,06	0,16 ±0,02	3,1 ±0,2	n.d	8,9E-3 ±2E-3	
	23.09.93	72 RU	4,97 ±0,10		4,1 ±0,7			
		72 NO	14,08 ±0,33	n.d.	3,0 ±0,2	9,0E-4 ±2E-4	5,8E-3 ±4E-4	n.d
5	24.09.93	0 RU	4,79 ±0,08		5,7 ±1,0			
	24.09.93	0 RU	4,80 ±0,09					
		0 NO	6,14 ±0,09	0,14 ±0,02	4,1 ±0,1		2,3E-3 ±4E-4	1,5E-3 ±1E-3
	25.09.93	25 RU	7,61 ±0,21					
	25.09.93	25 RU	8,93 ±0,18					
		25 NO	8,00 ±0,32	0,21 ±0,02	4,0 ±0,1	n.d	2,3E-3 ±5E-4	7,7E-3 ±8E-4
		25 NO			3,7 ±0,2	n.d	1,1E-2 ±1E-3	
	25.09.93	30 RU	6,25 ±0,10		4,7 ±0,7			
6	26.09.93	0 RU	5,10 ±0,12		5,8 ±1,0			
		0 NO	6,51 ±0,26	0,13 ±0,00	5,2 ±0,1	n.d	1,9E-3 ±4E-4	2,0E-3 ±4E-4
		0 NO			4,7 ±0,3			
		40 NO	31,87 ±1,27	0,21 ±0,01	26,4 ±0,3	n.d	6,0E-3 ±8E-4	n.d
		40 NO			22,7 ±1,4			
	27.09.93	45 RU	21,90 ±0,25		24,3 ±4,0			
	27.09.93	45 RU	31,10 ±0,48					
7		0 NO	6,34 ±0,24	0,12 ±0,12	6,5 ±0,2	n.d	2,9E-3 ±4E-4	
		0 RU	3,86 ±0,06		4,5 ±0,8			
	27.09.93	39 RU	6,16 ±0,11		3,7 ±0,7			
		39 NO	7,68 ±0,28	0,16 ±0,00	4,7 ±0,1	n.d	1,8E-2 ±2E-3	5,3E-3 ±8E-4
8	28.09.93	0 RU	5,76 ±0,92		3,1 ±0,1			
		0 NO	6,67 ±0,25	0,12 ±0,01	3,1 ±0,1	n.d	3,8E-3 ±6E-4	n.d
	28.09.93	0 RU	4,53 ±0,07					
	29.09.93	140 RU	5,63 ±0,19		3,0 ±0,6			
		140 NO	8,55 ±0,24	n.d	2,7 ±0,1	n.d	5,3E-3 ±6E-4	n.d
	29.09.93	360 RU	7,16 ±0,22		3,0 ±0,6			
		360 NO	7,62 ±0,28		2,6 ±0,1	n.d	7,0E-3 ±1E-3	n.d
9	30.09.93	0 RU	6,03 ±0,08		2,5 ±0,6			
	30.09.93	0 RU	3,80 ±0,10					
		0 NO	5,71 ±0,16	0,08 ±0,02	2,7 ±0,2	n.d	2,6E-3 ±5E-4	n.d
	30.09.93	140 RU	8,47 ±0,19		3,4 ±0,7			
		140 NO	8,70 ±0,30	0,23 ±0,05	3,2 ±0,2	n.d	6,1E-3 ±6E-4	n.d
	30.09.93	340 RU	13,90 ±0,36		3,1 ±0,6			
		340 NO	13,01 ±0,42	0,32 ±0,19	2,7 ±0,2	n.d	1,2E-2 ±1E-3	n.d

(1) 200 l, 0,45μ
(2) 200 l, 1μ
(3) 200 l total water
(4) 175l, 1E4 Dalton

ANNEX C

Watersamples form the 1993 Kara Sea expedition

All numbers in Bq/m³

St.	Sampling date	Station no.	Depth (m)	Averaged data Cs-137	Cs-134	Sr-90	Pu-238	Pu-239,240	Am-241
1	17.09.93	1	0	5,0 ±0,2	0,12 ±0,02	5,0 ±1,3		4,0E-3 ±2E-3	
	20.09.93								
			43	11,6 ±0,3	0,27 ±0,05	3,4 ±0,7			
	17.09.93								
	20.09.93		55	6,9 ±0,1		4,1 ±1,0			
	21.09.93								
	(1)								
	(2)								
	(3)								
	(4)								
	18.09.93								
	18.09.93		28	8,2 ±0,3		4,0 ±1,1		7,0E-3 ±2E-3	
	18.09.93								
3	22.09.93	3	0	4,5 ±0,1	0,14 ±0,04	5,7 ±1,1		9,8E-3 ±1E-3	
	22.09.93		40	6,1 ±0,1	0,21 ±0,06	3,5 ±0,7		2,6E-2 ±2E-3	
	22.09.93		70	10,0 ±0,2	0,23 ±0,07	3,5 ±0,7		8,1E-3 ±9E-4	
4		4	0	4,9 ±0,1	0,16 ±0,04	4,8 ±0,9		5,4E-3 ±8E-4	
			40	6,1 ±0,1	0,16 ±0,02	3,4 ±0,7		8,9E-3 ±2E-3	
	23.09.93		72	9,5 ±0,3		3,6 ±0,7	9,0E-4 ±0,0	5,8E-3 ±4E-4	
5	24.09.93	5	0	5,2 ±0,1	0,14 ±0,02	4,9 ±1,0		2,3E-3 ±4E-4	1,5E-3 ±1E-3
	24.09.93								
	25.09.93		25	8,2 ±0,4	0,21 ±0,02	4,0 ±0,2		2,3E-3 ±1E-3	7,7E-3 ±8E-4
	25.09.93								
	25.09.93		6	6,3 ±0,1		4,7 ±0,7			
6	26.09.93	6	0	5,8 ±0,3	0,13 ±0,00	5,2 ±1,0		1,9E-3 ±4E-4	2,0E-3 ±4E-4
			40	31,9 ±1,3	0,21 ±0,01	24,6 ±1,4		6,0E-3 ±8E-4	
	27.09.93		45	26,5 ±0,5		24,3 ±4,0			
	27.09.93								
7		7	0	5,1 ±0,3	0,12 ±0,12	5,5 ±0,8		2,9E-3 ±4E-4	
	27.09.93		39	6,9 ±0,3	0,16 ±0,00	4,2 ±0,7		1,8E-2 ±2E-3	5,3E-3 ±8E-4
8	28.09.93	8	0	5,7 ±1,0	0,12 ±0,01	3,1 ±0,1		3,8E-3 ±6E-4	
	28.09.93								
	29.09.93		140	7,1 ±0,3		2,9 ±0,6		5,3E-3 ±6E-4	#DIV/0!
	29.09.93		360	7,4 ±0,4		2,8 ±0,6		7,0E-3 ±1E-3	#DIV/0!
9	30.09.93	9	0	5,2 ±0,2	0,08 ±0,02	2,6 ±0,6		2,6E-3 ±5E-4	
	30.09.93								
	30.09.93		207	8,6 ±0,4	0,23 ±0,05	3,3 ±0,7		6,1E-3 ±6E-4	
	30.09.93		340	13,5 ±0,6	0,32 ±0,19	2,9 ±0,6		1,2E-2 ±1E-3	
	(1)								
	(2)								
	(3)								
	(4)								

ANNEX C

Watersamples form the 1993 Kara Sea expedition

St.	Sampling date	Station no.	Depth
1	17.09.93	1	0
			0
	20.09.93		0
			43
	17.09.93		43
	20.09.93		55
	21.09.93		55
	(1)		
	(2)		
	(3)		
	(4)		
	18.09.93		0
			0
	18.09.93		28
	18.09.93		28
			28
3	22.09.93	3	0
			0
	22.09.93		40
			40
	22.09.93		70
			70
4		4	0
			0
			40
			40
	23.09.93		72
			72
5	24.09.93	5	0
	24.09.93		0
			0
	25.09.93		25
	25.09.93		25
			25
			25
	25.09.93		30
6	26.09.93	6	0
			0
			0
			40
			40
	27.09.93		45
	27.09.93		45
7		7	0
			0
	27.09.93		39
			39
8	28.09.93	8	0
			0
	28.09.93		0
	29.09.93		140
			140
	29.09.93		360
			360
9	30.09.93	9	0
	30.09.93		0
			0
	30.09.93		140
			140
	30.09.93		340
			340
	(1)		
	(2)		
	(3)		
	(4)		

ANNEX C

Watersamples form the 1993 Kara Sea expedition

St.	Sampling date	Activity ratios Cs134/ Cs137	90-Sr/ 137-Cs	Pu-239/ Sr-90	Pu-239/ Cs-137
1	17.09.93		1,0 ±0,2		
		0,020 ±0,003		8,5E-4 ±4E-4	6,7E-4 ±3E-4
	20.09.93				
		0,024 ±0,004	0,3 ±0,0		
	17.09.93				
	20.09.93		0,6 ±0,1		
	21.09.93				
	(1)				
	(2)				
	(3)				
	(4)				
	18.09.93				
		0,026 ±0,005		9,4E-4 ±2E-4	8,4E-4 ±1E-4
	18.09.93		0,5 ±0,1		
	18.09.93				
				1,9E-3 ±5E-4	7,3E-4 ±2E-4
3	22.09.93		1,3 ±0,2		
		0,032 ±0,009		1,7E-3 ±2E-4	2,2E-3 ±3E-4
	22.09.93		0,6 ±0,1		
		0,025 ±0,007		8,5E-3 ±8E-4	3,1E-3 ±2E-4
	22.09.93		0,3 ±0,1		
		0,023 ±0,007		2,5E-3 ±3E-4	8,1E-4 ±1E-4
4			1,0 ±0,2		
		0,028 ±0,007		1,1E-3 ±2E-4	9,4E-4 ±1E-4
			0,6 ±0,1		
		0,019 ±0,002		2,9E-3 ±7E-4	1,1E-3 ±3E-4
	23.09.93		0,4 ±0,1		
				1,9E-3 ±2E-4	4,1E-4 ±3E-5
5	24.09.93		0,9 ±0,2		
	24.09.93				
		0,023 ±0,004		5,6E-4 ±1E-4	3,7E-4 ±7E-5
	25.09.93		0,5 #DIV/0!		
	25.09.93				
		0,026 ±0,003		5,8E-4 ±1E-4	2,9E-4 ±6E-5
				3,1E-3 ±3E-4	
	25.09.93		0,8 ±0,1		
6	26.09.93		0,9 ±0,2		
		0,020 ±0,001		3,7E-4 ±8E-5	2,9E-4 ±6E-5
		0,007 ±0,000	0,8 ±0,0	2,3E-4 ±3E-5	1,9E-4 ±3E-5
	27.09.93		0,9 ±0,2		
	27.09.93				
7		0,019 ±0,018	1,1 ±0,1	4,5E-4 ±6E-5	4,6E-4 ±7E-5
	27.09.93		0,6 ±0,1		
		0,021 ±0,001		3,9E-3 ±4E-4	2,4E-3 ±2E-4
8	28.09.93		0,5 ±0,1		
		0,018 ±0,001		1,2E-3 ±2E-4	5,7E-4 ±9E-5
	28.09.93				
	29.09.93		0,4 ±0,1		
				2,0E-3 ±2E-4	6,2E-4 ±7E-5
	29.09.93		0,4 ±0,1		
				2,7E-3 ±4E-4	9,2E-4 ±1E-4
9	30.09.93		0,5 ±0,1		
	30.09.93				
		0,014 ±0,004		9,6E-4 ±2E-4	4,6E-4 ±9E-5
	30.09.93		0,4 ±0,1		
		0,026 ±0,006		1,9E-3 ±2E-4	7,0E-4 ±7E-5
	30.09.93		0,2 ±0,0		
		0,025 ±0,015		4,5E-3 ±5E-4	9,4E-4 ±9E-5
	(1)				
	(2)				
	(3)				
	(4)				

Seaweed samples from the 1993 Kara-Sea expedition All numbers in Bq/kg						
Sample	species	Cs-137	Cs-134	Co-60	Sr-90	Pu-239,40
St1(3)	Fucus Evanescens	1,7 ±0,4	< 1,4	1,5 ±0,3		
St1(2)	Fucus Evanescens	< 2,2	< 3,1	< 2,6		
St1(2)	Fucus Evanescens	1,6 ±0,4	< 1,3	< 1,0		
St1(4)	Fucus Evanescens	2,7 ±0,4	< 1,1	< 0,9		
St5(1)	Fucus Evanescens	3,4 ±0,2	< 0,8	1,1 ±0,3		4,0E-1 ±2E-2
St6(1)	Fucus Evanescens	4,1 ±0,3	< 0,9	< 0,9		4,4E-1 ±5E-2
St1(2)	Laminaria Digitata	5,1 ±0,5	< 1,4	< 1,5		
St1(3)	Laminaria Digitata	2,8 ±0,3	< 1,1	< 1,1		
St2(1)a	Laminaria Digitata	< 2,4	< 3,4	< 3,1		
St2(2)a	Laminaria Digitata	4,1 ±0,6	< 2,0	< 2,1		
St2(2)b	Laminaria Digitata	< 1,7	< 2,1	< 1,7		
St2, mix	Laminaria Digitata	2,4 ±0,3	< 1,1	< 1,1		
St2, mix	Laminaria Digitata	2,7 ±0,2	< 0,9	< 0,6		
St5(1)	Laminaria Digitata	2,5 ±0,4	< 1,2	< 1,3		
St2(1)c	Laminaria Digitata Laminaria Saccharina	4,0 ±1,1	< 3,9	4,6 ±1,2		
St1(2)	Laminaria Digitata leaves some Saccharina	2,7 ±0,5	< 1,3	< 0,9		
St1(2)a	Laminaria Digitata leaves some Saccharina	< 1,6	< 2,6	< 2,0		
St1(3)	Laminaria Digitata leaves, some Saccharina	6,8 ±0,5	< 1,3	< 1,7	2,4 ±0,2	6,3E-2 ±7E-3
St1(3)	Laminaria Digitata lower stem some Saccharina	8,1 ±0,7	< 1,9	< 2,0	2,4 ±0,2	3,9E-2 ±2E-2
St1(4)	Laminaria Digitata stem	6,2 ±0,6	< 1,5	< 1,8		
St1(3)	Laminaria Digitata stems, some Saccharina	4,3 ±0,3	< 1,9	< 1,2	3,2 ±0,2	6,4E-2 ±9E-3
St1(4)	Laminaria Digitata, Laminaria Saccharina	2,8 ±0,3	< 1,0	< 0,8	5,4 ±0,3	5,8E-2 ±9E-3
St2(1)b	Laminaria Saccharina	< 2,2	< 2,9	< 2,7		
St2(2)a	Laminaria Saccharina	1,1 ±0,3	< 2,9	< 0,9		

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