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^{137}Cs content and concentration factors in benthic organisms in the dump sites for solid radioactive waste in the Kara Sea

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Abstract. Radioactive contamination was studied in macrobenthic invertebrates and algae of the Abrosimov, Stepovoy and Tsivolky Bays of the Novaya Zemlya Archipelago and the adjacent regions of the Kara Sea during the cruises 73d and 81st on board R/V *Professor Shtokman* in the years 2005–2006. Maximum concentration ^{137}Cs in sediment in studied area has been detected in the layer 10–12 cm in the Abrosimov Bay (150 Bq/kg) and in the layer 4–6 cm in the Stepovoy Bay (100 Bq/kg). Concentration of ^{137}Cs in benthos was up to 3.19 Bq/kg of wet weight. The highest concentration has been found in benthos of the Abrosimov and Stepovoy Bays: the holothurian *Myriotrochus rinkii,* the isopod *Saduria sabini*, ophiuroids *Ophiocten sericeum* and *Stegophiura nodosa*. *Myriotrochus rinkii, Saduria sabini* and the brown alga *Laminaria saccharina* were characterized by the highest ^{137}Cs concentration factor – 994, 599 and 425 respectively. Caesium-137 contamination occurs locally in the studied area closed to the radioactive waste disposal and does not affect on qualitative structure of the macrobenthic communities.

1. INTRODUCTION

Within the framework of the Joint Russian-Norwegian Commission for Cooperation in the Environmental Sector, International Atomic Energy Agency and European Union joint expeditions have been conducted to investigate radioactive contamination of Northern Seas. The main conclusion was that the dumping of radioactive waste does not influence the general level of radioactive contamination in the Kara Sea. Radiation doses from existing contamination would be negligible. However, local effects in the vicinity of the dumping sites could not be excluded, and it was necessary to undertake detailed investigations in these regions, and assess leaching and its consequences. The present report summarized the results of investigation radioactive contamination of the benthos organisms and plant in the Ambrosimov Bay, Stepovoy Bay, Tsivolky Bay and nearest regions of Kara Sea.

2. MATERIALS AND METHODS

Radioactive contamination of the benthos organisms and plant of the Ambrosimov Bay, Stepovogo Bay, Tsivolky Bay and nearest regions of Kara Sea were under investigation during 73 and 81 cruises R/V Professor Shtokman (2005–2006y) (Fig. 1).

The samples of biota were taken with trawl in the dump sites for solid radioactive waste.

The samples of sediment were taken with a bottom sampler « Ocean – 50 ». Measurement of ^{137}Cs in samples of biota and sediment performed by means of gamma-spectrometer with a detector made of super pure germanium GC-3020 with a relative efficiency of 30% (Co-60 line – 1,332 Mev) and a resolution of 1,8 Kev. To inspect the dumped objects underwater video camera and underwater gamma-spectrometer were used. Direct measurements of ^{137}Cs in the bottom sediments were performed *in situ* with gamma-spectrometer.

Concentration ^{137}Cs in groups of animals and plants, dominating in trawling samples was defined.

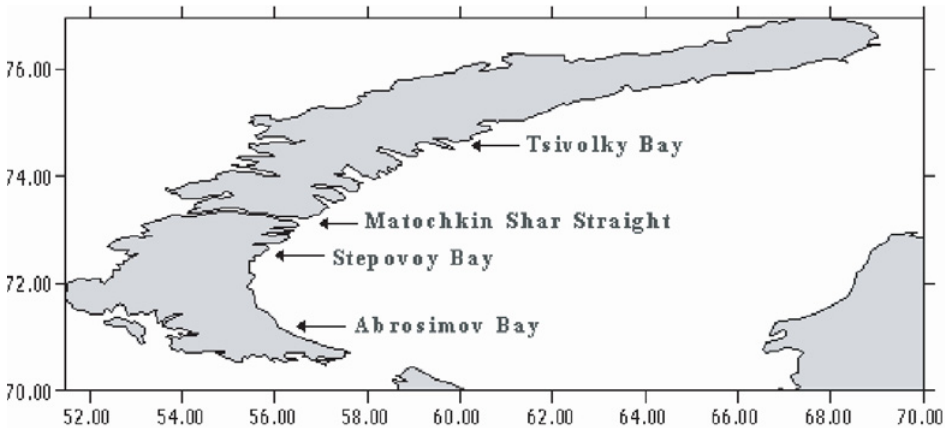

Figure 1. Sampling sites of the R/V Professor Shtokman (2005-2006y) Expedition.

3. RESULTS AND CONCLUSIONS

Maximum ^{137}Cs concentration was found in the holothurian *Myriotrochus rinkii* – 3.19 Bq/w · w · kg, ophiuroids *Ophiocten sericeum, Stegophiura nodosa* – 2.96 Bq/w · w · kg (Abrosimov Bay) and the isopod *Saduria sabini* – 2.37 Bq/w · w · kg (Stepovoy Bay). ^{137}Cs concentration for Astartid molluscs (*Astarte borealis, Astarte elliptica*) – 1.19 Bq/w · w · kg, the bivalve *Bathyarca glacialis* – 1.58 Bq/w · w · kg and the brown algae *Laminaria saccharina* – 1.77 Bq/w · w · kg (Table 1).

Influences of the raised concentration of ^{137}Cs in Abrosimov and Stepovoy Bays on qualitative structure of benthic communities have not been revealed. Qualitative structure of macrobenthic communities of investigated areas correspond to the one known from the coastal areas of the Kara Sea.

Concentrations of ^{137}Cs in benthos are higher from the stations located in the central part of the Abrosimov and Stepovoy Bays where underwater radioactive objects are deposited then in the open sea opposite to the bays (Fig. 2). Thus, it indicates the local character of radioactive contamination.

The average concentration of technogenic ^{137}Cs in benthos organisms in the Abrosimov and Stepovoy Bays is also higher then in open part of the Kara Sea and in other areas of a shelf of the Arctic seas. The best indicators of radioactive pollution among the investigated species were the brown algae *Laminaria saccharina* and the isopod *Saduria sabini*.

Comparing our data with received in 1992–1994 in the Abrosimov and Stepovoy Bays (Salbu et al., 1997), it is possible to conclude, that concentration of ^{137}Cs in benthic organisms decreases non-uniformly. So, concentration of ^{137}Cs in *Fucus inflatus* decreased in 7–7.5 times, whereas in *Laminaria saccharina* approximately in two times. Unfortunately, it is not possible to compare our data in detail as no any detailed radiological investigation of benthos was undertaken in these areas.

The concentration factors (*Kd*) for algae and invertebrates were calculated (table 2).

Table 1. Maximum Concentration of ^{137}Cs different species of macrobenthos dominated in trawl catches, Bq/kg wet weight.

	Abrosimov Bay	Stepovoy Bay	Tsivolky Bay	Matochkin Shar Straight	Novaya Zemlya Trench
Phaeophyta, Brown algae					
Laminaria saccharina (L.) Lamouroux, 1813	1.21 ± 0.17	1.77 ± 0.28	–	–	–
Fucus inflatus L., 1753	0.4 ± 0.09	–	–	–	–
Crustacea Isopoda, isopods					
Saduria sabini (Krøyer, 1849)	–	2.37 ± 0.36	–	–	0.17 ± 0.07
Saduria sabini, Saduria entomon (L., 1758)	–	–	0.18 ± 0.07	–	–
Bivalvia, Bivalvs					
Nuculana pernula (Müller, 1779), *Leionucula tenuis* (Montagu, 1808)	–	0.67 ± 0,23	–	–	<0.08
Bathyarca glacialis (Gray, 1824)	–	0.96±0.16	0.09±0.075	–	–
Astarte borealis (Schumacher, 1817)	1.1 ± 0.18	1.19 ± 0.25	–	–	–
Astarte crenata (Gray, 1824)	–	–	0.19 ± 0.05	–	–
Astarte elliptica (Brown, 1827)	0.96 ± 0,28	1.19 ± 0,25	0.48 ± 0.09	0.32 ± 0.12	–
Clinocardium ciliatum (Fabricius, 1780)	0.52 ± 0.12	–	–	–	–
Serripes groenlandicus (Bruguiere, 1789)	0.49 ± 0.2	–	–	–	–
Echinodermata, Echinoderms					
Molpadia borealis ssp. arctica M. Sars, 1859	–	–	–	–	0.56 ± 0.07
Myriotrochus rinkii Steenstrup, 1851	3.19 ± 0.51	–	–	–	–
Strongylocentrotus droebachiensis (Mueller O.F., 1776)	–	1.05 ± 0.33	–	–	–
Ctenodiscus crispatus (Retzius, 1805)	–	–	0.16 ± 0.07	–	–
Urasterias linkii (J. Mueller et Troschel, 1842)	–	0.66 ± 0.12	0.15 ± 0.07	–	–
Ophiocten sericeum (Forbes, 1852), *Stegophiura nodosa* (Luetken, 1854)	2.96 ± 0.41	–	–	–	–
Ophiocten sericeum, Ophiacantha bidentata (Retzius, 1805)	–	0.91 ± 0.12	<0.07	–	–
Ophiopleura borealis Danielssen et Koren, 1877	–	–	0.11 ± 0.07	<0.08	0.11 ± 0.06

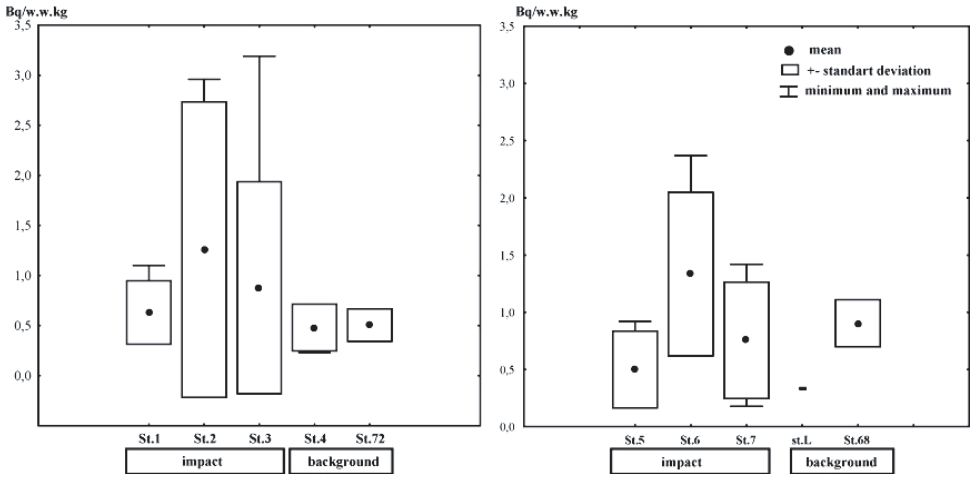

Figure 2. Cesium-137 concentration range in macrobenthos from impact-zone (close to radioactive objects) and background (in the distance) in Abrosimov Bay (left) and Stepovoy Bay (right).

Table 2. The concentration factors *Kd* for seaweeds and animals.

Species	*Kd* calculated per total water column	*Kd* calculated per near-bottom water layer
Laminaria saccharina	425	246
Fucus inflatus	128	46
Saduria sabini	600	329
Nuculana pernula, Leionucula tenuis	212	93
Bathyarca glacialis	194	133
Astarte borealis	376	165
Clinocardium ciliatum	115	59
Serripes groenlandicus	153	56
Myriotrochus rinkii	994	363
Strongylocentrotus droebachiensis	332	36
Urasterias linkii	133	92
Ophiocten sericeum, Stegophiura nodosa	373	336
Ophiocten sericeum, Ophiacantha bidentata	156	126

The greatest factors of accumulation of ^{137}Cs are found out in the holothurian *Myriotrochus rinkii*, brown algae *Laminaria saccharina* and the isopod *Saduria sabini*.

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