ENVIRONMENTAL ENGINEERING
The 8th International Conference
May 19–20, 2011, Vilnius, Lithuania
Selected papers

ISSN 2029-7106 print / ISSN 2029-7092 online
ISBN 978-9955-28-826-8 (1 Volume)
ISBN 978-9955-28-827-5 (3 Volumes)
http://enviro.vgtu.lt

RADIONUCLIDE ^{90}Sr VOLUME ACTIVITY VARIATIONS AT THE BALTIC SEA COAST NEAR JUODKRANTE

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Abstract. As far as radionuclide ^{90}Sr volume activity (VA) after the Chernobyl Power Plant accident in the Baltic Sea increased negligibly, so the self-purification process from it was very slow. Long-term measurements of VA of ^{90}Sr were carried out in 2004 at the Baltic Sea coast near Juodkrante. During June-November, 2004 the average VA of this radionuclide was 12 Bq/m^3 and extremely values were 7 and 17 Bq/m^3. The variations of absolute values depend on hydro meteorological situations change, precipitation amount variations, and extra penetration of ^{90}Sr into the Baltic Sea and so on. The average ^{90}Sr VA was decreasing since 2001 up to 2004 from 18 Bq/m^3 to 12 Bq/m^3. It is defined that ^{90}Sr VA values variation does not correlate with conductivity change in sea water. The self-purification process from radionuclide ^{90}Sr in the Baltic Sea mainly depends on its radioactive decay.

Keywords: radionuclides, volume activity, radioactive pollution, Baltic Sea, hydro meteorological situations.

1. Introduction

Artificial radionuclides entered the environment mostly as a result of nuclear explosions, accidents at nuclear power plants and due to the operation of nuclear industry (Butkus *et al.* 2008; Pliopaite Bataitiene and Butkus 2010). Global fallout is still the main sources of radioactive pollution of the hydrosphere (Styra *et al.* 2006). After the cessation of testing of nuclear and thermonuclear weapons in the atmosphere, the "background" of ionizing radiation of environment has been gradually decreasing. However, the main components of this "background" remain radionuclides ^{90}Sr and ^{137}Cs with half-lives of about 30 years (Styra *et al.* 2006). In comparison with the World Ocean the Baltic Sea waters were more contaminated by artificial radionuclides (Стыро 1989: 255). This fact is primarily due to its relatively shallow and the comparative isolation of the waters of the Atlantic Ocean. However Nuclear Plants, located near the Baltic Sea had negligibly effect on the radioactive state of its waters (Стыро 1989: 255).

It is known that the specific hydrological conditions of the sea can temporarily change the structure of the field of volume activity (VA) of artificial radionuclides in its surface waters, which leads to a significant change in their absolute values. Particularly intensive variations of VA of these radionuclides are possible in coastal waters in the shallows, where they affected by changes in meteorological conditions (Zalewska and Lipska 2006). In recent years, the main radioactive pollutants of the Baltic Sea waters after the Chernobyl power plant (ChPP) accident in 1986 was radionuclide ^{137}Cs. This radionuclide is considered as one of key artificial radionuclides in the environment (Butkus and Konstantinova 2008). Nowadays the small additional penetration of this radionuclide has place from the global fallout (Helcom 1995; 2003; 2009).

Before ChPP accident the other radioactive pollutant of the sea waters was ^{90}Sr (Styra et al. 1984; Styro *et al.* 2006). In the global transport after ChPP accident radionuclide ^{90}Sr almost did not participate. There was observed only a slight increase in its VA in the Baltic Sea (Helcom 2009; Стыро *et al.* 1989; Styro *et al.* 2005). When comparing the experimental and calculated data of ^{137}Cs VA in surface waters of the Baltic Sea only in some cases their coincidence was within the error of experiment, and for the radionuclide ^{90}Sr experimental data were always higher than the calculated (Styro *et al.* 2003). More effective agreement between the theoretical and experimental data of ^{137}Cs VA can be explained according to its gradual decrease as a result of natural radioactive decay and the relatively regular precipitation on the sea bottom, where the radionuclide is firmly held by the bottom sediments.

However, the radionuclide ^{90}Sr weakly linked to sediment and under the influence of hydrological processes, return into the water. This phenomenon is rather difficult to take into account in the theoretical model.The aim of this paper is to analyze the results of continuous long-term measurements of radionuclide ^{90}Sr VA in coastal waters of the Baltic Sea in 2004, comparing them with those of VA ^{137}Cs, obtained at the same time, as well as analysis of the causes of their variations.

2. Material and methods

The water samples (about 40 l) for the determination of ^{90}Sr concentration in the near-shore waters of the Baltic Sea (Juodkrante) were taken during different periods in 2004. In some cases water sampling was done along the Baltic Sea shore in Pervalka, Preila and Nida stations (Fig 1). The temperature, specific electric conductivity, water current direction and wind direction were registered during the time of sampling.

The ^{90}Sr was concentrated with ^{137}Cs after adding of stable carriers from the unfiltered sea water by ferrocyanide-carbonate precipitation (Styro *et al.* 2004). The scheme of the separation of ^{90}Sr from seawater is shown in Fig 2.

After radiochemical cleaning ^{90}Sr was measured by radionuclide ^{90}Y emission using of a low level background beta radiometer. The stable strontium yield was determined by atomic absorption spectrometer and Y-gravimetrically in Y_2O_3 form. The yield values varied within 60–80 %. The determination error for ^{90}Sr concentration amounted to 15 %.

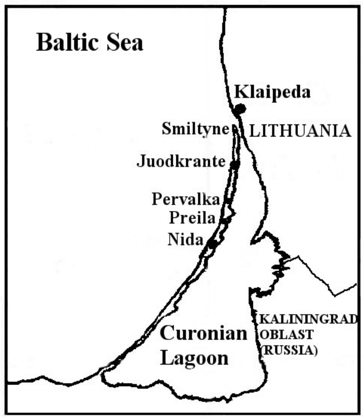

Fig 1. Water sampling stations at the Baltic Sea shore

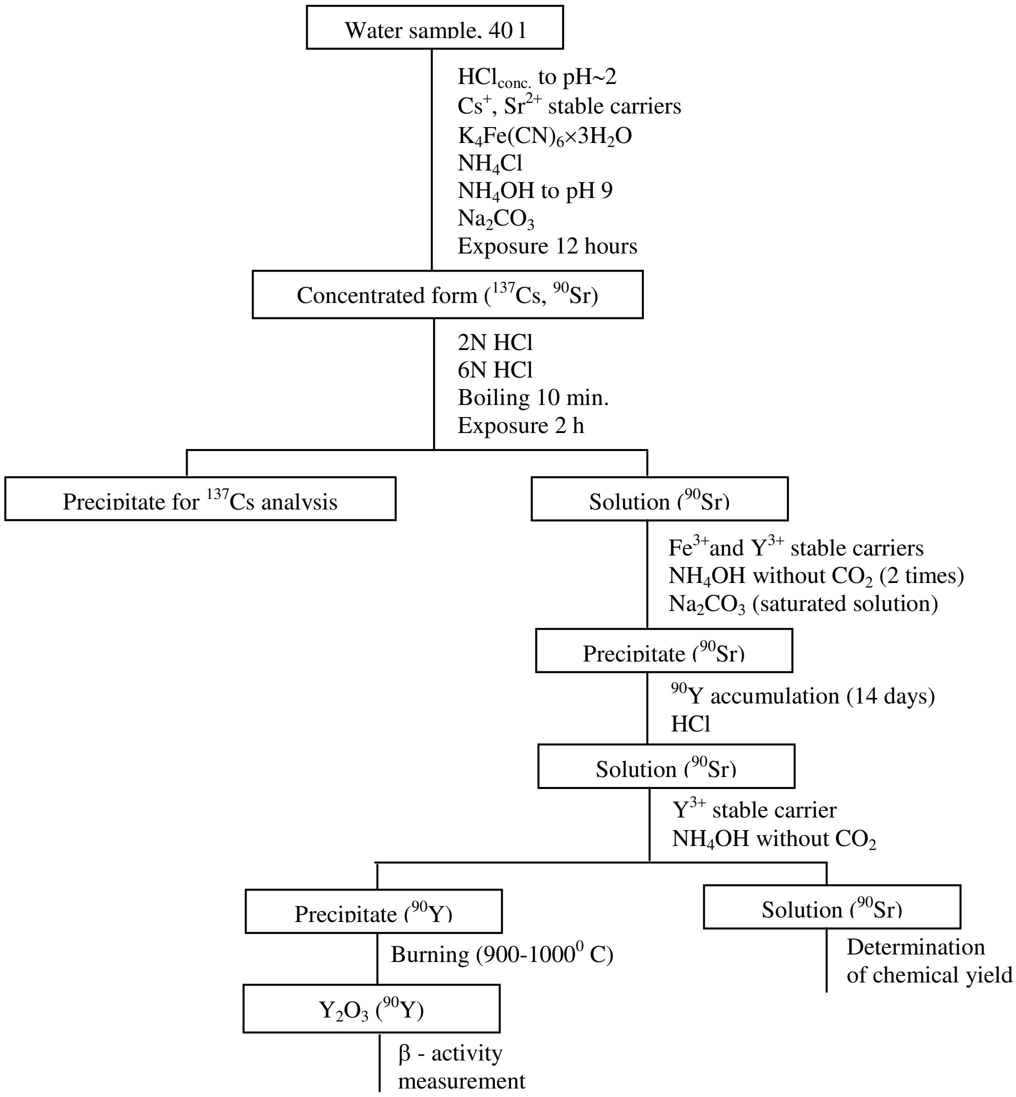

Fig 2. ^{90}Sr radiochemical analysis scheme

3. Results and discussion

Control of the volume activity of the radionuclide ^{90}Sr was carried out in the coastal waters of south-eastern Baltic Sea near settlement Juodkrante (Fig 1). A large number of continuous observations of the VA of this radionuclide were carried out from June to November 2004 under different meteorological conditions. Obtained results during this time were different, and the ratio of extreme values was about 2.5. It means that there were considerable variations of VA radionuclide ^{90}Sr in the coastal waters. The possible reason for such variations is a transfer of the water masses with different amount of this radionuclide, the different intensity of evaporation of sea water, depending on weather conditions, rainfall, storm activity, ^{90}Sr penetration into the water from forest fires, etc. However, finding of the specific reason for the changes of VA of the radionuclide is quite difficult because it can be affected by an individual factor and their combination. Therefore, with VA of ^{90}Sr there were simultaneously registered a number of meteorological parameters. The obtained results of observations are presented in Table 1.

Table 1. ^{90}Sr volume activity and some hydro meteorological parameters near the Baltic Sea shore (Juodkrante) in 2004 (t – water temperature, σ – conductivity)

No	Date	t, °C	σ, mS/m	Wind direction	Current direction	^{90}Sr volume activity, Bq/m^3
1	2004.06.30	16	740	W	to the south	14±2
2	2004.07.01	16	750	W	to the south	11±2
3	2004.07.02	15	760	SW	to the north	15±2
4	2004.07.03	16	755	SW	to the north	13±2
5	2004.07.04	17	760	SW	to the north	15±2
6	2004.07.05	17	755	SW	to the north	15±2
7	2004.07.06	16.5	750	SW	to the north	17±3
8	2004.07.07	17	760	SW	to the north	13±2
9	2004.07.08	17.5	705	SW	to the north	11±2
10	2004.07.09	17.5	705	E	to the north	10±2
11	2004.07.10	17	700	S-SW	to the north	7±1
12	2004.07.11	16.5	700	SW	to the north	-
13	2004.07.12	16	730	S	to the north	9±1
14	2004.07.13	16.5	700	SW	to the north	8±1
15	2004.07.14	16	790	SW	to the north	14±2
16	2004.07.15	16	700	W	to the south	11±2
17	2004.07.16	16	700	W-NW	to the south	13±2
18	2004.07.17	16	720	SW	to the north	13±2
19	2004.07.18	17	710	E	to the north	13±2
20	2004.08.24	17	710	SE	to the north	14±2
21	2004.08.25	16	700	SE	to the north	11±2
22	2004.08.26	17.5	700	SW	to the north	13±2
23	2004.08.27	19	705	S	to the north	12±2
24	2004.08.28	17	720	SW	to the north	14±2
25	2004.08.29	17.5	710	S	to the north	12±2
26	2004.08.30	18	715	S	to the north	12±2
27	2004.08.31	18	685	SW	to the north	12±2
28	2004.09.01	17.5	690	S-SW	to the north	14±2
29	2004.09.02	17.5	690	W	to the south	12±2
30	2004.09.03	17	680	W	to the south	13±2
31	2004.09.04	18	690	N	to the south	12±2
32	2004.09.05	18	685	E	to the north	14±2
33	2004.10.16	9.5	660	SE	to the north	13±2
34	2004.10.18	10	700	S	to the north	12±2
35	2004.10.20	10.5	700	W	to the south	12±2
36	2004.10.22	10	700	S	to the north	14±2
37	2004.10.24	11.5	710	SW	to the north	12±2
38	2004.10.26	11	700	SW	to the north	11±2
39	2004.10.28	10	680	SE-E	to the north	10±2
40	2004.10.30	10	690	E-NE	to the south	13±2
41	2004.11.01	10	700	W	to the south	9±1
42	2004.11.03	9	720	SE-S	to the north	11±2
43	2004.11.05	10	700	W	-	13±2
44	2004.11.06	9	720	W	-	13±2

The highest values of VA of ^{90}Sr in coastal waters were in the beginning of July 2004, i.e. from 7-th to 13-th of July. A gradual decrease in the absolute values of VA of the radionuclide had place. At the same time period, an increase in wind speed and its change direction was observed. However, the transfer of water masses was along the shore in a northern direction. At the same time there was a decrease in water conductivity (Table 1), which could be affected by the mixing of water masses under the influence of change of wind direction, as well as their penetration from the other parts of the sea and the possible impact of precipitation.

From 12-th of July up to 30-th of August the variations in water conductivity and simultaneous wind's velocity and direction were observed. However, a stable correlation between the course of VA of the radionuclide ^{90}Sr and conductivity of water wasn't observed. Also, there wasn't correlation between ^{90}Sr VA and temperature change (Styra et al. 2006) (Table 1). A great interest has the variations of ^{137}Cs VA, which were measured in the same time from the same water samples (Styra et al. 2006). Comparison of these data is presented in Fig 3 and 4. These figures show that the relative intensive variations of ^{90}Sr VA were observed during the first half of July (Fig 3), but significant changes of ^{137}Cs VA were only from 13-th to 18-th of July (Fig 4), when there was a change in water conductivity.

At the same time there was a change of wind direction, which usually leads to rapid mixing of sea water and change the direction of current (Table 1). Thus, changes in meteorological conditions lead to a change in the VA of radionuclides of artificial origin. Since the radionuclides ^{90}Sr and ^{137}Cs have different behaviour in sea water, therefore the variations in their VA as a function of meteorological conditions may be different too. The obtained results of measurements of VA of these radionuclides in the other stations of the coastal zone of the Baltic Sea (Fig 1) had a little difference from those obtained near Juodkrante (Table 2).

The exception was the obtained result on September 4, when the transfer of water masses was in a southern direction. In this case the greatest effect of water of Curonian lagoon on the sea water was in Juodkrante than in other areas (Fig 1). Consequently, the ^{137}Cs VA in Juodkrante was the lowest since the VA of this radionuclide in Curonian Lagoon is much smaller than in the Baltic Sea (Styro et al. 2004), and ^{90}Sr VA was about the same, i.e., it did not exceed experimental error. An average result during the measurement period from July to November 2004 in the coastal zone near Juodkrante was 12.3 Bq/m^3. Comparing this result with the same value obtained in the coastal waters of Poland (Zalewska and Lipska 2006), it turned out to be lower (8.4 Bq/m^3).

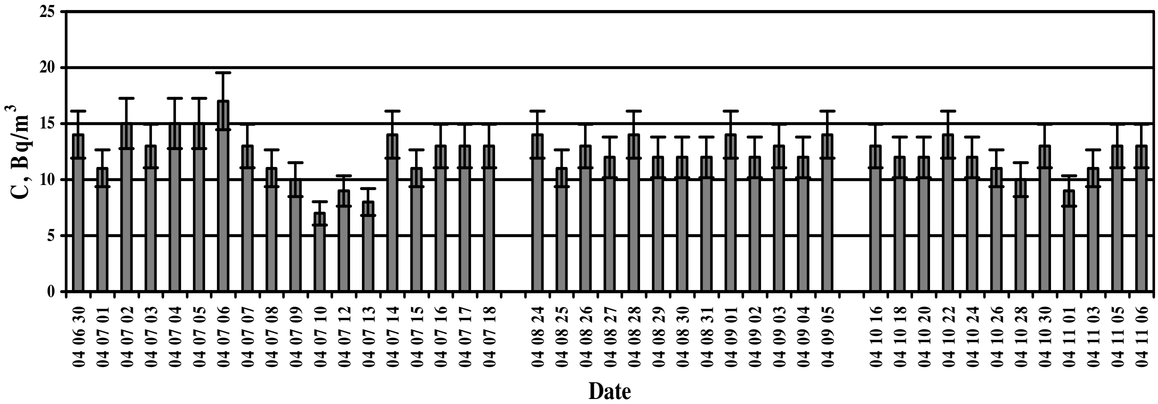

Fig 3. ^{90}Sr volume activity (Bq/m^3) in the Baltic Sea water near Juodkrante in 2004

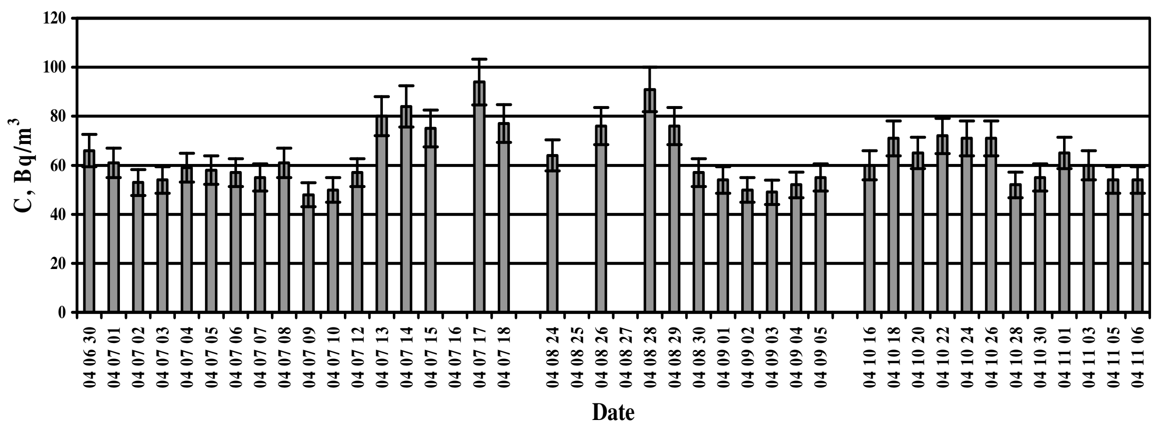

Fig 4. ^{137}Cs volume activity (Bq/m^3) in the Baltic Sea water near Juodkrante in 2004 (Styra *et al.* 2006)

Table 2. Results of ^{90}Sr and ^{137}Cs volume activity measurement along the Baltic Sea shore in 2004

No	Station	Date	^{90}Sr volume activity, Bq/m^3	^{137}Cs volume activity, Bq/m^3
1	Nida	2004.07.16	11±2	72±7
2	Pervalka	-"-	14±2	71±7
3	Nida	2004.09.04	13±2	69±7
4	Preila	-"-	13±2	70±7
5	Pervalka	-"-	17±3	70±7
6	Nida	2004.11.03	-	65±7
7	Preila	-"-	14±2	61±6
8	Pervalka	-"-	-	61±6

This divergence can be explained by the possible effect of the Vistula River and other small rivers in the coastal waters because the amount of radionuclide in river water is negligible. The same reason refers to explanation of different extremely values of ^{90}Sr VA, which were observed at the same time. Thus, the results of this work - 7 and 17 Bq/m^3, and the results of (Zalewska and Lipska 2006) - 5.6 and 10.9 Bq/m^3. However, in the both cases, the ratio of extremely values was like: 2.5 and 2.0 respectively. Consequently, variations in the VA of radionuclide ^{90}Sr can significantly exceed the error of experiment. It means that a temporary change in its VA can have significant impact of external factors, in particular, changes in meteorological conditions.

Therefore, the control of absolute values of artificial radionuclides VA under the influence of natural factors is necessary to determine a possible additional penetration of radioactive pollutants from anthropogenic sources.

4. Conclusion

The values of the variations of the VA of radionuclide ^{90}Sr in coastal waters of the Baltic Sea near Juodkrante were observed. Variations of VA of the radionuclide were in the range from 7 to 17 Bq/m^3 in 2004, and the ratio of extreme values was 2.5. The magnitude of the VA of radionuclide ^{90}Sr in coastal waters is strongly affected by meteorological conditions and atmospheric fallout. It is known that the external influences on coastal waters have a different effect on the course of VA of radionuclides ^{90}Sr and ^{137}Cs. If the absolute values of VA of these radionuclides in coastal waters exceed their highest value, those results can be regarded as additional impact of anthropogenic sources in the Baltic Sea.

References

Butkus, D.; Konstantinova, M. 2008. Modelling vertical migration of ^{137}Cs in Lithuanian soils. *Journal of Environmental Engineering and Landscape Management*, 16 (1): 23–29.

Butkus, D.; Pliopaite Bataitiene, I.; Bataitis T. 2008. ^{90}Sr kaupimosi paprastosios pušies (*Pinus sylvestris* L.) medienoje tyrimas [Investigation of ^{90}Sr accumulation in Pinewood (*Pinus sylvestris* L)]. *Journal of Environmental Engineering and Landscape Management,* 16 (3): 121–127.

Helcom (1995) Baltic Sea environment proceeding. Nr. 61: 182.

Helcom (2003) Baltic Sea environment proceeding. Nr. 85: 103.

Helcom (2009) Baltic Sea environment proceeding. Nr. 117: 64.

Pliopaite Bataitiene, I.; Butkus, D. 2010. Investigation of ^{137}Cs and ^{90}Sr transfer from sandy soil to scots pine (*Pinus sylvestris* L.) rings. *Journal of Environmental Engineering and Landscape Management,* 18 (4): 281–287.

Styro, D.; Kleiza, J.; Morkūnienė, R.; Daunaravičienė, A. 2006. Change of cyclicity of volumetric activity of radionuclide ^{137}Cs in coastal waters of the Baltic Sea and its possible reasons. *Journal of Environmental Engineering and Landscape Management*, 14 (2): 69–76.

Styro, D.; Morkūnienė, R. 2003. Baltijos jūros savivalos nuo dirbtinės kilmės radionuklidų eksperimentinių ir teorinių rezultatų palyginimas [Comparison of the measured and calculated results of the self-cleaning of artificial radionuclides in the Baltic Sea]. *Sveikatos mokslai* [*Health sciences*], 13 (3): 23–28.

Styro, D.; Morkūnienė, R.; Vdovinskienė, S. 2006. The process of self-purification of the Baltic Sea waters from artificial radionuclides, *Oceanology*, 46 (3): 258–367.

Styro, D.; Lukinskienė, M.; Morkūnienė, R. 2004. The Features of Self-Purification of the Baltic Sea Waters from ^{137}Cs Radionuclide. *Oceanology*, 44 (2): 183–191.

Styro, D.; Morkūnienė, R. 2005. Comparison of the measured and calculated results of ^{137}Cs and ^{90}Sr concentration change in the Baltic Sea after Chernobyl power plant accident. International Conference on the protection of the environment from the effects of ionizing radiation. Stockholm, Sweden, 6-10 October 2003: contributed papers. Vienna: International Atomic Energy, 171–174.

Zalewska, T.; Lipska, J. 2006. ^{137}Cs and ^{90}Sr distribution in the Southern Baltic environment in 2004 and 2005. Helsinki commission. Project Group for Monitoring of Radioactive Substances in the Baltic Sea (MORS). Eleventh Meeting. Monaco, 30 May-2 June 2006. Document code: 3/2: 2–5.

Zalewska, T.; Lipska, J. 2006. Contamination of the eastern Baltic Sea with ^{137}Cs and ^{90}Sr over the period 2000-2004. *Journal of Environmental Radioactivity*, 91: 1–14.

Стыро, Д. Б. 1989. Вопросы ядерной гидрофизики [Problems of Nuclear Hydrophysics]. Ленинград: Гидрометеоиздат [Hidrometeoizdat], 255.

Стыро, Д. Б.; Астраускене Н. П.; Банене Р. А.; Каджене Г. И.; Клейза И. В.; Лукинскене М. В.; Бумелене Ж. В.; Станкайтис А. К. 1989. Концентрация ^{90}Sr и ^{144}Ce в юго-восточной части Балтийского моря в июне 1986 г. [Concentrations of ^{90}Sr and ^{144}Ce in June 1986 in the south-eastern part of the Baltic Sea]. *Физика атмосферы* [*Atmospheric Physics*], 14: 98–104.

Стыро, Д. Б.; Каджене Г. И.; Клейза И. В.; Лукинскене М. В. 1984. О колебаниях концентрации искусственных радионуклидов в водах Балтийского и Северного морей в 1977-1982 гг. [On variation of artificial radionuclides concentration in the Baltic and North sea waters in 1977-1982] *Атомная энергия* [*Atomnaya energya*], 57 (6): 404–407.