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^{210}Po accumulation by components of the Black Sea ecosystem

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Abstract. The naturally occurring radionuclide ^{210}Po was determined in different components of the Black Sea ecosystem. The specific activity of ^{210}Po in water in the open part of the sea was about 1 Bq · m^{-3}. The range of ^{210}Po specific activity in bottom sediments was 4.5–500 Bq · kg^{-1} dry weight depending on their type, area and depth of collection. The highest values were found in the NW part of the Black Sea. Sediment distribution coefficients (Kd) of ^{210}Po for bottom sediments, calculated on a dry weight basis, varied from 0.5×10^4 to 5×10^5. The levels of ^{210}Po specific activity in molluscs and pelagic fishes anchovy and sprat were the highest among the investigated species of the Black Sea biota. Concentration factors (CF) of ^{210}Po, estimated on a wet weight basis, reached 1.5×10^3 for macrophytes, 4×10^3 for total zooplankton, 10^3–10^4 for the entire fishes depending on their ecological groups affiliation and $(0.7–6.0) \times 10^4$ for molluscs. So, the ability of the Black Sea biota to accumulate the natural radionuclide ^{210}Po is comparable with that of similar species from others marine and oceanic areas.

1. INTRODUCTION

The naturally occurring radionuclide ^{210}Po in marine ecosystems attracts special interest due to its chemical and radioactive properties. ^{210}Po is the dominant contributor to natural radiation doses received by marine biota [1–4] and one of natural tracers used in studies of marine biogeochemical processes [5–8]. Up to mid-1990s a very limited amount of data on ^{210}Po in the Black Sea water, sediments and biota had been published [4, 9, 10]. This work initiated by the IAEA Technical Co-operative Project RER/2/003 “Marine Environmental Assessment in the Black Sea Region” presents an extensive set of ^{210}Po data and related results obtained by authors in 1999–2006.

2. MATERIALS AND METHODS

Radiochemical procedure of the RISOE National Laboratory [11] was used for determination of ^{210}Po in these samples. The ^{208}Po was added as a yield tracer. Polonium was spontaneously plated onto silver disks. Alpha counting of ^{208}Po and ^{210}Po was done using a silicon surface-barrier detectors and alpha-spectrometer EG&G ORTEC. ^{210}Po specific activities in surface water, bottom sediments and biota are given in Bq · m^{-3}, Bq · kg^{-1} dry weight (dw) and Bq · kg^{-1} wet weight (ww), respectively. The results are reported as the mean of values measured for the individual samples/organisms and standard deviation (SD) for each group of data.

2.1 Sampling procedure

Surface water and bottom sediments were collected during scientific cruises aboard R/V “Professor Vodyanitsky” in the Black Sea open part. The small ships were used for sampling in the Sevastopol bays and other selected locations along the Crimea coast (Figs. 1, 2).

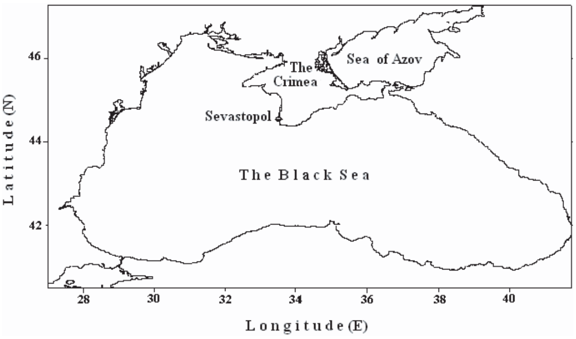

Figure 1. The scheme-map of the Black Sea.

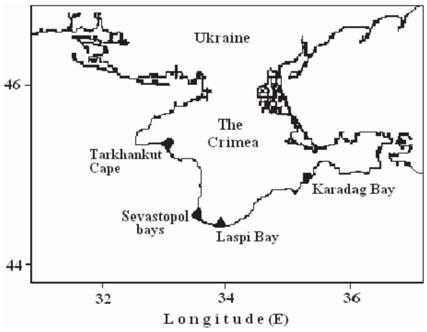

Figure 2. Sampling areas along the Crimea.

Investigated species of the Black Sea were seaweeds, total mesozooplankton, macrozooplankton, fishes and molluscs. Sevastopol bays and Laspi Bay were chosen for sampling of seaweeds (Figs. 1, 2).

The total mesozooplankton was collected in Sevastopol bays (Fig. 1) and along the Black Sea coast of Turkey. Its sampling was made by the Bogorov-Rass' ring net (the mouth diameter 80 cm, mesh 300 μm) on the small boat in Sevastopol Bay on August, 2001. The main species in these samples were *Acartia clausi*, *Nauplii Balanus* and meroplankton.

Along the coast of Turkey the total mesozooplankton was collected by the Gensen' ring net (the mouth diameter 70 cm and mesh 300 μm) on the R/V "Bilim", 2–8 July 2000. The total vertical hauls were carried out from the lower boundary of oxygen layer (the depth of isopycnic position sigma–t = 16.2) to the surface of the sea. The main species in the samples were *Calanus euxinus* Karavayev, 1894 ($\sim$95%). The amount of other species (*Pseudocalanus elongates*, *Acartia tonsa*, *Acartia clausi*) was insignificant.

The hauling of the representative species of the Black Sea jelly macroplankton – the ctenophore *Beroe ovara* Mayer, 1912 (Ctenophora, Atentaculata, Beroida) (beroe), was carried out by net from the surface of the sea on 30 September, 2000 and 11 September, 2001 in Kazachya Bay. The depth of Bay in the place of the collection was 10 m. ^{210}Po determination was carried out in 30 samples of the total mesozooplankton and 73 samples of beroe.

Fishing was carried out in Sevastopol bays and areas between Laspi Bay and the Tarkhankut Cape (Fig. 2). The fishing was made by line trawls and fish traps inside of Sevastopol bays. The trawlers were used for fishing from the depths 60–95 m in the coast zone of Sevastopol marine region (Fig. 2). 17 species of the Black Sea fishes belonging to three ecological groups – pelagic, demersal and benthic, were studied.

The mussels *Mytilus galloprovincialis* (Lamark, 1819), the main commercial molluscs species in the Black Sea, were collected in the bays of Sevastopol, Karadag, Laspi and near the Tarkhankut Cape (Fig. 2). The small mollusc nana *Nana nerithea* (Linne) was sampled in the Sevastopol bays. The Far-Eastern giant oyster *Grassostrea gigas* (Th.), the Black Sea oyster *Ostrea edulis* (Linne) and the invader scapharca Sc*apharca inaequivalvis* (Brunguiére, 1789) were collected on the artificial maricultural farms in the Sevastopol bays. Number of animals in each sample depended on their shell size, soft tissue weights and varied from 5 to 25.

3. RESULTS AND CONCLUSIONS

3.1 ^{210}Po in the Black Sea water and bottom sediments

The ^{210}Po specific activity range in surface water collected inside of Sevastopol bays was 0.58–0.78 Bq $\cdot$ m^{-3}. It was 0.84–1.1 Bq $\cdot$ m^{-3} in the samples collected on the distance about 10 miles out of these bays. The ^{210}Po specific activity in surface water in the NW Black Sea varied from 0.65 to 2.10 Bq · m^{-3} (Fig. 3) with the average value about 1 Bq · m^{-3} [12]. It is in a good agreement with data [4, 13].

The range of ^{210}Po specific activity in surface layer of the Black Sea bottom sediments was 4.5–500 Bq · kg^{-1} dw [12] depending on their type, area and depth of collection. The highest values were found in the NW Black Sea in the circumferential regions of the western cyclonic water circulation zone (Fig. 4) [12]. It is caused by interconnection of biological, physical and hydrological processes being in this area. Sediment distribution coefficients (Kd) of ^{210}Po for the investigated sediments, calculated on a dry weight basis, varied from 0.5×10^4 to 5×10^5. These results are the same range as summarized data (5–900 Bq · kg^{-1} dw) given in the review [13].

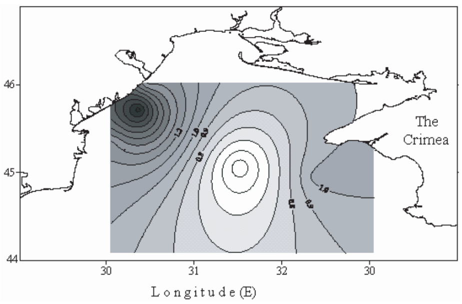

Figure 3. ^{210}Po distribution in surface water of the NW Black Sea.

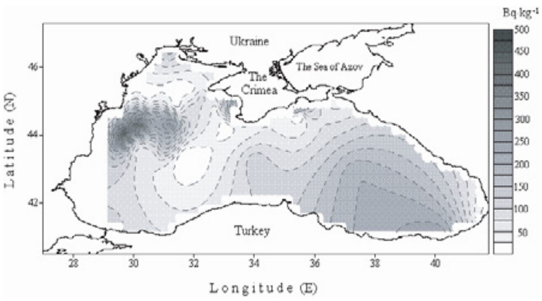

Figure 4. ^{210}Po distribution in bottom sediments of the Black Sea.

3.2 ^{210}Po in the Black Sea biota

Average values of ^{210}Po specific activity in investigated seaweeds decreased from Rhodophyta (1.5 Bq · kg^{-1} ww) to Phaeophyta (0.8 Bq · kg^{-1} ww) and Chlorophyta (0.35 Bq · kg^{-1} ww) [14]. This tendency is similar to the published data for other areas of the World Ocean [1, 15]. For the Black Sea seaweeds the maximum Concentration Factors (CF) of ^{210}Po, estimated on a wet weight basis, varied from 0.6×10^3 for Chlorophyta to 2.7×10^3 for Rhodophyta.

Zooplankton is a main food source for pelagic fishes and filter-feeder shellfishes. Among marine organisms its role in an accumulation of ^{210}Po can be demonstrated as follows: phytoplankton $<$ zooplankton $\leq$ fishes, molluscs [1]. Accumulation of ^{210}Po by zooplankton depends on the seasonal and regional factors [16]. The distribution of ^{210}Po specific activity in samples of total mesozooplankton collected along the coast near Turkey shown in Fig. 5. The range of the mean of ^{210}Po specific activity in

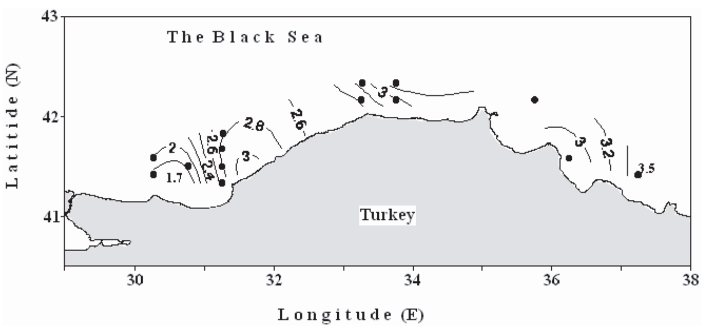

Figure 5. Distribution of ^{210}Po specific activity in total mesozooplankton collected along the Black Sea coast of Turkey on 2–8 July 2000 [17].

total mesozooplankton was 1.71–3.5 Bq · kg^{-1} WW [17]. The highest value of this radionuclide given as 2.75 Bq · kg^{-1} wet weight, is lower of one for the Mediterranean Sea zooplankton almost 3 times. It may be connected with lower salinity in the Black Sea water and as a result more lower concentrations nonisotopic carriers of ^{210}Po in it [14].

The Black Sea planktonic community was significantly changed during the last two decades. The main reason was an appearance of the new resident in the sea ctenophore *Mnemiopsis leidyi* (A. Agassiz) [18]. During the last several years the new one, also ctenophore as well, *B. ovata* had appeared in the Black Sea too [19]. The mentioned above species are interconnected in food pelagic chains: mesozooplankton is eaten by ctenophore *M. leidyi* and the last one is the main food for *B. ovata* [19]. ^{210}Po specific activity in super predator *B. ovata* reached 3.8 Bq · kg^{-1} ww [17]. So, average CF of ^{210}Po for the Black Sea zooplankton was 3.5×10^3.

The levels of ^{210}Po specific activity in investigated fishes depended on their ecological groups affiliation and decreased from pelagic to demersal and benthic ones [14]. The range of average value for all investigated species was 0.9–35.7 Bq · kg^{-1} ww in 1999–2003. Our results are in agreement with data given in [1, 13, 20]. The highest ^{210}Po specific activity was determined in anchovy *Engraulis encrasicolus ponticus* Aleksandrov and sprat *Sprattus sprattus phalericus* (Risso) in spring 1999. Last one is the main commercial fish in the Black Sea. It is requested to emphasize that the ^{210}Po specific activity in each ecological group varied significantly. The variability can be connected with season, dietary habits, availability of food and environment conditions. The range of CF for this radionuclide in the Black Sea fishes was 0.9×10^3–3.6×10^4.

^{210}Po specific activities in investigated species of the Black Sea molluscs vary widely (Fig. 6). The difference between highest and lowest values reached up to 9.7 times. It is connected with a food set of animals and areas they inhabited [21].

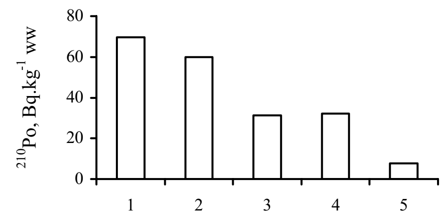

Figure 6. ^{210}Po specific activity in investigated species of molluscs: 1 – *G. gigas*, 2 – *M. galloprovincialis,* 3 – *O. edulis,* 4 – *S. inaequivalvis,* 5 – *N. nerithea.*

An ability of the Black Sea mussels to accumulate of ^{210}Po depended on its soft tissues individual wet weight (Fig. 7), stages of gametogenesis (Table 1) and sex structure (Fig. 8) [21].

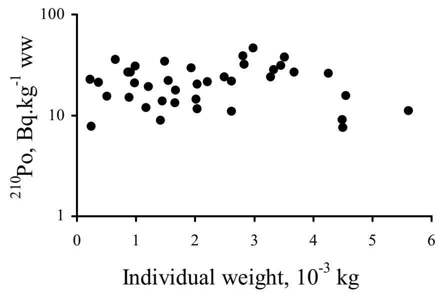

Figure 7. The dependency of ^{210}Po specific activity in soft tissues of a mussel on its individual weight.

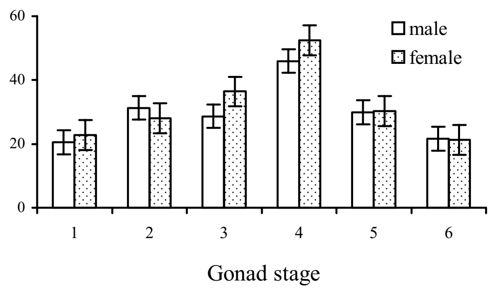

Figure 8. The dependency of ^{210}Po specific activity average values on sex structure and gonad stages of mussels.

Table 1. The stages of the Black Sea mussels *M.galloprovincialis* gametjgenesis cycle.

No stage	Name of stage
1	the relative quiescence after spawning
2	the beginning of gametgenesis
3	the active gametogenesis
4	the stage of gametogenesis just before the spawning
5	the spawning itself, gonads release sexual products
6	the realignment after spawning

The same dependency was observed for the Far-Eastern giant oyster *G. gigas*. The range of CF of ^{210}Po for investigated molluscs, estimated on a wet weight basis, was (0.7–6.7) $\times$ 10^4.

Summarizing all obtained data (1999–2006) we may conclude that an ability of the Black Sea biota to accumulate the natural radionuclide ^{210}Po is comparable with that of similar species from other marine and oceanic areas.

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