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NATURALLY OCCURRING RADIONUCLIDE ^{210}Po IN THE BLACK SEA MOLLUSCS

^{210}Po accumulation by five species of the Black Sea molluscs inhabiting the Sevastopol bays was studied. ^{210}Po concentrations in investigated mollusks vary widely and depend on the type of their nutrition. The highest concentration was found in the Far-Eastern giant oyster and the lowest one – in nana. ^{210}Po accumulation by the Black Sea mussels depends on their individual wet weight (WW), the stages of maturity of the gonads and inhabitancy condition. Such dependences were found for the Far-Eastern giant oyster. Concentration Factors (CF) of ^{210}Po for the Black Sea molluscs vary from $7x10^3$ to $5.2x10^4$. This is in good agreement with World Ocean average value for ^{210}Po CF for molluscs which equals $3x10^4$.

Keywords: ^{210}Po, concentrations, Concentration Factors, molluscs, Sevastopol bays, the Black Sea.

^{210}Po role, the naturally occurring radionuclide, in marine ecosystems is very important due to its alpha radiation, its binding with organic matter and formation of high doses in marine organisms [1, 2]. ^{210}Po largely contributes to radiation doses absorbed by marine biota with food [1, 2]. ^{210}Po concentrations in hydrobionts from different regions of the World Ocean may vary for orders of magnitude and they range widely in each species. Among marine hydrobionts the molluscs accumulate ^{210}Po to the highest levels [1, 2]. The purpose of this work was to determine of ^{210}Po in the Black Sea molluscs inhabiting the Sevastopol bays and to analyze some possible reasons of differences in the accumulation of this radionuclide.

Material and methods. The Far-Eastern giant oyster *Crassostrea gigas* (Thunberg, 1793), oyster *Ostrea edulis* (L., 1758) and the invader anadara *Anadara inaequivalvis* (Brunguière, 1789) were collected in Karantinnaya Bay (Sevastopol). The mussel *Mytilus galloprovincialis* (Lamarck, 1819), the main commercial species of molluscs in the Black Sea, was sampled in Kazachya Bay, Sevastopol Bay and Martynova Bay, and the nana *Nana nerithea* (L., 1758) was collected in Martynova Bay. The number of animals in each sample depends on their shell size, the weight of soft tissues and varies from 5 to 25 individuals. Total number of investigated mollusks is 1620.

The radiochemical procedures of RISOE National Laboratory [3] were used for ^{210}Po extraction from soft tissues of molluscs. As a yield tracer was ^{208}Po. ^{208}Po and ^{210}Po were measured after spontaneously plated onto silver disks on the alpha-spectrometer OCTÊTÊ PC EG&G ORTEC. The mean values of ^{210}Po concentration by each species expressed as $Bq \cdot kg^{-1}$ wet weight (WW) and the standard error (SE) of the mean are presented in Table 1.

Results and discussion. ^{210}Po concentrations in investigated species of the Black Sea molluscs vary widely. The ratio between highest maximum and lowest minimum values of concentrations was reached up to 9 times (Table 1).

Species	^{210}Po concentration, Bq·kg^{-1} WW
Crassostrea gigas	69.7 ± 6.2
Mytilus galloprovincialis	59.2 ± 5.0
Ostrea edulis	31.2 ± 2.9
Anadara inaequivalvis	32.2 ± 3.1
Nana nerithea	7.7 ± 0.7

Table 1 Maximum value of ^{210}Po concentrations in the Black Sea molluscs
Табл. 1 Максимальные концентрации ^{210}Po в моллюсках Черного моря

The comparison of some biological features of these animals was carried out for understanding of this difference. The specified criterions taken into consideration were the habitation mode and the food set (Table 2) [4 – 6].

Table 2 Some biological features of the Black Sea molluscs
Табл. 2 Ряд биологических характеристик моллюсков Чёрного моря

Species	Type of nutrition [4, 5]	Spawning in a year	Loss of soft tissues mass with sex products, % [6]
C. gigas	Suspended organic matter including dissolved organic matter, microorganisms, plankton, detritus	1	10 – 20
O. edulis	the same	1	10 – 20
A. inaequivalvis	the same	1	10 – 20
M. galloprovincialis	dissolved organic matter, microorganisms, plankton, detritus	2	11 – 29
M. galloprovincialis	dissolved organic matter, microorganisms, diatoms, unicellular algae, detritus	2	11 – 29
N. nerithea	carnivorous, necrophage, can consume algae and detritus	1	n.d.

Common feature for investigated molluscs excluding mussels is one spawning a year: June – August (giant oyster), May – July (oyster), August – September (anadara), June – July (nana). In most cases the temperature for the start of spawning is 13°C. On the contrary the Black Sea mussels have two spawning a year (spring and autumn).

C. gigas, *M. galloprovincialis*, *A. inaequivalvis* and *O. edulis* are filter-feeders (Table 2) [4]. The food set for these animals consists of suspended organic matter, including dissolved organic matter, phytoplankton and detritus. The ratio between them in food depends on ages of molluscs and areas they inhabited [4]. It is known that suspended organic matter and phytoplankton is the first step in transfer of ^{210}Po in marine ecosystems [1]. The detritus is the main food for the necrophage *N. nerithea* [5].

As one can see, the dietary habits (Table 2) [4, 5] and accumulative ability of the Black Sea molluscs in relation to natural radionuclide ^{210}Po are interconnected (Table 1, Fig. 1).

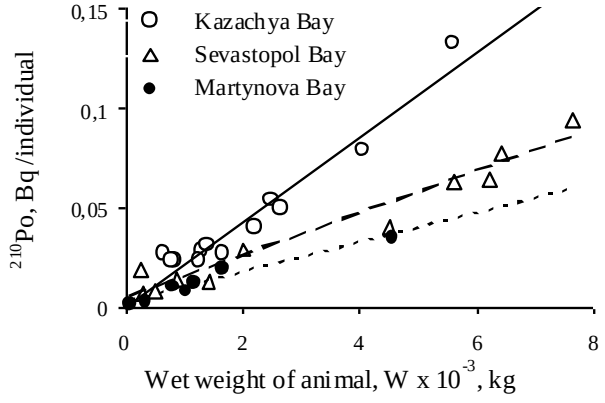

Fig. 1 Dependency of ^{210}Po content in soft tissue of mussel (Bq / individual) on its wet weight (W) [9]
Рис. 1 Зависимость содержания ^{210}Po в мягких тканях мидии (Бк / особь) от их сырой массы (W) [9]

It is in a good agreement with the conclusion by R. D. Cherry and M. Heyraud: «from the marine biological point of view, ^{210}Po has potential as a natural tracer of marine organism diet» [7]. M. Heyraud et al. [8] underlined important role of ^{210}Po in identification of different feeding regimes.

Among the Black Sea molluscs which were studied the large amount of data was obtained on mussels [9 – 11]. The ^{210}Po maximum concentrations varied from 13 to 60 Bq·kg^{-1} WW in mussels inhabited Sevastopol bays with different levels of contamination [9]. The highest values of ^{210}Po concentrations were found in mussels from Kazachya Bay characterized as relatively clean and the lowest ones – In animals from Martynova Bay, the most contaminated by municipal wastes. Sevastopol Bay with its intensive shipping is contaminated mainly by oil products.

The dependencies of ^{210}Po content in soft tissues per individual on wet weight of mussels from three locations (Fig. 1) may reflect the ecological state of both the animals and the bays they inhabited [9]. The difference between the food set for small and large mussels can be one of the reasons of it [9].

As one of the following reason a reproductive cycle may be considered. During the year there is a significant change of the weight of soft tissues of the Black Sea mussels together with a redistribution of the expenditures of assimilated energy by animals on somatic and generative growth, quantitative rations in their biochemical components, first of all, amino acids and proteins [6]. The losses of mass soft tissues of the Black Sea mussels to the end of spawning reached up to 11 – 29 % of the initial energy equivalent of the soft body [6]. Thus, during spawning the losses of proteins by the Black Sea mussels can be significant [6]. During spawning there is a loss of a number of reproductive products which is higher with age of mussels: with increasing of whole mass of an organism its individual fertility is increased as well [6, 12]. The greatest part of sex products are proteins. M. A. Wildgust et al. [13] have shown that about 80% of ^{210}Po in soft tissue of mussels *Mytilus edulis* was identified as being associated with proteins.

There are six stages of the reproductive cycle of the Black Sea mussels (Table 3) [12].

Table 3 The stages of the Black Sea mussels *M. galloprovincialis* reproductive cycle [12]
Табл. 3 Стадии репродуктивного цикла черноморских мидий

No stage	Name of the maturity stage of the gonads
1	the relative quiescence after spawning
2	the beginning of gametogenesis
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 results determination of ^{210}Po in animals from Kazachya Bay are presented in Fig. 2. As one can see ^{210}Po concentrations in soft tissues of investigated mussels depend on the sex structure and the reproductive cycle. The differences between them in females and males reach 8.4 % (3rd stage), 9 % (4th stage) and 4.5 % (5th stage). Between ^{210}Po concentrations in males and females 1st, 2nd and 6th stages the differences were equal to 2.1, 2.6 and 1.8 % accordingly.

Average values of ^{210}Po concentrations in males and females ranged from 20.6 to 46 Bq·kg^{-1} WW and from 21.8 to 52.5 Bq·kg^{-1} WW correspondingly (Fig. 2).

Thus, the levels of ^{210}Po concentrations in the Black Sea mussels change significantly and their variations in random samples of mussels are associated with stages of maturity of the gonads. The highest values were found in the fourth stage (before spawning) (Fig. 2).

The same dependency of ^{210}Po concentrations on gonad stages and sex structure was observed on oyster *C. gigas* with range in males 26.6 – 59.2 Bq·kg^{-1} WW and in females 27.5 – 69.7 Bq·kg^{-1} WW correspondingly (Fig. 3).

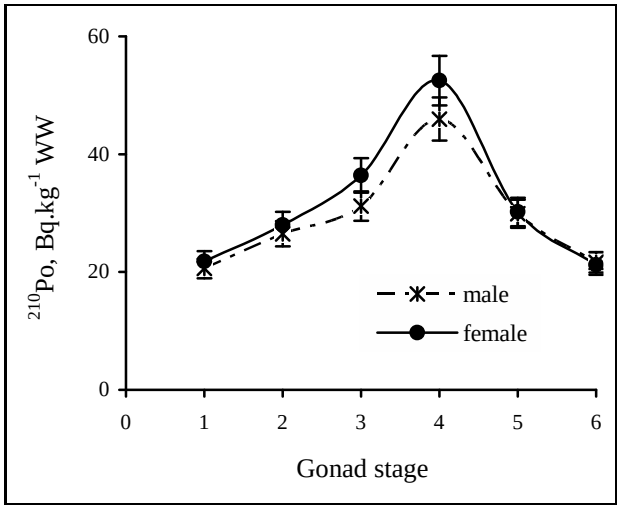

Fig. 2 The dependency of average values of ^{210}Po concentrations in soft tissues of the Black Sea mussels on their sex attributes and the stage of maturity of the gonads

Рис. 2 Зависимость средних концентраций ^{210}Po в мягких тканях черноморских мидий от их половой принадлежности и стадий зрелости гонад

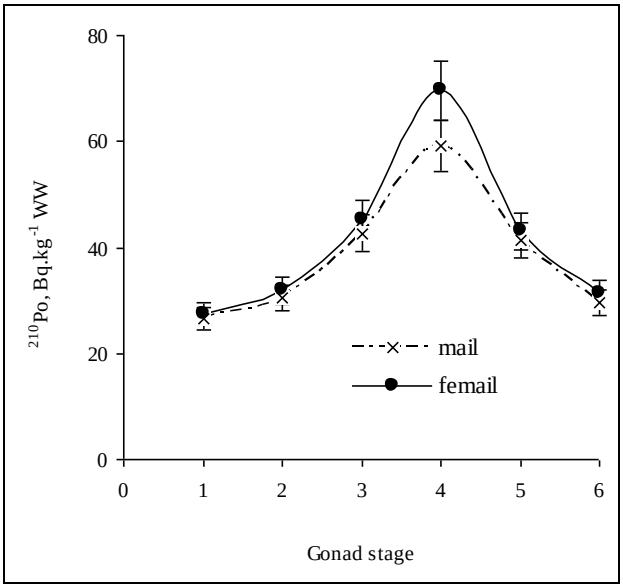

Fig. 3 The dependency of average value of ^{210}Po concentrations in the Far-Easter oyster *G. gigas* on its sex attributes and the stage of maturity of the gonads

Рис. 3 Зависимость средних концентраций ^{210}Po в мягких тканях дальневосточной гигантской устрицы *G. gigas* от её половой принадлежности и стадий зрелости гонад

It is seen that data presented in Fig. 2 and Fig. 3 reflect the fluctuation of weight and quantity of sex product in soft tissues of the mussel and giant oyster during reproductive cycle.

Therefore, if one needs to study an accumulative ability of molluscs relatively to ^{210}Po, it is necessary to take into consideration all possible approaches for better understanding of the processes occurring in animals. The main of them are ecological condition in the inhabitancy and stages of maturity of the gonads. In any case it is important to make the comparison for molluscs with the same sizes or ages.

^{210}Po concentration in water of investigated locations was about 1 Bq·m^{-3}. The range of the calculated average values of concentration factors (CF) for ^{210}Po in mussels from Sevastopol bays was (1.7 – 4.7) x 10^4. Thus, average value of CF for ^{210}Po in investigated mussels inhabited the Sevastopol bays (3.2 x 10^4) is in excellent agreement with World Ocean average value given in [1] for this radionuclide for mollusc (3 x 10^4) which was calculated mainly in mussels. CF range for giant oyster values was 2.8 x 10^4 to 6 x 10^4. For this species of mollusc number of data on the polonium is not so much as for the mussels.

Hence, the accumulative ability of the Black Sea molluscs in relation to the natural radionuclide ^{210}Po is comparable with that of similar species from others marine and oceanic areas.

Conclusion. ^{210}Po concentrations in investigated molluscs varied widely and depended on dietary habits. The ability of the Black Sea mussels to accumulate of ^{210}Po connects withindividual wet weight (WW) of its soft tissues, stages of maturity of the gonads and inhabitancy condition. ^{210}Po content in mussels soft tissues per an individual on wet weight reflects the ecological state of both the animals and the bays they inhabited. The accumulative ability of investigated molluscs in relation to the natural radionuclide ^{210}Po is comparable with that of similar species from others marine and oceanic areas.

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Природный радионуклид ^{210}Po в моллюсках Чёрного моря. Г. Е. Лазоренко, Г. Г. Поликарпов, А. В. Пиркова, И. Осват. Исследована способность 5 видов моллюсков Чёрного моря, обитающих в Севастопольских бухтах, аккумулировать ^{210}Po. Концентрации ^{210}Po в этих гидробионтах варьируют в широких пределах и зависят от типа их питания. Самые высокие из них определены в гигантской устрице, а самые низкие – в нане. Аккумулирование ^{210}Po мидиями зависит от сырой массы их мягких тканей (WW), стадий репродуктивного цикла и условий обитания. Подобные зависимости отмечены для гигантской устрицы. Коэффициент накопления (CF) ^{210}Po для черноморских моллюсков варьирует от $7x10^3$ до $5.6x10^4$, что находится в согласии с усреднёнными данными для моллюсков из других регионов Мирового океана ($3x10^4$).

Ключевые слова: ^{210}Po, концентрации, моллюски, Севастопольские бухты, Чёрное море.

Природний радіонуклід ^{210}Po у молюсках Чорного моря. Г. Є. Лазоренко, Г. Г. Полікарпов, Г. В. Піркова, І. Осват. Досліджено здатність п'яти видів молюсків, відібраних в Севастопольських бухтах, акумулювати ^{210}Po. Концентрації ^{210}Po у цих гідробіонтах варіюють у широких межах і залежать від типу їх живлення. Найвищі з них визначені у далекосхідній гігантській устриці, а найнижчі – у нані. Акумулювання ^{210}Po чорноморськими мідіями залежить від сирої маси їх м'яких тканин (WW), стадій репродуктивного циклу і умов місцепроживання. Подібні залежності відзначені для гігантської устриці. Коефіцієнт нагромадження (CF) ^{210}Po для чорноморських молюсків варіює від $7x10^3$ до $5.6x10^4$, що знаходиться у згоді з усередненими даними для молюсків із інших регіонів Світового океану ($3x10^4$).

Ключові слова: ^{210}Po, концентрації, молюски, Севастопольські бухти, Чорне море.

ВЫШЛА В СВЕТ МОНОГРАФИЯ:

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