Doses with α-Particles of Plutonium Anthropogenic Radioisotopes to the Black Sea Hydrobionts

Nataliya N. Tereshchenko¹ and Gennady G. Polikarpov²

The A.O. Kovalevsky Institute of Biology of the Southern Seas (IBSS), NAS Ukraine, Prospekt Nakhimova 2, Sevastopol, 99011, Ukraine; e-mails: ¹ tnn@ibss.iuf.net, ² g.polikarpov@ibss.org.ua

INTRODUCTION

About 950 tons were produced and about 10 tons of anthropogenic plutonium (Pu) were nebulized all over the Earth, that thousand times exceeds natural Pu induced with cosmic rays in upper layers of the Earth's crust (Vorobjev et al., 1994).

In radioecology and ecotoxicology Pu occupies a special place due to its chemical toxicity, as a heavy metal, and high radiotoxicity, as one of the group of radioactive nuclides, mainly alpha-emitting ones (among 15 known Pu isotopes 12 of them are alpha-active isotopes). Especially ²³⁹Pu stands out of other mentioned radioisotopes, because it has great practical value, and ²³⁹,²⁴⁰Pu together with ⁹⁰Sr and ¹³⁷Cs potentially highly contribute to radiation doses to men via sea products as a food (Transuranium elements…, 1980; SCOPE 50, 1993).

A special interest to plutonium contamination of marine environment appeared by necessity of evaluation and prediction of consequences of the Chernobyl nuclear power plant (ChNPP) accident in 1986 because ²³⁹,²⁴⁰Pu of the Chernobyl origin are potentially an additional source of anthropogenic radioactivity in the marine environment.

The objective of the investigation is to assess irradiation doses of the Chernobyl ²³⁹,²⁴⁰Pu to the Black Sea hydrobionts of different trophic levels.

MATERIALS AND METHODS

The biota consisted of multicellular algae (Cystoseira crinita (Desf.), Ulva rigida Ag.), mussels (Mytilus galloprovincialis Lam.) and fishes (Sprattus sprattus phalericus Risso, Merlangus merlangus eucus Nordman and Trachurus mediterranum ponticus Aleev) were sampled in 1998 – 2004 in the coastal water area near to Sevastopol.

Plutonium was determined with well-known radio-chemical methods (Talvitie, 1991). Procedure was based on thermic and chemical pretreatments of the environmental and biological samples with further adsorption and desorption of Pu on ion-exchange resin (Dowex 1-X2 or AG 1-X2 chloride form 50–100 mesh for Pu refining). After refining and separation, Pu isotopes were co-precipitated with fluoride of lanthanum (LaF₃) (Pavlotskaya et al., 1984) and obtained samples were measured with alpha-spectrometer “EG & G ORTEC OCTETE PC” provided by IAEA to the Dept of Radiation and Chemical Biology, IBSS. ²⁴²Pu was added to samples as a radio-tracer standard for determination of chemical yield. Total error of the Pu concentration determination was not more than 13% for hydrobionts samples and 20% for water samples. Measured Pu concentrations in hydrobionts were based on their wet weight (ww).
Absorbed dose rates formed with alpha-emitting radioisotopes were calculated by using their concentrations in hydrobionts and alpha-particles energy of the proper Pu radioisotopes in accordance to widely accepted procedures (Blaylock et al., 1993; Thomas and Liber, 2001). Equivalent dose rates were calculated by multiplication of the absorbed dose rates and radiation weighted factor equaled to 20 for alpha-particles.

RESULTS AND DISCUSSION

Basing on data regarding to Pu contamination levels as well as to dose levels of irradiation to abiogenic and biogenic components of marine ecosystems with proper long-lived radioisotopes of anthropogenic origin we have estimated of the modern radiation-ecological situation in the Black Sea during about 20 years after the Chernobyl NPP accident.

The rates of absorbed doses of internal irradiation from the alpha-radiation of incorporated $^{239, 240}$Pu to the Black Sea hydrobionts varied from 0.01 to 0.354 µGy·years$^{-1}$ (Tereshchenko et al., 2007). The range of changes of the absorbed doses rates in species of the Black Sea hydrobionts inhabited geographically different off-shore marine areas are represented in the Table 1 (calculated by us on our and other authors published data (Marine Environmental Assessment…, 2004; Tereshchenko, 2005a,b; Tereshchenko et al., 2007). Concentrations of $^{238}$Pu in studied the Black Sea marine organisms were below the limit of detection (Tereshchenko, 2005a).

### Table 1. Minimum and maximum of the absorbed dose rates, formed in the Black Sea hydrobionts with alpha-radiation of the incorporated $^{239, 240}$Pu radioisotopes

<table>
<thead>
<tr>
<th>Area of sampling</th>
<th>The Black Sea species of hydrobionts</th>
<th>Rate of absorbed dose, µGy/year</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Min</td>
</tr>
<tr>
<td>Area of the Black Sea at the Crimean coasts</td>
<td>Cystoseira crinita (Desf.) Bory</td>
<td>0.026</td>
</tr>
<tr>
<td></td>
<td>Ulva rigida Ag.</td>
<td>0.031</td>
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<tr>
<td></td>
<td>Mytilus galloprovincialis Lam.</td>
<td>0.020</td>
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<tr>
<td></td>
<td>Trachurus mediterranum ponticus Aleev</td>
<td>0.016</td>
</tr>
<tr>
<td></td>
<td>Merlangus merlangus euxinus Nordman</td>
<td>0.010</td>
</tr>
<tr>
<td></td>
<td>Sprattus sprattus phalericus (Risso)</td>
<td>0.016</td>
</tr>
<tr>
<td>Area of the Black Sea at the Caucasian coasts</td>
<td>Cystoseira barbata (Good. et Wood)</td>
<td>0.168</td>
</tr>
<tr>
<td></td>
<td>Mytilus galloprovincialis Lam.</td>
<td>0.039</td>
</tr>
<tr>
<td></td>
<td>Trachurus mediterranum ponticus Aleev</td>
<td>0.010</td>
</tr>
<tr>
<td></td>
<td>Sprattus sprattus phalericus (Risso)</td>
<td>0.010</td>
</tr>
</tbody>
</table>

The results of estimation of maximum annual doses as equivalent doses to separate taxonomic groups of the Black Sea hydrobionts (multicellular algae, bivalves, fishes) in areas at the Crimean coast near Sevastopol and in areas at the Caucasian coast near Anapa, Gelendzhic and Sochy are presented in Fig. 1. The obtained data testify that absolute values of the annual doses were differed in the studied districts of the Black Sea to the same groups of
hydrobionts, but there was the general tendency of change of dose levels between different taxonomic groups. The obtained results showed that doses with $^{239, 240}$Pu internal irradiation to different taxonomic groups of the Black Sea hydrobionts were diminished more, than one order of magnitude in a series: multicellular brown algae $>$ bivalves $>$ fishes.

Comparative analysis of dose levels formed with $^{239, 240}$Pu to studied hydrobionts of the Black Sea in this work and doses formed with natural alpha-emitting radionuclide of $^{210}$Po (Lazorenko et al., 2003) showed that $^{239, 240}$Pu irradiation doses are $10^3$-$10^4$ times lower, than irradiation doses with $^{210}$Po. Hence, doses created with $^{239, 240}$Pu to the Black Sea hydrobionts were in $n \cdot 10^5$-$10^7$ times less than the dose level offered by IAEA (International Atomic Energy Agency, 1992), at which there are no negative consequences in populations of aquatic organisms.

![Graph](image_url)

**Figure 1.** Maximum annual equivalent doses ($D_{EQU}$, $\mu$Sv) created with $^{239, 240}$Pu to different taxonomic groups of the Black Sea hydrobionts in off-shore areas: I – at the Crimean coast and II – at shores of the Caucasus.

As the half-life of $^{239, 240}$Pu exceeds thousand years, their internal irradiation to hydrobionts is practically a permanent irradiation. In obedience to the radiation-ecological conceptual model of ecological influence zones of chronic ionizing irradiation (Polikarpov, 1998), doses with alpha-radiation of $^{239, 240}$Pu to the Black Sea hydrobionts are characteristic for the “well-being zone” and for the “uncertainty zone”. Therefore, remaining for many hundred years as registered radiation-ecological factor, nevertheless the modern concentration levels of the Chernobyl origin plutonium in the Black Sea do not render noticeable influence upon the biological functions and structures in components of the Black Sea ecosystems. Also the obtained regularities may be of immediate practical radioecological value in a case of unexpected (but not excluded in the nuclear epoch) an appearance of much greater amounts of Pu in marine ecosystems.
REFERENCES


