Marine Pollution Bulletin xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Review

# Contemporary radioecological state of the North-western Black Sea and the problems of environment conservation

N.N. Tereshchenko [a,*], N.Yu. Mirzoyeva [a], S.B. Gulin [a], N.A. Milchakova [b]

[a] Radiation and Chemical Biology Department, The A.O. Kovalevsky Institute of Biology of the Southern Seas, National Academy of Sciences of Ukraine (IBSS NAS of Ukraine), Ukraine
[b] Laboratory of Phytoresources, IBSS NAS of Ukraine, 2, Nakhimov Avenue, Sevastopol 99011, Ukraine

ARTICLE INFO

*Keywords:*
Chernobyl nuclear power plant accident
North-western Black Sea ecosystems
$^{90}$Sr, $^{137}$Cs, $^{239,240}$Pu
Dose assessment
Fluxes of radionuclides
Marine protected areas

ABSTRACT

Review is devoted to the analysis of a radioecological situation in the North-western Black Sea and concerns the levels of contamination of the components of an ecosystem by the main artificial radioactive isotopes ($^{90}$Sr, $^{137}$Cs, $^{239,240}$Pu). The long-term accumulation trends of these radionuclides were analyzed in components of the Black Sea ecosystem after the Chernobyl nuclear power plant accident. Zones that have an increased ability to accumulate these radioisotopes were revealed. The assessment of irradiation dose rates formed by $^{90}$Sr, $^{137}$Cs and $^{239,240}$Pu in Black Sea hydrobionts was obtained. The strategy for biodiversity conservation and sustainable management of natural resources should include monitoring of the radioecological state of the marine ecosystems, and the formation of a complex of biogeochemical criteria for assessment of an ecological situation in the sea. This approach is important for marine protected areas, since it allows the formation of a basis for scientific and practical function.



**Contents**



* Corresponding author. Tel.: +380 692474645; fax: +380 692557813.
*E-mail addresses:* n.tereshchenko@ibss.org.ua (N.N. Tereshchenko), natmirz@mail.ru (N.Yu. Mirzoyeva), milchakova@gmail.com (N.A. Milchakova).

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http://dx.doi.org/10.1016/j.marpolbul.2014.01.003

## 1. Introduction

The contemporary ecological situation on the planet, that has developed as a result of large-scale negative human impact on natural ecosystems, requires development and application of actions on its reduction and activity on conservation of biological diversity in both terrestrial and marine biocenoses, because the state of ecosystems stipulates a sustainable development of society and solution of many social and economic problems (Convention on Biological Diversity, 1992).

The Black Sea is one of the most polluted inland seas (Oguz, 2008). The radiochemoecological state of the Black Sea greatly depends on its catchment area, which is located within the territory of 20 states and covers an area of about 2 million km$^2$. Considering the uniqueness of the Black Sea ecosystem, because of presence of the hydrogen sulfide zone (deeper than 80–110 m in the center of the cyclonic gyres and to 160–250 m in the periphery) and a very high proportion of the hydrogen sulfide zone – up to 87% of the sea water (Eremeev and Konovalov, 2006; Ivanov and Belokopytov, 2011), the study of biogeochemical processes, peculiarities of entry and the migration of nuclear and non-nuclear pollutions is a major environmental problem.

The largest pollution of the basin is caused by the entry of waste, surface, river and soil waters. The North-western Black Sea (NWBS), within the boundaries from Chersonesus Cape to Cape of Kaliakra, is characterized by the maximum degree of anthropogenic pressures and pollution. This region occupies 16% of its sea area (68.390 km$^2$) and 0.7% of its volume (3555 km$^3$) (Ivanov and Belokopytov, 2011). The amount of the average annual river flow in the NWBS reaches 350 km$^3$ year$^{-1}$; it is 70% of the total river flow incoming to the Black Sea (Ivanov and Belokopytov, 2011).

In the Black Sea basin the greatest length of the boundaries belongs to Ukraine. In the fields of environmental protection, natural resource management and environmental safety, the priority directions in Ukraine are: pollution prevention and improving the quality of the Black Sea ecosystems, biodiversity conservation and development of protected natural territories and water areas, and ensuring nuclear safety while minimizing the consequences of the Chernobyl nuclear power plant (ChNPP) accident (The Fourth National Report of Ukraine, 2010).

Accident on the ChNPP, which happened on 26th of April 1986 at the catchment basin of the Black Sea, was the most dramatic accident in the history of nuclear reactors exploitation. This led to the discharge of significant amounts of radioactive substances, into the Black Sea basin; the secondary contamination still takes place (Polikarpov et al., 2008). After the ChNPP accident, the total release of radionuclides into the environment (not including radioactive noble gases) was estimated at 1.9 EBq ($\times 10^{18}$ Bq) or 3.5% of the total number of radionuclides in the reactor at the time of the disaster (Gudiksen et al., 1991). According to various estimations, the 1.3–7.4–8 PBq of $^{90}$Sr (0.6–5% of its content in the reactor core) as well as 137 PBq of the $^{134,137}$Cs and about 94 TBq of plutonium alpha-radionuclides ($^{238,239,240}$Pu) were released into environment (Izrael, 1990). The artificial gamma-radioactive isotope cesium – $^{137}$Cs, beta-radioactive isotope of strontium – $^{90}$Sr and alpha-radioactive isotopes of plutonium – $^{239,240}$Pu are the after-accident radionuclides that form the main radiation dose commitments for the Black Sea hydrobionts (Bar'yakhtar, 1995; IAEA, 2004; Polikarpov et al., 2008). In general, anthropogenic radioactive contamination of marine ecosystems began with a discharge of the artificial radionuclides into the biosphere, which were absent before the middle of the twentieth century (Polikarpov, 1966; Warner and Harrison, 1999). The normative values of the contamination concentrations in the water, the bottom sediments and the hydrobionts of the Black Sea were identified on the basis of long-term monitoring data that concerns the radiochemoecological state of the ecosystem. Radiochemoecological monitoring was based on determination of the levels of pollutants accumulation by the indicator species of hydrobionts, as well as comparative analysis of distribution of the radioactive and chemical contaminants in the biotic and abiotic components of the Black Sea ecosystem.

At the same time, the study of radioecological characteristics of anthropogenic radionuclides (nuclear contamination) in the Black Sea and the regularities of their distribution after the ChNPP accident enable forecasting assessments of their migration in the ecosystem, prediction of the state of the marine environment in different radioecological situations, including emergencies, as well as developing science-based recommendations for minimization of the accident's consequences, and maintenance and conservation of biological diversity, primarily in marine protected areas (MPAs).

The aims of this review were to examine the contamination levels of the abiotic and biotic components of the NWBS ecosystems by artificial radionuclides ($^{137}$Cs, $^{90}$Sr, $^{239,240}$Pu), to analyze and synthesize own and published data, to identify the redistribution trends of the radioactive contamination, to assess the fluxes of the radioactive contamination into the bottom sediments, to calculate irradiation doses formed by the man-made radionuclides in the marine hydrobionts, to receive the time scales forecast of the reduction radionuclides concentration to before-accident levels in the different water areas of the Black Sea in the period after the ChNPP accident.

Radiochemoecological research within these objectives is important for environment conservation because the largest MAPs such as Nature Botanical Preserves «Zernov's *Phyllophora* Field» (ZPF) and «Small *Phyllophora* Field» (SPF) are located at the NWBS (4025 km$^2$ and 385 km$^2$, respectively, or 6% of the north-western shelf of the Black Sea); however, these waters have the highest levels of anthropogenic contamination in comparison to other areas of the Black Sea (Polikarpov, 2000; Polikarpov et al., 2008; Oguz, 2008).

In the last decade in Ukraine, as in many others countries, great attention is paid to development of the national ecological network as a part of the Pan-European ecological network (Law of Ukraine, 2012) and to development of actions for environmental protection (National Action Plan on Environmental Protection for 2011–2015, 2011).

Increasing the area of MAPs and areas for conservation of biological and landscape diversity, reduction of pollution of natural ecosystems, strategy development for sustainable development of regions, particularly the Black Sea, and improving the socio-economic benefits of a network development of MAPs are the main objectives of these state nature-protective measures.

Therefore, ensuring ecological safety actions for the NWBS, and all the Black Sea basin is an actual natural protective task that will preserve the unique ecosystem and sustainable development of the coastal regions. Such actions are of particular importance, and they should be considered when developing a set of actions for environment protection, including coastal and MAPs on the shelf of the Black Sea that belong to Ukraine territorial waters as well as the other Black Sea states (Milchakova, 2008, 2011).

## 2. Description of sample sites, samples and methods

Monitoring of the radiochemoecological state of the Black Sea ecosystem was carried out after the ChNPP accident in the period between 1986 and 2011. Materials for investigation were taken during expeditions as a rule on scientific research vessels such as "Professor Vodyanitskiy" and "Academician Kovalevskiy", IBSS

Please cite this article in press as: Tereshchenko, N.N., et al. Contemporary radioecological state of the North-western Black Sea and the problems of environment conservation. Mar. Pollut. Bull. (2014), http://dx.doi.org/10.1016/j.marpolbul.2014.01.003