Artificial Radionuclides $^{137}$Cs and $^{90}$Sr in the Components of the Ecosystems of the Salt Lakes of the Crimea

Mirzoyeva Natalya*

FSBIS Institute of Marine Biological Research named A.O. Kovalevsky, Russian Academy of Sciences (FSBIS IMBR RAS), Sevastopol, the Crimea, 299011, Russia

Abstract:
In 2016, for the first time a radioecological study was made of 11 salt lakes of the Crimea to investigate the contamination of their ecosystems by $^{137}$Cs and $^{90}$Sr. There was a positive correlation between the salt content and the concentration of anthropogenic radionuclides $^{90}$Sr and $^{137}$Cs in the water of the studied groups of lakes. Absorbed doses of $^{137}$Cs and $^{90}$Sr radiation in aquatic plants in the lakes were 7.7∙10$^{-6}$ and 3.2∙10$^{-6}$ Gy/year, respectively, and lay within the “Uncertainty Zone” according to the scale “Zones of Chronic Exposure to Ionizing Radiation”, proposed by Polikarpov.

Keywords: Crimean salt lakes; Black sea; Chernobyl NPP accident; $^{90}$Sr; $^{137}$Cs; Absorbed doses

Received date: January 08, 2018
Accepted Date: February 12, 2018
Published Date: February 15, 2018

*Corresponding author: Natalya Mirzoyeva, FSBIS Institute of Marine Biological Research named A.O. Kovalevsky, Russian Academy of Sciences (FSBIS IMBR RAS), Sevastopol, the Crimea, 299011, Russia, E-mail: natmirz@mail.ru

Citation: Natalya, M. Artificial radionuclides $^{137}$Cs and $^{90}$Sr in the components of the ecosystems of the salt lakes of the Crimea. (2018) J Marine Biol Aquacult 3(1): 5-10.

Copyright: © 2018 Natalya, M. This is an Open access article distributed under the terms of Creative Commons Attribution 4.0 International License.

DOI: 10.15436/2381-0750.18.1774
The aim of this investigation was to conduct a comparative study of the salt lakes of the Crimea in regard to migration and redistribution of the post-accident $^{90}$Sr and $^{137}$Cs within the components of the studied aquatic ecosystems, and determination of the rate of the biogeochemical processes in the salt lakes of the Crimea using of $^{90}$Sr and $^{137}$Cs as radiotracers.

In accordance with the formulated purpose of investigations the following tasks were performed:

To determine the concentration and peculiarity of redistribution of the $^{90}$Sr and $^{137}$Cs in the components of aquatic ecosystems of the lakes;

To conduct a comparative analysis of the content of $^{90}$Sr and $^{137}$Cs in the water of the Black Sea ecosystems located in areas close to the location of the salt lakes and the content of these radionuclides in the lake water, and to identify possible sources of intake of $^{90}$Sr and $^{137}$Cs into the aquatic ecosystems;

To calculate the exposure dose received by various ecological groups of hydrobionts of the salt lakes of the Crimea from the ionizing radiation of $^{90}$Sr and $^{137}$Cs in the post-accident period.

Materials and Methods

Sample sites and samples characteristics

In 2016, for the first time in the history of the salt lakes of the Crimea, as well as for the entire period after the nuclear weapons test and the Chernobyl NPP accident, a radioecological study was conducted on the contamination of the ecosystems of 11 salt lakes by $^{137}$Cs and $^{90}$Sr. The following lakes were investigated: Krasnoye, Kiyatskoye, Kirleutskoye lakes from the Kerchenskaya group, Chokrakskoe, Chokrakskoe, Aktashskoe lakes from the Kerchenskaya group, Moinakskoe lakes from the Evpatoriyskaya group, and Tobe-chikskoe, Chokrakskoe, Aktashskoe lakes from the Kerchenskaya group [Table 1, Figure 1]. They have a marine origin (closed lagoons), are drainless, and can be temporally fully or partly dried [1, 18–20].

| Table 1: Coordinates and Characteristics of the Sampling Stations |
|--------------------------------------------------|
| Name of objects of study (material of research) | Sampling date | Sampling co-ordinates | Salinity,‰ | pH |
| Perekopskaya group | | | | |
| Lake Kiyatskoe (water, bottom sediments (0-5 cm)) | 14.06.2016 | 45°59.729′ N 33°53.310′ E | 200.0 | 7.7 |
| Lake Kiriukstoe (water, bottom sediments (0-5 cm), cysts of Artemia) | 14.06.2016 | 45°55.231′ N 34°02.681′ E | 235.0 | 7.9 |
| Lake Krasnoe (water, bottom sediments (0-5 cm)) | 14.06.2016 | 45°59.437′ N 33°57.319′ E | 330.0 | 9.3 |
| Tarkhankutskaya group | | | | |
| Lake Dzarlilgach (water, bottom sediments (0-5 cm), cysts of Artemia) | 18.05.2016 | 45°33.965′ N 32°54.599′ E | 115.0 | 8.5 |
| | 08.11.2016 | 45°33.968′ N 32°51.582′ E | 140.0 | 7.9 |

Figure 1: Map-scheme of the sampling stations in the Crimea region (2016)
We collected and analyzed 36 samples of water, 18 samples of bottom sediments, 6 samples of water plants (Cystoseira sp., Polyssiphonia subulifera (C. Agardh) Harvey, Stuckenia pectinata (L.) BÖRNER) and cysts of Artemia. Samples of sea water in the Black Sea areas located close to the salt lakes were collected to conduct a comparative analysis on the content of $^{90}\text{Sr}$ and $^{137}\text{Cs}$ with the concentrations of these radionuclides in the water of the salt lakes, and to identify possible sources of entry of $^{90}\text{Sr}$ and $^{137}\text{Cs}$ into the aquatic ecosystems.

$^{90}\text{Sr}$ radiochemical procedures

The method of $^{90}\text{Sr}$ determination was based on the following radiochemical procedure. After acid leaching and/or preconcentration of strontium with a carbonate (for water) or an oxalate (for hydrobionts and bottom sediments), purification from interfering elements is performed by hydroxide precipitation. After equilibrium between interfering elements is performed by hydroxide precipitation. After Cerenkov’s radiation in a low background liquid-scintillation counter (LSC) LKB “Quantulus 1220”. The Lower Limit of Detection (LLD) was 0.01-0.04 Bq/kg for hydrobionts and bottom sediments and the limit (in Bq/m$^3$) was similar for water samples. Recoveries are calculated from stable Sr recovery by flame photometry for $^{90}\text{Sr}$ and gravimetrically from ytrrium oxalate for $^{90}\text{Y}$.[21, 22] Each result is reported as the mean of the values activity of parallel duplicate samples, which were measured separately. Total relative error of the each result does not exceed 20 %.

The quality of the analytical methods and the reliability of the results were supported by the constant participation in international intercalibrations during 1990-2004 under the aegis of the IAEA (Vienna, Austria). Results of the IBSS participation in the intercalibration were included in the intercalibration report materials[23,24] and they were certified as reliable data.

Gamma-spectrometric measurements of $^{137}\text{Cs}$

The $^{137}\text{Cs}$ content was measured using a “1282-CompuGamma CS” gamma spectrometer (LKB Wallac, Finland) with a NaI (TI) scintillation detector, as well as the but semiconductor gamma detectors Canberra-Packard XiRa GX2019 and ORTEC GMX-10 (USA), made on the basis of crystals of ultrapure germanium, with a relative efficiency of 16-23 %. Analysis of the obtained gamma spectrum was carried out with the help of the Canberra-Packard MCA S100 analyzer, System 100[13].

Radiological dose calculation

The radiological dose (Gy/y) for the hydrobionts were calculated using individual coefficient DCF (dose-rate conversion factors) and the mean of $^{90}\text{Sr}$ concentrations for each group of hydrobionts, as well for water and bottom sediments from the habitat area of the hydrobionts.[25,28] Values of dose conversion factors for calculation of internal and external doses of $^{90}\text{Sr}$ for aquatic organisms were taken from the worksheets of the computer program of the RAD-BCG Calculator.[29] The dose estimates were compared with the dose limits for aquatic organisms from DOE Standard (2001) and with the scale of Zones of chronic dose rates and their effects in the biosphere proposed by Polikarpov (1998)[27].

Results and Discussion

$^{90}\text{Sr}$ and $^{137}\text{Cs}$ in the water of the aquatic ecosystems of the salt lakes of the Crimea

Among all the studied objects the greatest concentration of the artificial radionuclides $^{90}\text{Sr}$ and $^{137}\text{Cs}$ in water in 2016, as well as one of the highest levels of salt concentrations, was observed in the Sasik-Sivash Lake of the Evpatoriyskaya group, exceeding the concentrations of $^{90}\text{Sr}$ 3.7-38 times and of $^{137}\text{Cs}$ 2-120 times those found in the water of all other lakes [Table 2, Figure 2].

| Name of objects of study | Sampling date | Salinity, % | Concentration, Bq/m$^3$ |
|--------------------------|---------------|------------|------------------------|
|                          |               |            | $^{137}\text{Cs}$ | $^{90}\text{Sr}$ |
| Lake Krasnoe             | 14.06.2016    | 330        | 37.4 ± 0.2            | 54.7 ± 21.3        |
| Lake Kiyatskoe           | 14.06.2016    | 235        | 5.3 ± 0.3             | 60.1 ± 4.7         |
| Lake Kirleutskoe         | 14.06.2016    | 200        | 2.3 ± 0.1             | 18.7 ± 2.3         |
| Lake Dzarilgach          | 18.05.2016    | 115        | 22.2 ± 2.4            | 54.6 ± 4.1         |
| Lake Bakalskoe           | 27.06.2016    | 46.5        | 31.4 ± 2.7            | 40.0 ± 2.7         |
| Lake Kyzyly-Yar          | 18.05.2016    | 3.5        | 0.8 ± 0.04            | 9.3 ± 1.1          |
| Lake Sasik-Sivash        | 27.06.2016    | 280        | 95.9 ± 8.1            | 313.6 ± 25.0       |
| Lake Moinakskoe          | 18.05.2016    | 47         | 29.8 ± 1.4            | 8.3 ± 1.1          |
| Lake Tobechikskoe        | 07.06.2016    | 176        | 8.7 ± 0.4             | 28.9 ± 2.2         |
| Lake Chokrakske          | 08.06.2016    | 226        | 49.3 ± 3.1            | 46.0 ± 3.4         |
| Lake Aktashskoe          | 08.06.2016    | 88.5       | 11.5 ± 0.5            | 85.8 ± 3.9         |

In the first months after the Chernobyl NPP accident the maximum concentrations of $^{137}\text{Cs}$ and $^{90}\text{Sr}$ were 134.1 and 53.0 Bq/m$^3$, respectively[12,13]. To identify the sources of these artificial post-accident radionuclides entering the salt lakes of the Crimea, we assume that the same concentrations of $^{137}\text{Cs}$ and $^{90}\text{Sr}$ were present in the water of the investigated objects in the first months after the Chernobyl NPP accident [Figure 1]. Values exceeding these values of concentrations of $^{137}\text{Cs}$ and $^{90}\text{Sr}$, taking into account their decay by 2016, indicates a secondary source of entry of these pollutants into the studied reservoirs, primarily with the Dnieper water along the North-Crimian canal[26-28].

We believe that the lower values of the $^{137}\text{Cs}$ and $^{90}\text{Sr}$ concentrations in the water of the salt lakes of the Crimea compared to the maximum concentration of these radionuclides that fell with atmospheric transport on the territory of the Crimea after the Chernobyl NPP accident and corrected for decay by 2016 can be explained either by the absence of secondary sources of post-accident radionuclides, or their redistribution by components of the ecosystems of these reservoirs.
In 2016 the concentration of $^{90}$Sr in the water of practically all salt lakes studied, except for the Moinakskoe and Chokrakskoe lakes, was 1.3-12.3 times higher than that for $^{137}$Cs [Table 2, Figure 2]. At the same time, the initial entry of $^{137}$Cs was 2.5 times higher than the initial entry of $^{90}$Sr on the water area of Crimea’s water bodies [13]. These differences can first of all be explained by the secondary entry of dissolved forms of $^{90}$Sr with the waters of the Dnieper through the NCC into the salt lakes of the Crimea, and by the peculiarities of the $^{90}$Sr and $^{137}$Cs redistribution between the components of the ecosystems of these water objects.

The content of $^{137}$Cs and $^{90}$Sr in the water of all studied lakes, whose salinity was higher than that of the Black Sea, exceeded by 2.3-34.5 times the concentration of these radionuclides in the waters of the adjacent areas of the Black Sea [Table 2, Figure 2]. It is known that alkali metal chlorides and other salts sharply increase the solubility of strontium salts by 25 times [31]. $^{137}$Cs also has a very high solubility in salt water [31,32]. A positive correlation between the increase of salinity and the retention of radionuclides $^{137}$Cs and $^{90}$Sr in the water column of the salt lakes was observed [Figure 3].

Thus, the level of the content of the artificial radionuclides $^{137}$Cs and $^{90}$Sr in the salt lake ecosystems was primarily determined by the sources of their entry into the water bodies. Subsequently, the redistribution of these radionuclides depended on the levels of salinity of the water in the lakes [Table 2, Figure 3] and their hydrochemical and hydrological properties.

It may be noted that in 2016 the concentration of $^{90}$Sr and $^{137}$Cs in the water of all the investigated salt lakes of the Crimea and the control sampling stations did not exceed the maximum permissible concentration for $^{90}$Sr in drinking water (RSS–99/2009).

$^{90}$Sr and $^{137}$Cs in the bottom sediments and water plants of the aquatic ecosystems of the salt lakes of the Crimea

According to the results of our investigations, which were obtained in 2016, no direct correlation was found between the salinity of water and the $^{90}$Sr and $^{137}$Cs concentrations in the bottom sediments of the salt lakes. The lowest concentrations of $^{90}$Sr and $^{137}$Cs were observed in the bottom sediments of Lake Sasik-Sivash, the highest concentrations were in Lake Kyzyl-Yar. So the concentrations of both $^{90}$Sr and $^{137}$Cs in the bottom sediments showed the opposite trend of the concentrations of these radionuclides in the water of these lakes [Table 2, Table 3 and Figure 4].

The concentration of $^{90}$Sr in the bottom sediments of 6 out of 10 lakes was lower than that for the bottom sediments of the Black Sea. The $^{137}$Cs content in the bottom sediments of all investigated reservoirs was 1.6-32 times lower than the values for marine bottom sediments [Figure 4]. This indicates lower rates of biogeochemical processes in the salt lakes in comparison with the Black Sea. The flow of the radioactive contaminants from the water column to the bottom sediments of the lakes is slowed down. The high salinity of the lakes, exceeding that of the Black Sea water, contributed to keeping the dissolved forms of $^{137}$Cs and $^{90}$Sr in the aquatic environment, and it reduced the deposition of post-accident radionuclides into the bottom sediments of the studied reservoirs [Figure 4].

Table 3: Concentrations $^{137}$Cs and $^{90}$Sr in the bottom sediments of the salt lakes of the Crimea

| Name of objects of study | Sampling date | Salinity, ‰ | Concentrations, Bq•kg$^{-1}$ DW |
|--------------------------|---------------|-------------|---------------------------------|
|                          |               |             | $^{137}$Cs | $^{90}$Sr                  |
| Perekopskaya group       |               |             |           |                               |
| Lake Krasnoe             | 14.06.2016    | 330         | below detection level            | 2.2 ± 0.3                      |
| Lake Kiyatskoe           | 14.06.2016    | 235         | below detection level            | 3.3 ± 0.4                      |
| Lake Kirleutskoe         | 14.06.2016    | 200         | below detection level            | 2.6 ± 0.5                      |
| Tarkhankutskaya group    |               |             |                               |                               |
| Lake Dzurilgach          | 18.05.2016    | 115         | 6.2 ± 1.2                      | 22.7 ± 1.3                     |
| Lake Bakalskoe           | 27.06.2016    | 46.5        | 5.8 ± 1.4                      | 0.7 ± 0.2                      |
| Yevpatoriyskaya group    |               |             |                               |                               |
| Lake Kyzyl-Yar           | 18.05.2016    | 3.5         | 24.4±6.7                       | 15.0 ± 2.1                     |
| Lake Sasik-Sivash        | 27.06.2016    | 280         | 4.1 ± 2.5                      | 2.0 ± 0.2                      |
| Kerchenskaya group       |               |             |                               |                               |
| Lake Tobecheikskoe       | 07.06.2016    | 176         | 16.5 ± 1.6                     | 5.0 ± 0.8                      |
| Lake Chokrakskoe         | 08.06.2016    | 226         | 13.5 ± 1.3                     | 5.1 ± 0.5                      |
| Lake Aktashskoe          | 08.06.2016    | 88.5        | 5.3 ± 0.9                      | 2.6 ± 0.4                      |

Figure 3: Concentrations of $^{137}$Cs and $^{90}$Sr depending on salinity of water of the salt lakes of the Crimea (sampling 2016)
The concentrations of the 90Sr and 137Cs in aquatic plants, as well as in the bottom sediments of the lakes were insignificant [Figures 4, 5].

The cysts of Artemia which were collected in lakes Kirleutskoye, Dzarilgach and Aktashskoye in 2016 were relatively radioresistant to such long-lived post-accident radionuclides as 137Cs and 90Sr.

The absorbed doses from ionizing radiation of 137Cs and 90Sr on the water plants Stuckenia pectinata (Lake Kyzyl-Yar) and Polisiphonia subulifera (Lake Bakalskoe) amounted to 7.7·10^{-4} Gy per year and 3.2·10^{-4} Gy per year, respectively. They were within the “Uncertainty Zone” according to the scale “Chronic Exposure to Ionizing Irradiation”, proposed by Polikarpov (1998), i.e., they did not have a noticeable effect on aquatic plants in the period after the Chernobyl NPP accident.

Conclusions

The main sources of the artificial radionuclides 137Cs and 90Sr after the Chernobyl NPP accident have been identified in the salt lakes of the Crimea. The primary entry of radionuclides to waters of the lakes occurred as a result of the atmospheric transport from the site of the Chernobyl NPP accident to a remote region such as the Crimea by May 1986. Subsequently (until 2014), dissolved radionuclides entered with the Dnieper waters through the North-Crimean canal. In 2016, the concentration of 90Sr in the water in virtually all the lakes was 1.3-12.3 times higher than that for 137Cs. At the same time, the initial entry of 137Cs was 2.5 times higher than the initial entry of 90Sr. The secondary entry of 90Sr into the ecosystems of the salt with the waters of the NCC and the Black Sea is more significant than its atmospheric transport after the Chernobyl NPP accident. For 137Cs this way of entering into the salt lakes is less important than for 90Sr. The content of the artificial radionuclides 137Cs and 90Sr in the salt lake ecosystems was primarily determined by the sources of their entry into water bodies. Subsequently, the redistribution of these radionuclides depended on the levels of salinity of the lakes and their hydrochemical and hydrological properties.

A positive correlation between the increase of salinity and the retention of the radionuclides in the water column of the salt lakes was observed. Their salinity, exceeding that of the Black Sea, contributed to the stability of the dissolved forms of 137Cs and 90Sr in the aquatic environment and reduced their deposition into the bottom sediments of the studied reservoirs. In 2016, the highest concentrations of 137Cs and 90Sr in the water column and the lowest content of these radionuclides in bottom sediments were observed in Lake Sasik-Sivash (water salinity 280 g/L).

The investigated lakes are drain less, so that radioactive material that had entered these aquatic ecosystems accumulate over time and redistribute between the components of these water objects.

In 2016 the concentration of 90Sr and 137Cs in the water of all the investigated lakes and the control sampling stations did not exceed the maximum permissible concentration for 90Sr in drinking water[33].

The cysts of Artemia which were collected in lakes Kirleutskoye, Dzarilgach and Aktashskoye in 2016 are relatively radioresistant to such long-lived post-accident radionuclides as 137Cs and 90Sr.

The absorbed doses from ionizing radiation of 137Cs and 90Sr on the water plants Potamogeton pectinatus (Lake Kyzyl-Yar) and Polisiphonia subulifera (Lake Bakalskoe) did not have a noticeable radiation effect on these hydrobionts in the period after the Chernobyl NPP accident.

Acknowledgements: This work has been carried out within the framework of the State task on theme № 1001-2014-0013 for the period 2015-2017 and of the Russian Foundation of basic research grant No. 16-05-00134.

References

1. Ponizovskiy, A.M., Salt resources of the Crimea. (1965) Simferopol: Crimea, 166.
2. Anufriieva, E., Holyska, M., Shadrin, N. Current invasions of Asian Cyclopoid species (Copeoda: Cyclopidae) in Crimea, with taxonomical and zoogeographical remarks on the hypersaline and freshwater fauna. (2014) Annales Zoologici, 64(1): 109-130.
3. Shadrin, N.V. Hypersaline lakes as polyextreme habitats for life. In: Zheng M, Deng T, Oren A. (eds.) Introduction to salt lake sciences. (2017) Beijing: Science Press 173-178.
Citation: Natalya, M. Artificial radionuclides 137Cs and 90Sr in the components of the ecosystems of the salt lakes of the Crimea. (2018) J Marine Biol Aquacult 3(1): 5-10.