ASSESSMENT OF THE BLACK SEA RESPONSE TIME-SCALE TO POLLUTION WITH ^{90}SR AND ^{137}CS FOLLOWING THE CHERNOBYL NPP ACCIDENT

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Abstract

This assessment summarises studies of ^{90}Sr and ^{137}Cs pollution of the Black Sea Basin carried out during the period 1986-1998 following the accident at the Chernobyl NPP. Its goal is to assess the temporal evolution of ^{90}Sr and ^{137}Cs mass balance and inventories in some typical Black Sea ecosystems. It was found that the time scale of the Black Sea ecosystem response to the Chernobyl-derived pollution ranged between 21-73 years for ^{90}Sr and 11-77 years for ^{137}Cs.

Keywords: Black Sea, pollution, ^{90}Sr, ^{137}Cs, hydrobionts.

During the first weeks after the Chernobyl NPP accident, the ^{90}Sr concentration in Black Sea waters increased by 7-20%, and ^{137}Cs activity doubled due to atmospheric fallout [1]. Afterwards, the Black Sea was subjected to radioactive contamination mainly through river discharge. The present paper deals with an assessment and large-scale prognosis of pollution of Black Sea waters, biota and sediments with ^{90}Sr and ^{137}Cs, using results of measurements and subsequent modelling [1-5]. The purpose was to estimate inventories and the time scale of Black Sea ecosystem response to radioactive contamination, and to assess time periods during of which the concentrations of ^{90}Sr and ^{137}Cs in water, marine biota and the upper sediments may decrease to the pre-accidental levels.

Methods and materials

The study was carried out in 1986-2000 on oceanographic vessels and in the framework of radioecological monitoring of Sevastopol Bay with support of the EU programs EROS-2000 and EROS-21, IAEA projects NR 7400 RB and RER/2/003, and in collaboration with WHOI and EPA (USA). Intercomparison of the measurements was fulfilled jointly with WHOI, EPA (USA), Riso National Laboratory (Denmark) and IAEA.

Results and discussion

The study has shown that shortly after radioactive contamination of sea surface with atmospheric fallout, a relatively rapid decrease in ^{90}Sr and ^{137}Cs concentrations in the ecosystem compartments was observed during the first year (Fig. 1). In sediments adjacent to the Danube Delta, the ^{137}Cs concentration increased up to 1991. During the following years a decrease in radioactive contamination of waters, biota and sediments was found, and the trends may be successfully approximated by exponential equations. This allows calculating parameters A and p of the exponents:

$q = A\,exp\,(-p\,t)$ (1) where q is inflow or outflow fluxes of radionuclide (TBq), or radionuclide concentration in the ecosystem compartment (Bq m^{-3} or

Fig. 1.Temporal variations in radionuclide concentrations in the Black Sea
a and b – annual average ^{90}Sr and ^{137}Cs fluxes with the Dnieper and Danube river run-off; c – ^{90}Sr (_) and ^{137}Cs (+) outflow through the Bosporus Strait; d – change of ^{90}Sr concentration in front of the Dnieper-Bug estuary; e – dynamics of ^{90}Sr (_) and ^{137}Cs (+) concentrations in the western mid-gyre; f and g – change of 90Sr and 137Cs concentrations in Sevastopol Bays; h – ^{90}Sr concentration in algae Cystoseira crinita; i – ^{90}Sr concentration in mussel Mytilis galloprovincialis (_) and fish Odontogatus merlangus (_); j – ^{137}Cs concentration (W.W.) in mussel Mytilis galloprovincialis (+) and in the upper sediments (D.W.) adjacent to the Danube Delta (_).

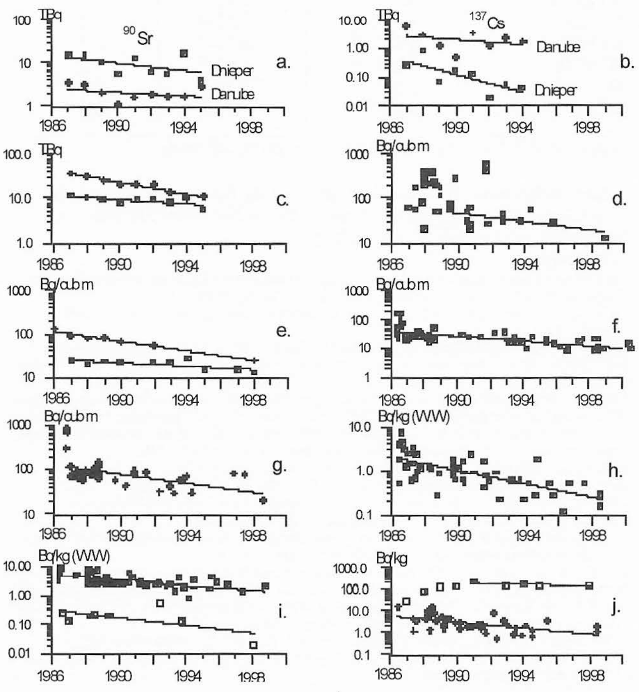

Table 1. Mass balance components and prognostic estimations for 90Sr and 137Cs in the Black Sea Basin. *Note: * - Estimations for the period 1986-1995*

Components of balance	90Sr (TBq) Input/Outpu Assessments	Prognosis of consequent input/Output	Total	137Cs (TBq) Input/output Assessments	Prognosis of consequent input/output	Total
Inventory in the whole volume before 26.04.86	---	---	≈ 1500	---	---	1400 ± 300
Atmospheric fallout in 05.86	100-300	---		1700-2400	---	
Inflow from the Dnieper River	90.2*	57.8	148.0	2.0*	0.1	2.1
Inflow from the Danube River	24.5*	32.8	57.3	24.0*	13.6	37.6
Outflow through Bosporus Strait	94.0*	130.2	224.2	225.0*	64.7	289.7

Table 2. Half – lives (T0.5) and complete response times (T) for mass balance components in some ecosystems of the Black Sea Basin to the pollution with 90Sr and 137Cs after the Chernobyl NPP accident (years) *Including period before an exponential decreasing.*

Components	^{90}Sr T0.5	^{90}Sr T	^{137}Cs T0.5	^{137}Cs T
Inflow from the Dnieper River (since 1987)	7.0	36.0	2.0	11.0
Inflow from the Danube River (since 1987)	14.4	73.0	6.9	35.5
Outflow through the Bosporus Strait (since 1987)	13.1	66.5	4.4	23.0
Surface waters near the Dnieper estuary (since 1989)	9.6	52.0	---	---
Surface waters of the Central Western Black Sea (since 1986)	15.6	78	5.4	27.0
Danube Delta marine bottom sediments (since 1991)	---	---	14.4	77.0
Region of the Sevastopol Bay:				
Surface waters (since 1987)	6.9	35.5	5.9	30.5
Brown seaweed Cystoseira crinita (since 1987)	4.0	21.0	4.4	23.0
Mollusc Mytilis galloprovincialis (since 1986)	6.7	33.5	4.3	21.5
Fish Odontogatus merlangus (since 1986)	4.7	23.5	---	---

Bq kg^{-1}) at time t (year); A and p are parameters. The time periods of decrease to half of the original levels (half-lives) were calculated as $T_{05} = 0.693/p$, and the time for decrease of ^{90}Sr and ^{137}Cs concentration in water, biota and sediments to the pre-accidental levels were determined with 95% probability as $T = 5\,T_{05}$. The predicted integral components of the Black Sea radioactive balance were calculated from equation:

$$Q = A \int_0^T exp\,(-p\,t)\,dt \quad (2)$$

where Q is the predicted flux (TBq). The results of calculations using equations (1) and (2) are shown in Tables 1 and 2. They suggest that the time scale of the Black Sea ecosystem response to the Chernobyl-derived pollution ranges between 21-73 years for ^{90}Sr and 11-77 years for ^{137}Cs.

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