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Monitoring of Radionuclide Concentrations in Marine Algae from the Turkish Black Sea Coast and Bosphorus During the Period of 1984-2001

1984-2001 Yılları Arasında, Karadeniz Türkiye Sahilleri ve İstanbul Boğazı Deniz Alglerinde Radyoaktivite Konsantrasyonları

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Abstract

The anthropogenic radionuclide concentrations were reviewed in macroalgae species were collected from Black Sea and Bosphorus stations in 1984 to 2001. The results showed that the Sinop region was more contaminated than the Şile region on the Black Sea coast of Turkey from the Chernobyl accident. The highest concentration of ^{137}Cs radionuclide was found after Chernobil accident in *C. linum* as 34 Bq kg^{-1} (dry weight) during July 1986. The concentrations of the ^{137}Cs activity in 1987 and 1988 samples were gradually decreased. However, the ^{137}Cs activity detected as 11 Bq kg^{-1} (dry weight) in 1992. On the other hand, ^{137}Cs levels in tested algae samples were found as below limit of detection after 1994. The natural radionuclide concentration of ^{210}Po, ^{210}Pb and ^{40}K in macroalgae samples are within the range of cited values in the literature.

Keywords: Radionuclide, macroalgae, Black Sea, Bosphorus

Introduction

Development of nuclear technology has increased the probability of anthropogenic radioactive pollution in marine environment. There are many Nuclear Power Plants in the countries around the Black Sea and most of them obtain their cooling water from the rivers which are connected to the Black Sea. At the same time, it is well known that, some anthropogenic radionuclides entered into the Black Sea after Chernobyl accident. Moreover, nuclear weapon tests have also spread artificial radionuclides to the Turkish marine environment during the global fallout contribution. Nowadays, the artificial radionuclides in the Black Sea and Bosphorus regions are originated from river inborn radionuclides from the Chernobyl accident site or contaminated regions and inputs from the nuclear power plants in countries around the Black Sea (Topcuoğlu, 2000).

In the present day, the study of natural radionuclides in marine environment has received increasing attention due to enchanced levels of some natural radionuclides from use of fertilizers, fossil fuel industry, detergent or phosphate industry and use of pesticides.

This review highlights the selected macroalgae studies of the Black Sea and Bosphorus related to radioactive pollution during the period of 1984-2001.

The sampling stations of the macroalgae are given in Fig 1.

Eleven species macroalgae (green algae) were examined: *Chaetomorpha linum, Ulva lactuca, Ulva rigida, Enteromorpha linza;* (brown algae) *Cystoseira barbata*; *Corallina rubens, Corallina granifera,* (red algae) *Phyllophora nervosa, Ceramium rubrum, Gelidium latifolium, Gelidium. sp.*

Güven *et al*., (1990) were determined radionuclides of ^{106}Ru, ^{134}Cs, ^{137}Cs and ^{40}K in the macroalgae samples collected from Şile and Sinop regions before and after Chernobyl accident (Table 1). As it can be seen in the table no radionuclides were detected in the tested algae species collected before Chernobyl accident, except ^{137}Cs in *Corallina. rubens* and *Phyllophora nervosa.* On the other hand, the Chernobyl radionuclides reached peak values in all the samples collected soon after the accident in 1986. The highest accumulation of ^{137}Cs radionuclide was found in *Chaetomorpha linum* at the Sinop region. At the same time, the results showed that the Sinop region was more influenced by Chernobyl accident than Şile region. In that study, the activity levels of ^{137}Cs radionuclide in 1987 and 1988 samples were found at diminishing rates.

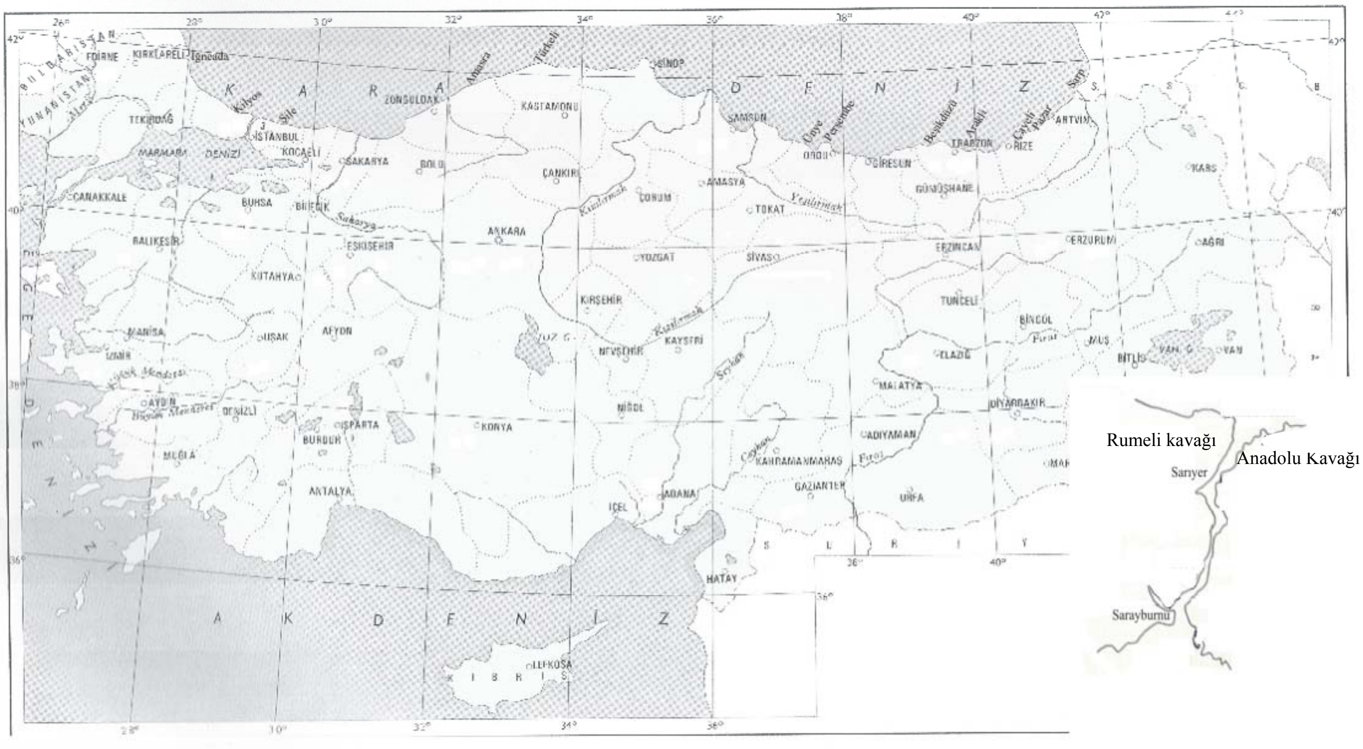

Figure 1. Sampling stations

The ^{137}Cs radionuclide concentrations in the macroalgae samples at the Black Sea stations were determied after collection in 1989 (Güven *et al*., 1993). The results are given in Table 2. The highest contamination of ^{137}Cs radionuclide appeared at İğneada, Beşikdüzü, Çayeli and Şile stations. The highest activity was found in *Cystoseria barbata* species among the tested algae in 1989.

In another study, ^{137}Cs radionuclide concentrations reported in macroalgae samples after collectio from different stations of the Bosphorus in 1989 and 1990 (Topcuoğlu and Güngör, 1999). The levels of activities are given in Table 2. The highest accumulation of the ^{137}Cs was showed in *Enteromorpha linza* species. The macroalgae species collected in the Bosphorus can be ranked as *E. linza* >*U. lactuca* > *C. barbata* according to their ^{137}Cs content.

The ^{137}Cs activity concentrations in macroalgae samples were determined in Şile and Sinop stations during the period of 1990 and 1995 (Topcuoğlu *et al*., 1996). In that study, the natural depuration rates of ^{137}Cs radionuclide was also investigated for each algae division. The activity concentrations in the macroalgae samples are given in Table 3. The ^{137}Cs activity levels in Sinop algae are higher than those found in algae collected from Şile. The highest ^{137}Cs activity detected to be 11 Bq kg^{-1} (dry weight) in *P.nervosa* species after collected from Sinop in 1992. The natural depuration rates estimated as biological half-lives. The biological half-lives of ^{137}Cs in red, green and brown samples are calculated as 18.5, 21.6 and 29.3 months, respectively.

Concentrations of ^{137}Cs in algae samples at the eight stations of the Black Sea were also investigated in 1997 and 1998 (Topcuoğlu *et al*., 2001). The ^{137}Cs concentrations in tested algae samples were found to be below the lower limit of detection (<3 Bq kg^{-1}) except *C.barbata* at the Şile station (Table 4). The similar results are also found in *C. barbata* and *U. lactuca* collected from Pazar and Rize stations in 1998 and 2001, respectively (Topcuoğlu *et al*., 2003). At the same time, the ^{137}Cs level determined to be below the lower limit detection in *C. barbata* after collected from Ünye in 2001 (Topcuoğlu *et al*., 2004). The results are given in Table 4.

The ^{210}Po activity levels in brown algal are higher than those found in green algae species collected from Amasra, Sinop, İğneada and Kilyos (Güngör *et al*., 2001). In tested algae species, the high concentration of ^{210}Po detected at Amasra station (Table 5). The ^{210}Po concentrations in algae samples ranged between 8.0 and 54.7 Bq kg^{-1}. The highest concentration of ^{210}Pb was found in brown algae at İğneada samples. The ^{210}Pb levels ranged between 0.5 - 17.5 Bq kg^{-1}.

Table 1. Radioactivity concentrations in macroalgae samples from 1984 to 1988 (Bg kg^{-1} dry weight) (Güven *et al.*, 1990)

Species	Collection Date	Station	^{134}Cs	^{137}Cs	^{106}Ru	^{40}K
C.barbara	05.1985	Şile	nd	nd	nd	908±203
C.rubens	10.1984	Şile	nd	<5	nd	249±58
P.nervosa	09.1985	Şile	nd	<5	nd	399±85
P.nervosa	01.1986	Şile	nd	nd	nd	308±141
C.linum	07.1986	Sinop	15±5	34±7	<1	968±201
U.lactuca	07.1986	Sinop	6±3	21±5	<1	418±91
C.barbata	07.1886	Sinop	<5	24±8	nd	682±109
P.nervosa	10.1986	Şile	<5	19±8	nd	493±177
C.linum	10.1987	Sinop	<5	27±8	nd	806±108
U.lactuca	07.1987	Sinop	6±4	18±5	nd	532±94
C.barbata	09.1987	Şile	<5	13±7	nd	826±402
C.barbata	07.1987	Sinop	<5	11±3	nd	938±134
P.nervosa	09.1987	Şile	<5	10±3	nd	423±191
C.rubens	07.1987	Sinop	<5	12±3	<1	145±39
C.linum	07.1988	Sinop	<5	13±5	<1	893±281
U.lactuca	09.1988	Şile	nd	nd	nd	409±103
U.lactuca	07.1988	Sinop	<5	7±4	nd	472±106
C.barbata	09.1988	Şile	nd	14±6	nd	774±172
C.rubens	07.1988	Sinop	nd	12±1	nd	269±128
P.nervosa	09.1988	Şile	<5	12±1	<1	351±33

Table 2. Radioactivity concentrations in macroalgae samples from 1989 to 1990 (Bq kg^{-1} dry weight)
(1) Güven *et al.*, 1992; (2)Topcuoğlu and Güngör 1999

Species	Collection date	Station	^{137}Cs	^{40}K
C.linum	06.1989	Şile	10±6	1476±216 (1)
C.linum	06.1989	Sinop	11±5	896±135 (1)
U.rigida	06.1989	Şile	11±6	878±458 (1)
U.rigida	07.1989	Amasra	6±3	541±228 (1)
U.rigida	07.1989	Araklı	7±4	537±230 (1)
C.barbata	06.1989	İğneada	15±9	901±175 (1)
C.barbata	07.1989	Türkeli	8±5	309±120 (1)
C.barbata	07.1989	Beşikdüzü	15±9	340±203 (1)
C.barbata	07.1989	Çayeli	15±7	430±126 (1)
C.barbata	07.1989	Sarp	7±3	1579±1379(1)
C.rubrum	06.1989	İğneada	7±5	798±145 (1)
C.rubrum	06.1989	Şile	6±4	817±209 (1)
C.rubrum	06.1989	Sinop	12±7	906±301 (1)
P.nervosa	.06.1989	Şile	9±5	597±149 (1)
E.linza	06.1989	Sarıyer	8.3±3.5	570±338 (2)
E.linza	09.1989	Sarıyer	9.1±2.6	- (2)
U.lactuca	06.1989	Sarıyer	<2	404±144 (2)
E.linza	06.1989	Sarayburnu	6.4±1.2	- (2)
E.linza	06.1989	Sarayburnu	7.4±6.5	743±165 (2)
E.linza	02.1990	R.Kavağı	6.2±4.1	878±35 (2)
E.linza	02.1990	A.Kavağı	<2	780±390 (2)
E.linza	02.1990	Sarayburnu	4±4	539±84 (2)

Table 3. Radioactivity concentrations in macroalgae samples from 1991 to 1995 (Bq kg^{-1} dry weight) (Topcuoğlu *et al.*,1996)

Species	Collection date	Station	^{137}Cs	^{40}K
E.linza	08.1990	Şile	3±1	650±161
U.lactuca	08.1990	Şile	<0.5	507±196
C.granifera	08.1990	Şile	<0.5	786±49
C.barbata	12.1991	Şile	3±2	278±19
P.nervosa	12.1991	Şile	1.2±0.3	372±17
P.nervosa	12.1992	Sinop	11.1±4.7	218±80
C.barbata	12.1992	Sinop	2±1	1145±437
C.barbata	12.1992	Şile	<0.5	1925±88
P.nervosa	12.1992	Şile	1±0.3	169±25
G.latifolium	12.1992	Şile	2.5±1.0	328±44
U.lactuca	10.1993	Sinop	5±3	146±12
C.barbata	10.1993	Sinop	7±3	185±21
C.granifera	10.1993	Sinop	6±3	221±11
Gelidium sp.	10.1993	Sinop	7±4	332±15
Gelidium sp.	10.1993	Şile	<0.5	385±22
C.barbata	10.1993	Şile	2.5±1.0	506±52
C.linum	10.1993	Şile	2.6±1.1	685±35
C.barbata	02.1994	Şile	1.3±0.8	509±32
P.nervosa	02.1994	Şile	0.5±0.3	356±26
E.linza	02.1994	Şile	<0.5	220±19
C.barbata	06.1995	Şile	1.4±1.0	752±12
P.nervosa	06.1995	Şile	~0.4	306±12
U.lactuca	06.1995	Şile	<0.5	375±16

Table 4. Radioactivity concentrations in macroalgae samples from 1997 to 2001 (Bq kg^{-1} dry weight) (Topcuoğlu *et al.,* 2001)

Species	Collection date	Station	^{137}Cs	^{40}K
C.barbata	11.1997	Amasra	<3	328±39
U.lactuca	11.1997	Amasra	<3	312±17
C.barbata	11.1997	Sinop	<3	806±230
U.lactuca	11.1997	Sinop	<3	145±37
C.barbata	11.1997	Perşembe	<3	425±78
C.barbata	02.1998	İğneada	<3	869±125
U.lactuca	02.1998	İğneada	<3	428±94
C.barbata	03.1998	Kilyos	<3	646±120
U.lactuca	03.1998	Kilyos	<3	385±61
C.barbata	10.1998	Şile	5.9±2.8	521±81
C.barbata	06.1998	Rize	<3	1122±115
C.barbata	10.1998	Pazar	<3	1180±132
U.lactuca	10.1998	Pazar	<3	<170
C.barbata	06.2001	Rize	<3	1269±116
U.lactuca	02.2001	Rize	<3	<170
C.barbata	11.2001	Ünye	<3	543±297

Table 5. ^{210}Pb and ^{210}Pb concentrations (Bq kg^{-1} dry weight) in macroalgae samples (Güngör *et al.,* 2001)

Species	Collection date	Station	^{210}Po	^{210}Pb
C.barbata	11.1997	Amasra	54.7±2.6	11.6±08
U.lactuca	11.1997	Amasra	42.3±1.6	11.3±0.6
C.barbata	11.1997	Sinop	29.4±1.0	0.5±0.3
U.lactuca	11.1997	Sinop	15.3±0.6	0.9±0.6
C.barbata	11.1997	Perşembe	8.3±0.4	2.5±0.1
C.barbata	02.1998	İğneada	13.4±0.6	17.5±1.2
U.lactuca	02.1998	İğneada	12.1±0.9	3.6±0.4
C.barbata	03.1998	Kilyos	25.3±1.5	5.2±0.5
E.linza	03.1998	Kilyos	8.0±0.7	5.9±0.6

Conclusion

Following the Chernobyl accident, the Chernobyl radionuclides in the Black Sea and Bosphorus fish samples were determined weekly and monthly for three years. High levels of total gamma activity (iodine-131, ruthenium-106, cesium-134 and cesium-137) in fish samples were found in the range of 37 to 65 Bq kg^{-1} wet weight during May 1986. The total radioactivity levels in the fish samples gradually decreased during the first three months after May 1986. The Chernobyl radionuclides were also investigated in mussel and sea snail samples beside the macroalgae species. The results showed that the Chernobyl radionuclides levels in fish, mussel and sea snail samples were not higher than the macroalgae samples especially one year after accident. At the same time, the preliminary results showed that the maximum concentrations of the natural radionuclide (^{238}U and ^{232}Th) in macroalgae are significantly higher than mussel, sea snail, fish and sediment samples in the Black Sea marine environment (Topcuoğlu, 2000).

The use of macroalgae could conveniently be taken for biomonitoring of long-term trends in radioactive contamination of coastal marine environment. The presented data could be useful for comparing these stations in the Black Sea and Bosphorus with future data of radioactive pollution.

Özet

1984-2001 yılları arasında Karadeniz ve Boğaziçi'nin çeşitli istasyonlarından toplanan makroalg örneklerindeki yapay radyonüklid bulguları bu derleme özetlenmiştir. Sonuçlar göstermiştir ki, Çernobil kazası nedeniyle Sinop bölgesi Şile'ye göre daha fazla radyonuklidle kontamine olmuştur. En yüksek ^{137}Cs konsantrasyonu 34 Bq kg^{-1} olarak Temmuz 1986'da *C.linum*'da bulunmuştur. Bu radyonüklid 1987 ve 1988 yıllarında giderek azalmıştır. Bununla beraber, ^{137}Cs radyonüklidi 1992 yılında 11 Bq kg^{-1} olarak dedekte edilmiştir. Buna karşılık, 1994'den sonra ^{137}Cs düzeyi test edilen makroalg türlerinde dedeksiyon limiti altında bulunmuştur. Doğal radyonüklidlerden ^{210}Po, ^{210}Pb ve ^{40}K konsantrasyonları literatürde verilen değerler ölçüsünde tesbit edilmiştir.

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