THE LEVEL OF ^{137}Cs CONCENTRATION IN GREEK SOILS ONE DECADE AFTER THE CHERNOBYL ACCIDENT

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During nuclear accidents fission products are released in the atmosphere [1], [2]. These radioactive substances are transferred by the air in the form of radioactive cloud imposed on the ground or aspirated by the human and the animals and inevitably enter, in the biological circle.

The main characteristics, which determine how dangerous are the radio-nuclides, are their physical and biological half-life and the kind and the energy of their radiation emitted by them. From the long-living radionuclides, cesium (^{134} Cs and ^{137} Cs) and strontium (^{89}Sr and ^{90}Sr) isotopes burden the environment for greater time period. The absorbance of radioactive substances by the plants, by the man and animals can be direct and indirect. In the direct absorbance the plant but, also, man and animals are directly incorporating the radioactive substances. This way of incorporation plays an important role in the first days after the accident. The second way of incorporation - the indirect - presupposes the absorbance of radionuclides through the way ground - roots - plant - animal - man. The indirect way of contamination is the most important and influences the food for greater period of time.

One of the most serious consequences of the Chernobyl accident was the greatest radioactive contamination of the biosphere including the soil cover. It is well known that a soil analysis is a principal systematic method to estimate the radioactivity level in the particular area since deposition pattern is determined by measuring activity in grass and soil [3].

The aim of the present work is firstly to identify the level of the existing ^{137} Cs contamination over Greece ten years after the Chernobyl accident. Secondly, a comparison between the 1986 ^{137} Cs - distribution and the present measured one in more - less the same areas of Greece, has been attempted. The ^{40}K (0.0118% of natural K) concentration in soils as ratio ^{137} Cs/ ^{40}K has been, examined, even this ratio is not as constant in biological systems as the ratio Sr/Ca [4].

During the period of January 1993 - May 1995, 380 soil samples of surface soil (0-5 cm) were collected over Greece (Fig. 1). It was tried the soil samples to be taken from apparently undisturbed sites in open areas at the ground surface. Deeper soil samples (5-50 cm) were collected as well, but no didactable amount of ^{137}Cs has been recorded, as it was expected since the mobility for Cs is very low, 0.2 y^{-1} [5]. The sampling of surface soil, of about 500 cm^3 each, were taken from geographic divisions of Greece with emphasis to those where in 1986 serious depositions of ^{137}Cs (from 15 kBq/m^2 and more) were observed [6]. The ^{137}Cs concentration, near the soil surface is strongly time dependent , because of its variable deposition rates over many years and its gradual depletion by decay, erosion and leaching [7]. The uptake of ^{137}Cs from soil has been show to be inversely proportional to the K content of soils [4] that was also the case in the present work.

The ^{137}Cs average deposition in Greece was ranged in 1986 between, 0.01 to 137 kBq/m^2 [8]. Similar measurements of ^{137} Cs concentration in England for the period of 1990-1991, shows, a range of 0.7-0.8 kBq/m^2 [9], in Denmark the total

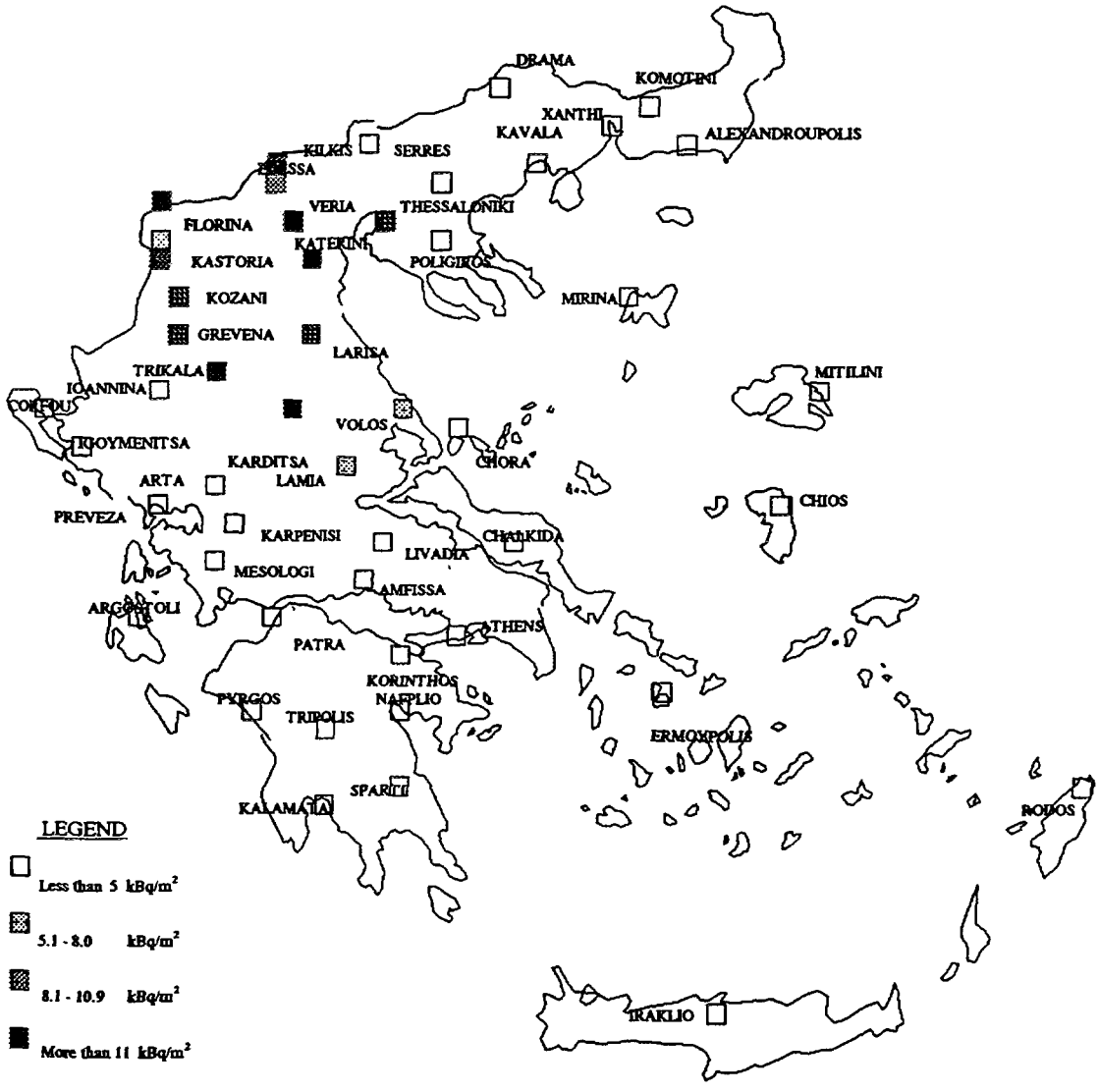

Figure 1: Total ^{137}Cs deposition on Greece (1995) following the Cernobyl accident

deposition of ^{137}Cs ranged from 0.66 to 3.6 kBq/m^2 [10] while the ^{137} Cs deposition in Italian soils had a mean value of 30 $\pm$17 kBq/m^2 immediately after the Chernobyl accident [5]. The present work estimates the ^{137}Cs accumulation in the Greek soils ten years after the Chernobyl accident, to be ranged between 0.4-14.4 kBq/m^2 (Fig. 2). The ^{40}K activity is between 5.1 and 16.5 kBq/m^2 (Fig. 3). ^{40}K and the radionuclides of the U and Th series contribute most of the naturally occurring radioactivity in soils. It is known that ^{40}K concentration in soils ranges between 0.51-15.54 kBq/m^2 [4].

All samples were kept in sealed containers for at least 15 days to allow equilibration between the isotopes ^{226}Ra and ^{222}Rn.

The collected soils samples were air-dried weighted and counted in Marinelli beakers with a gamma-spectroscopy system, consisting of a high purity coaxial Germanium detector p-type (CP2100, Tennelec). The sample chamber was a cylinder 12 cm in diameter and 25 cm in height and it was shielded by 5 cm of lead and 0.5 cm

of copper in order to low the back ground. The full width at half maximum (FWHM) of the system was found to be 1.95 Kev at 1332 Kev of ^{60}Co. The linearity of the detector was checked with a ^{152}Eu source and a simple regression analysis gave a straight line with a correlation coefficient of 0.999. The radionuclides used were supplied by "The Nucleus", Oak Ridge, U.S.A. The counting time was 86,400 sec for all the soil samples in order the time to be sufficient to measure almost any level of radiocontamination (from 0.1 kBq/m^2). The activity per unit mass (Bq/Kgr) of each sample was first evaluated. The activity per unit area (kBq/m^2) was calculated afterwards by assuming the soil sample volume equal to the surface of a layer with depth 1 cm. The mean value and the standard deviation of the density of the 380 samples was 1.43 $\pm$0.23 Kgr/L. The concentration of ^{137}Cs and ^{40}K per prefecture all over Greece are given in Table I.

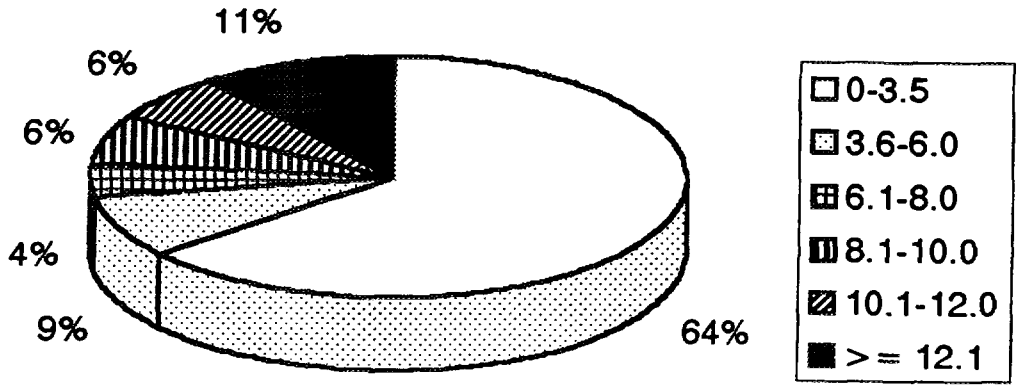

Figure 2: Percentage concentration of ^{137}Cs (kBq/m^2)

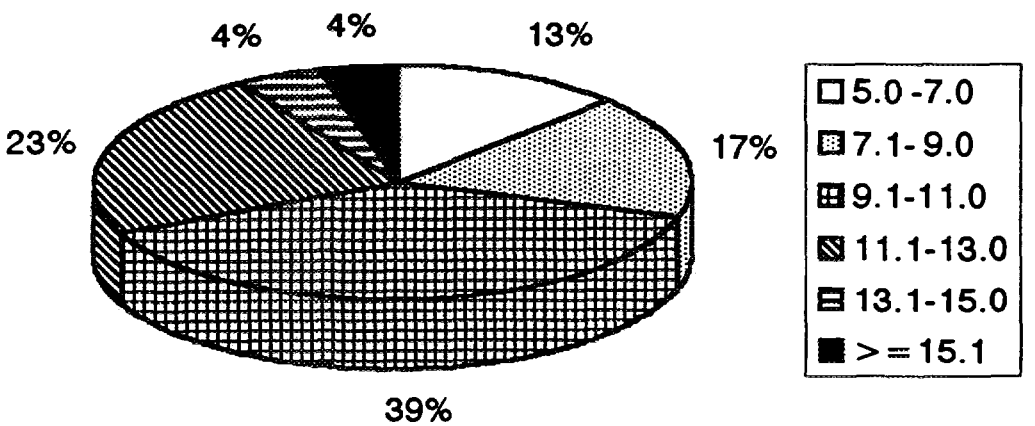

Figure 3: Percentage concentration of ^{40}K (kBq/m^2)

Table I: Distribution of ^{137}Cs and ^{40}K per Prefecture in Greece

Ser. Num.	PREFECTURE	CAPITAL	Numb.of Samples	(kBq/m²)±SD	
				^{137}Cs	^{40}K
1	ACHAIA	Patra	8	1.8 ± 0.1	8.7 ± 0.2
2	ARGOLIDA	Nafplio	7	2.1 ± 0.1	9.9 ± 0.2
3	ARKADIA	Tripoli	7	3.1 ± 0.2	8.8 ± 0.3
4	ARTA	Arta	5	1.0 ± 0.1	9.4 ± 0.2
5	ATTIKI	Athens	10	4.0 ± 0.2	9.5 ± 0.3
6	CHALKIDIKI	Poligiros	11	3.0 ± 0.2	10.2 ± 0.2
7	CHIOS	Chios	4	0.4 ± 0.1	11.6 ± 0.3
8	CORFOU	Corfou	8	3.1 ± 0.2	10.5 ± 0.1
9	DODEKANISA	Rodos	5	0.4 ± 0.1	12.9 ± 0.2
10	DRAMA	Drama	8	4.8 ± 0.3	11.6 ± 0.1
11	ETOLOAKARNANIA	Mesologi	5	0.8 ± 0.1	12.9 ± 0.2
12	EVIA	Chalikida	6	0.7 ± 0.1	11.9 ± 0.4
13	EVRITANIA	Karpenisi	7	1.7 ± 0.1	14.3 ± 0.2
14	EVROS	Alexandroupoli	5	2.2 ± 0.1	15.8 ± 0.4
15	FLORINA	Florina	17	11.9 ± 0.3	8.2 ± 0.6
16	FOKIDA	Amfissa	8	1.6 ± 0.1	11.3 ± 0.7
17	FTHIOTIDA	Lamia	3	7.6 ± 0.2	6.2 ± 0.4
18	GREVENA	Grevena	7	10.6 ± 0.4	9.4 ± 0.3
19	ILIA	Pirgos	4	1.3 ± 0.1	9.9 ± 0.3
20	IMATHIA	Veria	15	12.7 ± 0.2	5.4 ± 0.1
21	IOANNINA	Ioannina	14	3.1 ± 0.4	11.1 ± 0.4
22	KAFALONIA	Argostoli	5	1.9 ± 0.1	10.7 ± 0.2
23	KARDITSA	Karditsa	14	12.5 ± 0.4	6.7 ± 0.3
24	KASTORIA	Kastoria	8	12.6 ± 0.5	6.6 ± 0.1
25	KAVALA	Kavala	6	2.7 ± 0.1	11.8 ± 0.4
26	KIKLADES	Ermoupolis	5	3.0 ± 0.2	12.8 ± 0.2
27	KILKIS	Kilkis	5	3.7 ± 0.1	10.0 ± 0.3
28	KORINTHOS	Korinthos	4	1.1 ± 0.1	10.1 ± 0.5
29	KOZANI	Kozani	10	8.8 ± 0.3	11.7 ± 0.2
30	KRITI (ISLAND)	Iraklio (I. town)	12	2.9 ± 0.2	10.7 ± 0.3
31	LAKONIA	Sparti	5	2.0 ± 0.1	8.9 ± 0.4
32	LARISA	Larisa	12	9.4 ± 0.2	8.1 ± 0.2
33	LESVOS	Mitilini	3	1.0 ± 0.2	11.8 ± 0.3
34	LIMNOS (ISLAND)	Mirina	5	3.5 ± 0.1	9.6 ± 0.5
35	MAGNISIA	Volos	12	7.9 ± 0.3	6.7 ± 0.4
36	MESSINIA	Kalamata	5	2.2 ± 0.2	10.9 ± 0.5
37	PELLA	Edessa	5	10.0 ± 0.5	7.6 ± 0.2
38	PIERIA	Katerini	18	14.4 ± 0.3	5.1 ± 0.1
39	PREVEZA	Preveza	5	1.4 ± 0.1	9.3 ± 0.2
40	RODOPI	Komotini	8	0.8 ± 0.1	10.1 ± 0.9
41	SERRES	Serres	11	4.0 ± 0.1	14.5 ± 0.5
42	SKOPELOS (SPORADES)	Chora of	8	3.0 ± 0.1	9.9 ± 0.3
43	ALONISOS (SPORADES)	Skiathos			
44	THESPROTIA	Igoumenitsa	6	2.8 ± 0.1	10.9 ± 0.3
45	THESSALONIKI	Thessaloniki	20	11.3 ± 0.4	7.8 ± 0.4
46	TRIKALA	Trikala	14	12.3 ± 0.6	7.9 ± 0.5
47	VIOTIA	Livadia	5	1.8 ± 0.1	10.2 ± 0.3
48	XANTHI	Xanthi	5	1.0 ± 0.1	16.5 ± 0.6

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