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DOSE CONTROLLING LEVELS IN CONTAMINATED FOODSTUFFS WITH RADIONUCLIDES AND A SAMPLE APPLICATION WITH CHERNOBYL FALLOUT DATA IN TURKEY

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RADYONÜKLİTLERLE KİRLENMİŞ GIDA MADDELERİNDE DOZ KONTROL DÜZEYLERİ VE TÜRKİYE'DEKİ ÇERNOBİL SERPİNTİ VERİLERİYLE ÖRNEK BİR UYGULAMA

Abstract:

Fission and activation products result by nuclear reactions in a nuclear accident or explosion. These products are emitted to atmosphere because of high pressure and temperature, by concentrating in the atmosphere, they descend to the earth with the effect of gravity and create the fallout. Some of the radioactive particles are dispersed from near source circles to the distant surroundings. Dispersed radionuclides contaminate air, water and soil and can harm the human health and whole ecosystem by emitting radiation. The radioactive contamination and irradiation dimensions vary in qualitative and quantitative terms according to the phases of the accident and the distance from the accident site. These differences are taken into consideration when determining the protection measures. Radionuclides reach the human from the environment directly or through different intermediate step food chains. Radionuclide contamination levels which are determined in foods are evaluated according to the regionally calculated contamination limits and it is decided to allow restrict or prevent the consumption of food. In this way, society individuals are prevented from being exposed to radiation, which is over the effective dose equivalent, through digestion. The best way to achieve emergency decision is to determine derived intervention levels of radionuclide contamination according to the latest food data. In this study, radioactive contamination levels in basic foodstuffs which were measured by Turkey Atomic Energy Agency after Chernobly Reactor Accident in 1986 in Turkey, were evaluated. Contamination levels and contamination limits were calculated for the four basic foodstuffs: dairy products, meat, bakery products, vegetables and fruits. Contamination limits (D, Bq / kg) were calculated as $D_{I\text{-}131}$: 288.4; $D_{Cs\text{-}134}$: 6345; $D_{Cs\text{-}137}$: 9762 in dairy products; $D_{Cs\text{-}134}$:18657; $D_{Cs\text{-}137}$: 28703 in meat products; $D_{Cs\text{-}134}$: 1257; $D_{Cs\text{-}137}$: 1934 in bakery products; $D_{I\text{-}131}$: 96.2; $D_{Cs\text{-}134}$: 2117; $D_{Cs\text{-}137}$:3257 in vegetables and fruits. Contamination levels (D^x, Bq / kg) was calculated as $D^x_{I\text{-}131}$: 211; $D^x_{Cs\text{-}134}$: 739; $D^x_{Cs\text{-}137}$:1478 in dairy products; $D^x_{Cs\text{-}134}$:10076; $D^x_{Cs\text{-}137}$:13200 in meat products; $D^x_{Cs\text{-}134}$: 547; $D^x_{Cs\text{-}137}$: 1093 in bakery products; $D^x_{I\text{-}131}$: 80; $D^x_{Cs\text{-}134}$: 160; $D^x_{Cs\text{-}137}$: 134 in vegetables and fruits. When the calculations were compared, it was evaluated that the foodstuffs were consumable since the contamination levels (D^x) were smaller than the contamination limits (D). The total contamination level were calculated as 0,050 for the four basic foodstuffs. Since this value was less than 1, it was determined that the four basic foodstuffs were consumable together.

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Özet:

Bir nükleer kaza veya patlamada fisyon ve aktivasyon ürünleri yüksek basınç ve ısıl etki ile yükselerek, atmosferde dağılır ve yer çekimi etkisi ile yeryüzüne inerek radyoaktif serpintiyi oluşturur. Radyoaktif partiküllerin bir kısmı atmosferik olaylarla kaynaktan uzak çevrelere dağılarak hava, su ve toprağı kirletip yaydığı radyasyonlarla tüm ekosisteme ve insan sağlığına zarar verebilir. Radyoaktif kirlenme ve ışınlanma boyutu kazanın evrelerine ve kaza yerinden olan uzaklığa göre nitel ve nicel olarak farklılıklar gösterir. Bu farklılıklar koruma önlemlerinin belirlenmesinde göz önünde tutulur. Radyoaktivite çevreden insana doğrudan veya farklı gıda zincirleriyle ulaşır. Gıdalarda belirlenen radyonüklit kirlenme düzeyleri bölgesel olarak hesaplanmış kirlenme sınırlarına göre değerlendirilerek gıdanın tüketiminin iznine, kısıtlanmasına veya önlenmesine karar verilir. Bu şekilde toplum bireylerinin sindirim yoluyla etkin doz eşdeğeri üstünde radyasyona maruz kalması önlenir. Bu çalışmada 1986 da vuku bulan Çernobil Reaktör Kazası sonrası Türkiye Atom Enerjisi Kurumunca Türkiye'deki temel gıda maddelerinde ölçülen radyoaktif kirlenme düzeyleri incelendi; süt ürünleri, et, unlu mamüller, sebze ve meyve olmak üzere dört temel gıda maddesi için kirlenme düzeyleri ve kirlenme sınırları hesaplandı. Kirlenme sınırları (D, Bq/kg) süt ürünlerinde D_{I-131}: 288.4; D_{Cs-134}: 6345; D_{Cs-137}: 9762; et ürünlerinde D_{Cs-134}:18657; D_{Cs-137}: 28703; unlu mamüllerde D_{Cs-134}: 1257; D_{Cs-137}: 1934; sebze ve meyvelerde D_{I-131}: 96.2; D_{Cs-134}: 2117; D_{Cs-137}:3257 olarak hesaplandı. Kirlenme düzeyleri (D^x, Bq/kg) süt ürünlerinde D^x_{I-131}: 211; D^x_{Cs-134}: 739; D^x_{Cs-137}:1478; et ürünlerinde D^x_{Cs-134}:10076; D^x_{Cs-137}:13200; unlu mamüllerde D^x_{Cs-134}: 547; D^x_{Cs-137}: 1093; sebze ve meyvelerde D^x_{I-131}: 80; D^x_{Cs-134}: 160; D^x_{Cs-137}: 134 Bq/kg olarak hesaplandı. Karşılaştırıldığında, kirlenme düzeylerinin (D^x) kirlenme sınırlarından (D) küçük olduğu görüldüğünden incelenen gıda maddelerinin tüketilebilir nitelikte olduğu değerlendirildi. Dört temel gıda grubu için hesaplanan toplam kirlenme düzeyi 0.050 olarak bulundu. Bu değer 1'den küçük olduğundan dört temel gıda grubunun birlikte tüketilebilir düzeyde olduğu belirlendi.

Key Words: Radionuclide, nuclear accident, fallout, derived intervention levels

Anahtar Kelimeler: Radyonüklit, nükleer kaza, serpinti, türetilmiş müdahale seviyesi

1. Introduction

Radionuclides are formed depending on the characteristics of the nuclear plant as a result of fission reactions of U-235 and Plutonium formed by the neutron activation of U-238 up to 200 fission products of atomic weights 80-108 and 126-154, and a number of activation products. Nuclear reactions take place in the reactor core formed by solid fuel elements in the reactor envelope covered with safety shell. Radioactive contamination occurs over a large area of the earth by the dispersion of radioactive fission and activation products emitted from the fuel elements and the safety shell of the reactor through high pressure and heat effect as a result of a nuclear accident (Özden,1983). On the other hand, the primary source of radionuclides produced in the fission process and found in the environment is atmospheric testing of nuclear weapons. The public has been exposed to these and other radionuclides for the past three decades or longer, but there has been a substantial decline in atmospheric testing in the past two decades. Therefore the major source of fission product radionuclides in recent years has been from nuclear accidents. While internal and external irradiation has been in the near areas formed by the accident center and its surroundings; in areas far from the center of the accident, there is usually internal irradiation through food. Radionuclides classified as activation products are created in nuclear reactors and other nuclear devices by the reactions of the neutrons with fuel and construction materials. Activation products include

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the isotopes of the transuranic elements and radioisotopes of hydrogen, carbon, cesium, cobalt, iron, manganese, zinc, and a host of other radionuclides, all of which should be recognized and considered in determining the environmental pathways to human exposure. In regard to internal exposure from ingestion of food and water and to the contamination of environmental materials which are part of the immediate pathways leading to contamination of food, the most important radionuclides to be assessed following a release of radionuclides from a uranium-fuelled reactor to the environment are ^{134}Cs, ^{137}Cs, ^{131}I and other gamma emitters, the beta emitters ^{89}Sr, ^{90}Sr and tritium, and the alpha emitters ^{238}Pu, $^{239+240}$Pu, ^{241}Am and ^{242}Cm (IAEA, 1989). On 26 April 1986, an accident at Unit 4 of the Chernobyl nuclear power station in the Ukraine, USSR, destroyed the reactor core and part of the building in which it was housed, resulting in the uncontrolled release to the environment of large quantities of radioactive material. Heat generated as a result of the accident lifted the radioactive material high into the air, much of it then being transported through the atmosphere by normal air currents, in the form of gases and dust particles. Radioactive contaminants were widely dispersed in this manner throughout the northern hemisphere, although the majority of the material released remained within the USSR. This progressive spread of contamination to large distances from the release point demonstrated an urgent need, not only comprehensive guidance but also for specific numeric values. Guideline values for foodstuffs at the point of consumption should be aimed at the specified population groups. Because most people acquire their own diet components in different areas, only a fraction of the food consumed due to the accumulation of radioactivity in their area can be contaminated. For the application of a protective precaution, the dose of radiation can be controlled by calculating the derived intervention levels corresponding to the threshold doses which should not be exceeded (IAEA, 1986).

The aim of present study is to determine the specific fission and activation product radionuclides in foodstuffs and to calculate the contamination limits against regional food consumption amounts and intervention levels are derived. A sample application was made on food consumption and dose control that humans were exposed by using radioactive contamination levels which is determined in the foodstuffs in Turkey after Chernobyl nuclear reactor accident.

2. Method

Dosage calculations are made on the mathematical models that determine the transfer of radionuclide from environment to human with the data collected for the surrounding radioactivity. The ICRP (International Commission for Radiological Protection) has determine that personal effective dose equivalent of 5 mSv / y for adults (IAEA, 1986), 3 mSv / y for children the first year after the nuclear accident (IAEA, 1982). Dose calculations are based on mathematical models that determine the transfer of each radionuclide from the environment to the human with the data collected for radioactivity in the environment. Derived Intervention Level (D) is the amount of radioactivity that reaches the personal effective dose equivalent for reference individuals (WHO,1988). D is calculated according to the reference individuals of different age groups and their average air, food, water intake and dose of 1 Bq of the corresponding radionuclide in this individual (TAEK No:1, 2007:11).

Derived Intervention Level is defined as in the following equation.

$$D = \frac{E}{m.d} \qquad (1)$$

where;

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E: Reference Intervention level of dose (Sv/y)
m: Mass of food consumed annually (kg/y)
d: Dose per unit intake (Sv/Bq)
D: Derived Intervention Level (Bq/kg)

Derived intervention level for a food is inversely proportional to the food consumption amount and the dose conversion factor of the corresponding radionuclide as seen in the equation (1)(WHO,1988).

The derived intervention levels have been calculated on the basis of a single radionuclide in a single foodstuff leading to the intervention level of dose. According to WHO 1988, the recommendation is that, if more than one food category is affected, or if there are several radionuclides present, modified derived intervention levels should be calculated according to the additivity formula (WHO,1988).

Modified derived intervention levels;

$$\sum_i \sum_f \frac{C(i,f)}{D(i,f)} \leq 1 \qquad (2)$$

C(i,f): concentration of i radionuclide in f food (Bq/kg, Bq/L)
D(i,f): derived intervention level of i radionuclide in f food

If the result of this sum is more than 1, the consumption of food is not allowed as the reference intervention level of dose (E = 5 mSv / y) will be exceeded.

If various foods are consumed together with the radioactive amount measured in foods, the specific derived intervention level for each food is calculated by considering the combined effect (WHO,1988).

$$D^x(i,f) = \frac{g(i,f)}{\sum_i \sum_f \frac{g(i,f)}{D(i,f)}} \qquad (3)$$

$$D^x(i,f) \leq D(i,f) \qquad (4)$$

g(i,f): rate of radioactivity concentrations in foods.

3. Results and Discussion

In a nuclear accident, a certain threshold dose must not be exceeded in order to take certain protective measures. Threshold doses are the radiation doses to which the reference individuals will be exposed within a certain period of time. Intervention levels derived from different country, region and individual characteristics and varying qualitative / quantitative food consumption data should be continuously recalculated and final values used for correct dose control after a nuclear accident.

Radionuclides contaminating environment and food in different environments specifically determined by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) as shown in the Table 1.

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Table 1. Radionuclides in Environmental and Food Samples (IAEA, 1989).

Environment	Radionuclide
Air	^{131}I, ^{134}Cs, ^{137}Cs
Water	^{3}H, ^{89}Sr, ^{90}Sr, ^{131}I, ^{134}Cs,^{137}Cs
Milk	^{89}Sr, ^{90}Sr, ^{131}I, ^{134}Cs, ^{137}Cs
Meat	^{134}Cs, ^{137}Cs
Other Food	^{89}Sr, ^{90}Sr, ^{95}Zr, ^{95}Nb, ^{103}Ru, ^{106}Ru, ^{131}I, ^{134}Cs
Phytonutrient	^{137}Cs, ^{141}Ce, ^{144}Ce
Soil	^{90}Sr, ^{134}Cs, ^{137}Cs, ^{238}Pu, $^{239+240}$Pu, ^{241}Am, ^{242}Cm

In the emergency decision after the accident, derived intervention levels corresponding to the effective dose equivalent per person are used. Derived intervention levels, D (i, f), are the amount of radioactivity corresponding to the personal effective dose equivalent for the reference individuals.

Dose conversion factor is determined by ICRP according to age groups and as shown in the Table 2.

Table 2. Dose Conversion Factors by Age Groups (Sv / Bq) (WHO, 1988)

Radionuclide	One Year Old	10 Year Old	Adults
Strontium -90[a]	1.1×10^{-7}	4.0×10^{-8}	3.6×10^{-8}
Iodine-131[b]	3.6×10^{-6}	1.0×10^{-6}	4.4×10^{-7}
Cesium -134[a]	1.2×10^{-8}	1.2×10^{-8}	2.0×10^{-8}
Cesium -137[a]	1.0×10^{-8}	1.0×10^{-8}	1.3×10^{-8}
Plutonium -239[a]	2.4×10^{-6}	1.4×10^{-6}	1.3×10^{-6}
a Total effective dose equivalent			
b Effective dose equivalent for thyroid			

After the Chernobyl accident the various foodstuff consumption of individuals in Turkey are shown in Table 1 (FAO,1986).

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Table 3. Annual Consumption of Foodstuff (per caput in kg per year) (FAO, 1986)

Diet Type	**Consumption (kg/year)**
Cereals	198.90
Roots and Tubers	18.60
Vegetables	70.50
Fruit	29.00
Meat	13.40
Fish	3.10
Milk	39.40
Water	700.00

Derived intervention levels, D(i,f) is the maximum permissible radionuclide contamination limit in a food. As seen in Equation (1); derived intervention levels depends on the age group of the individuals, the characteristics of the radionuclide, and the amount of annual or national food consumption. Therefore, D(i,f) is a national or regional value and must be determined in advance.

In this study for Turkey, by using the Equation (1) (taking the effective dose limit, E: $5*10^{-3}$ Sv and using the dose conversion factor from Table 2), the variation of D(i,f) with food consumption amount (Table 3) for Cs-137, Cs-134, Sr-90, I-131 and Pu-239 in Turkey is shown in Figure 1.

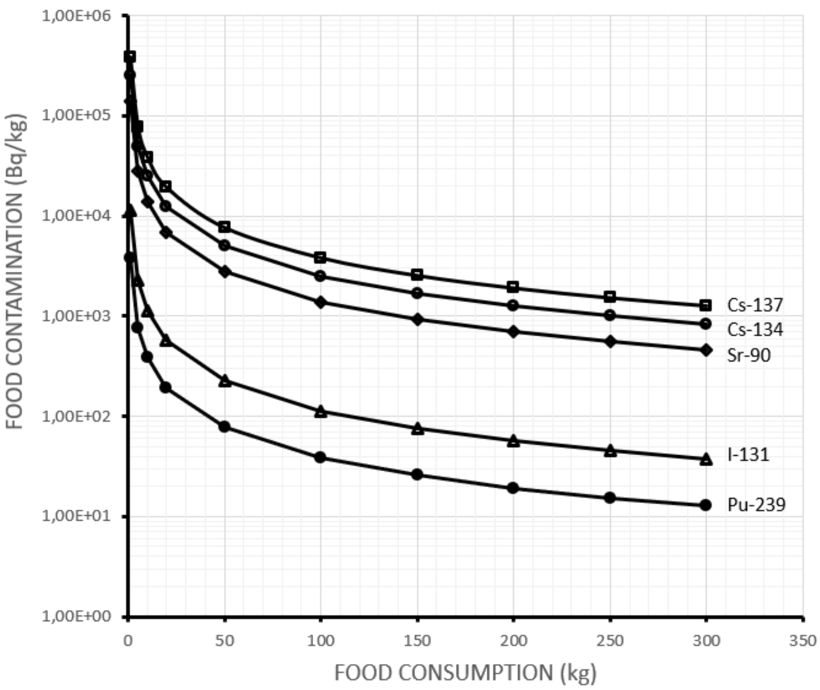

Figure 1. Semi-logarithmic plot of food contamination versus food consumption for Cs-137, Cs-134, Sr-90, I-131 and Pu-239 to give a dose of 5 mSv using relevant dose conversion factors (Sv/Bq) $1,3x10^{-8}$, $2,0x10^{-8}$, $3,6x10^{-8}$, $4,4x10^{-7}$ and $1,3x10^{-6}$ respective.

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As can be seen from the Figure 1, as the amount of food consumption increases, the level of contamination decreases. So the relationship between contamination and the amount of food consumption is inversely proportional.

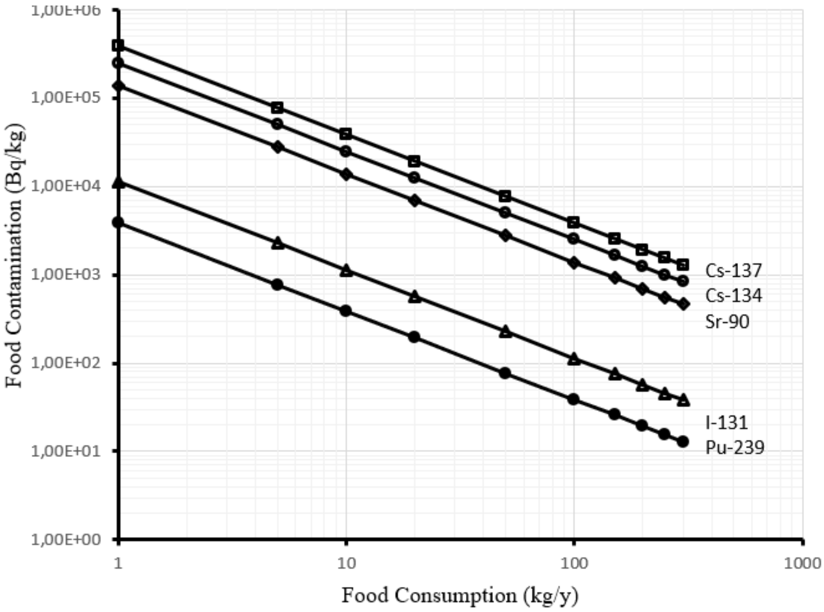

Figure 2. Plot of food contamination versus food consumption for Cs-137, Cs-134, Sr-90, I-131 and Pu-239 to give a dose of 5 mSv using relevant dose conversion factors (Sv/Bq) 1.3×10^{-8}, 2.0×10^{-8}, 3.6×10^{-8}, 4.4×10^{-7} and 1.3×10^{-6} respectively for adults

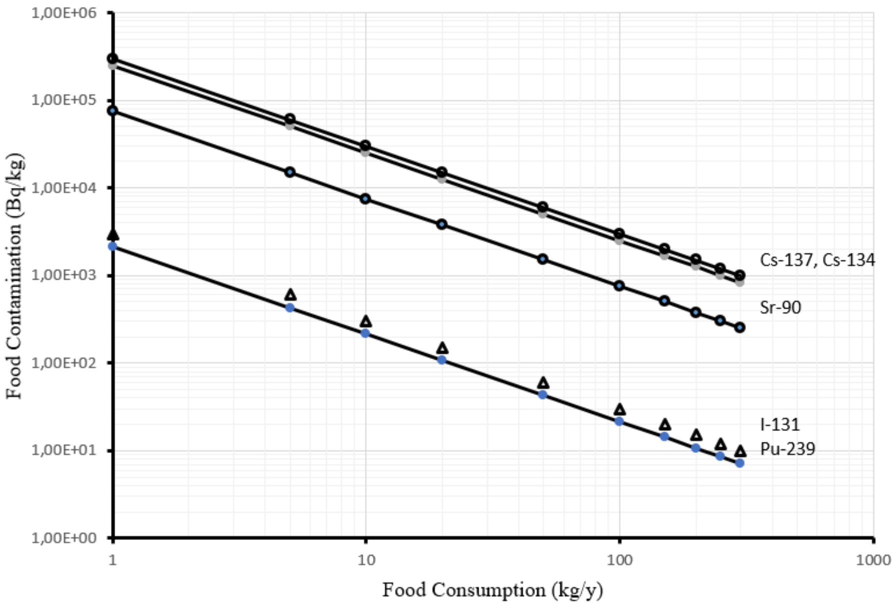

Figure 3. Plot of food contamination versus food consumption for Cs-137, Cs-134, Sr-90, I-131 and Pu-239 to give a dose of 3 mSv using relevant dose conversion factors (Sv/Bq) 1.0×10^{-8}, 1.2×10^{-8}, 4.0×10^{-8}, 1.1×10^{-6} ve 1.4×10^{-6}respectively for ten-year

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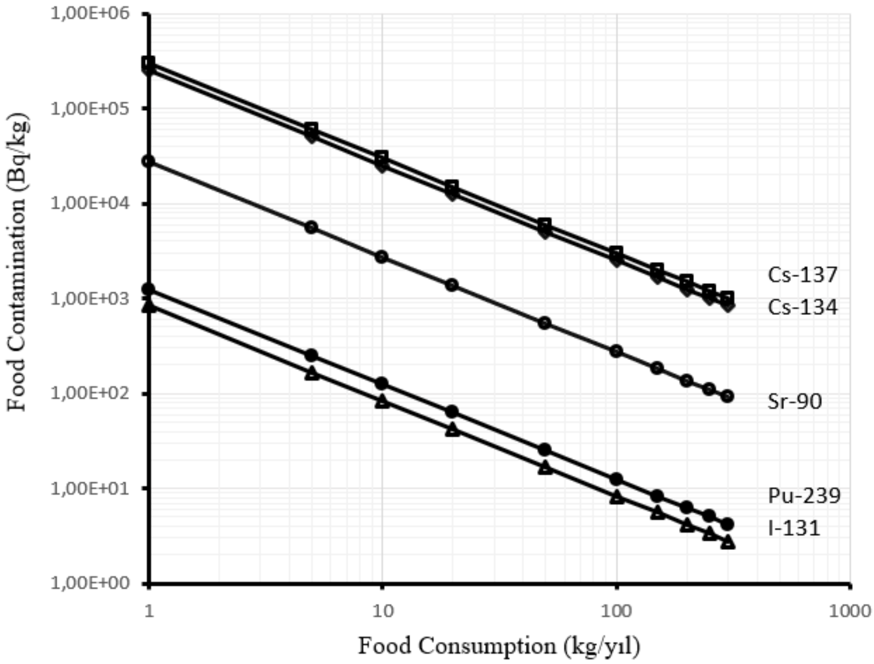

Figure 4. Plot of food contamination versus food consumption for Cs-137, Cs-134, Sr-90, I-131 and Pu-239 to give a dose of 3 mSv using relevant dose conversion factors (Sv/Bq) $1.0x10^{-8}$, $1.2x10^{-8}$, $1.1x10^{-7}$, $3.6x10^{-6}$ ve $2.4x10^{-6}$ respectively for one-year

According to the Figure 2, 3 and 4, the calculated contamination limit values are lower for 1 year old and 10 year olds than adults. Food consumption after a possible accident should be determined according to age groups under the effective dose. Consumption of food is not permitted if the specific derived intervention level, $D^x{}_{(i,\ f)}$, exceeds the derived intervention level, $D_{(i,\ f)}$, in Figure 2-4.

$$D^x(i,f) \leq D(i,f) \tag{4}$$

Contamination limit of one or more foods with one or more radionuclides is calculated from Equation (2).

$$\sum_i \sum_f \frac{C(i,f)}{D(i,f)} \leq 1 \tag{2}$$

If the result of this sum is more than 1, the consumption of food is not allowed as the personal effective dose (E = 5 mSv/y for adults and E = 3 mSv/y for one year-old and ten years-old inviduals) will be exceeded in Figure 2-4.

The radionuclides groups used in these calculations from the report of Radiation and Radioactivity measurements in Turkey After Chernobyl (TAEK, 2007). Contamination limits are determined from Figure 1 and specific contamination levels are calculated by using Equation (3). Calculated DIL values are given in the Table 4. As shown in Table 4 $D^x{}_{(i,\ f)} \leq D_{(i,\ f)}$, the specified food groups were determined to be suitable for consumption.

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Table 4. Amount of radioactivity and contamination levels in food groups which was consumed by adults in Turkey in 1986

Diet Type	**Food Consumption kg/y (FAO, 1986)**	**Average Radioactivity Concentrations Bq/kg (TAEK, 2007)**	**Specific Derived Intervention Level, D^X Bq/kg**	**Derived Intervention Level, D Bq/kg**
Dairy Products	39.4	I-131: 3 Cs-134: 10.5 Cs-137: 21	211 739 1478	288.4 6345 9762
Vegetables and Fruits	118.1	I-131: 2.5 Cs-134: 5 Cs-137: 9.5	80 160 304	96.2 2117 3257
Meat	113.4	I-131: - Cs-134: 13 Cs-137: 17	- 10076 13200	848 18657 28703
Bakery Products	198.9	I-131: - Cs-134: 2 Cs-137: 4	- 547 1093	571 1257 1934

The ratio of the concentration of a given radioonuclide in a foodstuff to the calculated contamination limit is shown in the Table 3 by 'X'.

$$\sum_i \sum_f \frac{C(i,f)}{D(i,f)} = X_{(I-131,\ \text{süt ürünleri})} + X_{(Cs-134,\ \text{süt ürünleri})} + X_{(Cs-137,\ \text{süt ürünleri})} + \cdots + X_{(i,f)} \leq 1$$

The consumption of foodstuffs is decided according to this formula. If the sum of X is less than 1, the value obtained is below the limit dose and foods can be consumed. If one of the X is greater than 1, this food is either retained from consumption or diluted with non-radioactivity food to reduce the radioactivity concentration.

Table 5. Total calculated contamination limit according to the amount of radioactivity in 1986 in Turkey

Diet Type	**X_{I-131}**	**X_{Cs-134}**	**X_{Cs-137}**	**X_{TOPLAM}**
Dairy Products	0.0104	0.0017	0.0022	**0.0142**
Vegetables and Fruits	0.0260	0.0024	0.0029	**0.0313**
Meat	-	0.0007	0.0006	**0.0013**
Bakery Products	-	0.0016	0.0021	**0.0037**
			Total Contamination Limit	**0.0504**

x_i: The ratio of the radionuclide i concentration in the foodstuff to the contamination limit of the radionuclide i in the foodstuff

According to the results shown in Table 5, since the total pollution level (x_{total}) is less than 1, all four basic food groups can be consumable.

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In addition, if the first three food groups in Table 4 were obtained from domestic production and floury foods were obtained by importing cereals containing 800 Bq / kg Cs-134, 1600 Bq / kg Cs-137, the total contamination limit is given in Table 6. When Table 5 and Table 6 are compared, an increase in X_{Cs-134} and X_{Cs-137} rates is observed for bakery products. As a result, when the total contamination level is calculated (X_{total}) for four basic foodstuffs, this value is found to be greater than 1. The results show that food groups are not recommendable to consume.

Table 6. Total calculated contamination limit values with the supply of flour containing cereals containing 800 Bq / kg Cs-134 and 1600 Bq / kg Cs-137

Diet Type	X_{I-131}	X_{Cs-134}	X_{Cs-137}	X_{TOPLAM}
Dairy Products	0.0104	0.0017	0.0022	**0.0142**
Vegetables and Fruits	0.0260	0.0024	0.0029	**0.0313**
Meat	-	0.0007	0.0006	**0.0013**
Bakery Products	-	0.6364	0.8309	**1.4673**
			Total Contamination Limit	**1.5141**

x_i: The ratio of the radionuclide i concentration in the foodstuff to the contamination limit of the radionuclide i in the foodstuff

In such a case, when the calculations are examined, the level of contamination for bakery products is very high. According to this result, cereal consumption can be reduced. However, cereal plays an important role for human health due to its high nutritional value. In addition, this situation can cause economic difficulties. Reducing cereal consumption may not be an appropriate solution. However, food consumption management is carried out by mixing imported cereal with low-activity domestic cereal products, or partially replacing other clean foods, ensuring that the pollution level is less than 1.

After the accident, the status of tea, which has an important place in export and consumption in Turkey, has always been discussed. According to the Turkey Atomic Energy Agency, under the 5 mSv effective dose, the derived intervention level of the tea consumption on the abscissa corresponds to the ordinate of Figure 2 is determined and the specific derived intervention level is calculated by using Equation (3). These data are given in Table 7.

Table 7. Specific Derived Intervention Level and Derived Intervention Level for tea

Diet	**Food Consumption kg/y (TAEK, 2007)**	**Average Radioactivity Concentrations Bq/kg (TAEK, 2007)**	**Specific Derived Intervention Level, D^X Bq/kg**	**Derived Intervention Level, D Bq/kg**
Tea	1	I-131: - Cs-134: 3500 Cs-137: 9000	- 93458 240187	11364 250000 384615

According to the results in Table 7, the calculated contamination levels, Dx, are less than the calculated contamination limit, D, for tea foodstuff. In this case, the decision for tea can be consumed.

It is recommended that the derived interference levels for radionuclides in the first

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column of Table 8 should be less than the DIL values in the second column.

Table 8. DIL values for total food components (DIL, Bq/kg) (IAEA, 1989)

Radionuclide Group	**DIL (Bq/kg)**
Strontium-90 (Sr-90)	160
Iodine-131 (I-131)	170
Cesium-134+ Cesium-137 (Cs-134, Cs-137)	1200
Plutonium-238+ Plutonium-239+ Americium-241	2
Ruthenium-103 + Ruthenium-106 (Ru-103, Ru-106)	C3/6800 + C6/450 < 1

When specific contamination levels ($D^x_{(i,f)}$) exceed the derived contamination limits, the measures which is in Table 8 apply. In addition, the maximum permissible radionuclide limit levels in children and adults were determined as I-131:100 Bq/kg, Cs-134 and Cs-137 1000 Bq/kg (JOINT FAO / WHO, 2006). When contamination levels ($D^x_{(i,\ f)}$) exceed the derived contamination limits, the measures which is in Table 9 apply.

Table 9. Intervention levels recommended (IAEA, 1986)

	Early dose (mSv)		Organ dose (mSv)	
Counter Measure	low	top	low	top
Early Period	(Short-term doses)			
Shelter and stable iodine giving	5	50	50	500
Evacuation	50	500	500	5,000
Interim Period	(First year doses)			
Controllind foodstuffs	5	50	50	500
Transport	50	500	50	500

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Protective actions depends on the specific foods having the greatest sources of radiation dose to population. Factors that determine which foods are most significant include the area of contamination and the stage of the growing at the time of the accident. In general, foods consumed fresh, such as milk, leafy vegetables, and fruit, are initially most important.

In this study, derived intervention levels was calculated under personal effective dose limit and the annual food consumption per individual in Turkey. The personal effective dose was taken as 5 msv for adults and 3 msv for children and Figure 1,2,3 and 4 were plotted. From these graphs, contamination limits for different age groups can be determined against food consumption.

Derived intervention levels for consumed foodstuff after the Chernobyl data in Turkey were calculated for I-131, Cs-134 and Cs-137 radionuclide groups for adults. According to the results in the Table 4, contamination levels and contamination limits were calculated for four basic foodstuffs: dairy products, meat, bakery products, vegetables and fruits. Contamination limits (D, Bq / kg) were found as D_{I-131}: 288,4; D_{Cs-134}: 6345; D_{Cs-137}: 9762 in dairy products, D_{Cs-134}: 18657 D_{Cs-137}: 28703 in meat products, D_{Cs-134}: 1257; D_{Cs-137}: 1934 in bakery products, D_{I-131}: 96,2; D_{Cs-134}: 2117; D_{Cs-137}: 3257 in vegetables and fruits. Contamination levels (D^x, Bq / kg) were calculated as D^x_{I-131}: 211; D^x_{Cs-134}: 739; D^x_{Cs-137}: 1478 in dairy products, D^x_{Cs-134}: 10076; D^x_{Cs-137}: 13200 in meat products, D^x_{Cs-134}: 547; D^x_{Cs-137}: 1093 in bakery products, D^x_{I-131}: 80; D^x_{Cs-134}: 160; D^x_{Cs-137}: 134 Bq / kg in vegetables and fruits. When compared, it was evaluated that the foodstuffs were consumable as the contamination levels (D^x) were found to be smaller than the contamination limits (D). The total contamination level calculated for the four main food groups was found to be 0.050. Since this value was less than 1, it was determined that four basic food groups were consumable together. The contamination levels, D^x, are smaller than the calculated contamination limits, D, indicating that these food groups can be consumed on the food consumption rate of Turkish adults.

After a nuclear accident, public health authorities should take measures to limit the risk of exposure to radiation. Regulations can be made to prevent or minimize the consumption of foods according to derived intervention levels. For this purpose, regional, national or local food consumption data should be known. In addition, according to the characteristics of the pollutant source and the prepared accident scenarios for different reactor, the fallout must be evaluated for fuel plant or nuclear weapons explosions. Since the radionuclides in the contaminated environment enter the vegetable and animal food chain at slow speed and in a long time, it is necessary to carry out continuous monitoring in food and environment. Contaminated food consumption management should be done over derived intervention levels. Protective and corrective measures should be developed to reduce the possibility of contamination of the population by fallout radioactivity.

In a nuclear accidents or radiological incident that might affect our country, determinated DILs values from Figure 2, 3 and 4, can be used to prevent or reduce exposure due to consumption of foodstuffs.

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