THE CHERNOBYL NUCLEAR ACCIDENT and ITS IMPORTANCE FOR TURKEY

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The Chernobyl nuclear reactor accident which occurred on April, 26th 1986 has been the worst nuclear accident in world history until now. Countries which were most affected by the accident were Belarus, Russian Federation and Ukraine. In addition to these three countries, almost all European countries were more or less affected by the accident on the basis of various factors especially including meteorological conditions and distance from the accident place. Turkey is also one of the countries affected by the accident.

Radioactive pollution accumulated at the earth's surface was observed in all northern hemisphere countries. Within the first week after the accident, a large amount of accumulation in soil was composed of radionuclides with short half-lives. 131I is the most important one among these radionuclides in terms of radiology. 137Cs radionuclide was taken as basis for characterizing extent of radioactive accumulation on the ground due to convenience of measurement and its long half-life. After radioactive decomposition of 131I radionuclide, public dose was mostly from 137Cs isotope.

The most polluted regions were usually within 30 km radius-area surrounding the reactor where soil accumulations of 137Cs exceeded 1480 kBq/m2. Distant regions which were highly polluted by 137Cs were the places where largest amount of rain/snow fell during passage of clouds.

INFLUENCES OF THE CHERNOBYL ACCIDENT

Behaviour of Radionuclides

Environmental behaviour of radionuclides are dependent on formation of radioactive precipitation, physical and chemical characteristics of radionuclides, wetness or dryness of accumulation at

earth's surface, size and shape of particles and environmental characteristics.

Humans are exposed to dose from short half-life radionuclides due to consumption of plants with leaves within a few days or consuming milk of cows or goats grazing on the polluted pasture. For example, since half-life of 131I is 8 days, it is not possible to observe long term influence.

Open spaces in settling areas such as parks, streets, squares, roofs, walls and roads are the areas mostly polluted by radionuclides. It was observed that radioactive materials, carried from roofs due to rain, are the most important reason for 137Cs pollution around houses.

Level of radiation significantly decreased as a result of discharging people within highly polluted regions as well as due to wind, rain and human activities such as washing roads and cleaning surfaces. However, those measures gave rise to radioactivity increase in sewage system.

Radionuclides accumulated in soil pass towards the lower layers of soil in the course of time and leak towards the lower part of soil and arrive to roots of plants; hence they can be transferred to plants during their development. This situation is especially taken into consideration for long half-life radionuclides such as.137Cs and 90Sr. Direction and speed of movement for radionuclides are dependent on various natural processes such as structure and content of soil, type of plant, conditions of irrigation, air condition and especially on existent conditions during accumulation.

Since radioactive materials precipitating onto water masses, dilute within a fairly large volume of water; transfer by water is very rare for 137C and 90Sr when they are taken with food. However, influence by water is relatively more important in lakes in the Scandinavian countries and some parts of Russia. It can be observed that radioactive pollution increases in lower parts of mountains. For example, 137Cs pollution of soil samples was 1760 Bq/kg in southern parts of French Alps in 1992. In some small parts (equal to fraction of square meter), hot points were measured as 55,800 Bq/kg in 1992; as 314,000 Bq/kg in 1995 and as 500,000 Bq/kg in 2000. These hot points have emerged as a result of snow which fell onto the upper parts of the mountain and melted downwards after the pollution in 1986. These points were in small basins at lower parts of forests or on European black pines on which snow was collected. However, those small-surface hot points (cm2 to m2) are not on trekking routes and their radiation risk is very low for climbers. For example, a mountaineer who takes a 4-hour break around such a hot point, will be exposed to an approximate dose of 0,001 mSv .

Whole Body Doses

After the Chernobyl accident, external radiation was mainly caused by 95Zr, 95Nb, 131I, 132Te, 132I, 134Cs, 137Cs, 140Ba, 140La radionuclides which emitted gamma rays. Due to widespread measurements of 137C in polluted areas, the intensity of other radionuclides was connected with 137Cs.

Consumption of locally produced milk was the primary source for humans for intake of caesium immediately after the accident.

Dose exposed by people were caused by short half-life radionuclides and especially by 131I right after the accident; and then by internal radiation as a result of consuming goods which had been polluted due to radioactivity and external radiation resulting from 137Cs.

Doses Exposed By Employees

Approximately 400 workers who were in the Chernobyl nuclear power station were exposed to radiation by respiration and external radiation. Since all dosimeters used by workers were extremely radiated, personal dosimeter rates could not be used for dose estimations. However, we have information regarding radiation exposed by 237 people who were removed to hospital due to diagnosis of Acute Radiation Syndrome (ARS). As a result of measurements performed by biological dosimeter, it was seen that;

Whole body radiation for 41 of them was between 1-2 Sv resulting from external radiation,

50 of them were exposed to radiation between 2-4 Sv,

22 of them were exposed to radiation between 4-6 Sv,

The remaining 21 of them were exposed to radiation between 6-16 Sv. According to the results of these measurements, it was seen that the number of ARS which had previously been notified as 237, was actually 134.

Radiation exposed by the improvement staff had increased up to 500 mSv within the first 4 years after the accident. The average radiation was approximately 100 mSv.

Radiation Exposed By the Public Evacuated In the Former Soviet Union

Within the first few weeks after the accident, more than 100,000 people living in the most polluted areas of Ukraine and Belarus, especially those in the 30-km zone around the reactor, were evacuated immediately after the accident. Before the evacuation process, those individuals were exposed to internal radiation by respiring radioactive

materials emitted from clouds and to external radiation by radioactive materials carried by clouds and emitted to soil.

Dose rates exposed by the evacuated people in Ukraine were between 0,1-380 mSv and their average was approximately 17 mSv. On the other hand, it was approximately 31 mSv in Belarus and the average dose rate was 300 mSv for the two villages affected most.

Radiation Exposed by the Public Living in the Polluted Areas of the Former Soviet Union

In the former Soviet Union, radiation doses were also evaluated for people living in and not evacuated from the polluted areas in which the 137Cs pollution was higher than 37 kBq/m^2. Among these, approximately 400,000 people were living in the accumulation zones, namely the "Strict Control Zones" which had an activity higher than 137Cs. In this region, intensive protection measures including control of food consumption have been implemented.

In the last 20 years, the average active radiation exposed by people living in the polluted areas has varied between 10-20 mSv. It was seen that this radiation exposure reaches hundreds of mSv in some places, whereas it has a lower level in other places.

Radiation Exposed By the General Public Outside the Former Soviet Union

Although radioactive materials released during the Chernobyl accident principally affected Belarus, Russian Federation and Ukraine, radionuclides which were emitted into the atmosphere and which were of primary importance spread over countries of the northern hemisphere.

Evaluations of Thyroid Dose

Thyroid doses exposed by people living in the polluted areas of Belarus, Russian Federation and Ukraine due to consumption of food polluted by radioactive iodine significantly vary according to the age of individuals and pollution of the earth's surface. The average thyroid doses were between 0,003 - 0,3 Gy in accordance with the pollution level of the living area and the age of a person during the incidence; however in some Russian villages, the average thyroid dose exceeded 1 Gy and personal thyroid dose exceeded 10 Gy. Rates were determined up to 50 Gy.

It was seen that thyroid doses in rural areas were approximately two times higher than in urban areas. According to the results of detailed studies which had been performed on 25000 persons in Belarus and Ukraine by direct usage of thyroid measurements and taking into account residence information, dietary habits and other necessary information, the median for thyroid dose was observed to be 0.3 Gy, and a significant number of dose values exceeding 1 Gy were found.

Children living in Gomel region of Belarus were exposed to the highest dose. The average thyroid dose obtained was approximately 1000 mGy for children between 0-7 years old in Belarus.

Acute Radiation Syndromes

Employees of the reactor and emergency response teams were exposed to a high dose of external radiation between 1-20 Gy due to external radiation. 134 persons were determined to have Acute Radiation Syndrome (ARS). 28 of these people passed away within the first 4 months due to radiation and burns. The remaining 19 people passed away one by one until 2004 due to various reasons. The total number of emergency response employees who passed away due to ARS or other reasons was 50. In the coming years, it is foreseen that there will be further deaths among individuals diagnosed as ARS.

There was not any observed death due to ARS among members of the general public affected by Chernobyl.

With an exaggerated approach and numbers, it is anticipated that the number of people who passed away and who will pass away due to the Chernobyl accident will be approximately 4000. Obviously, this does not mean that 4000 people will pass away due to radiation-based cancer.

As a result of studies performed by experts of various countries on emergency employees, improvement personnel and public living in the most polluted areas of Belarus, Russian Federation and Ukraine, it was determined that there was not any increase in normal death rate (except death of 9 children and adults due to thyroid cancer) due to leukaemia, other cancers and reasons other than cancer.

Thyroid Cancer

It was determined that most of the thyroid cancer cases occur in people exposed to a high dose of thyroid. For children, thyroid is one of the most sensitive organs to radiation together with bone marrow. Age of person is the most determining factor during the radiation. In various studies, it was determined that the risk is inversely proportional with age. From studies made with the atomic bomb survivors, it is known that thyroid cancer cases are observed among children who were 10 years old or younger during the radiation, that the highest risk was observed 15-29 years after the radiation, and that this risk might increase even after 40 years.

Although it had been anticipated that the incubation period would occur 10 years after the radiation on the basis of studies made before the accident; increase in thyroid cancer rates was mostly observed within the

first 5 years in Belarus, Russian Federation and Ukraine which were the countries affected from the accident most (Figure 1).

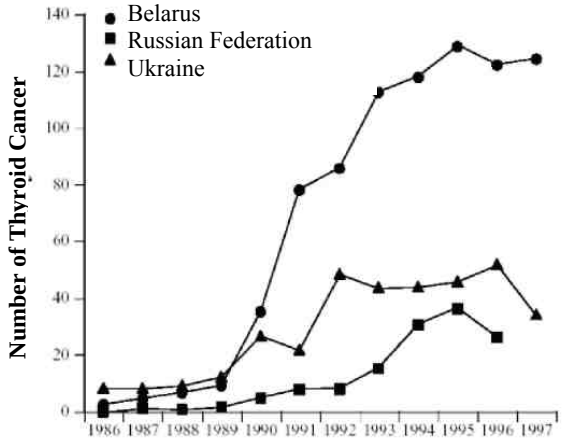


Figure 1. Change in number of thyroid cancers diagnosed among children who were younger than 14 years old during the accident according to years

3000 of 4000 children, between 0-18 years old, who were diagnosed as thyroid cancer in the Russian Federation, Belarus and Ukraine in 1992-2000 were between 0-14 years old at the date of the accident. 1152 thyroid cancers were diagnosed and treated in children of Belarus between 1986-2002. 98.8% of them survived, 8 people passed away due to thyroid cancer and 6 people passed away due to other reasons. 1 person passed away in Russia because of thyroid cancer.

According to the results of the research which had been performed between 1991-2001 among 184,919 girls and 188,908 boys living in Bryansk region of the Russian Federation, it is estimated that thyroid cancer will be seen until 2050. Thus, according to the results of the detailed researches in the Russian Federation, Belarus and Ukraine, it is declared that thyroid cancer monitoring programs should be continued systematically.

Leukaemia and other Cancers

It was observed that the leukaemia incidences doubled between 1986-1996 among improvement and emergency employees who were exposed to a radiation dose higher than 150 mGy. Researches on the increase of leukaemia incidences still continue. But, because of the time elapsed from the date of the radiation, the risk of radiation-based leukaemia has decreased, so leukaemia-based mortality or disease rates will have lost their importance by time.

Epidemiological studies have clearly shown that radiation causes increase in the risk of leukaemia. But, no increase was observed in the leukaemia risk related to ionizing radiation among the children and people of the former Soviet Union as well as other regions which were seriously polluted by the Chernobyl accident.

According to the results obtained from long term epidemiological researches, the emergence periods of cancers caused by reasons other than radiation-based leukaemia start 10 years after the incubation period. That is why annual controls must continue for medical follow-ups of over-radiated people.

Birth Anomalies and Genetic Effects

According to the results of studies on people living in the regions affected from Chernobyl, there was no decrease in reproduction functions of women and men caused by radiation. Occurrence of incidences such as birth anomalies, abortion, and premature birth is not considered as probable.

Decrease in birth rate can be observed in the region affected by Chernobyl due to anxiety of having children. A low level but regular increase in birth anomalies was observed due to researches performed in the highly and lowly populated regions of Belarus. It is thought that this increase is a result of the developments in the registry system, and it is not related with radiation.

No increase in genetic effects was anticipated as mentioned in the reports of the previous years.

Other Diseases and Health Problems

Recently some findings implying increase in cardiovascular diseases, which can be associated with high dose of radiation, were observed in some research groups.

A specific amount of increase in the number of deaths and diseases caused by circulation system diseases is observed among the Russian emergency and treatment employees. Emergence of circulation system diseases must be examined carefully because they can also be related with other active factors such as stress and unhealthy living conditions.

Ophthalmologic examinations done after the Chernobyl accident on children, emergency and improvement employees clearly stated cataract development caused by radiation. According to the results of the researches, doses over 250 mGY can cause cataract.

Some researchers reported chronic effects of high percentage in digestive, nervous, skeleton, muscle and circulation systems. But many researchers consider that these findings are related with the worsening of life quality and some measures such as resettlement after the accident.

In the last decade, many publications have been prepared about the effects of the radiation caused by Chernobyl accident on immunity

system. But it is difficult to comment on these results due to ambiguity in other factors like nutrition and infections which can change the results completely.

DOSE ASSESSMENTS FOR TURKEY

Effects of atmospheric dispersion on Turkey started to be observed after May 1st, 1986 and it varied from one region to another according to the movement of the radioactive cloud and amount of precipitation. An average pollution rate of 137Cs in the soil was found as 6 kBq/m2 in 1986, in the regions of Turkey where measurements had been carried out, except the Black Sea Region. Some hot points were detected where the activity was measured up to 181 kBq/m2 at the coastline between Pazar – Hopa in the Black Sea Region which was exposed to intensive precipitation during the passage of clouds.

In short term, the radiation dose exposed due to radioactive pollution of the environment mostly results from external radiation caused by radionuclides accumulated in the atmosphere and on earth's surface, respiring the air and consuming the directly polluted food. But in long term, the radionuclides on the earth's surface, increase the radiation exposed by humans through the food chain. The radionuclides which are taken into body by respiring radioactively polluted air or consuming food and beverage are kept by the body and cause internal radiation. The decrease in the dose rate has to be determined during the measurement of the radiation dose exposed in a specific time period in various ways. The main reason of this decrease is the radioactive disintegration of radionuclides in different manners and periods. Furthermore, biological and ecological factors also cause decrease in the dose rate.

Although radioactive iodine is very important in radiological terms and especially in determination of thyroid dose; very few measurements could be obtained due to ambiguity just after the accident and short half-life of 131I. In the following years, 137Cs became the most important isotope in radiological terms because of its long half-life, and it will also be important in the following years.

The amount of radionuclides precipitated in land and water changes according to the chemical and physical characteristics of the radionuclides, dry or wet precipitation type and topographic and meteorological environmental conditions.

In ANAEM and CNAEM, where the radioactivity values were daily measured within the context of this measurement program, by the increase in radioactivity of air, measured on April 29-30, 1986, the arrival of the radioactive fallout into our country was observed. After this date, radionuclide concentration was observed in air samples collected in ANAEM and ÇNAEM.

The values for 1986 in terms of unit area were calculated from the measurements of soil samples which were taken according to deepness from the Black Sea region in 1990, Trakya in 1992, and Aegean – Mediterranean regions in 1995.

Velocities of isotopes while moving downwards in the idle soil significantly vary in the regions, even between very close points, where the geological, demographical, and meteorological conditions are different from the average. The dose rates in the last 20 years which have been exposed due to external radiation from ground and which were calculated out of the regional averages are shown in Figure 2.

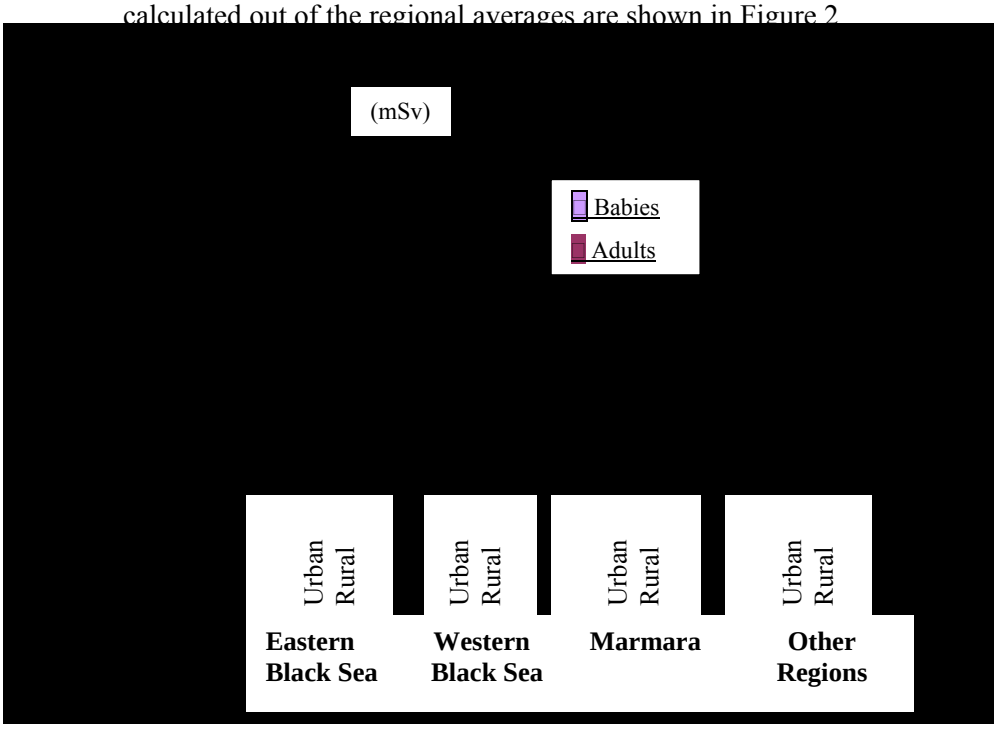


Figure-2. Distribution of external radiation doses from caesium in the soil for 20 years according to regions (mSv)

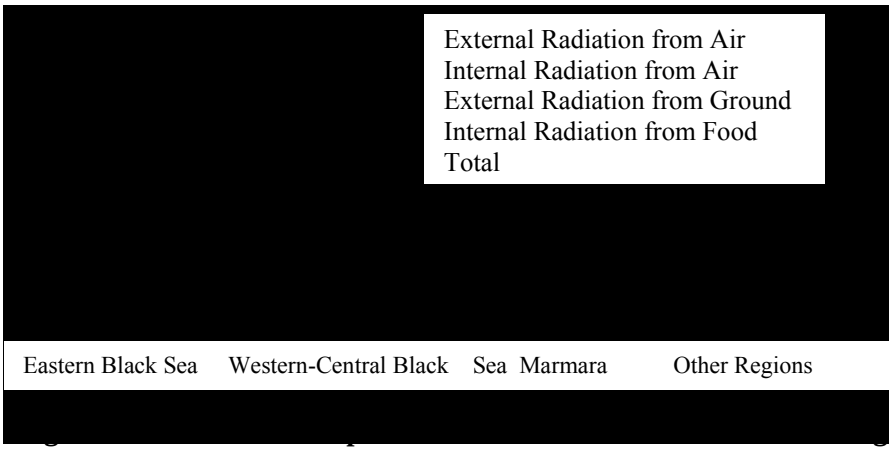
The internal radiation doses exposed by organs and tissues due to intake of radionucleides by breathing or food consumption are calculated for 70 years for children and 50 years for adults during the period when radionuclides are kept by the body.

The active doses exposed by people during their life times caused by the isotopes taken in by respiration were calculated from air measurements of 131I, 134Cs, and 137Cs activity concentrations suspended in air until the mid June of 1986.

Consuming radioactively polluted food is one of the most important reasons of exposure to radiation. The food affected from the fusion products emitted after the accident at the first stage are plants with leaves and milk. Radionuclides can directly precipitate on plants or can cause the food to be polluted through a variety of environmental ways. These environmental transfer dynamics can depend on physical, chemical and environmental characteristics of radionuclides as well as the features of soil and seasonal and agricultural characteristics of the said food. After radioactivity precipitation on agricultural land, catering behaviours, the amount of the food consumed and agricultural characteristics of the region are the factors determining the radiation of people. Besides, the activity rates of radionucleides in the food; decrease according to the type of the radioactivity, the type of food and type and time of food preparation.

Average active doses for life were estimated as 0.884 mSv for adults and 0.766 mSv for 2-7 year old children as the date of the accident on the basis of average amount of food consumption according to ages and annual average activity concentrations measured in various food and drinking waters up to now.

Average dose rates which were calculated according to regions were indicated in Figure 3. In calculations made for the 4 regions, since only the data provided by two centres in Turkey are selected to calculate the average air measurements, average radioactivity values in food and consumption habits in Turkey, the difference of total active dose between regions principally results from external radiation from the ground.



to regions (mSv)

After the Chernobyl accident, the increase of thyroid cancer in people who had been exposed to a high thyroid dose as a result of intake of 131I into the body was observed earlier than expected. The average of the equivalent thyroid doses caused by respiration of the radionuclides in the air or radionuclides taken into the body by consumption of food or water was 4,2 mSv for those who were adults at the time of the accident, and 14,9 mSv for those who were children between 2-7 at the time of the accident.

The most important way of the radiation-causing thyroid dose is consumption of milk including radioactive iodine. The amount of 131I gets more important in fresh cow milk because of its high consumption rate. As a result of having a lower thyroid volume and consuming milk in higher amounts, the thyroid dose is higher especially in children than in adults. For example, in 1 year old babies, 81 % of the total dose is due to milk consumption. Moreover, the dose exposed by this age group was found 9 times more than the dose taken by adults.

According to measurements in milk, one of the regions which had the highest 131I activity concentration was around Edirne province. In this respect, in 1986, average 131I activity concentration was 2826.5 Bq/l for milk samples collected from around Edirne, whereas activity concentration was 5044 Bq/l in Eskikadın where highest rates were detected. It was calculated that, in the Edirne province, the thyroid dose was 70.59 mSv for 3 month old babies; 320.52 mSv for 1-4 month old babies; 93.45 mSv for 5 year old children; 27.98 mSv for 10 year old children, 17.55 mSv for 15 year-old children and 10.35 mSv for the adults. However, thyroid dose was significantly reduced as a result of measures such as seizing milks, corralling animals, and feeding them with radioactivity-free feed.

20 years after the accident, in the light of the latest scientific data, results of evaluations and assessments for Turkey are as indicated below:

The average active dose rates for life according to specific regions vary between 1.28 mSv and 3.65 mSv for the adult living in cities; and between 1.37 mSv ile 4.49 mSv for the adult living in rural areas. These rates vary between 0.94 mSv and 2.66 mSv for 3 month old babies and between 2.31 mSv and 4.03 mSv for 1 year-old babies.

In general in Turkey, the average thyroid dose rates for life were determined as 10.71 mSv for 3 month babies, as 37.22 mSv for 1 year old babies, as 14.96 mSv for 5 year old children, as 7.86 mSv for 10 year old children, as 5.89 mSv for 15 year old children, and as 4.21 mSv for the adult.

When we take Turkey in general into consideration, the most affected regions were determined as Edirne-Eskikadın, İsmailce, Kapıkule and Büyükdoğanca regions in Trakya and Hopa-Pazar in the

Eastern Black Sea region due to intensive precipitation during the passage of the radioactive cloud.

Individual active dose rates were higher in the environs of Fındıklı, Hopa, Arhavi, Pazar, Rize and Of in the Black Sea Region as compared with other regions. However, even in this region, dose rates of two very close cities can be sharply different. In the Edirne region, the dose exposed by the people of the region could be reduced to the level of other regions of Turkey thanks to the measures adopted following the accident.

4.49 mSv which is calculated as the average of highest dose rate exposed by the adult during their whole life in Turkey is almost half of the dose exposed due to a single lung tomography and is lower than the permitted limits which are determined by ICRP and IAEA and adopted by various national authorities.

Total additional dose which was exposed within 1 year after the accident was lower than the dose exposed by people in various regions due to natural radiation.

Average rates of thyroid dose in Turkey are considerably lower than the rates of the countries most affected by the accident. However, it was considered that doses of persons who mostly consumed locally-produced food of animal origin in Trakya and Eastern Black Sea and who had been in infanthood or childhood during the accident could be higher than averages of country.

That's why, a household surveillance was carried out by Ministry of Health Cancer Control Department in Edirne- Eskikadın, Fındıklı, Pazar and Ardeşen, which were determined as the regions most affected by the accident, for the purpose of obtaining realistic data regarding influences of accident on health. Furthermore, biological dose determination was carried out for people living in the Eastern Black Sea region on the basis of blood samples taken from them.

BIOLOGICAL DOSE STUDY ON PATIENTS WITH CANCER AND THEIR RELATIVES IN BLACK SEA REGION BY CYTOGENETIC TECHNIQUES

The most reliable method which is regularly used for biological dose determination is Chromosomal Aberration Analysis (CA) in circulating blood lymphocytes of humans. This method depends on assessment of the quantitative relation between biological dose absorbed by the human body as a result of exposure to ionizing radiation and chromosome damages due to influence of radiation on chromosomes.

Micronucleus Technique (MN) is used for assessing the total chromosome damages caused by ionizing radiation and chemical agents.

On the other hand, Fluorescence in situ Hybridization (FISH) technique is the most preferred technique for retrospective studies. FISH

method shows the chromosome damages caused by radiations in the past.

Biological Dosimeter Laboratory in TAEK, Çekmece Nuclear Research and Training Centre is one of the 12 internationally recognized laboratories and the only laboratory in Turkey.

In this study, biological dose determination in the Black Sea Region was carried out in blood samples of patients who had been diagnosed as cancer but not been treated yet as well as in blood samples of their relatives. For this purpose, chromosome damages were examined through 3 different cytogenetic methods (Dicentric chromosome aberration, Micronucleus and FISH). This study aimed to clarify responses of the following questions:

Are there any chromosome damages in people of the region as a result of exposure to radiation within the last 2-3 years?

Are there any damages resulting from exposure to radiation in the past?

Are there any differences between chromosome damages of people living in this region and of the control group not affected by Chernobyl?

Is it possible to determine chromosome damages in patients with cancer, peculiar to family and / or the region?

Is it possible to specify existence of physical and chemical factors (such as toxic chemicals) other than radiation that are peculiar to the region and that cause chromosome aberration?

The first blood samples were received from Trabzon Numune Hospital on 29.09.2005. Up to now, blood samples of 58 people have been cultured for the purpose of Chromosome Aberration Analysis (CA) and Micronucleus (MN) analysis in Black Sea Region. It was observed that there were dicentric aberrations in 9 of 23 people (doses of 5 people were lower than 100 mGy) whose chromosome analyses could be performed. Almost all of these patients declared for diagnosis purposes that they had been exposed to ionizing radiation.

It was determined that MN frequency was high in blood samples of 8 people whose Micronucleus analysis had been performed. These results were due to environmental factors, namely chemical agents, rather than ionizing radiation. In recent years, it is observed that there is an increase in MN frequency of the entire society.

It is considered that the reasons of this are factors such as regularly increasing fast food consumption in our society, smoking, medical radiation, usage of medicines, environmental pollution, usage of petroleum and its derivatives. Control of this study was assigned as Isparta province and CA and MN were cultured for 31 blood samples which had been forwarded since 15.06.2006; and MN slides were assessed.

Consequently, if we take data obtained until now into consideration, it can be said that influence of exposure to radiation on chromosome damages has not been observed except radiation for medical purposes within the last 2-3 years.