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CIRCUMSTANCES OF POLLUTION BY RADIOACTIVITY RELEASED FROM CHERNOBYL IN JAPAN AND IN BELORUS

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ABSTRACT

On April 26 in 1986, the catastrophe at Chernobyl unit-4 reactor occurred about 100km north of Kiev in the Ukraine. A lot of radioactivity was released from the damaged reactor into the environment. A vast land and many people living there were contaminated by the radioactivity. After about 7 days the radioactivity reached Japan, a remote country about 8,000km from Chernobyl and was detected in all the prefectures there. Needless to say, the nuclear facility and its surrounding countryside have been highly polluted by the radioactivity. Naturally this radioactivity was found in people's bodies, too. The high concentration of 300Bq/kg (24,000Bq at weight of 79kg) was detected in the inhabitants living in Checherusk about 200km north of Chernobyl in 1991. Some estimations of 10,000 to 400,000 deaths in the future due to cancer caused by the accident were reported[0]. A catastrophe at only one nuclear reactor leads to

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global pollution by radioactivity and inflicts damage on people.

1. Introduction

Fifty years have already passed since atomic energy as a bomb was first released on July 16 in 1945. Since then nuclear detonations have been repeated more than 905 times[1,2] in the stratosphere, in the atmosphere, on the surface, underground and in the water. Recently, nuclear tests were made underground on June 8 and on July 29 in 1996 in China. So far the nations which have carried out the tests are the USA, ex-USSR, CIS, UK, France, China and India, most of which have held nuclear arms. Besides them, many other countries have been constructing nuclear reactors and storing up nuclear materials mainly or partly for atomic bombs.

A large quantity of radioactive materials are introduced into the environment by the explosions of atomic bombs and from nuclear facilities. Especially in such facilities as nuclear power plants, reprocessing plants and facilities for waste storage, enormous amounts of radioactivity are stored daily. When a reactor of 1,000 MWe(mega watts of electric power output of a reactor) runs throughout a year, radioactivity accumulated in a core amounts to more than a thousand times as much as that released by the atomic bomb in Hiroshima. For example about 2,000 MCi(mega curie; = 74,000,000 TBq(tera becquerel)) were released from the Chernobyl unit-4 on the day of the accident on April 26 in 1986[3]. Therefore it could be well estimated that an accident at a nuclear power plant would lead to global-scale radioactive pollution.

On May 25 in 1979, a nuclear reactor accident took place at Three-Mile Island in the USA and radioactivity was released into the environment. Fortunately the radioactive contamination was local, but since then, people have been afraid that another catastrophe will occur some day. Seven years later, on April 26 in 1986, one did occur at the Chernobyl unit-4 reactor. The radioactivity released from the unit-4 hit the European region of ex-USSR[4,5,6,7] and Europe[8,9]. After that, it reached Japan[10,11]. Thus global-scale pollution actually occurred.

The radioactive contamination of two regions is studied in this report: one is in Japan and the other Belorus. Although these data are mainly based on information obtained ten years ago, it is our duty as scientists to open them to the public, because the number of people suffering due to the Chernobyl accident

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is still growing year by year.

2. Methods for the Measurements of Radioactivity

There are several methods to estimate radioactive contamination levels. In this paper, the levels were measured, first, using environmental samples and then human bodies. In the future, the measured data will be used to study the influence on the human body.

(I) Environmental samples of radioactivity in the air were dust samples which were collected every day at Uji City located 16km south-east of the city of Kyoto in Japan. The high-volume air sampler (Staplex) with filters (TOYO No.5A) was used for the collection of these samples. The sampling period was from 12:00 on April 28 to 11:00 on June 20 in 1986. The sampler ran 23 hours and was suspended for an hour for cooling every day. The volume of collected air was 552m^3. These samples were measured by a Ge(Li) detector.

The measured data show the daily change of radioactivity from Chernobyl in the air. The data can be used to estimate the amount of radioactivity taken into a human body through breathing.

(II) As environmental samples for studying the distribution of radioactivity, pine needles collected throughout Japan were used. Pine trees are widely found in Japan and these needles can be collected under identical conditions, so that their age can be easily determined. Besides, the levels of environmental contamination at a certain time are reflected in the radioactivity contained in the needles from the same time. Thus pine needles germinated in spring of 1995 were chosen for the purpose. The sampling locations amounted to 64 points in 47 prefectures (all in Japan). In addition to these samples, pine needles growing in Uji City were collected every few days from April 29 in 1986. They were used for calibration on radioactivity in pine needles which had been picked up at various times in various prefectures. These samples were measured by a Ge(Li) detector.

The measured data show the distribution of radioactivity, and the data can be used to estimate its intake through food.

(III) The contamination level on the surface can be measured directly using a radiation survey meter. The survey meter of scintillation type was used for the

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investigation (August 21 to September 3 in 1990). The dose rate was measured at several points in Belorus. A measurement of the dose rate variation of the surface contamination was carried out from Minsk to Checherusk on August 28 in 1990. Measurement started at 09:21 in Minsk and ended at 14:04 in Checherusk. The distance between the two cities is about 260km.

The measured data show the contamination levels on the surface.

(VI) The levels of radioactivity in human bodies can be estimated using some kind of detection system. The portable system with a NaI(Tl) detector, a pulse height analyzer and a personal computer were used for the estimation. The survey was made in cooperation with 28 males including 14 children under 15 years old and 38 females including 14 children under 15 years old living in Checherusk in Belorus, about 200km north of Chernobyl, and of Japanese scientists staying there at the time of the survey. The investigation was carried out from August 26 to 28 in 1991.

The measured data reflect the intake through breathing, eating and drinking, and the data can be used to estimate internal doses.

3. Levels of Radioactive Pollution in Japan after the Damage of the at Chernobyl in 1986

3-1. Radioactivity in the Air at Uji City of Japan after the Accident:

Figure 1 shows the gamma-ray energy spectra of dust samples measured by a Ge(Li) detector with 80,000sec. The horizontal axis is the relative energy and the vertical is a logarithm scale of the relative intensity of gamma-rays. One spectrum was of dust gathered from 12:00 on April 29 to 11:00 on April 30 in 1986 (Dust No.1). The other was gathered from 12:00 on May 3 to 11:00 on May 4 in 1986 (Dust No.5). Typical radioisotopes such as K-40, I-131 and Cs-137 are shown in Fig.1. Potassium of mass number 40 (K-40) is a natural radioisotope with a half-life of 1.28×10^9 years and has existed since the creation of the universe. Iodine of 131 (I-131) with 8.04 days and cesium of 137 with 30.0 years are artificial radioisotopes made by nuclear fission.

Radioactivity in samples of Dust No.1-No.4 was estimated to be at the natural level. The radioactivity released from the Chernobyl unit-4 reactor was first detected in the sample of Dust No.5, and continued to be found in the samples thereafter. The radioisotopes detected in Japan were Zr-95, Nb-95, Mo-99, Tc-

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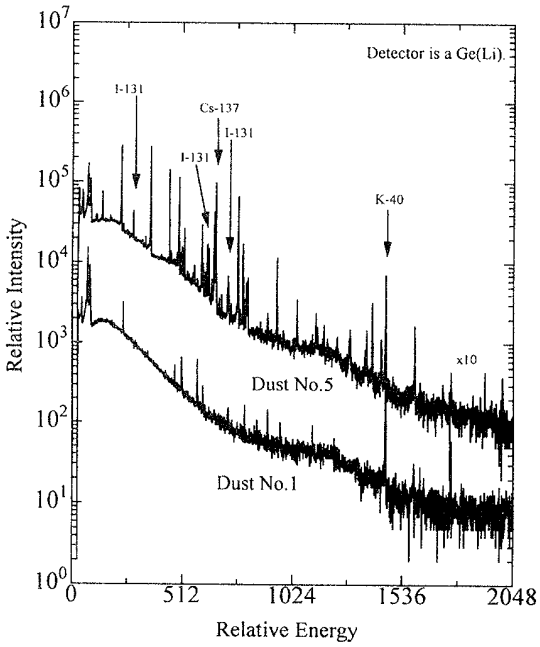

Figure 1. γ-Ray Spectra of Dust Samples

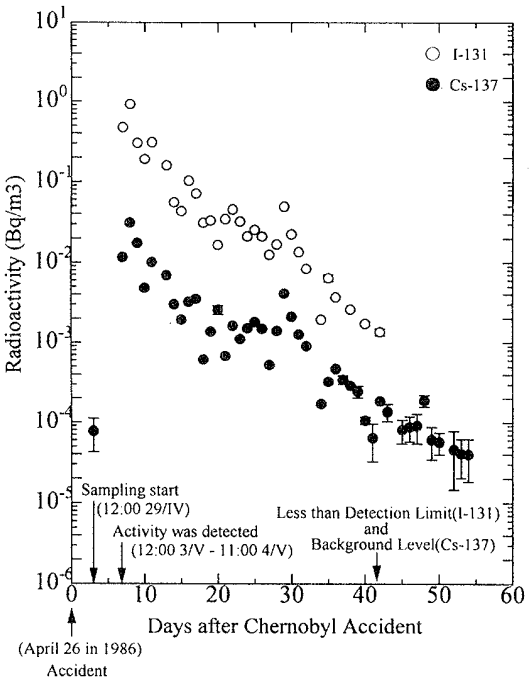

Figure 2. Daily Variation of I-131 and Cs-137 in the Air at Uji in 1986

99m, Ru-103, Ru-106, Ag-110m, Sb-125, Sb-127, Te-129m, I-131, I-133, Cs-137, Ba-140, La-140, Ce-141 and Ce-144. These are made by nuclear fission of Uranium or Plutonium. In addition to these, Cs-134 was detected, which is the special radioisotope made by neutron capture of stable cesium (Cs-133; the natural isotope of cesium) in the core of a nuclear reactor. This suggests that the radioactivity detected in Japan after the accident originated in the damaged reactor in Chernobyl.

Figure 2 shows the daily variation of the concentration of I-131 and Cs-137 in the air in Uji City in Japan. The horizontal axis is the day after the accident and the vertical is a logarithm scale of the concentration of radioactivity (Bq(becquerel)/m^3 in the air). The figure tells that the radioactivity released from Chernobyl reached Uji City at the earliest after 12:00 on May 3 in 1986 or at the latest before 11:00 on May 4 (Dust No.5). It was carried from Chernobyl to Uji City in about a week. The maximum concentration of radioactivity was Dust No.6 which was gathered from 12:00 on May 4 to 11:00 on May 5. The maximum value of I-131 was 0.92Bq/m^3 and that of Cs-137 was 0.031Bq/m^3. After that, these levels decrease suddenly. Thirty seven days after the radioactivity was first detected, I-137 could no longer be detected (<0.003Bq/

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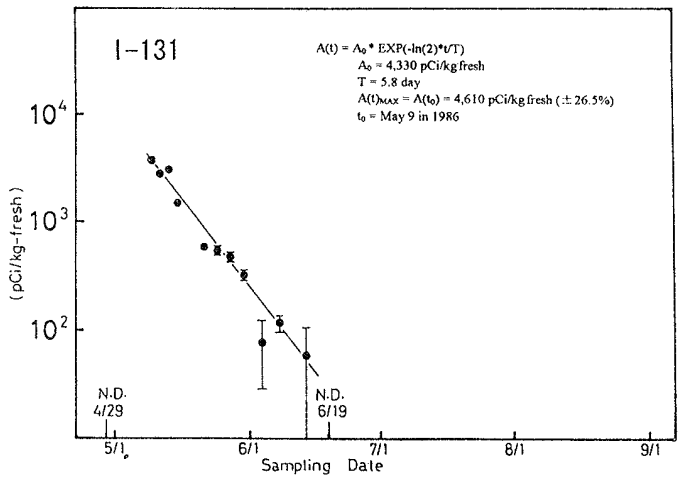

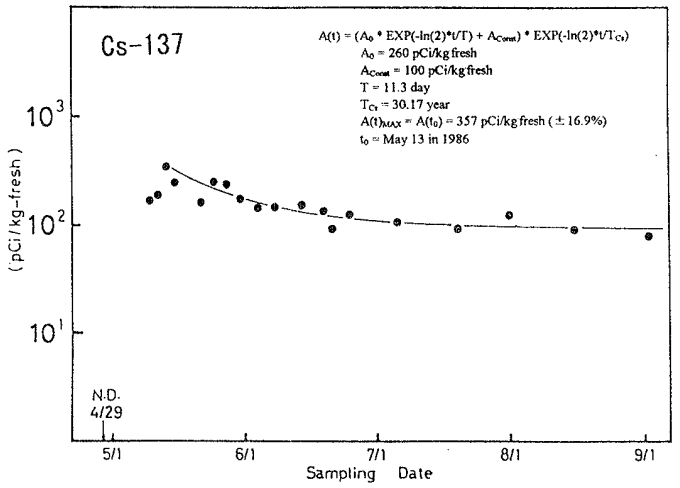

* (1 pCi = 0.037 Bq)

Figure 3. Daily Variation of I-131 and Cs-137 in Pine Needlesat Uji in 1986

m^3) in Uji City. In about 37 days, Cs-137 returned to the same level as before the accident (<0.0001Bq/m^3). These facts show us that the month following a nuclear reactor accident is the most critical period for protecting people from radioactivity in the air.

3-2. Radioactivity in Pine needles in Japan after the Accident:

Figure 3 shows the daily variation of the concentration of I-131 (Fig.3-1) and Cs-137 (Fig.3-2) in pine needles in Uji City. The horizontal axis is the day after the accident and the vertical is a logarithm scale of the concentration of

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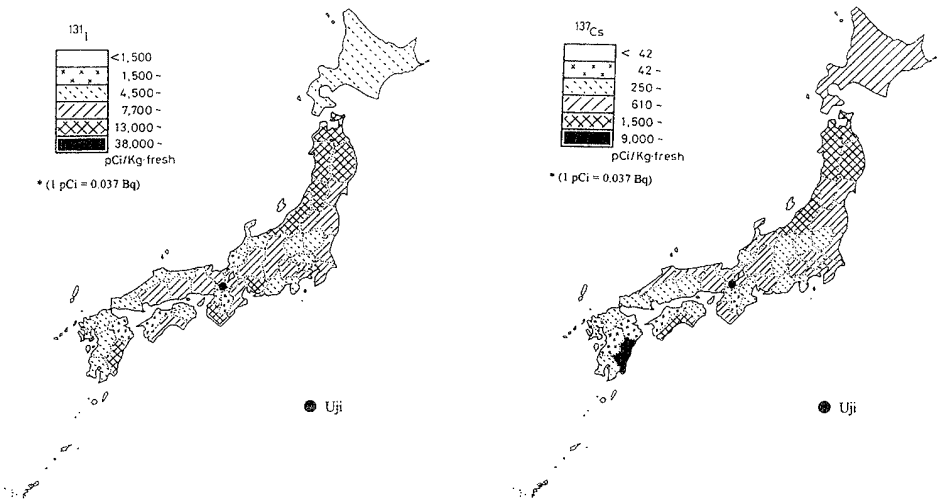

Figure 4. Distribution of I-131 and Cs-137 in Japan in Pine Needles in 1986

radioactivity (Bq/kg in fresh weight). I-131 in pine needles decreased day by day since we started detection and could no longer be detected (<2.96Bq/kg) from the samples collected on June 19 in 1986 and thereafter. Meanwhile, Cs-137 remained at a constant level of radioactivity (about 3.7Bq/kg) for more than four months though its radioactivity decreased about one fourth in the early days. These results tell that all farm products growing in the highly contaminated regions cannot be used for food. People living there need to be provided with more clean food carried from non-contaminated areas or need to migrate to non-contaminated areas. The former USSR administration adopted the policy as above[5,13]. In the beginning, the administration, however, made such a mistake as to move residents from one contaminated region to another contaminated region without conducting sufficient surveys.

The levels of radioactivity in pine needles picked up at various times from all prefectures in Japan were calibrated by using the variation of radioactivity in them at Uji City. The day that the concentration of radioactivity in pine needles in Uji City was at maximum level was May 9 in 1986 for I-131 and May 13 in 1986 for Cs-137. Figure 4 shows the relative levels of radioactive pollution in Japan in five groups. Radioactivity of I-131 and Cs-137 in northeastern Japan is higher than that of the other parts in Japan except Miyazaki prefecture which, though located in the southern part of Japan, had the hottest area of Cs-137 because of rain at the time of its arrival from Chernobyl.

In Japan, all prefectures were more or less polluted by radioactivity from

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Chernobyl. The fact suggests that there is no border for radioactivity.

4. Circumstances of Radioactive Pollution in Belorus in 1990 and 1991

4-1. Dose rates by the surface contamination in Belorus in 1990

In Belorus, some contaminated points were measured by a scintillation survey meter. The typical dose rates are shown as follows:

1) 0.06 to 0.08μSv(micro sievert)/h: in Minsk. a background (natural) level.
2) 0.22 to 0.36μSv/h: in the hotel of Vlagin.
3) 0.29 to 0.49μSv/h: at the center of Checherusk. The place was covered with asphalt after the accident and washed out with water every few days.
4) 4.10μSv/h: in Strozhevich. The point was by a house, where raindrops from a roof poured.
5) 6.20μSv/h: at a site of a village that was destroyed and buried under the ground.
6) 22.0μSv/h (on the surface): in a small park for children, which was covered with grass and located near Gomel.
7) more than 40.0μSv/h: about 200m from the Chernobyl unit-4 reactor in the Ukraine.

Many people still live in the regions 2), 3) and 4), but no one could live in these places if the Japanese regulation of 1mSv(milli sievert)/year without natural background were adopted. Though the regulation of 5mSv/year which was the formerly permissible dose advised by ICRP in 1977 was used in Belorus, it seems that the social and political situation didn't permit abiding by even such a regulation.

Figure 5 shows a variation of the dose rate of the surface contamination from Minsk to Checherusk measured all the way in a moving car. The horizontal axis is the time on August 28 in 1990 and the vertical is the dose rate. The dose rate increased as we approach the contaminated area. In one area, the dose rate jumped to a very high level when the car ran through a forest. Irregularities in the variation of the dose rate in this figure seems to be caused by relatively heavier contamination of forests.

Seeing such environmental pollution, we rightly apprehend the danger of nuclear energy even for peaceful use.

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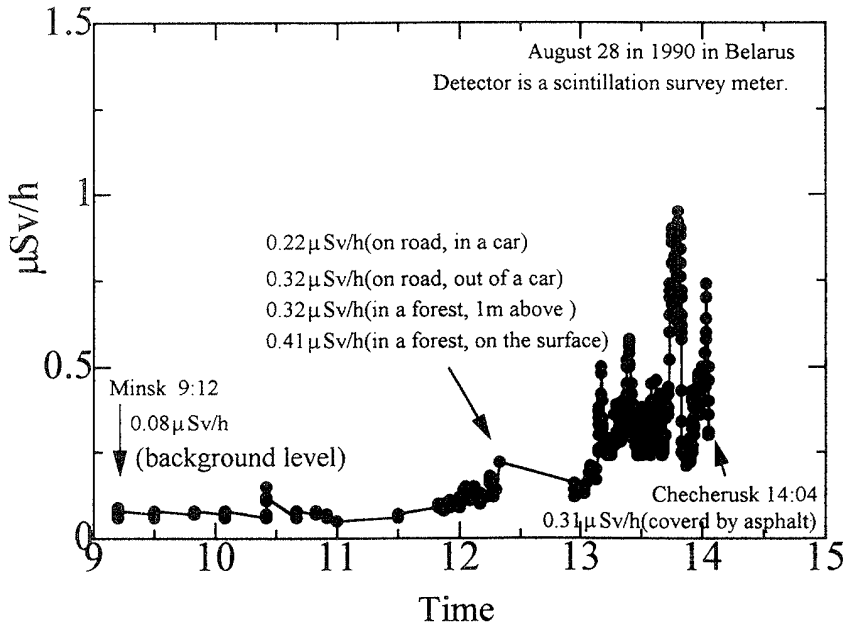

Figure 5. Variation of Dose Rate from Minsk to Checherusk on Rord in 1990

4-2. Levels of Radioactive Contamination in Human Body Living in Checherusk in Belorus in 1991

In 1991, the radioactivity in human bodies was investigated with 66 residents in Checherusk in Belorus. Figure 6 shows the typical gamma-ray energy spectrum measured by a NaI(Tl) detector. The horizontal axis is the relative energy and the vertical is a logarithm scale of the relative intensity. The upper spectrum is of a man living in the contaminated area, and the lower one is of the space of a measuring room in Checherusk Heath Center. The measuring time is 500sec for the upper and is 1,500sec for the lower. The spectrum of the room has a small peak of Cs-137, because a building of the Center was just located in the contaminated area. The spectrum of the male has Cs-134 and Cs-137. As mentioned above, the existence of Cs-134 shows that the contamination was from the Chernobyl accident.

Figure 7 shows the accumulated levels of Cs-137 in 1991 (August 26 to 28). The horizontal axis is the age of the residents and the vertical is the concentration level of Cs-137. In this work, 66 people, 28 males and 38 females, were subjected to the survey. The highest accumulation of Cs-137 in this group is about 300Bq/kg (24,000Bq in weight of 79kg) in a male. As for the accumulated level, it is

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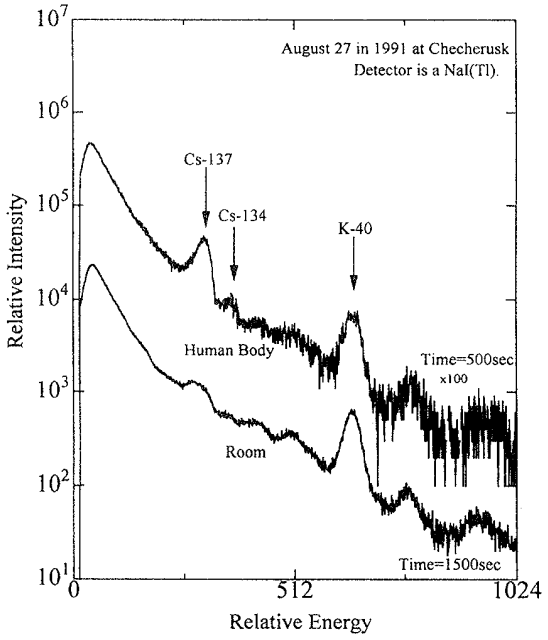

Figure 6. γ-Ray Spectra of Human Body and Background

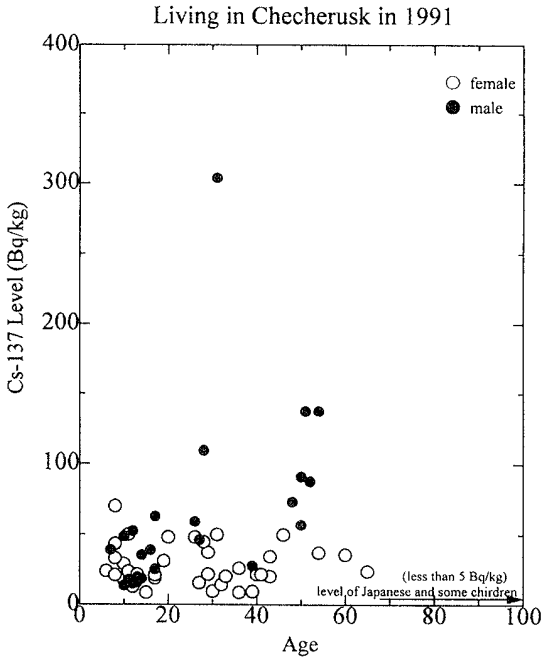

Figure 7. Accumlated Cs-137 Level of Prople Living in Checherusk in 1991

higher in adults than children. Among adults, males have a higher rate of contamination than females. Less difference was found to exist between boys and girls. Cs-137 could not be detected in 6 persons, 4 boys and 2 girls all under 15 years old (<5Bq/kg). It seems that these levels depended on their living environment including breathing, eating and drinking. The average Cs-137 intake of residents in Gomel region was 0.64μCi (23,680Bq) and that of those in the same region but higher contaminated area was 0.98μCi (36,260Bq) in 1989[12]. In this figure, the level in the bodies of Japanese visitors is shown by an arrow. The level of Cs-137 in this case was, however, too low to be detected by the detector and thus the maximum value of the detection limit of the measuring system is adopted here. This figure also shows that the residents in the highly contaminated area are even now living under conditions which make it hard to make a living. When comparing the above results to the concentration of Cs-137 in children in Germany, about 10Bq/kg in 1987 and about 1Bq/kg in 1989 and 1990[13], it is quite obvious that the region highly contaminated by the Chernobyl accident is no longer a place where people can live.

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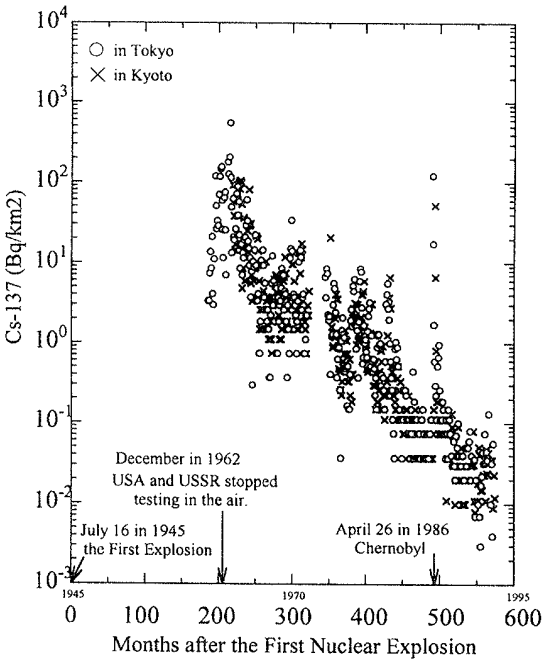

Figure 8. Months after the First Nuclear Explosion

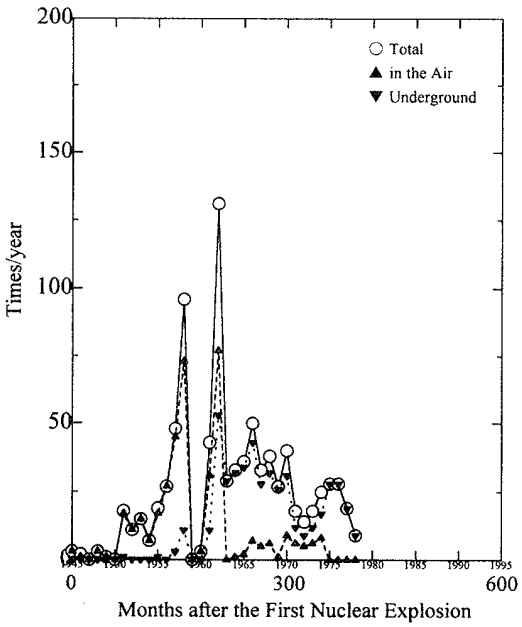

Figure 9. Times of Nuclear Explosions

5. Concluding Remarks

Before closing the present report, it is useful to compare the nuclear fallout data of nuclear bomb testing and those of the Chernobyl accident. Figure 8 shows the monthly deposition of Cs-137 in Kyoto and Tokyo constructed by using the data base of radioactivity in Japan[14]. Figure 9 shows the number of nuclear explosions in the past 600 months since 1945[1,2], including the period when the fallout data are lacking in Fig.8, that is, from 1945 to 1962. These figures and the above mentioned facts confirm that not only a lot of nuclear explosion tests but also a catastrophe at only one nuclear reactor result in global radioactive pollution.

The stern realities of radioactive pollution suggest that international cooperation is indispensable in assisting the sufferers living in areas highly contaminated by radioactivity. Radioactive pollution has no border. This fact tells us that it is necessary for people throughout the world to discuss environmental problems.

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Acknowledgment

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APPENDIX

Some terms and units appearing in this report are briefly explained in this part.

Terms:

background:

The natural level of radiation or the radiation level without a measurement subject.

becquerel(Bq):

A unit of radioactivity originating from Antoine Henri Becquerel. He discovered radioactivity in 1896. This unit has been officially used since 1986 in Japan.

curie(Ci):

A former unit of radioactivity originating from Mr. and Mrs. Curie. They discovered radioactive materials (polonium and radium) in 1898. One gram of radium has the radioactivity of 1 Ci.

dose:

A quantity for the estimation of radiation effect. Radiation dose.

electric power output of a reactor:

A unit of electric power output from a reactor. One third of the generated heat in the core of a reactor changes to electricity. Naturally two third of it is released into the environment.

external dose:

Absorption dose of radiation from outside of a body.

Ge(Li) detector:

This detector is made with a semiconductor of germanium doped lithium and has good energy resolution of gamma rays, but it needs to be cooled by liquid nitrogen.

half-life:

A period in which radioactivity decreases by half.

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ICRP:

An abbreviation for International Commission on Radiological Protection. The commission privately advises on the standard level for radiological protection.

internal dose:

The absorption dose of radiation which is released from radioactive materials taken into a body.

NaI(Tl) detector:

This detector is made with a solid scintillator of sodium iodide doped thallium and can be used under room temperature.

permissible dose:

A concept introduced by ICRP. Perhaps we can scientifically estimate total the dose of people living in contaminated regions with more exact investigations. For example, we know that people living in Japan get about 1~2mSv/year from the environment and feel the effect but we don't know how many people and/or who were killed only by environmental radiation. No one can exactly estimate the effect under the laws of probability but God. The permissible dose isn't a scientific idea.

sievert(Sv):

A unit of dose equivalent that is used for estimation of human damage.

survey meter:

A handy tool for the detection of radioactivity.

Units:

Bq(becquerel)

1 Bq = 1 decay/sec of atom

Ci(curie)

1 Ci = 3.7×10^{10} Bq

MCi(mega curie)

1 MCi = 1×10^{6} Ci = 3.7×10^{16} Bq

MWe(mega watt of electric power output of a reactor)

1 MWe = 1×10^{6} W

mSv(milli sievert) 1 mSv = 1×10^{-3} Sv

pCi(pico curie) 1 pCi = 1×10^{-12} Ci = 0.037 Bq

Sv(sievert)

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1 Sv = 1 J/kg

TBq(tera becquerel)

1 TBq = 1 x 10^{12} Bq

μSv(micro sievert)

1 μSv = 1 x 10^{-6} Sv

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