A COMPARATIVE EVALUATION OF THE CONSEQUENCES OF THE CHERNOBYL ACCIDENT BASED ON THE INTERNAL DOSE OF ^{137}Cs TO JAPANESE MALE ADULTS

M. UCHIYAMA, T. ISHIKAWA, M. MATSUMOTO, S. KOBAYASHI
National Institute of Radiological Sciences,
Ibaraki, Japan

XA9745501

1. INTRODUCTION

The Chernobyl accident released a large quantity of radionuclides into the environment. Many measurements were carried out to assess the consequent radiation doses around the world. The health and environmental consequences, however, have not been fully evaluated. The Chernobyl accident reminded us that it is important to establish methodology for the evaluation of measurements obtained with diverse methods when we estimate radiation effect in different countries. Even with limiting the assessment of internal exposure to the whole-body counting of ^{137}Cs, there still remain many unsolved factors related to dose accumulation. These include the calibration of measurements, the timing of measurements, and so on. It will take long time to develop a reliable and generally agreed upon method for the reasonable evaluation of measurements in different countries. As a substitute for such a method, the measurements of subjects from different countries at a given institution can serve for the comparative evaluation of their internal doses when one apparatus is used consistently for the measurements.

We have measured radiocesium body burdens of both Japanese and foreigners since the Chernobyl accident using a whole-body counter. In the occasion of 10th anniversary of the accident, we evaluated the body burdens in order to compare the internal doses among countries.

2. MATERIAL AND METHODS

A whole-body counter at the National Institute of Radiological Sciences (NIRS) was used to measure the radiocesium body burdens of the human subjects under evaluation. The counter is equipped with two identical NaI(Tl) detectors 8" in diameter and 4" in thickness [1]. It was operated in a scanning mode of 5 cm/min in a shielded iron room with walls 20 cm in thickness.

Measurements were carried out on the following four groups. The first group was made up of healthy male researchers from the NIRS who resided in Chiba or Tokyo. This group was measured for ^{137}Cs every 3 months from February 1986 to December 1995. This group was used as the reference for comparative evaluation with the other groups. The subjects of second group were healthy adult individuals who visited the NIRS from various locations within Japan during spring, early summer or autumn of each year. The third group was composed of Japanese returnees from the former USSR and European countries, where they had resided for some duration after the accident. This group included subjects of both genders with a wide spectrum of ages. The fourth group was made of both male and female adult subjects, mainly from European countries that occasionally visited the NIRS.

The internal dose of ^{137}Cs to the whole-body was estimated using the Medical Internal Radiation Dose (MIRD) method. The difference in the specific absorbed

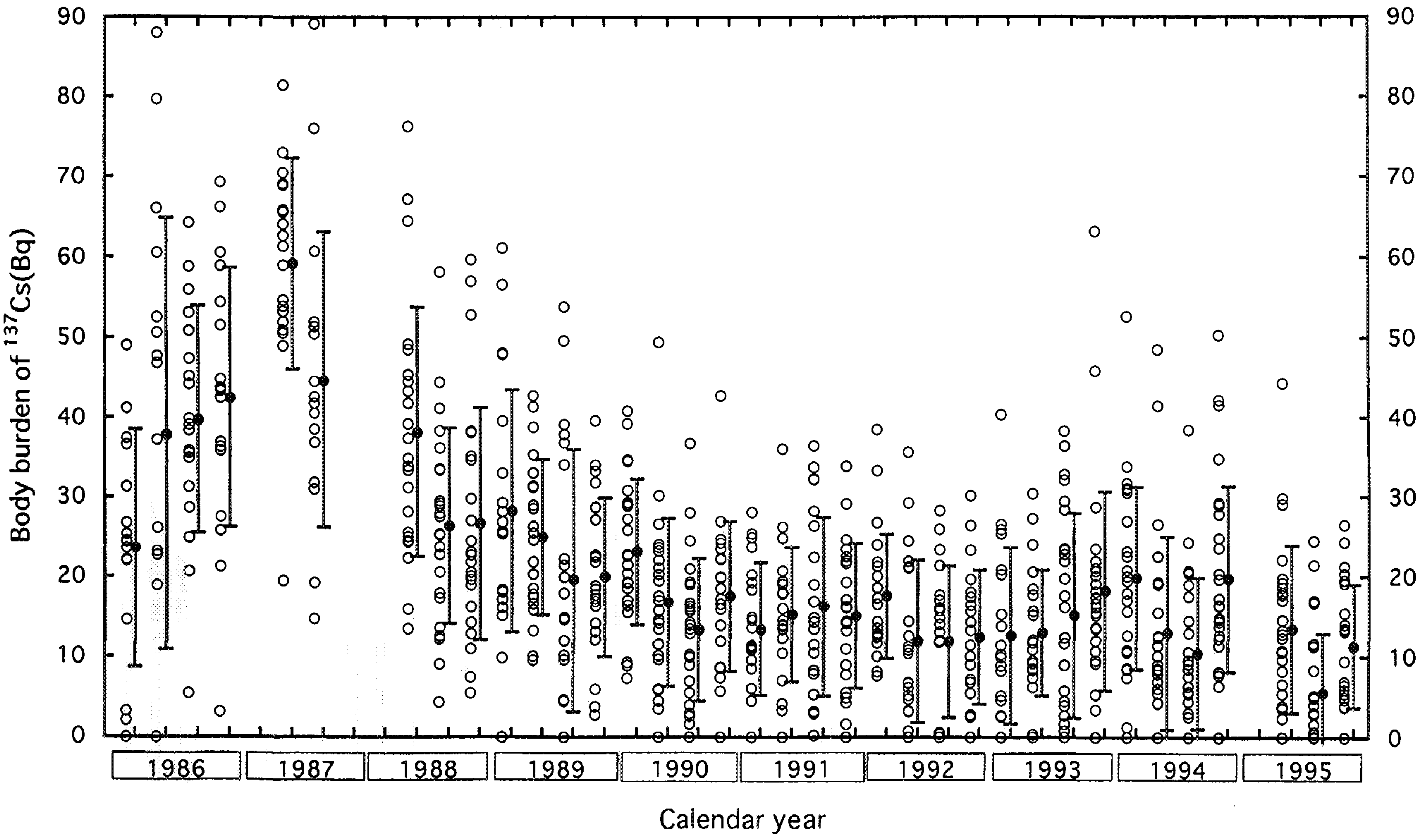

Fig. 1 Temporal changes in ^{137}Cs body burdens for a selected male adult group of Japanese.

fraction to penetrating radiation in weight between the subjects and the standard man of the MIRD was taken into account and the actual absorbed fraction was corrected accordingly [2].

3. RESULTS

3. 1. Japanese subjects

For the first group, ^{137}Cs body burdens were indicated as a function of time as shown in Fig. 1. The body burden began to increase in May 1986 and it attained a maximum of 59 Bq in May 1987. This was the estimated maximum consequence of the accident on the radiocesium body burden for the first group. The temporal change in their average body burden can be explained by a single-compartment model. The average individual dose was 1.5 μ Sv for the first year. Using the above mentioned single compartment model for ^{137}Cs body burden, together with the daily ^{137}Cs intake data for each district in Japan, consequences of the Chernobyl nuclear power plant accident on the Japanese people were assessed. The doses were an average of 1.24 μ Sv and 148 man Sv for the population of 120 million for the one-year period from May 1986 [3].

The annual change in the body burden decreased with a human radioecological half-time of 1.8 years by May 1991. Five years were sufficient to reduce the effects of the accident to the level before the accident for the first group. The dose from radiocesium was below 2 μ Sv/year even in the most contaminated period. The cumulative dose for 5 years was estimated to be 5.6 μ Sv. After May 1991, the body burden fluctuated erratically, reaching a small peak of 16Bq in 1993.

When comparing the human radioecological half-time and the cumulative dose of ^{137}Cs body burden due to the worldwide fallout from the atmospheric nuclear weapons tests carried out during the years 1961 and 1962 on the fifth group of Japanese male subjects [4], the half-time is 0.3 years longer in the first group. The variance in the half-times between the first and the fifth groups can perhaps be explained by the difference in the contribution of imported food to the total food consumption in Japan. The consumption of domestic products decreased rapidly from 91% in 1964 to just 65% in 1991. The cumulative dose is much smaller than the committed dose of 82 μ Sv to the year 2000 that includes the dose from the atmospheric nuclear explosion tests carried out over approximately 20 years from 1963.

The trends and the levels of ^{137}Cs body burden in the second group were similar to the first group. This suggests that the dose caused by ^{137}Cs intake in Chiba was insignificantly different from that in other areas within Japan, although a larger distribution was observed among individual body burdens in the second group.

No detectable health risk was expected for the two groups or the Japanese population.

3.2. Japanese returnees

A regression line for the biological half-time on the body weight was obtained for 16 individuals in the third group, the Japanese returnees. The half-time (Tb in days) was expressed as 1.14 times W (body weight in kg) +9.47 with a correlation coefficient of 0.72. When a subject could not be measured for the body burden immediately after their return, the body burden on the day of return was estimated using the formula explained above. As for the third group, the relationship

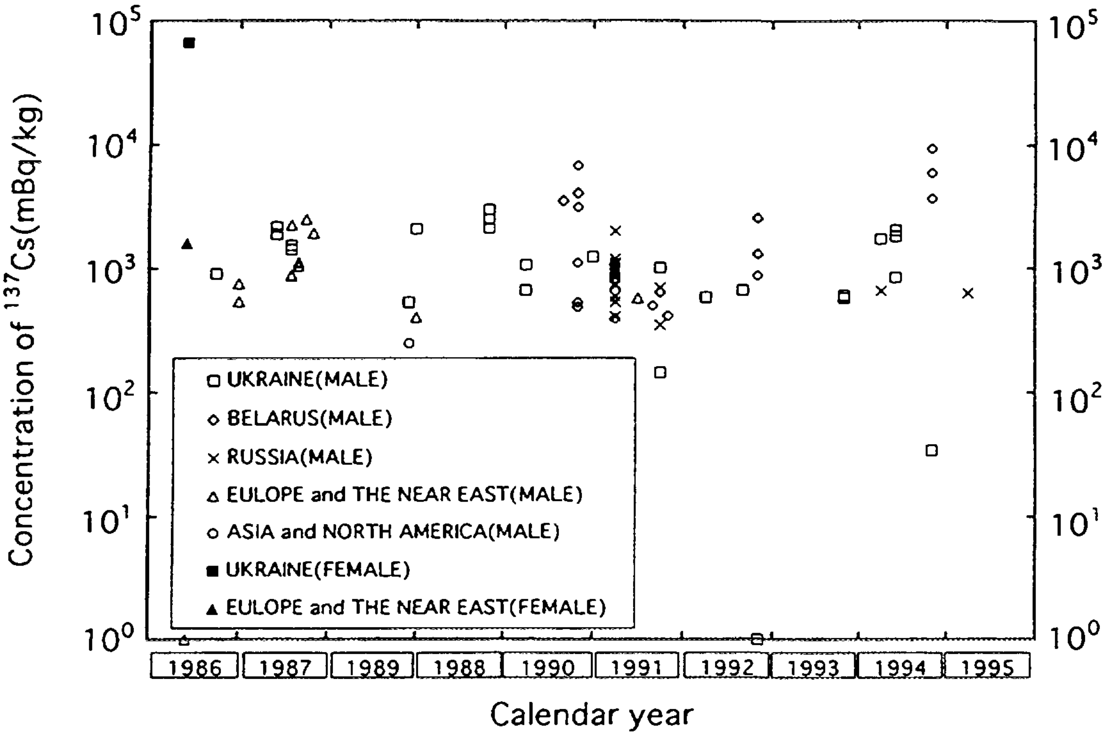

Fig. 2a Temporal changes in ^{137}Cs concentration in whole-body for Japanese returnees. - Period of stay < 1 month -

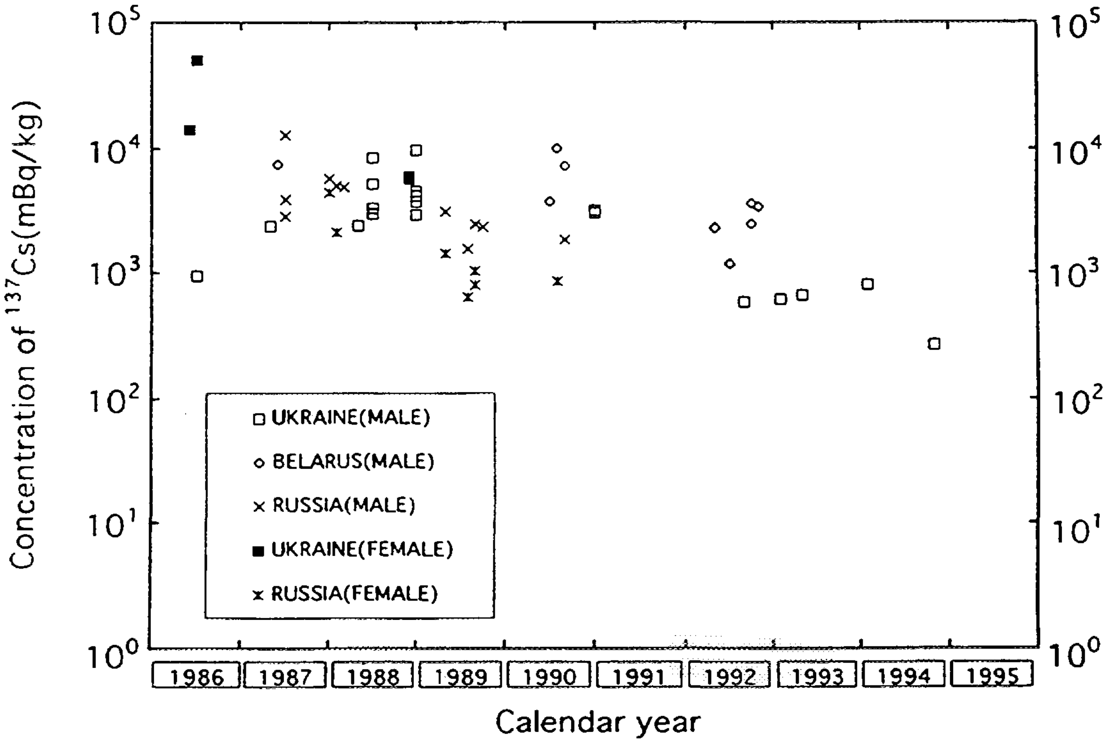

Fig. 2b Temporal changes in ^{137}Cs concentration in whole-body for Japanese returnees. - Period of stay ≳ 1 month -

between the time elapsed after the Chernobyl accident and the duration of each individuals' stay according to the length of their stays: less than 1 month and 1 month or greater. The secular changes in the concentration of ^{137}Cs in the body are explained graphically for the subgroup 1 in Fig. 2a and for subgroup 2 in Fig. 2b. The number of individuals as of December 1995 was 82 for subgroup 1 and 59 for subgroup 2.

3.3. Foreigners

The fourth group was composed of foreigners who visited the NIRS occasionally. It was divided into 5 subgroups according to origin of each subject. They were; (1) Ukraine; (2) Belarus; (3) Russia; (4) the rest of Europe except for just mentioned 3 areas and the Near East; (5) Asia and North America. Only one foreigner was measured before the year 1988, a subject from Hungary in July 1986. Figure 3 represents annual changes in the ^{137}Cs concentration in mBq/kg. The highest concentration of ^{137}Cs including ^{134}Cs was 67,400mBq/kg. It was observed in a male Ukrainian. The subjects from the most affected countries, Ukraine, Belarus and Russia were principally at similar levels to one another by 1992. A slight increasing tendency was observed thereafter with occasional high levels. Foreigners from Europe and the Near East had larger concentrations than the first group. The concentration in subjects from Asia and North America did not exceed the level of the first group. This tendency in the concentration of body burden primarily coincided with the order of areas contaminated with fallout radiocesium of the Chernobyl accident that had been analyzed by the UNSCEAR in 1988 [5].

In Kiev, the concentration had decreased considerably by 1991. The trend was complicated from then on. The circumstances in Belarus and Russia were similar to Ukraine as described above. It must be emphasized that in all the former USSR regions under study, there were individuals who showed ^{137}Cs concentrations at extreme levels, sometimes as much as two orders higher than that for the first group.

The consequences of the Chernobyl accident on the citizens in Kiev in Ukraine, Minsk in Belarus and Moscow in Russia were evaluated according to the ratio of ^{137}Cs concentration for the third and fourth groups to that in the first group. The ratio of ^{137}Cs concentration in the whole-body to the first group was about one-twentieth for the third and fourth groups. In Minsk, an increasing trend in the ^{137}Cs concentration was observed from 1992. The ratio to the first group was approximately at the same level as Kiev. A fairly large distribution in the concentration existed in individuals from these cities. In Moscow, the concentration decreased to one-seventh in 1990. Thereafter it seems to show an increasing trend. The ratio to the first group was rather large, one-sixth to one-eighth for Moscow. The doses of the groups mentioned above were evaluated relative to the dose in the first group. The risk can be estimated to be not larger than 2 orders greater than the first group. These dose evaluations led us to conclude that there may not be any serious consequences expected for the health of individuals in the third and fourth groups except for some extreme cases.

3.4. Estimate of ^{137}Cs ingestion by citizens in Kiev and Moscow

A model was used to describe the temporal change in radiocesium body burden following the continuous ingestion of radiocesium. The daily amount of radiocesium intake in mBq per kg of body weight was estimated for the returnees. The regression of the estimated concentration of radiocesium resulting from the

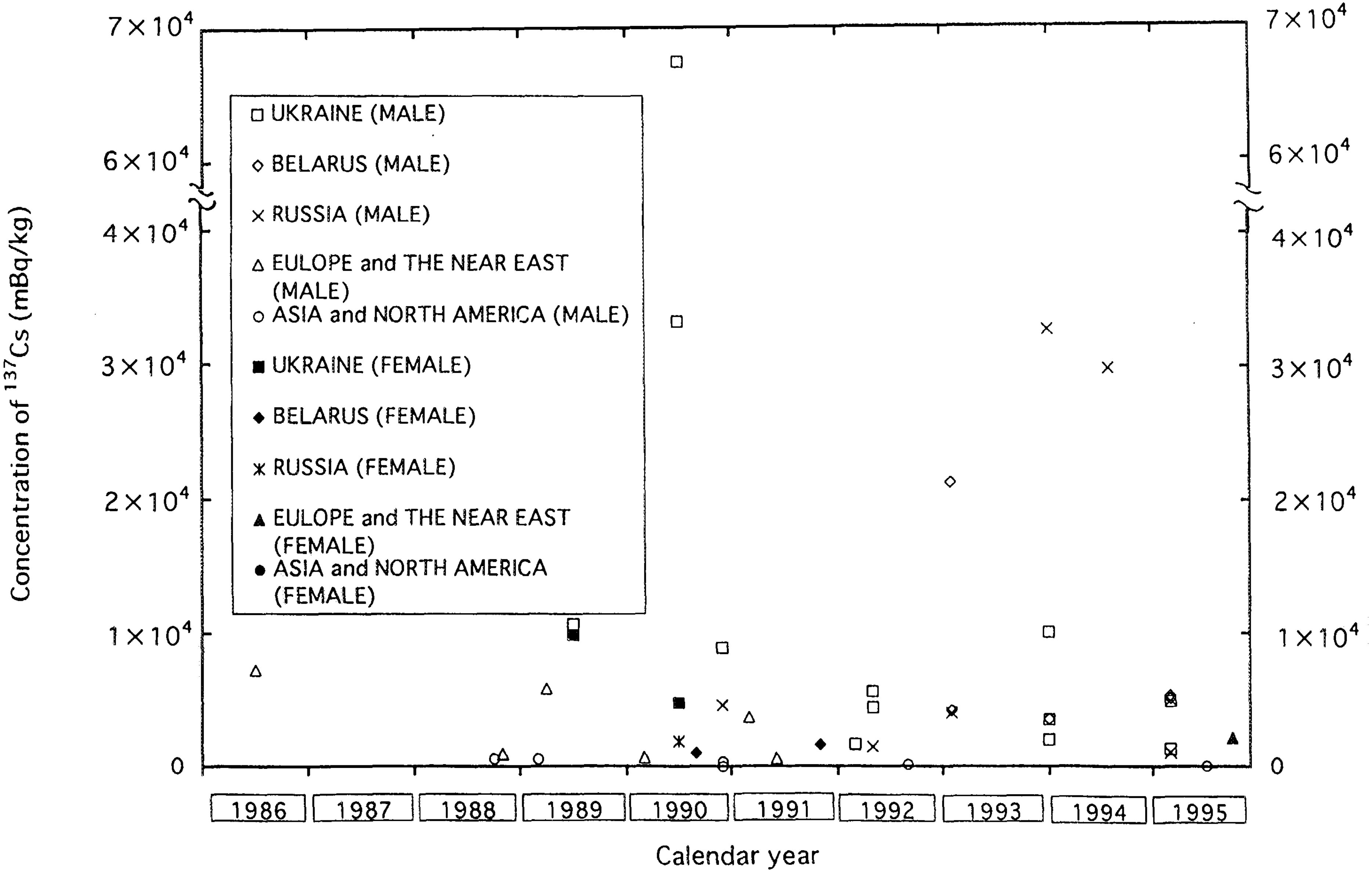

Fig. 3 Temporal changes in ^{137}Cs concentration in foreigners that occasionally visited the NIRS.

daily intake of ^{137}Cs against the elapsed time after the Chernobyl accident varied according to the period of the analysis. For the people that returned from Kiev, an apparent half-time of 460 days was estimated for adults for the period from 1986 to 1992. It varied from 391 to 920 days when changing the period or the number of individuals included in the analysis. For the returnees from Moscow, the apparent half-time was estimated to be 358 days for the period from 1987 to 1990. Recent measurements indicate trends in ^{137}Cs body burden that can not be explained by the current methods of estimation. However, a decreasing trend in the body burden was observed in returnees who consumed strictly controlled foodstuffs. This indicates that the regulation of the food distribution systems might have loosened up in the former USSR countries. The prognosis of dose estimation should be changed with regard to this situation.

4. Conclusion

The internal dose from radiocesium due to the Chernobyl accident was estimated to be 5.6 μ Sv for 5 years for the body burden of Japanese male adult group. The highest average recorded level was 59 Bq in May 1987. No detectable health risk was expected for the Japanese population. In Kiev, the concentration had decreased considerably by 1991. The trend was complicated from then on. The circumstances in Belarus and Russia were similar to that in Ukraine. The ratio of ^{137}Cs concentration in the whole-body to the first group ranged from about one-twentieth for Kiev to one-seventh in 1990 for Moscow. A fairly large distribution in the concentration existed in individuals. It must be emphasized that in all the former USSR regions under study, there were individuals who had ^{137}Cs concentrations at extreme levels. The risk can be estimated as being not larger than 2 orders greater than the first group. These dose evaluations led us to conclude that there may not be any substantial consequences to the health of individuals expected in the third and fourth groups, except for some extreme cases.

Acknowledgment
The authors would like to extend their grateful acknowledgment to Mr. Damien Andrews for his help in correcting the English in this manuscript. They are also thankful to Ms. Noriko Kuroda for her excellent help in the preparation of this manuscript.

References

[1] ETO, H., et al., The whole-body counter at the Japanese national Institute of Radiological Sciences, Whole-body Counting, IAEA, (1962) 211-18.
[2] BRONELL, G.L.,et al., Absorbed fractions for photon dosimetry, J. of Nucl. Med.,suppl.no. 1,pamphlet no. 3 (1968) 27-39.
[3] UCHIYAMA, M. and KOBAYASHI, S., Consequences of the Chernobyl Reactor Accident on the ^{137}Cs internal dose to the Japanese population, J.Environ.Radioactivity 8 (1988)119-127.
[4] UCHIYAMA, M., et. al., Body burdens of ^{137}Cs in a selected group of male adult residents in Chiba, Japan from 1967 to 1976, Health Phys., 42 (1982)145-150.
[5] SOURCES, EFFECTS AND RISKS OF IONIZING RADIATION, United Nations, New York(1988).