THE IMPACT OF THE CHERNOBYL ACCIDENT ON THE ITALIAN POPULATION: A REASSESSMENT

XA9745477

S. FABBRI, R. SOGNI
CRR-PMP-SFA, Azienda USL,
Piacenza, Italy

G. TARRONI
ENEA-AMB-IRP,
Bologna, Italy

E. TABET, A. ROGANI
National Institute of Health,
Rome, Italy

1. RADIOACTIVE CONTAMINATION DISTRIBUTION IN ITALY

As the radioactive contamination distribution has been very inhomogeneous in Italy, the dosimetric evaluations have been carried out on the basis of radioactivity values averaged over three geographical areas corresponding to Northern, Central and Southern Italy.

The most significant food matrices, in addition to air and soil, have been taken into account: milk, cereals, meat, vegetables and fruit.

The highest contamination levels have been found in Northern Italy; for this area, figures 1 and 2 show, as an example, the specific activity of iodine 131 in leafy vegetables and of caesium 137 in milk and cow meat until the end of 1992.

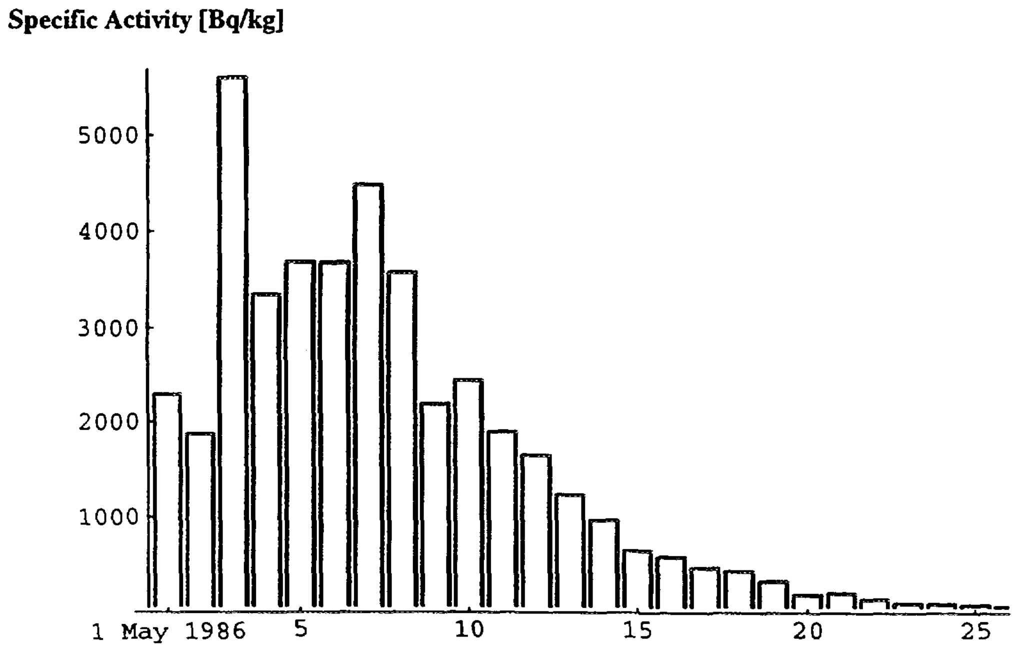

Fig.1 Iodine 131 average specific activity in vegetables, in Northern Italy, in the first month after Chernobyl accident.

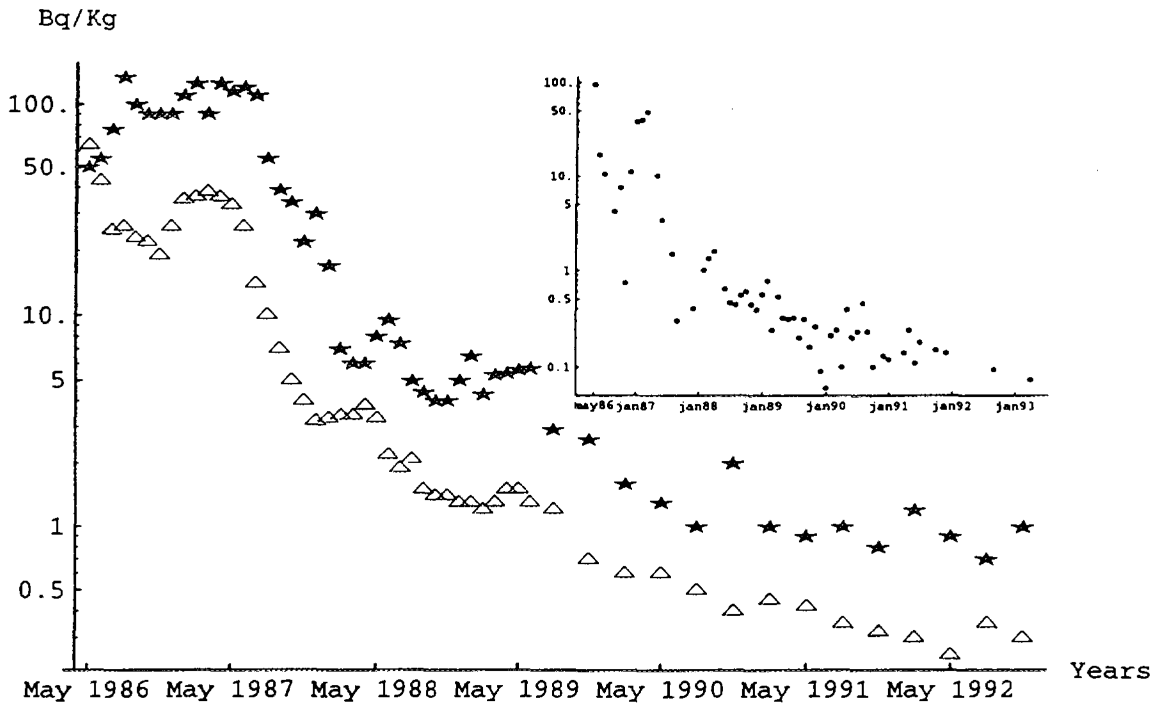

Fig.2 Cs-137 contamination levels in cow meat (indicated with the stars) and milk (triangles) in Northern Italy. The figure in the upper right corner shows the Cs-137 contamination of milk in the Emilia-Romagna district (see text for the meaning of these data in the context of global dose evaluation).

In the other areas the radioactivity levels were lower by a factor 1.5÷3. Ground deposition data for caesium 137 (the major term for external dose) were about 13 kBq/m^2 in Northern Italy, 4.5 kBq/m^2 in Central Italy and 3 kBq/m^2 in Southern Italy and were approximately twice as large as those for caesium 134. Nevertheless, the soil contamination data showed a strong dependence on local fluctuations in the rain-fall and this caused markedly different contamination levels also in adjacent areas.

2. DOSIMETRIC EVALUATIONS

The individual dose calculations have been carried out according to three age-groups: infants (0-1 year); children (7-12 years); adults .

The following exposure pathways have been considered: external irradiation from deposited material, inhalation of contaminated air and ingestion of contaminated food. The other exposure pathways (external irradiation from the cloud and inhalation of resuspended material) were negligible in Italy.

The dose coefficients internationally adopted for different pathways [1,2,3] have been used. The dose from material deposited on the ground has been calculated on the basis of average values of activity measured on the ground and a dynamic model describing the time trend of radioactive contamination [4]. The most significant contributions come from I-131, Ru-103, Ru-106, Cs-134 and Cs-137.

The exposure from inhalation and ingestion has been calculated using the average values of measured concentrations of radionuclides in air and in food, together with appropriate breathing rates [5] and dietary intake rates[6].

During the first month, three radionuclides (I-131, Cs-134, Cs-137) contributed for most of the ingestion dose; during the following time after the accident only the caesium isotopes were still significant. For the inhalation dose the most significant radionuclides were Ru-106, I-131 and Te-132.

2.1 Committed effective dose in the first year

Figure 3 shows the individual effective doses in the first year following the Chernobyl accident according to age-groups, geographical areas, and exposure pathways.

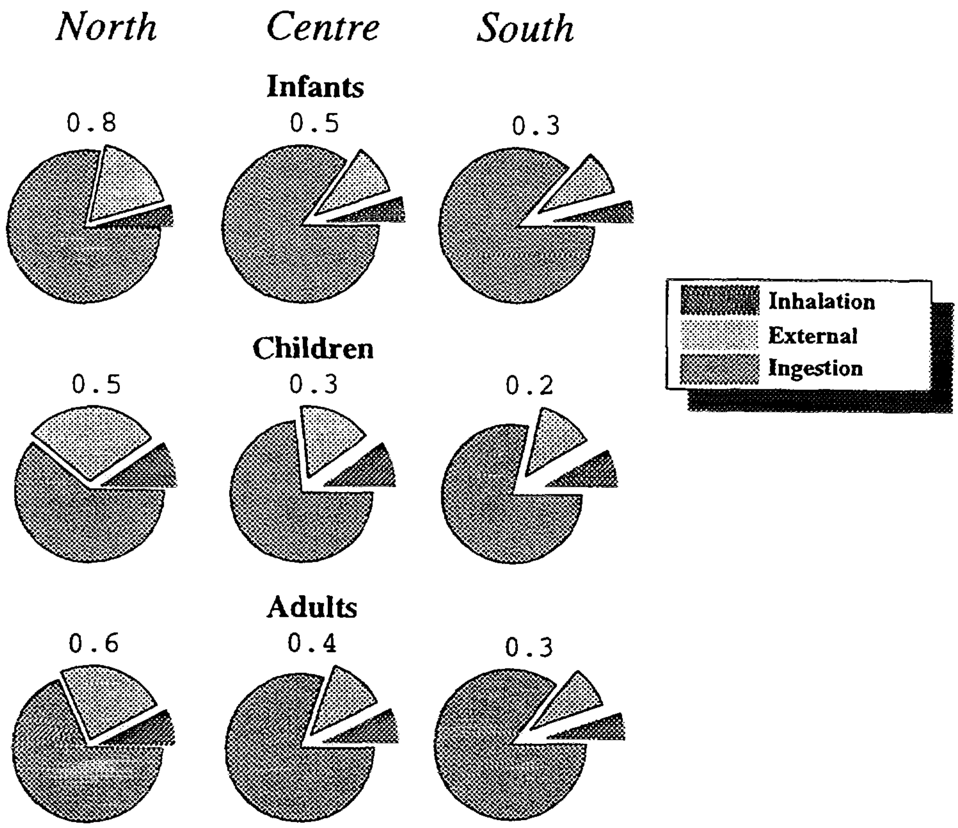

Fig. 3 First year effective dose distribution in the three main areas in Italy [values are given in mSv].

These doses have been calculated taking into account the countermeasures adopted in Italy for the consumption of milk and vegetables as shown in Table I. In all the areas the infants represent the critical group, with the highest dose being received in the North for all ages groups. Ingestion appears to be the main pathway, ranging from 60% to 85% of the total dose, according to the geographical area and the age group.

Table I. Food restrictions imposed in Italy: countermeasures period in the different areas

	North	Centre	South
Ban on sale of leafy vegetables	3/5 - 17/5	3/5 - 12/5	3/5 - 12/5
Consumption of milk by children and pregnant women	3/5 - 24/5	3/5 - 24/5	3/5 - 24/5

2.2 The effect of countermeasures

The effectiveness of the restrictions adopted in Italy on milk and vegetables consumption has been assessed, assuming that the bans were abided by strictly. The countermeasures introduced until the end of May 1986 have allowed a significant reduction of the ingestion dose from iodine 131. The largest reduction in thyroid dose is that for infants whose ingestion dose decrease ranges from 68% to 85%, according to the geographical area. Figure 4 shows the collective thyroid dose saved in Italy, equal to 105 000 person-Sv; in the same figure is reported the collective thyroid dose committed in Italy in the first year, according to age groups. In both cases, the largest contribution to collective doses comes from adults, but the other age groups contributed more than their percentage ratio with the combined population.

The overall collective thyroid dose reduction the restrictions allowed has been equal to about 54% of the expected value.

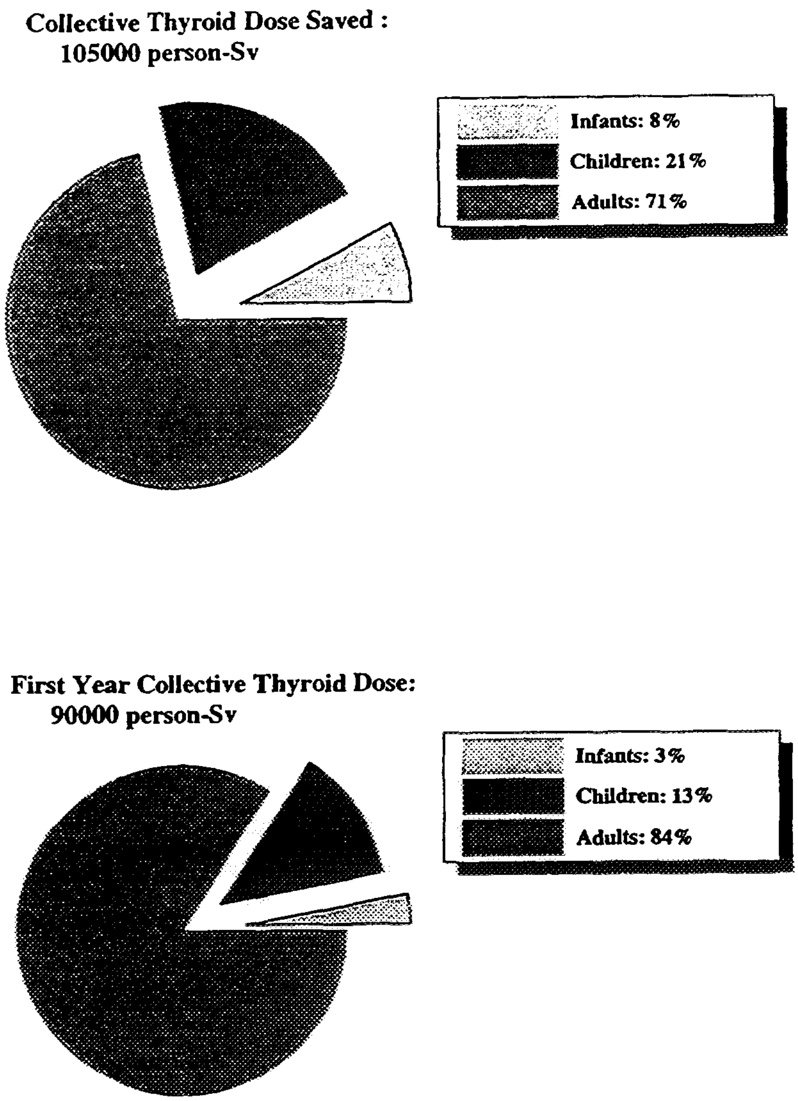

Fig.4 The effect of countermeasures in thyroid dose saving.

2.3 Time trend of the ingestion dose

In order to calculate the time trend of ingestion effective dose, the food activity levels measured in Northern Italy up to December 1992 have been considered.

In this geographical area, indeed, the values of ingestion dose have decreased down to about 1 μSv after 6 years following the accident, while in the other areas this dose value has been reached already after 3-4 years.

In order to check the time trend of ingestion dose obtained by radiometric data averaged on extensive geographical areas, the radioactivity levels measured in Emilia Romagna district (Northern Italy) have been also considered. In that district, indeed, the measurements have been both systematic and highly reliable.

As can be seen in Fig. 5, the time trend of ingestion dose calculated for adults living in Emilia Romagna matches the time behaviour of that obtained for Northern Italy.

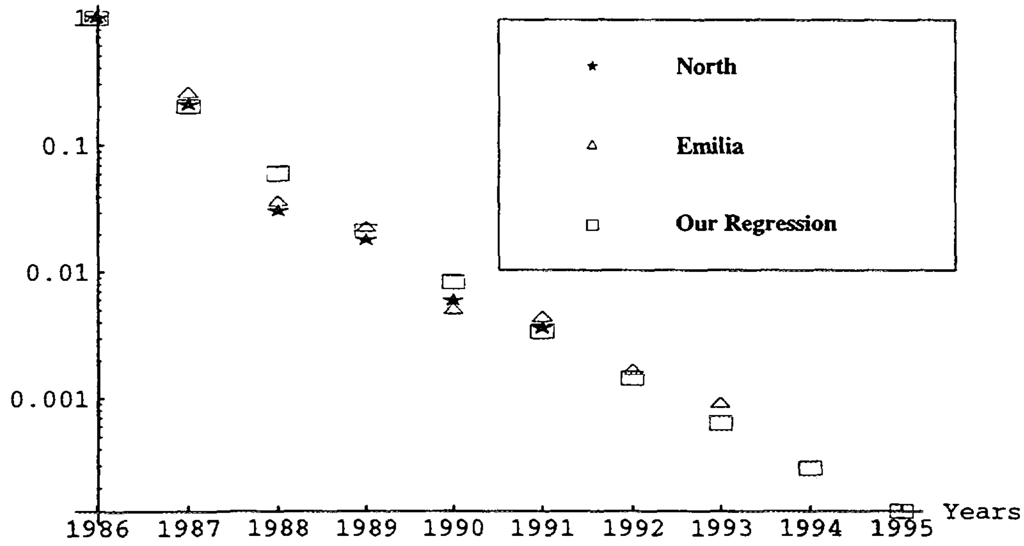

Fig.5 Ingestion doses for the North and for the Emilia district. The values, including those of our regression [with $R^2 = .99$], have been normalised to the initial (1986) value.

All the ingestion data, including those from the Central and Southern areas, and even those for the different age groups, can be shown to follow a rather simple equation of the form x^{-a} Exp[-bx] with a and b $\approx$ 1. One should, finally, stress that the dominant contribution to ingestion doses, for all the three areas, comes from the few first years terms, where the doses are still of the order of hundreds or tens of μSv.

3. EFFECTIVE DOSE COMMITMENT

By using a model which takes into account the migration of nuclides in soil [4] , the effective dose commitment due to external irradiation has been assessed.

In Fig. 6, the ingestion and external irradiation doses as a function of time in the first ten years following the Chernobyl accident are compared for Northern Italy. This figure shows that the external irradiation contribution to the effective dose becomes very soon the main term.

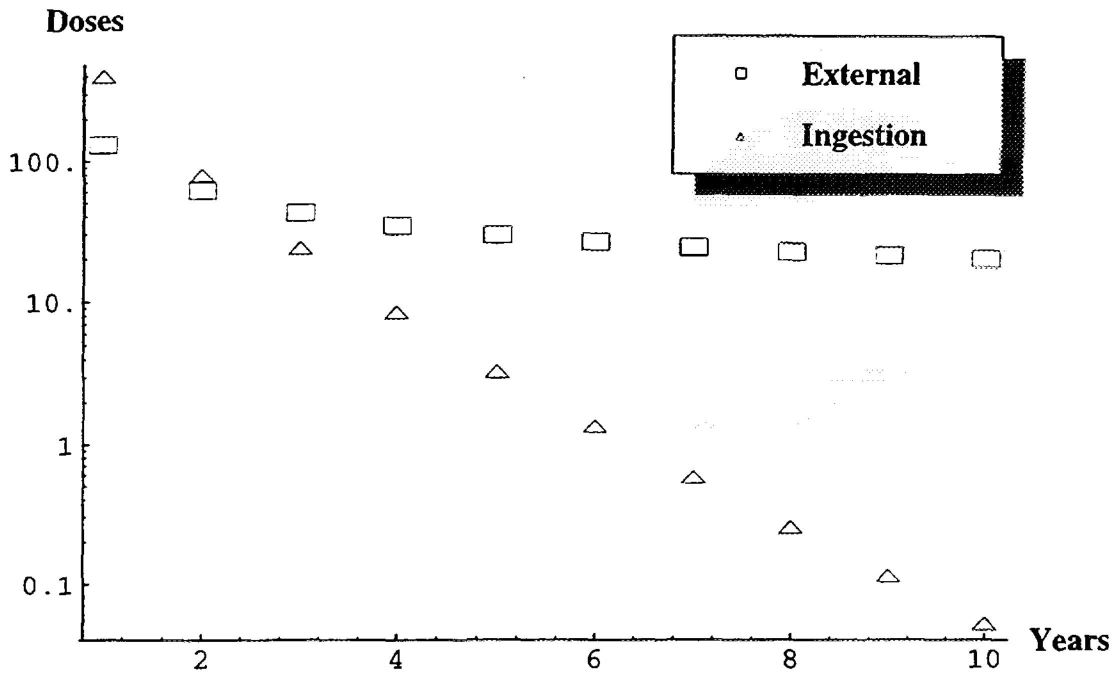

Fig.6 External and ingestion effective doses [µSv] in Northern Italy as a function of time.

Here and elsewhere, the ingestion doses on the long term have been calculated by means of the non linear fit discussed in the previous paragraph. The dosimetric evaluations as for the effective dose commitment values are shown in Table II.

Table II. Effective dose commitments [mSv] in Italy for different age groups in the three geographical areas.

	Infant	Children	Adults
North	1.8	1.4	1.6
Centre	0.9	0.7	0.8
South	0.6	0.5	0.6

The average effective dose commitment for an Italian individual is equal to about 1.1 mSv. Figure 7 shows the collective effective dose commitment in Italy, compared with the committed collective effective dose in the first year for the main exposure pathways.

The first year collective dose represents about 41% of the total dose. Moreover the ingestion is the most important pathway in the first year (75% of the total dose), while the external irradiation gives the largest contribution to the dose commitment (about 60% of the total dose).

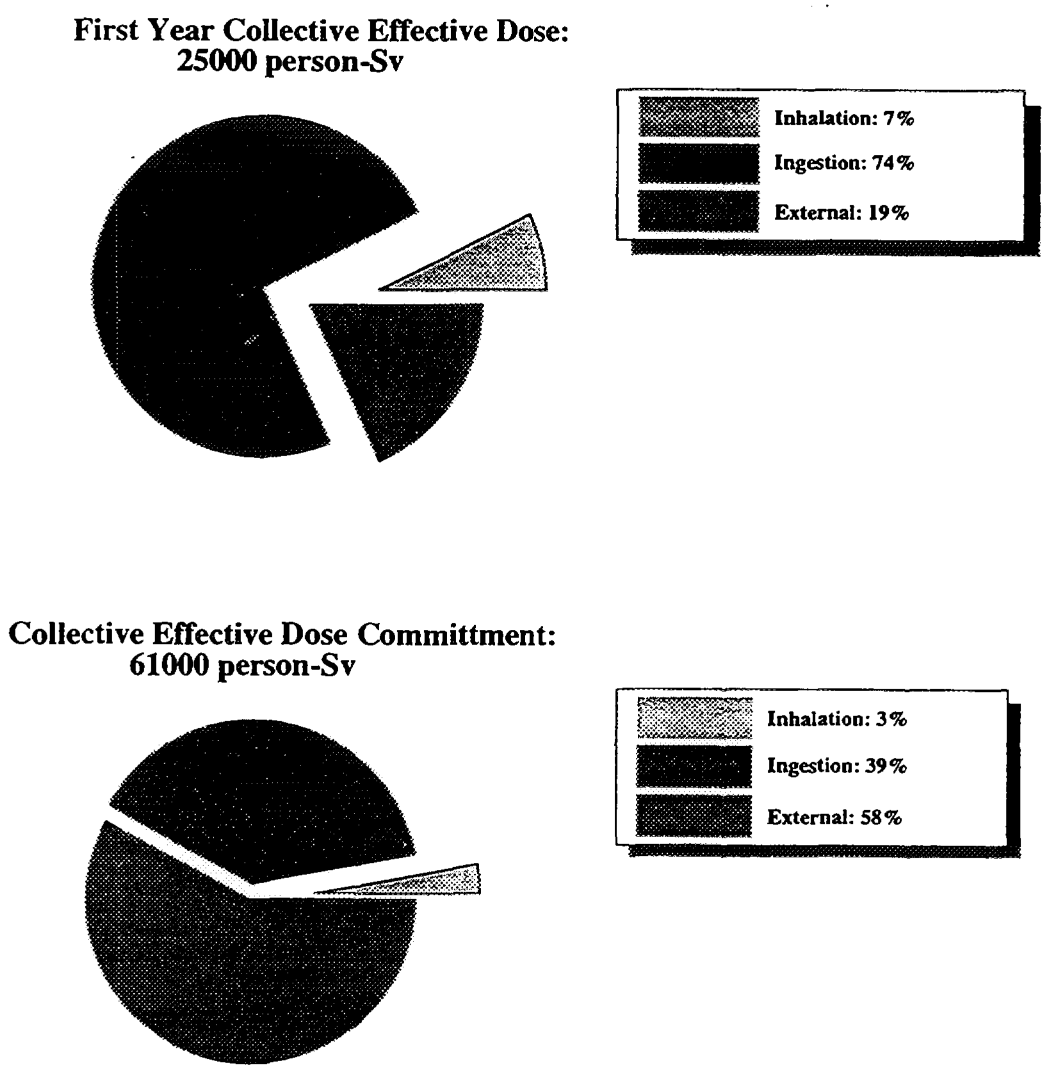

Fig. 7 Collective dose commitment and first year collective dose in Italy.

4. COMPARISON WITH DATA FROM WHOLE BODY COUNTER

Mean body activity of Cs-134 and Cs-137 were measured until September 1989 by means of the whole body counter by the ENEA laboratory in Bologna[7]. The data are referred to adults living in Bologna (Reference Group), but measurements performed on other adults living in areas surrounding Bologna (up to a distance of about 100 km) have shown that the mean activity measured in Reference Group can be taken as representative of the adults living in Emilia Romagna district. The individual effective dose due to Cs-134 and Cs-137 ingestion from WBC data have been calculated by applying the ICRP 30 metabolic model [8]; it resulted equal to 234 μSv in the period from 1 June 1986 to 30 September 1989.

This dose value has been compared with the Cs-134 and Cs-137 adults ingestion dose of 250 μSv evaluated in the same period using the food activity concentration and the dietary intake rates in Emilia Romagna [9]. Then the ingestion dose from WBC data differs only about 10% from the calculated dose.

Figure 8 shows the remarkably good agreement between the Cs-137 mean body activity measured in the Reference Group and the Cs-137 body content calculated from radioactivity levels in the food for adults living in Emilia Romagna district.

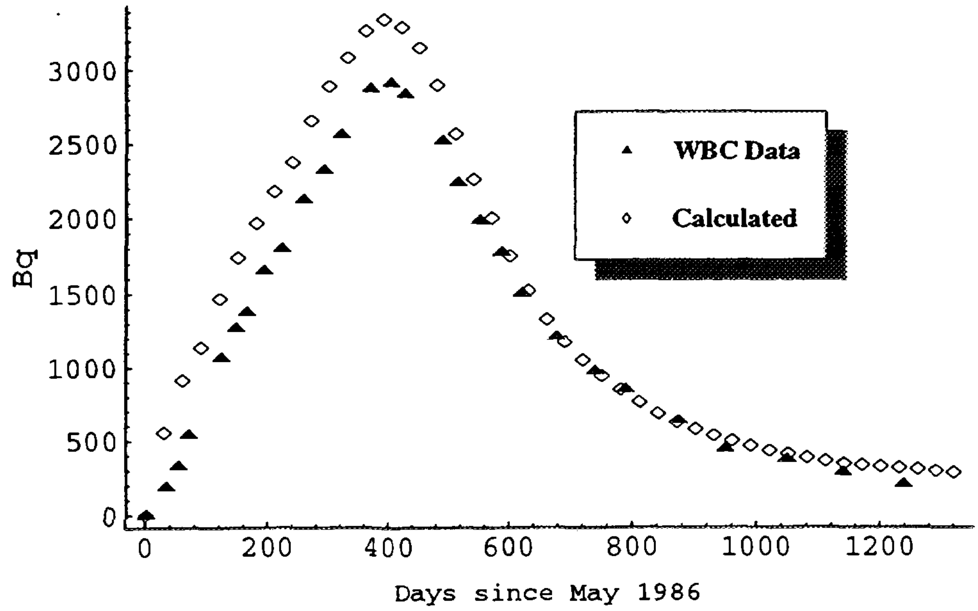

Fig.8 Mean Cs-137 body activity in adults, relative to Emilia-Romagna, compared with our calculations. The last data have been taken in September 1989.

5. STRONTIUM 90 CONTAMINATION

In the Chernobyl reactor at the time of the accident, the Sr-90 activity could be compared with that of Cs-137, whereas the OECD-NEA evaluation [10] ascribed to Sr-90 a release fraction approximately eight times as little.

The measurements in different European countries show a $\sim 10^{-2}$ ratio between strontium 90 and caesium 137. Our data confirms this ratio in the first year following the accident.
In Fig. 9 the time trend of Sr-90 concentration in milk in Emilia Romagna district, compared with that of Cs-137, clearly shows the well-known effect by which Sr-90 activity will in time equal that of Cs-137, due to the strong unbalance between the biological half-lives of the two nuclides.

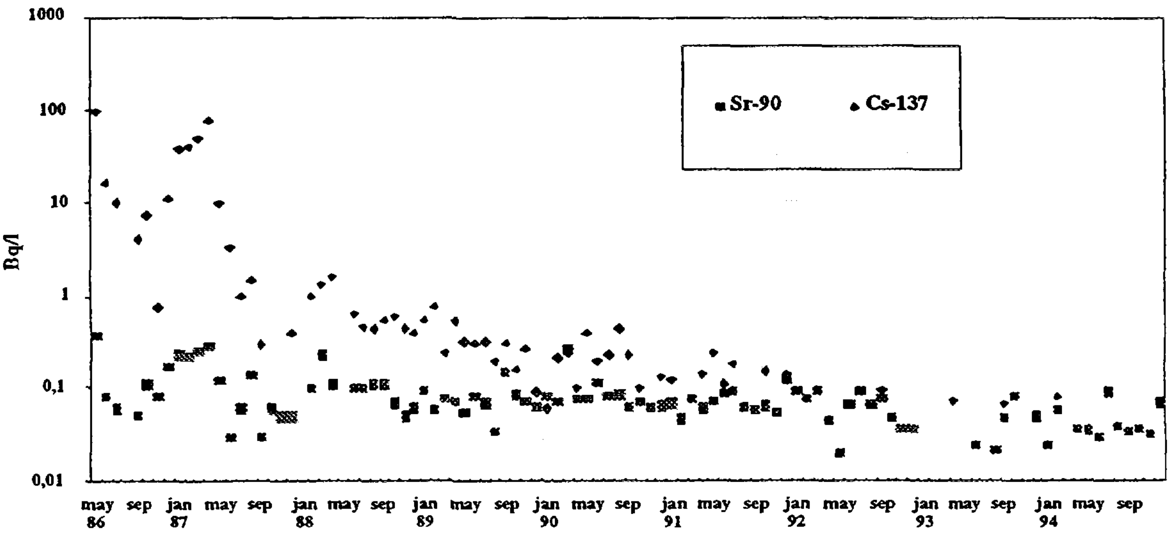

Figure 9. The time trend of Sr-90 and Cs-137 concentration in milk in Emilia Romagna district.

Dose evaluations have been performed in order to take into account the contribution to ingestion dose from the relatively weak contamination from Sr-90. The Sr-90 ingestion dose for infants starts from a few percent of the Cs-137 dose and reaches values which are comparable with those from the other nuclide in August 1987. In 1994 the ingestion dose ratio Sr/Cs is approximately equal to ten. The overall Sr-90 contribution equals about ten percent of the global ingestion dose for infants {these data are relative to the Emilia district}.

6. CONCLUSIONS

In 1987 a preliminary evaluation of the radiological impact of Chernobyl accident on Italian population was performed [11] . This evaluation took into account both the first year activity levels measured in various matrices and models for the time behaviour of radioactive contamination. It comes out that the dose assessment which was then performed is in good agreement with the present evaluation, with some differences that should be noticed. The ingestion dose, as evaluated in 1987 from the models that were then available [12], turns out to be lower than the dose now calculated from the real experimental data. Moreover, the recent change in the dose coefficients [1,2] leads to a new distribution of individual doses according to age groups, as the dose to children is significantly lowered, and becomes even smaller than that of adults.

Last, but not least, the 1987 values for the thyroid dose have been strongly reduced, mainly as a consequence of the reassessment of the corresponding dose coefficients.

References

[1] ICRP, Age-Dependent Doses to Members of the Public from Intake of Radionuclides, Part 2: Ingestion Dose Coefficients, Publication 67, Ann. ICRP **23** 3-4 (1993).

[2] IAEA, International Basic Safety Standards for Protection Against Ionizing Radiation and for Safety of Radiation Sources, Safety Series n.115-I, IAEA, Vienna (1994).

[3] NATIONAL RADIOLOGICAL PROTECTION BOARD, Derived Emergency Reference Levels for the Introduction of Countermeasures in the Early to Intermediate Phases of Emergencies Involving the Release of Radioactive Materials to Atmosphere, NRPB DL 10, Chilton, Didcot (1986).

[4] UNITED STATES NUCLEAR REGULATORY COMMISSION, Reactor Safety Study, WASH 1400, NUREG 75/014 (1975).

[5] ICRP, Human Respiratory Tract Model for Radiological Protection, Publication 66, Ann.ICRP **84** 1-3 (1994).

[6] ISTITUTO CENTRALE DI STATISTICA, I consumi delle famiglie, Anno 1987, Collana di Informazione, Edizione 1989, n.14.

[7] TARRONI, G., MELANDRI, C., BATTISTI, P., CASTELLANI, C.M., FORMIGNANI, M., RAMPA, E., ^{137}Cs and ^{134}Cs Human Internal Contamination in Italy Following the 1986 Chernobyl Event, Radiat.Prot.Dosim. **32** 4 (1990) 259-271.

[8] ICRP, Limits for Intakes of Radionuclides by Workers, Publication 30, Part 1, Ann.ICRP 2 3-4 (1979).

[9] ISTITUTO CENTRALE DI STATISTICA, Le Regioni in cifre, Edizione 1989.

[10] OECD, Chernobyl, Ten Years on Radiological and Health Impact, November 1995.

[11] ROGANI, A., TABET, E., Radiological Impact of the Chernobyl Accident on the Italian Population, National Institute of Health Report, ISTISAN 88/40 (1988).

[12] PROHL, G., FRIEDLAND, W., PARETZKE, H.G., Intercomparison of the Terrestrial Food Chain Models FOOD-MARC and ECOSYS, Report G.S.F. 18/86, Neuherberg (1986).