Prenatal Exposures Avoided in Italy in the Aftermath of the Chernobyl Accident

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Abstract. In Italy, on May 2, 1986, in the aftermath of the Chernobyl accident, the Health Minister banned the sale of leafy vegetables for the whole population and the consumption of milk for children up to the age of ten and pregnant women. In the following years a critical analysis of the avoided doses made it possible to assess the number of thyroid cancers prevented in adults, children and infants as a consequence of the ban. However, in Byelorussia, Ukraine and Russia it was shown that ^{131}I contamination of foodstuff also caused significant doses for exposure *in utero*, with a relevant significant increase of thyroid cancers in children born some months after the emergency phase. For this reason it may be worthwhile, as is done in this paper, to make use of the dose coefficients for embryos and foetuses issued at the end of 2001 by the International Commission on Radiological Protection, to assess the avoided doses for embryos and foetuses due to acute exposure of the mothers at different pregnancy stages. Calculations show that countermeasures were effective in reducing doses for embryos and foetuses, particularly for ^{131}I. Therefore, emergency planning should provide for possible countermeasures for pregnant women.

1. Introduction

In recent years, the possible health effects of prenatal exposure to ionising radiation have been re-evaluated and at the end of 2001 a new ICRP publication was issued [1] supplying prenatal dose coefficients for exposure of women at different pregnancy stages, both at work and as part of the population, due to inhalation and ingestion. This is an essential tool for making new assessments of the effects of different types of exposure (see e.g. [2]).

In the past, estimates had already been made of the doses avoided by infants, children and adults in Italy as a consequence of the ban on sale and/or consumption of some food in the aftermath of the Chernobyl accident [3, 4]. The aim of this paper is to assess the doses avoided by embryos and foetuses (in the following *offspring*), as a consequence of pregnant women's compliance with these protective measures. Particular attention was given to thyroid equivalent doses, due to the high ^{131}I concentration in foodstuffs in the first period and as there are strong indications of an age dependence for risk of induction of thyroid cancer by radioiodine, given the higher sensitivity to radioiodine of children and offspring [5, 6].

2. Food contamination in Italy

As a consequence of the Chernobyl accident, huge quantities of radioactive materials were released into the atmosphere over a period of several days with Italy also receiving a considerable amount. The radioactive contamination on Italy's territory was not uniform and for this reason the contamination data measured by various laboratories in three geographical areas were averaged [3]: Northern, Central and Southern Italy. The radioactive fallout was higher in Northern Italy, where ^{137}Cs ground deposition was found to be about 13 kBq·m^{-2}, whereas in Central and Southern Italy it was about 4.5 kBq·m^{-2} and 3 kBq·m^{-2}, respectively [4]. In figures 1 and 2, ^{131}I and ^{137}Cs concentration in vegetables and in milk, respectively, in Northern Italy are shown in the first months after the accident. It can be noted that mean concentration of ^{131}I in vegetables for Northern Italy exceeded the emergency reference level for the population set at that time by the Italian regulation [7] at 3070 Bq·kg^{-1} (or Bq·l^{-1}) (see fig.1), whereas ^{137}Cs mean concentration did not exceed the relevant

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value set at 2480 Bq·kg^{-1} (or Bq·l^{-1}). Attention levels were ten times lower for both radionuclides and it can be noted that in Northern Italy mean concentrations of both radionuclides in vegetables were much higher than those levels. In the other two areas, radioactive concentrations in vegetables were found to be from 2 to 3 times lower for iodine and even lower for ^{137}Cs. As regards milk contamination, large variations among the three areas were not observed due to different habits in animal feeding (in Central and Southern Italy temperatures are higher and external grazing is much more frequent).

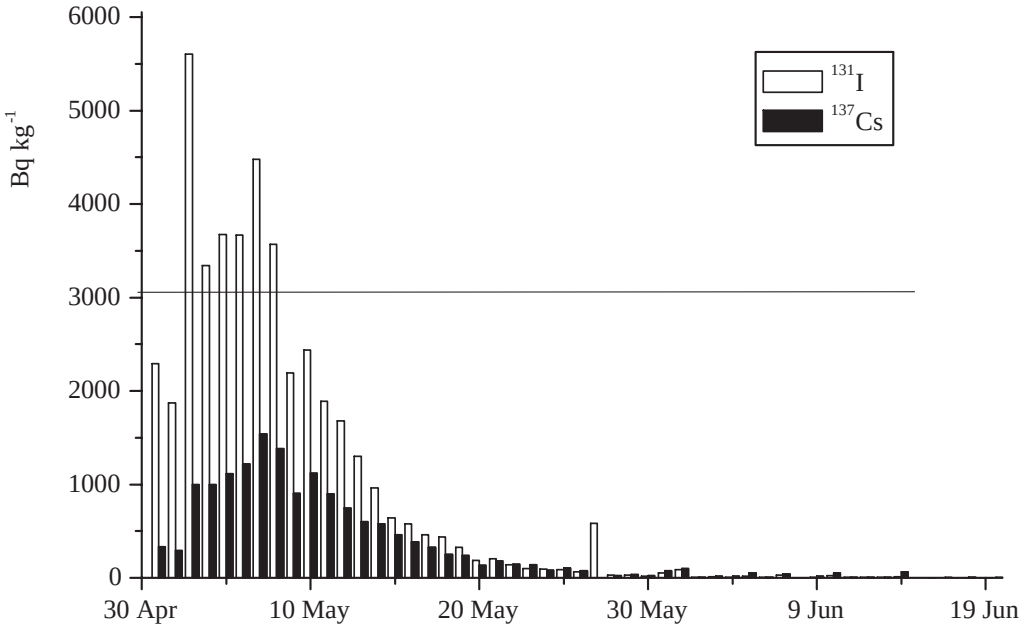

FIG. 1. Activity concentration in vegetables in Northern Italy

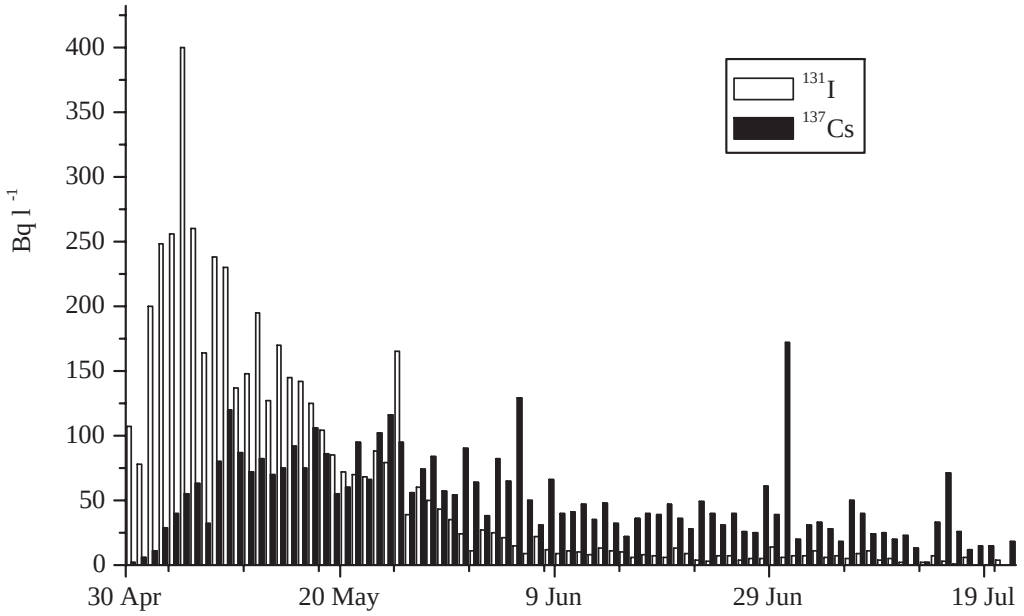

FIG. 2. Activity concentration in milk in Northern Italy

Since the ^{131}I emergency reference level for the population had been exceeded, on May 2, 1986 the Minister of Health banned the sale of leafy vegetables for the whole population and the consumption of fresh milk for infants and children up to the age of ten as well as for pregnant women. The ban lasted for different lengths of time in the three Italian areas (Northern, Central and Southern Italy) and

for the two types of foodstuffs, according to the decrease in their radioactive contamination (see table I). During the first month, the ingestion doses received by the Italian population were due almost totally to ^{131}I, ^{137}Cs and ^{134}Cs. Successively, only the caesium isotopes were still significant.

Table I. Duration of food restrictions in Italy in May 1986 [8]

Food restrictions	North	Centre	South
No consumption of fresh milk by children and pregnant women	3 – 24	3 – 24	3 – 24
Ban on sale of leafy vegetables	3 – 17	3 – 12	3 – 12

A few days after the Italian ban (May 6), the EU Commission, following several meetings of experts from Member States, issued a first recommendation [9] aimed at limiting radioactive contamination of foodstuffs in the internal market of Member States and for export outside the European Union. The levels fixed by the EU recommendation are reported in table II. These levels were to be applied to all radionuclides, but it is evident from their quick decrease that the main idea was to limit ^{131}I. It can be noted that these levels are comparable to the Italian attention levels.

Table II. EU Commission Recommendation issued May 6, 1986 [9]

From	Maximum Activity ($Bq \cdot kg^{-1}$)	
	Milk and milk products	Fruit and vegetables
May 6, 1986	500	350
May 16, 1986	250	175
May 26, 1986	125	90

3. Prenatal doses

ICRP Publication 88 [1] gives dose coefficients for offspring following acute and chronic intake of 31 elements, either through inhalation or ingestion, by the mother (members of the public as well as workers). A range of acute intake times for women is adopted both before and during pregnancy, whereas for continuous exposure a constant intake is assumed for three different periods during pregnancy or before conception.

In order to assess the effectiveness of countermeasures on offspring, ingestion doses for acute exposure for the three Italian areas – Northern, Central and Southern Italy – were calculated in the two hypotheses: pregnant women neglecting the restrictions or, vice versa, complying accurately with the adopted countermeasures. Calculations were made for thyroid equivalent doses - with the coefficients reported in table III - and effective doses - with the coefficients reported in table IV - at different pregnancy stages for acute exposures.

Table III. Thyroid equivalent dose coefficients for offspring and infants ($Sv \cdot Bq^{-1}$) [1, 10]

	week 5	week 10	week 15	week 25	week 35	infants
^{131}I	$2.4 \cdot 10^{-10}$	$3.2 \cdot 10^{-9}$	$2.4 \cdot 10^{-7}$	$6.8 \cdot 10^{-7}$	$1.1 \cdot 10^{-6}$	$3.7 \cdot 10^{-6}$

Table IV. Effective dose coefficients for offspring and infants ($Sv \cdot Bq^{-1}$) [1, 10]

	at conception	**week 5**	**week 10**	**week 15**	**week 25**	**week 35**	**infants**
^{131}I	$7.8 \cdot 10^{-11}$	$8.1 \cdot 10^{-11}$	$2.1 \cdot 10^{-10}$	$1.2 \cdot 10^{-8}$	$3.4 \cdot 10^{-8}$	$6.0 \cdot 10^{-8}$	$1.8 \cdot 10^{-7}$
^{134}C	$1.1 \cdot 10^{-8}$	$1.1 \cdot 10^{-8}$	$1.0 \cdot 10^{-8}$	$1.0 \cdot 10^{-8}$	$8.6 \cdot 10^{-9}$	$4.5 \cdot 10^{-9}$	$2.6 \cdot 10^{-8}$
^{137}C	$7.2 \cdot 10^{-9}$	$7.0 \cdot 10^{-9}$	$6.7 \cdot 10^{-9}$	$6.5 \cdot 10^{-9}$	$5.5 \cdot 10^{-9}$	$3.2 \cdot 10^{-9}$	$2.1 \cdot 10^{-8}$

In the former case only ^{131}I was considered, due to its accumulation in the thyroid. Week 5 and 10 values were not taken into account, due to the much lower dose coefficients (see table III), probably connected with thyroid formation after the third month of pregnancy. In the two tables the dose coefficients are shown together with those for infants for purposes of comparison.

The diet of pregnant Italian women has already been analysed by the authors in the past [11] showing, in particular, that in our country pregnant women do not increase their milk consumption with respect to the adult population in general. Taking this fact into account, in this paper the mean Italian adult diet at that time [12] was considered, assuming a daily consumption of 220 g of milk and 200 g of vegetables.

4. Results

The calculation (see table V) shows that the maximum avoided thyroid equivalent dose was an acute exposure at week 35 in Northern Italy, where the restrictions on the consumption of milk and vegetables allowed for a dose reduction of about 83%. This reduction is relevant only to ^{131}I ingestion, but it should be recalled that in the first months after the accident ^{131}I ingestion constituted the main contribution to the total thyroid dose for the entire population [13].

Table V. Thyroid equivalent doses avoided by offspring in Italy (mSv)

Stage of pregnancy	**North**	**Centre**	**South**
week 15	2.0	1.0	0.7
week 25	5.5	2.6	1.9
week 35	9.0	4.2	3.1

In figure 3 these avoided thyroid doses are compared with previous results [4] obtained for infants, children and adults. It can be noted that infants avoided higher doses than offspring, due to the lower milk consumption of pregnant women. In the figure, the different behaviour in milk and vegetable contamination between Northern, Central and Southern Italy, explained in the second paragraph, can also be noted: infant avoided doses in the three areas were, indeed, much more similar than those of offspring.

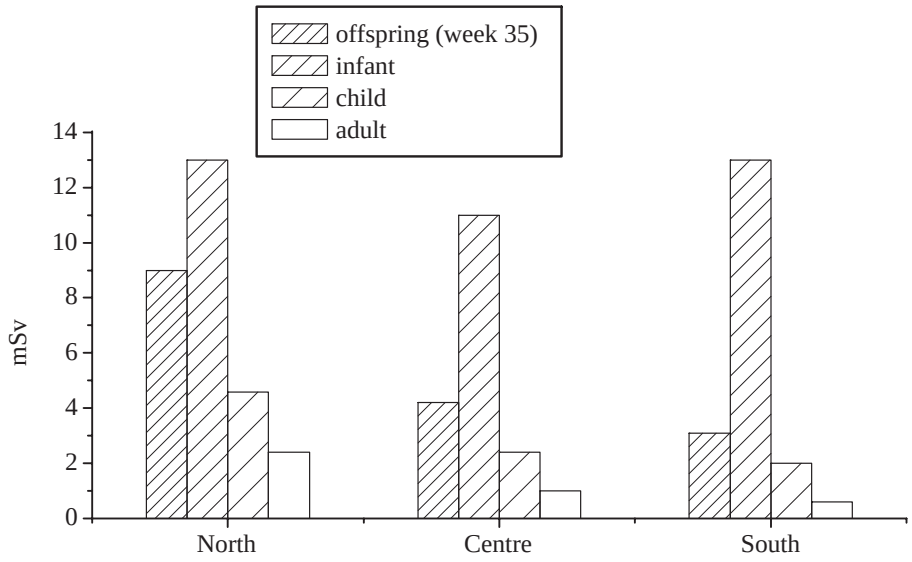

FIG. 3. Thyroid equivalent doses avoided in Italy

Analysis of the contribution of the two types of food (milk and vegetables) to the avoided thyroid dose (see fig.4) confirms, naturally, that milk is of predominant importance in an infant's diet. On the other hand, the restrictions on consumption of vegetables for the whole population (pregnant women included) is evident looking at the dose avoided by offspring.

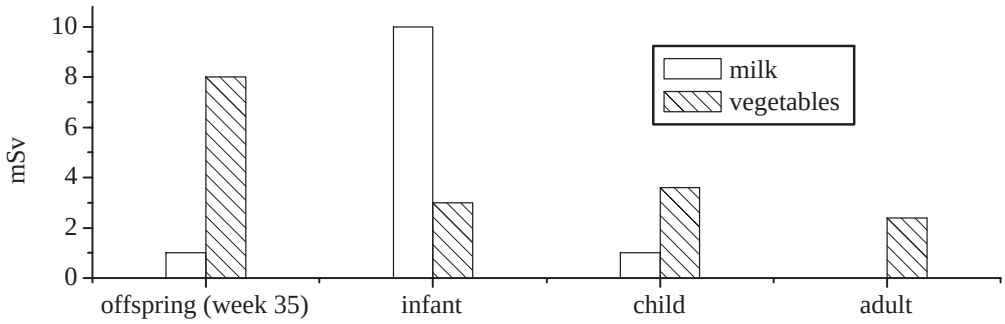

FIG. 4. Thyroid equivalent doses avoided in Northern Italy: contribution of milk and vegetable restrictions

The effective doses avoided by offspring and infants in Northern Italy as a consequence of the countermeasures are shown in table VI for iodine and caesium isotopes. In Central and Southern Italy the avoided doses for offspring were found to be from 2 to 3 times lower.

Table VI. Effective doses avoided by offspring and infants in Northern Italy (μSv)

	at conception	**week 5**	**week 10**	**week 15**	**week 25**	**week 35**	**infants**
^{131}I	$6.3 \cdot 10^{-1}$	$6.6 \cdot 10^{-1}$	1.7	97	275	486	634
^{134}Cs	26	26	24	24	20	11	21
^{137}Cs	30	29	28	27	23	13	30
Total	57	56	54	148	318	510	685

It can be noted that the largest reduction in effective dose occurred for ^{131}I (due to the high values of ^{131}I contamination in food in the period of the ban) at week 35, while for caesium isotopes this occurred at conception. Moreover, the avoided effective dose, likewise the thyroid equivalent dose, is higher for infants than for offspring.

5. Conclusion

As a result of these assessments some conclusions can be drawn.

First of all, the countermeasures adopted in Italy by the Minister of Health in May 1986 allowed for a significant reduction in thyroid doses from ^{131}I ingestion not only for the population, but for offspring as well.

Secondly, the effectiveness of the restrictions was greater for infants and offspring, due to their higher sensitivity to radioiodine. Therefore, in case of possible radiological emergency, possible countermeasures should be decided considering pregnant women as a critical group.

Finally, the largest reduction in thyroid and effective doses for offspring due to ^{131}I was at week 35. This means that estimating the trend of avoided doses in relation to the pregnancy stage is a useful tool for planning emergency interventions more effectively.

In 1989, the EU Commission issued a regulation [14] "… laying down maximum permitted levels of radioactive contamination of foodstuffs and feedingstuffs following a nuclear accident or any other case of radiological emergency". This regulation takes into account the different radiosensitivity of age groups, fixing the lowest permitted radionuclide concentrations for baby food, but gives no advice or obligation for pregnant women. Our calculations show that pregnant women should also be considered a critical group. Then again, the importance of taking account of possible offspring doses is stressed in the already cited and very recent document [6] of the IAEA, which suggests lowering the intervention level for iodine prophylaxis foreseen in the Basic Safety Standards for children and offspring (for a detailed analysis and discussion of the Chernobyl observations on this issue, see ref.[5]).

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