TEST OF EXISTING MODELS ON THE LONG-TERM RADIOACTIVE CONTAMINATION OF FOODSTUFFS THROUGH FIELD MEASUREMENTS ON WHEAT CROPS

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The processes of uptake through plant roots and deposition of resuspended material onto vegetation have longly been recognised as the main routes of the transfer of radioactive contamination from soil to vegetables. It is well known/1-2/ that the predictions of existing models of such processes are strongly affected by uncertainties related to the complexity of several chemical and biological processes which rule the transfer. The radioactive contamination caused by the Chernobyl plume is a chance of testing the existing models on the dynamics of radionuclides in the environment in order to improve the assessment of the environmental consequences of nuclear accidents.

The Italian National Institute of Health (ISS), with the collaboration of the Istituto Sperimentale per la Patologia Vegetale (ISPV), has planned a research devoted to the study of the transfer of caesium from agricultural soils to wheat crops. The choice of wheat has been motivated by its relevance in the Italian diet (about 110 kg/y for adults/3/).

The main features of the experimental methodology adopted are: i) selection of soil plots for which it is possibile to get information about meteorological conditions and ordinary culture practices; ii) sampling of soil in order to determine the distributions of Cs-134 and Cs-137 at various depths; iii) chemical analysis of soil in order to measure the acidity, the content of clay and organic matter, the concentrations of exchangeable calcium and potassium; iv) sampling of wheat plants during their growth up to the harvest; v) determination of the specific activities of Cs-134, Cs-137 and K-40 in various components of the wheat (namely, straw, chaff, bran, shorts, red-dog and flour) in order to study the translocation of caesium and potassium inside the plant, in particular inside the grain.

The gamma spectrometry of all the samples has been performed with an intrinsic Ge (resolution 1.95 keV, efficiency 38%).

Two soil plots, belonging to the ISPV, have been selected near Rome (labelled hereafter as soil I and II). In Table 1 the values of the specific activities of Cs-134 and Cs-137, measured in samples taken in July 1986 after the harvest, are reported.

In ref./4/ it has been shown that the observed distribution of Cs-137 in the selected soil plots arises from two different contributions, namely: i) a uniform component due to the fallout relative to the nuclear weapon tests in the sixties; ii) an exponential undisturbed component due to the fallout of the Chernobyl plume. It turned out that/4/ the total deposition in 1986 (vegetation + soil) can be estimated to be equal to ~ 400 Bq/m² in both soil plots.

In Fig. 1 the Cs-137 specific activity measured in 5-cm thick samples of soil I taken in July 1987 is shown. It can be seen that

Table 1. Specific activities of Cs-134 and Cs-137,in Bq/kg, of soil samples taken in July 1986 after the harvest (errors with a 95% confidence level).

depth (cm)	soil I Cs-134	soil I Cs-137	soil II Cs-134	soil II Cs-137
0 - 2	4.8 ± .4	18.7 ± .5	3.4 ± .5	16.4 ± .7
2 - 4	1.1 ± .5	11.4 ± .5	1.4 ± .3	11.3 ± .5
4 - 6	1.0 ± .3	9.9 ± .5	< .3	9.1 ± .7
6 - 10	< .2	9.2 ± .5	< .2	8.6 ± .5
10 - 14	< .2	9.2 ± .5	< .2	8.0 ± .6
14 - 20	< .2	9.5 ± .5	< .2	8.4 ± .6

after one ploughing the distribution of Cs-137 is not completely uniform, whereas the drop after 45 cm is clearly connected to the depth of the disturbed soil.

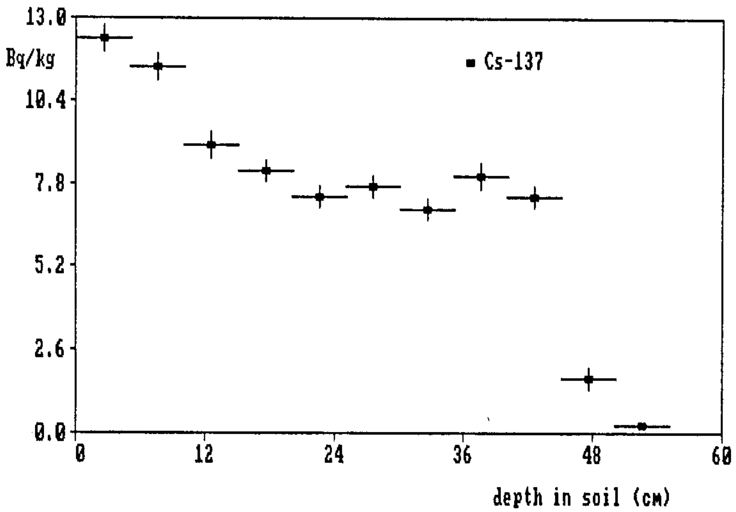

Fig. 1. Distribution of Cs-137 in samples of soil I taken in July 1987 after the harvest (errors with a 95% confidence level).

In Table 2 the results of the chemical analyses of samples of soil I and II are reported. It should be pointed out that both the concentrations of exchangeable cations and the content of organic matter are different in the selected soil plots. This difference is expected to play a role in determining the caesium and potassium content of wheat plants in 1987.

After the harvest in July 1986 the specific activities of Cs-134, Cs-137 and K-40 have been measured in several samples of various components of the wheat plants. The results of the gamma spectrometry for the varieties CRESO (durum wheat) and MEC (tender wheat) are shown in Table 3.

It can be seen that the distributions of Cs-134, Cs-137 and K-40 are not uniform within the wheat plant, as it is known also for other non radioactive elements. In particular, the specific

Table 2. Results of the chemical analyses of the selected soil plots. The acidity, the percentage (in weight) of clay, slime, sand and organic matter, the concentrations of some exchangeable cations are reported.

	pH	% clay	% slime	% sand	% organic matter
Soil I	7.8	33	35	32	2.8
Soil II	6.3	37	17	46	1.5

	Exchangeable cations (ppm)					
	K	Na	Sr	Ca	Mg	Rb
Soil I	537	31	37	21	222	1.4
Soil II	465	116	106	36	690	13

Table 3. Specific activities of Cs-134, Cs-137 and K-40,in Bq/kg (fresh weight) measured in samples of various components of the varieties CRESO (durum wheat) and MEC (tender wheat) harvested in July 1986 (errors with a 95% confidence level).

Component	CRESO (durum)			MEC (tender)		
	Cs-134	Cs-137	K-40	Cs-134	Cs-137	K-40
straw	49±2	97±3	231± 50	38±7	85±8	336±123
chaff	42±5	93±7	204±101	83±6	174±8	< 125
bran	54±2	114±2	335± 37	69±4	135±5	423± 61
shorts	27±2	54±2	186± 26	37±2	76±3	315± 36
red-dog	14±1	30±1	78± 15	14±1	32±2	69± 24
flour	16±1	34±1	112± 15	8±1	16±1	< 35
grain	25±1	50±2	129± 19	20±1	40±2	107± 18

activities are higher in straw and chaff as well as in the external components of the grain (namely, bran and shorts). The ratio between the Cs-137 specific activity observed in the grain and the estimated total deposition on soil turns out to be equal to $\sim$ 0.1 m^2/kg. This value is just twice the value predicted by the compartimental models FOOD-MARC/5/ and ECOSYS/6/. However, in our opinion such a discrepancy should be traced to a non precise knowledge of some parameters appearing in the mentioned models, like the dependence of the initial interception factor on the growth stage.

In 1987 the sampling of four different varieties of wheat has been carried out periodically from April to the harvest in July. The samples have been dried at 130 ^{o}C for 24 h before measuring the activities. The ratio between the dry and the fresh weight of the samples varies with the plant growth going from 20% in April up to 80% - 90% at harvest. The specific activity of Cs-134 was below the sensitivity threshold (about 0.4 Bq/kg) in all the samples. The Cs-137 specific activity measured in samples of wheat plants collected in April 1987 was within the range 1 - 2 Bq/kg (d.w.). After the ear emergence (occurred approximately at the end of April) the specific activity of Cs-137 dropped below 1 Bq/kg (d.w.); measurements with better sensitivity are in progress. In

Table 4 the values of the K-40 specific activity measured in the collected samples of wheat plants are shown.

Table 4. Specific activity of K-40 (in Bq/kg d.w.) measured in samples of the varieties CRESO (durum), MEC (tender), LATINO (durum) and ANIENE (tender) collected from April to June 1987 (errors with a 95% confidence level).

sampling date	CRESO	MEC	LATINO	ANIENE
2/4/87	803 ± 19	881 ± 23	960 ± 24	901 ± 19
15/4/87	657 ± 17	---	1173 ± 28	---
15/5/87	673 ± 13	664 ± 14	728 ± 15	785 ± 15
5/6/87	338 ± 7	463 ± 9	486 ± 9	475 ± 15
25/6/87	163 ± 4	286 ± 8	301 ± 7	283 ± 7

It can clearly be seen that after the ear emergence the plant growth drastically reduces the K-40 specific activity. It should be pointed out that the K-40 specific activity found in the last sampling (25/6/87) in the variety CRESO, which growths in soil II, is about one half of the corresponding values relative to the other three varieties, which growth in soil I. In our opinion the final data, including also the time evolution of the Cs-137 specific activity up to the harvest, will allow a meaningful comparison with the corresponding values predicted by the existing dinamical compartimental models on the soil-to-plant transfer. Furthermore, it will be possible to add information on the relationship between soil composition and caesium or potassium levels in wheat crops.

REFERENCES

1. Coughtrey P.J. & Thorne M.C. 1983. Radionuclide distribution and transport in terrestrial and acquatic ecosystems. A critical review of data. A.A. Balkema, Rotterdam.
2. Peterson H.T. 1983. Terrestrial and acquatic food chain pathways. In: Radiological assessment. A textbook on environmental dose analysis. Ch. 5. U.S. Dpt. of Commerce: NTIS. Washington D.C. (NUREG/CR-3332).
3. ISS-Physics Laboratory 1987. Il rischio ambientale nella produzione di energia: risultati sperimentali, calcoli e riflessioni dopo Chernobyl. Ann. Ist. Super. Sanita' 23, p. 110.
4. Campos Venuti G., Felici F., Grisanti A., Grisanti G., Imbroglini G., Mariutti G., Risica S. & Simula S. 1987. Studio dei processi di trasferimento del cesio dal terreno al grano. Proceedings of the XXV Congress of AIRP, Monteporzio Catone (Rome), October 14-16.
5. Simmonds J.R., Linsley G.S. & Jones J.A. 1979. A general model for the transfer of radioactive materials in terrestrial food chains. Report NRPB-R89, Harwell, Didcot, Oxon.
6. Proehl G., Friedland W. & Paretzke H.G. 1985. Intercomparison of the terrestrial food chain models FOOD-MARC and ECOSYS. Institut fur Strahlenschutz, Munchen. Report GSF-Bericht 18/86.