Bull. Environ. Contam. Toxicol. (1991) 46:14–21

Environmental Contamination and Toxicology

Short and Medium Effects on the Environment of Valencia, Spain, of the Chernobyl Nuclear Plant Accident

A. Moreno,[1] E. Navarro,[1] F. Senent,[1] A. Baeza,[2] C. Miró,[2] and M. del Río[2]

[1]Corpuscular Physics Institute, Centro Mixto C.S.I.C. – Universitat de València, Spain and [2]Department of Physics, Veterinary Science School, Universidad de Extremadura, Cáceres, Spain

As a consequence of the 26 April 1986 accident at the Chernobyl nuclear plant, a large amount of radioactivity was released into the atmosphere. The radioactive plume formed could be detected in practically the whole of the Northern Hemisphere a few days later (Hennies 1986). The zone most affected by the radioactive cloud over Spain was that of the Mediterranean coast and the Balearic Islands (CSN 1986). In Valencia, on the east coast of Spain, specific activities for 11 man-mode isotopes were recorded, with an aggregate specific activity peak of 3 Bq/m^3 on the 3rd and 4th of May. (Ferrero et al. 1987).

In this paper we examine the level of the radioactive contamination reached in various receptive media in Valencia, such as air, dry-fallout, water, soil, grass and milk samples collected in Valencia inmediately after the accident. The activity levels are compared with those found during 1964 and 1965 due to the Chinese nuclear atmospheric explosions. The levels of contamination presented by four species of migratory birds which spend the winter in this area is analyzed. Lastly, an estimate is made of the absorbed dose.

MATERIALS AND METHODS

The aerosols were collected on SM-11405 cellulose nitrate filters, with a pore size of 0.6 micron, the method used being described in detail in a previous paper (Ferrero et al. 1987). Dry fallout was collected over 24 hour periods on 0.5 m^2 stainless steel boxes. There were no wet-fallout samples because no rain fell during the sampling period. The samples of drinking water were taken from the city of Valencia. Soil samples were collected taking a slab to a depth of 10 cm., at the same locations as the fresh grass. Cow milk samples were obtained from a local dairy farm near to the same locations and sixty six migratory birds were captured.

The air filter, dry-fallout, drinking water, soil, grass, milk and migratory bird samples were analyzed by gamma spectrometry, using

---

Send reprint request to A. Moreno at Department of Applied Physics, Avda. Dr. Moliner nº 50, 46100 (Valencia) Spain.

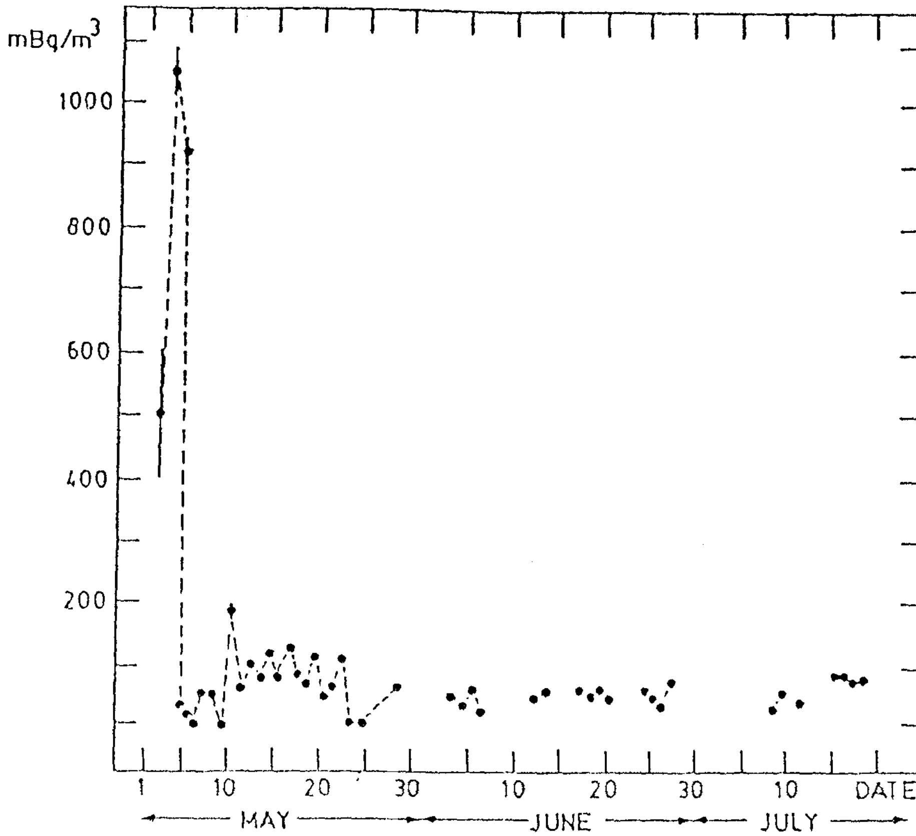

Figure 1. Gross beta activity of atmospheric aerosols (per m^3 of air) in Valencia from May to July 1986.

a Ge intrinsic detector with 13.5% relative efficiency and a resolution of 1.79 KeV (FWHM) for the 1332 KeV peak.

RESULTS AND DISCUSSION

Figure 1 shows the gross beta specific activities of the aerosols present in the Valencia atmosphere between 1 May and 20 July. Measurements were made two days after collecting the air filters, in order to permit a significant decay of the beta activity of short-lived radioisotopes descending from ^{220}Rn and ^{222}Rn.

It should be noted that there are two peaks in the activity. The first, with a value of (1050 $\pm$ 30) mBq/m^3, was reached on 3 May, coincidings with the maximum of the specific activity in the gamma spectrometric analysis (Ferrero et al. 1987). This maximum concentration was observed approximately one day after being reached in the atmosphere over Paris (Thomas et al. 1986). The second peak has value of (182 $\pm$ 11) mBq/m^3, and corresponds to 10 May. This observation coincides with obtained by other autors (Ballestra et al. 1987, Thomas and Martin 1986).

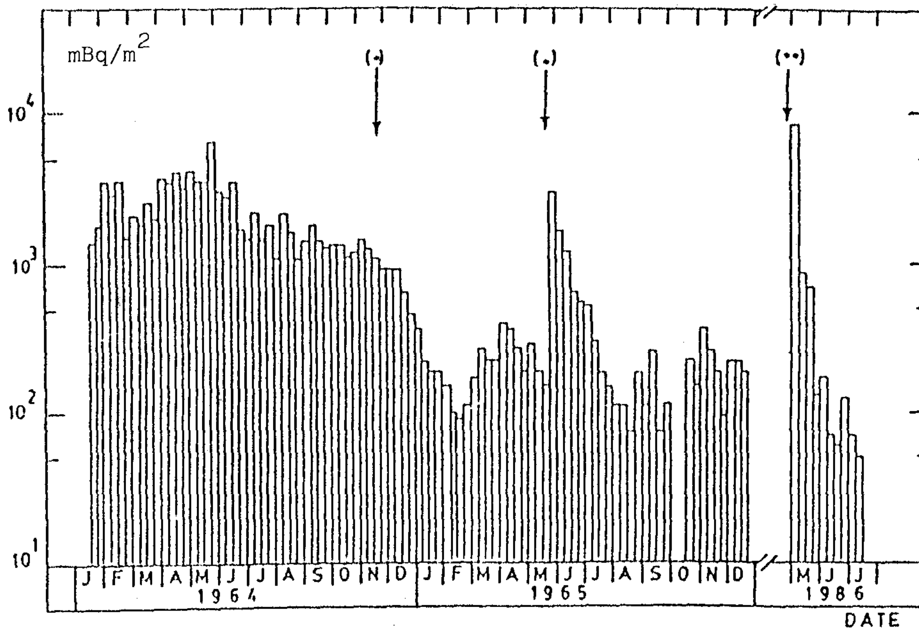

Figure 2. Comparison between the aggregate specific activity of dry fallout samples in Valencia during the years 1964 and 1965, and the values obtained from May 1986. (*) Date of China's nuclear test in the atmosphere. (**) Date of accident at the Chernobyl Nuclear Plant.

Figure 2 shows the aggregate activity present in the dry deposition samples, expressed as average weekly values. These samples were taken in Valencia between 1964 and 1965 (Catalá et al, 1966) and likewise in May, June and July of 1986. A steady fall in the levels of radioactive contamination can be observed from 1964 onwards, due to the signing in Moscow in 1963 of the treaty to ban nuclear tests in the atmosphere. However, at the end of May 1965, an increase in activity was detected, due to a Chinese nuclear atmospheric explosion of 40 Kiloton carried out on 14 May (asterisk in the figure 2). After the Chernobyl accident (double asterisks in figure 2), a considerable increase in dry fallout activity is observed. During the first week of May 1986, the estimated value is 8.5 Bq/m^2, which is 2.9 times greater than the peak detected at the end of May 1965.

Deposition on vegetation and the ground surface is a crucial link in the transmission of the contaminating agents present in a plume through the food chain. The deposition velocity is the ratio between the rate of deposition and the concentration of atmospheric aerosols in the layer inmediately above. This value depends greatly on diverse physical and chemical factors (Karol 1974). From aggregate activity measurements on both aerosols and dry-fallout samples, we have obtained the following values for the dry deposition velocity: (0.26 $\pm$ 0.06) mm/s in the month of May, (0.020 $\pm$ 0.006) mm/s in June, and (0.010 $\pm$ 0.007) mm/s in July.

Table 1 shows a summary of the gamma spectrometric analysis carried out on some of the different types of sample collected. The criteria followed in order to determine the detection limits in the samples analyzed are based on the ideas proposed by Hartwell (1975). A confidence level of 95% has been used at all times, and when net activity is detected, the value obtained is corrected for the decay that occurred between the time of collection and the time of analysis of the sample.

Examination of the gamma spectrometer results allowed us to pick out the following results: a) in the soil samples, there was no significant variation in activity levels in relation to those from samples collected previously, b) in the sample of grass which corresponds to 7 May, a notable increase in the levels of the isotopes ^{103}Ru, ^{131}I, ^{134}Cs, ^{137}Cs is detected. These contamination levels fall steadily in samples from succesive days. In the last sample of grass to be analyzed, corresponding to 2 July, which does not appear in Table 1, it is impossible to detect specific activity above the detection limit.

From the activities registered between 7 May and 18 June for ^{103}Ru, ^{134}Cs and ^{137}Cs, one can calculate the effective half-life of these radioisotopes on grass. From the effective (Tef) and the physical half-life (T), one has the field-loss half-life (Tf) for each radionuclide in grass.

$$\frac{1}{Tef} = \frac{1}{T} + \frac{1}{T_f}$$

T_f is due to loss of material from the grass by weathering and by agricultural process, and may also be affected by transfer to grass from the soil. The values obtained for the field-loss half-life are 18.2 days for ^{103}Ru, 30 days for ^{134}Cs and 27.4 days for ^{137}Cs. These values are compared to those obtained by other authors (Aarkrog 1986; Fulker 1986), the differences simply being due to the location of the sampling. From these results it can be deduced that the external agents responsible for the radioactive contamination loss in grass act with different efficiency on both chemical elements.

c) Table 2 shows the transfer factor for ^{134}Cs and ^{137}Cs for dry-fallout to grass, and grass to milk. As can be seen these factors depend upon the medium from which the contamination comes, and the medium to which it is transmitted. Likewise, it is interesting to note that the value found for the transmission of caesium from grass to milk coincides with the value considered as standard in the transmission of ^{131}I between these media (IAEA 1974).

Another way in which the radioactive contamination affects Valencia, is that due to the arrival for the winter of migratory birds contaminated in Central Europe. In order to evaluate this effect, we carried out a gamma spectrometric study on the edible parts of diverse species of migratory birds during October, at which time the arrival of these birds in our country begins to be noticeable.

Table 1. Specific activities detected for different samples collected in Valencia.

SAMPLE	DRY FALLOUT (Bq/m^2)		SOIL (Bq/Kg)		GRASS (Bq/kgdry)			MILK (Bq/l)
SAMPLING DATE	3/5/86	4/5/86	27/3/86	15/5/86	30/4/86	7/5/86	18/6/86	15/5/86
Counting Time (sec)	86400	86400	86400	86400	93400	153700	165400	136000
RADIOISOTOPES								
^{103}Ru	7 ± 5	< 29	< 1.0	1.1 ± 0.9	< 6.5	59 ± 7	6 ± 5	< 0.17
^{131}I	< 1.0	< 2.0	< 1.2	< 1.2	< 7.6	510 ± 40	< 13	< 0.19
^{134}Cs	3.7 ± 1.7	1.2 ± 0.6	< 2.7	1.7 ± 0.6	< 9.0	16 ± 5	6 ± 5	0.6 ± 0.1
^{137}Cs	7.6 ± 1.6	2.7 ± 0.8	4.1 ± 0.1	6.1 ± 1.0	< 10	34 ± 7	12 ± 7	1.1 ± 0.1
$^{134}Cs/^{137}Cs$	0.49	0.44	---	0.27	---	0.47	0.50	0.54

The species analyzed, see Table 3, are: Chaffinch (Fringilla coelebes), Twite (Acanthis cannabina), Jay (Garrulus glandarius) and Thrush (Turdus philomelos).

Table 2. Transference factors of ^{134}Cs and ^{137}Cs for the samples indicated.

			^{134}Cs	^{137}Cs
DRY FALLOUT (Bq/m^2) 3/5/86	/	GRASS (Bq/kgdry) 7/5/86	4.3 ± 3.3	4.5 ± 1.8
GRASS (Bq/kgdry) 7/05/86	/	MILK (Bq/l) 15/5/86	0.037 ± 0.018	0.032 ± 0.009

The activities detected are listed in Table 3, per unit of fresh weight, for the only two gamma man-made amitters identified: ^{134}Cs and ^{137}Cs. The Turdus philomelos species is the only one to present net specific activity in all the samples analyzed. Its breeding ground is the Scandinavian countries and in those of Central and Eastern Europe, and it spends the winter in the North of Africa, the South of Italy, the French Mediterranean coast, and in practically the whole of the Iberian Peninsula (Hienzel et al. 1981).

The radioactive plume which affected the atmosphere of Valencia from the beginning of May proved to have average levels of activity which did not produce important increases in the concentrations of man-made radionuclides in other receptive media. Because of this, inhalation is the main process responsible for any increase in the individual dose equivalent.

In order to calculate the dose received by inhalation, we have the following conservative assumption: the aerosol activity during the first week of the mounth of May is taken to be equal to that of the sample which revealed peak activity (that of 3 May). Considering that the average consumption of air per adult is 154 m^3/week, and taking into account the conversion factors of mBq to mSv (NRC 1977), we have calculated the values of absorbed individual dose for diverse critical organs. These are: for the thyroid 10^{-3} mSv/week, for the intestine 1.3 10^{-4} mSv/week, and for the total body 4.10^{-5} mSv/week. The doses estimated for other organs are lower by several orders of magnitude than these values.

The Turdus philomelos species was the only type of migratory bird found in the province of Valencia in the month of October to present considerable radioactive contamination levels. However, they are lower than the 600 Bq/kg-fresh which is the maximum permitted by the European Economic Communities in meat for consumption (CEC 1986). Its incidence in the dose absorbed through food consumption is totally negligible; only the dose absorbed through inhalation is significant.

Table 3. Specific activity detected, in Bq per kgfresh, for different species of migratory birds, hunted in Valencia during October 1986.

SPECIES	SAMPLE SIZE	WET WEIGHT ($x10^{-3}$ Kg)	^{134}Cs (Bq/kgfresh)	^{137}Cs (Bq/kgfresh)
Fringilla coelebes	12	110	< 2.5	< 3.6
Acanthus cannabina	12	99	< 3.6	< 3.9
Garrulus glandarius	2	45	< 6.1	< 6.9
Turdus philomelos	10	165	39 ± 11	99 ± 14
Turdus philomelos	10	174	44 ± 8	113 ± 14
Turdus philomelos	10	137	6 ± 4	13 ± 4
Turdus philomelos	10	99	14 ± 5	41 ± 8

REFERENCES

Aarkrog A (1986) Preliminary conclusion to be draw from the studies of Chernobyl debris in Denmark. Seminar on the cycling of long-lived radionuclides in the biosphere; September 15-19, Madrid.

Ballestra SB, Holm E, Walton A, Whitehead E (1987) Fallout deposition at Monaco following the Chernobyl accident. J. Environ. Radioactivity 5: 391-400.

Catalá J, García A, Díez R, Pérez R (1966) Medidas de radiactividad ambiental en Valencia durante 1964. Anales de Física 62A: 75-78.

CSN Consejo de Seguridad Nuclear. (1986) Informe resumen de la fase inmediata del accidente de la central nuclear de Chernobyl y su impacto radiológico en España. CSN/DTINF03/86. Available from: Spain Governement Printing Office, Madrid.

CEC Commission of the European Communities. (1986) Derived reference levels as a basis for the control of foodstuffs following a nuclear accident - A recommendation from the group of experts set up under article 31 of the Euratom Treaty. Regulation 1707/86. Available from: CEC Printing Office, Brussels.

Ferrero JL, Jordá ML, Milió J, Monforte L, Moreno A, Navarro E, Senent F, Soriano A, Baeza A, del Río M, Miró C (1987) Atmospheric radioactivity in Valencia due to the Chernobyl reactor accident. Health Phys 53: 519-524.

Fulker MJ (1987) Environmental monitoring by British Nuclear Fuels plc following the Chernobyl reactor accident. J Environ Radioactivity 5: 235-244.

Hartwell JK (1975) Detection limits for radioanalytical counting

techniques. Washington DC: Atlantic Richfield Handford Company; ARN-SA-215. Richland, Washington, USA.
Hennies H (1986) Radiation measurements in Germany resulting from the Chernobyl accident. Nuclear Europe 7:22-25.
Hienzel H, Fitter R, Parslow J, (1981) The birds of Britain and Europe with North Africa and the Middle East. First printing. London: Willian Collins Sons and Co. Ltd.
IAEA (1974) Environmental Surveillance around Nuclear Installations, International Atomic Nuclear Energy, Vienna, Austria.
Karol IL (1974) Radioisotopes and global transport in the atmosphere, 1st Edn, Jerusalem, ISPST.
NRC (1977) Calculation of annual doses to Man from routine releases of reactor effluents for the purpose of evaluating with 10CFR part 50, apendix J NRC Regulatory guide 1109, rev. 1, Washington, USA.
Thomas AJ, Martin JM, (1986) First assessement of radioactive plume over Paris. Nature 321: 817-819.

Received February 22, 1990; accepted June 6, 1990.