HEALTH PHYSICS

Air Radioactivity and Fallout Deposition Monitoring : Y. Prulov, M. Stiller, Y. Feige and E. Shalmon.

Fallout monitoring during 1965 included the following measurements:

(i) Gross beta activity of dust samples and gummed tapes at Nahal Soreq.

(ii) Sr^{90}, Cs^{137} and gross beta activity of fallout collected in water-containing pots at four stations, and of dust samples obtained from air monitors at three stations.

(iii) As in (ii) for rain samples collected at two stations.

(iv) Gamma spectra of various fallout samples.

(v) I^{131} in air dust, milk and thyroid samples (see p.247), during the period following the Chinese nuclear test of May 14.

The gross beta activity of the dust samples collected at Nahal Soreq is shown in Fig.42. The low values obtained during the latter part of 1964 (0.2 - 0.35 pc/m^3) continued till March 1965, when a "spring peak" of 0.5 - 0.8 pc/m^3 was observed. The radioactive fallout from the second Chinese nuclear test on May 14, was observed at the beginning of June 1965, when the air activity rose to 1.7 pc/m^3 with a corresponding rise in the short-lived radioisotopes I^{131}, Zr^{95}-Nb^{95}, and Ba-La^{140}. These values dropped gradually during the summer of 1965. The air activity during Oct.-Nov. 1965 ranged between 0.03 and 0.14 pc/m^3, values which are far below those recorded since 1960/61.

The gross beta activity on gummed tapes ranged between 0.003 and 0.9 mc/km^2/day during 1965 (see Fig. 43). At the beginning of 1965 and on rainy days fallout values were usually above 0.1 mc/km^2/day. On dry days the values were always below 0.1 mc/km^2/day except for the "spring peak" during March-April 1965, and after the Chinese nuclear test. The latter

was reflected in the peak in deposited beta activity during the first half of June 1965 (0.8 mc/km^2/day). During the summer of 1965, the beta deposited activity was below 0.01 mc/km^2/day.

Deposition of Sr^{90} and Cs^{137} collected in water-containing pots is summarized in Table 26. The deposition at all four collection stations was higher during the rainy months, the rise being related to the amount of rain. For the first three stations shown in the table the average pot-collected activity ranged from 6.3 to 8.8 pc Sr^{90}/m^2/mm rain and from 9.8 to 12.2 pc Cs^{137}/m^2/mm rain. These values are about one half to one quarter of those obtained during the previous year[1]. At Eilat the activity per mm of rain was much higher than at the other three stations, but the total deposition was lower, owing to the very low rainfall.

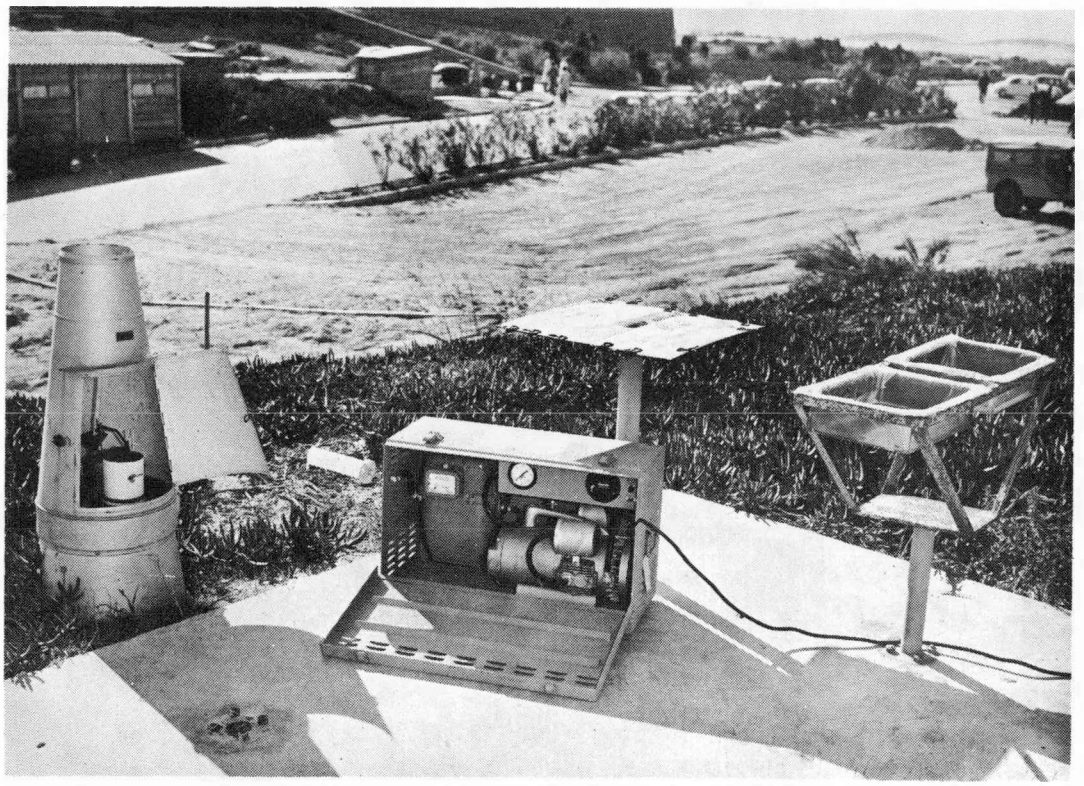
Table 27 summarizes the results for air dust samples. At Nahal Soreq and Beersheba the concentrations are about the same, while at Eilat they are lower.

Analyses of rain samples for the winter of 1964/65 (Table 28) showed lower activities than those of the previous two years.

Figure 44 shows a typical gamma spectrum of an air dust sample collected and counted shortly after the second Chinese detonation. Fresh fallout isotopes are clearly distinguished (Ba^{140}-La^{140}; Zr^{95}-Nb^{95}). The I^{131} is less clearly seen, being masked by the 0.33 MeV peak of La^{140}. Fig. 45 is the gamma spectrum of a rain sample collected at the reactor site on October 7, 1965, and counted two weeks later. At that time the contribution of fresh fallout activity had almost disappeared, and the spectrum has the same pattern as before the Chinese detonation, except for the presence of a very low activity of Zr^{95}-Nb^{95}.

Reference:

1. STILLER, M., PRULOV, J. and FEIGE, Y., Israel AEC Semi-Annual Report, Jan.-June 1964, IA-984, p. 139



Fallout monitoring

TABLE 26

Monthly Sr^{90} and Cs^{137} deposition during 1965 (analysis of water-containing pot collectors)

Month	Nahal Soreq			Tirat Yael			Beersheba			Eilat		
	mm rain	mc/km²		mm rain	mc/km²		mm rain	mc/km²		mm rain	mc/km²	
		Sr^{90}	Cs^{137}		Sr^{90}	Cs^{137}		Sr^{90}	Cs^{137}		Sr^{90}	Cs^{137}
January	180.0	0.50	1.00	427.4	1.33	0.90	186.4	0.29	0.73	22.8	0.33	0.56
February	88.0	0.81	0.65	76.9	0.80	0.92	3.7	0.13	0.21	-	0.15	0.15
March	72.6	0.32	0.64	76.5	0.46	1.27	34.5	0.22	0.58	0.9	0.20	0.07
April	10.5	0.51	0.47	120.0	0.94	1.21	30.0	0.55	0.83	0.9	0.07	0.15
May	-	0.11	0.15	-	1.39	0.48	-	0.10	0.27	-	0.05	0.20
June	-	0.06	0.14	-	0.30	0.73	-	0.05	0.25	-	0.05	0.20
July	3.3	0.12	0.13	-	0.18	1.16	-	0.21	0.14	-	0.05	0.12
August	-	0.04	0.14	-	0.12	0.71	-	0.04	0.08	-	0.04	0.16
September	-	0.07	0.15	-	0.69	0.20	-			-	0.04	0.10
Total	354.4	2.59	3.47	700.8	6.21	7.58	254.6	1.59	3.09	24.6	0.98	1.71
$\frac{\text{pc } Sr^{90}/m^2}{\text{mm rain}}$ (ave.)	7.3			8.8			6.3			40.0		
$\frac{\text{pc } Cs^{137}/m^2}{\text{mm rain}}$ (ave.)	9.8			10.8			12.2			70.0		
average ratio Cs^{173}/Sr^{90}	1.3			1.2			1.9			1.8		

TABLE 27

Average monthly air concentrations of gross beta, Sr^{90} and Cs^{137} activities (pc/m^3)

Month 1965	Nahal Soreq			Beersheba			Eilat		
	Gross	Sr^{90}	Cs^{137}	Gross	Sr^{90}	Cs^{137}	Gross	Sr^{90}	Cs^{137}
January	0.155	lost	0.027	no sample collected			0.15	0.011	0.012
February	0.14	0.012	0.018	0.18	0.030	0.024	0.17	lost	0.008
March	0.25	0.042	0.027	0.31	0.024	0.047	0.09	0.011	0.009
April	0.26	0.017	0.037	0.33	0.018	0.035	0.095	0.006	0.016
May	0.19	0.015	0.035	0.39	0.021	0.027	0.11	0.005	0.013
June	0.29	0.027	0.035	0.33	0.032	0.028	lost	lost	lost
July	0.23	0.034	0.037	0.18	0.034	0.033	no sample collected		
August	0.10	0.012	0.014	lost	0.021		no sample collected		
September	0.08	0.011	0.011				no sample collected		
Cs^{137}/Sr^{90}	1.3			1.2			1.4		

TABLE 28

Comparison of Sr^{90} and Cs^{137} fallout in rain during the seasons of 1962 to 1965

Rainy season	Site	Rain (mm)	Sr^{90} mc/km^2	Cs^{137} mc/km^2
1962/63	Tirat Yael	786.8	21.4	-
	Nahal Soreq	274.3	13.7	-
1963/64	Tirat Yael	1081.3	29.5	43.7
	Nahal Soreq	586.9	14.2	21.1
1964/65	Tirat Yael	1238	7.8	9.4
	Nahal Soreq	724.4	3.9	>4.1

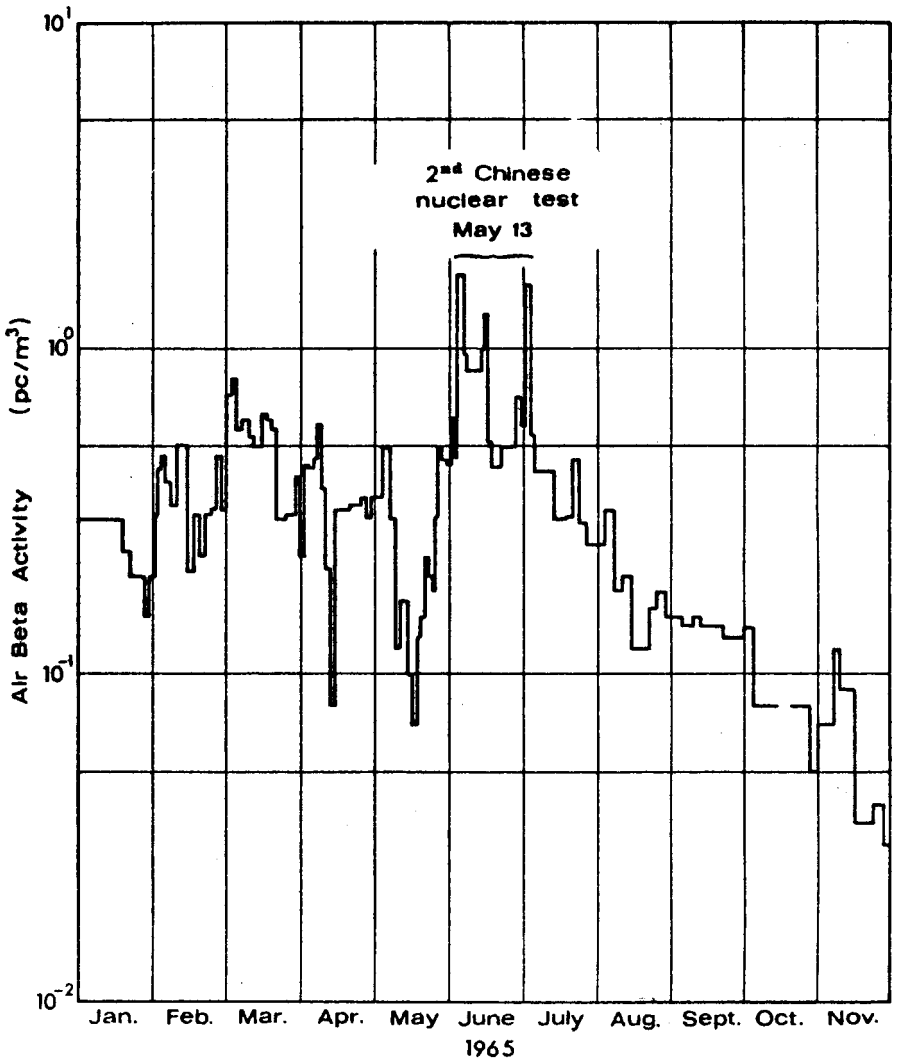


Fig. 42

Daily gross beta activity in air at Nahal Soreq during Jan.-Dec.1965.
Activity is measured 7 days after collection.

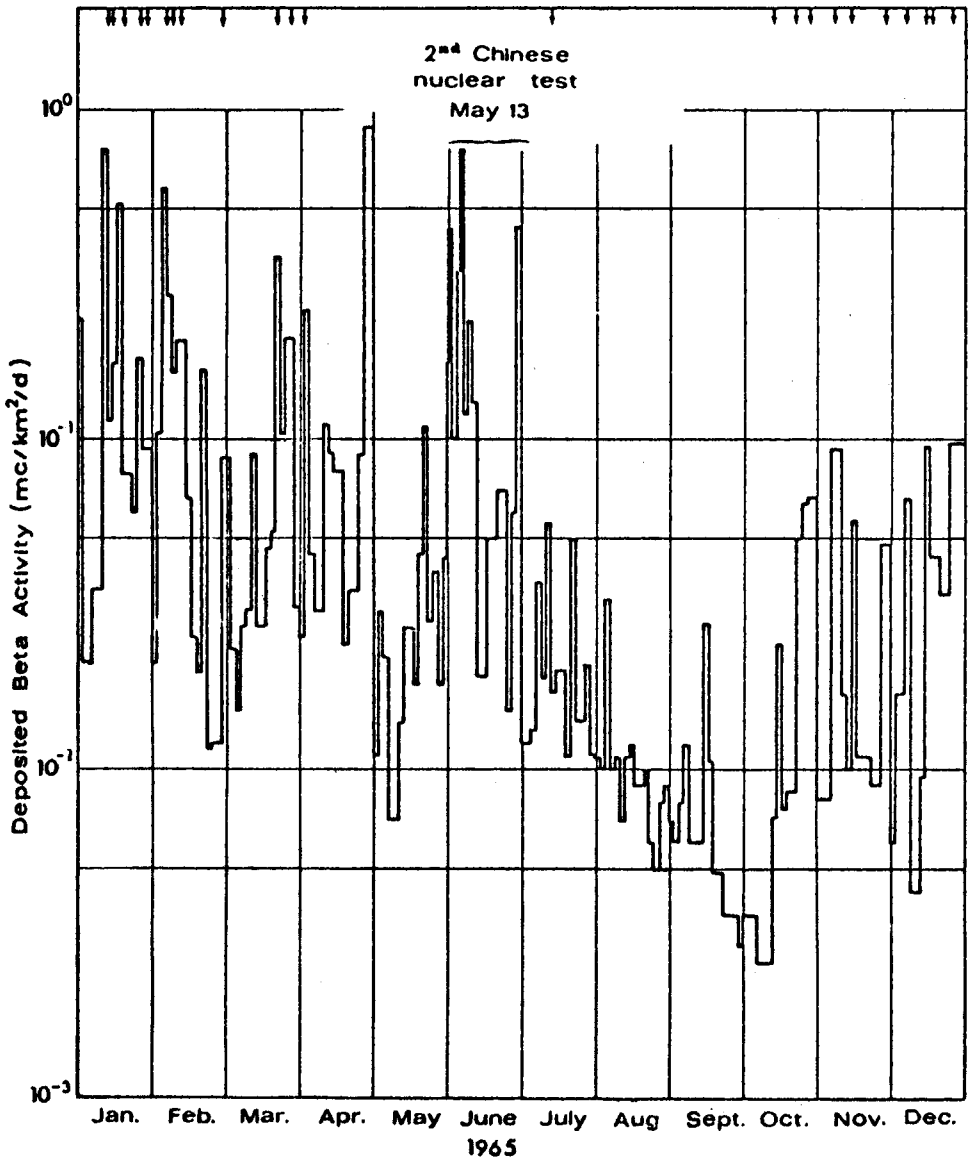


Fig. 43

Daily gross beta activity deposited at Nahal Soreq during Jan.-Dec. 1965.
The samples were measured 7 days after collection.
Rain days are indicated by arrows.

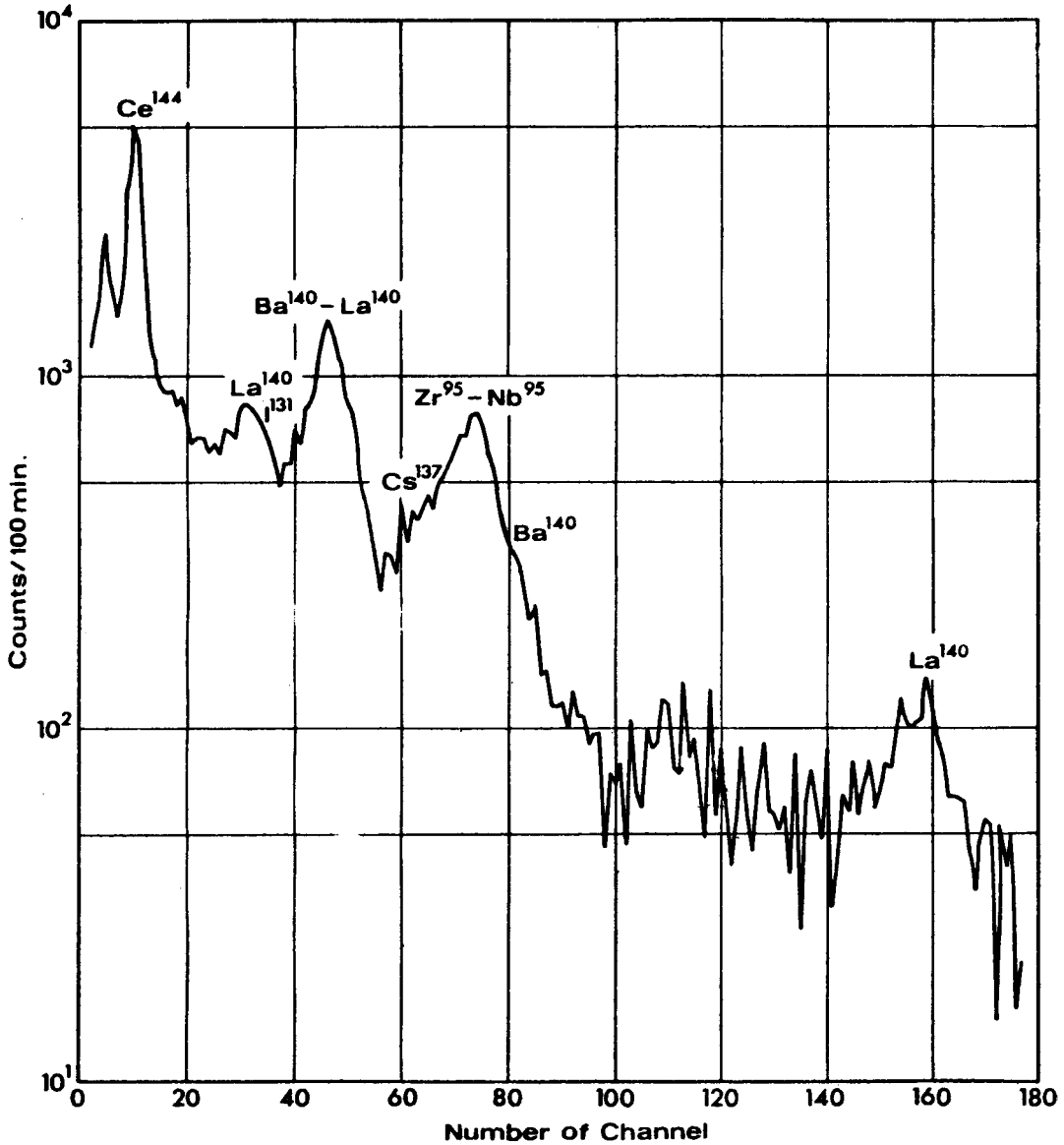


Fig. 44

Gamma spectrum of air dust sample from Palmachim. The sample was counted 6 days after collection.

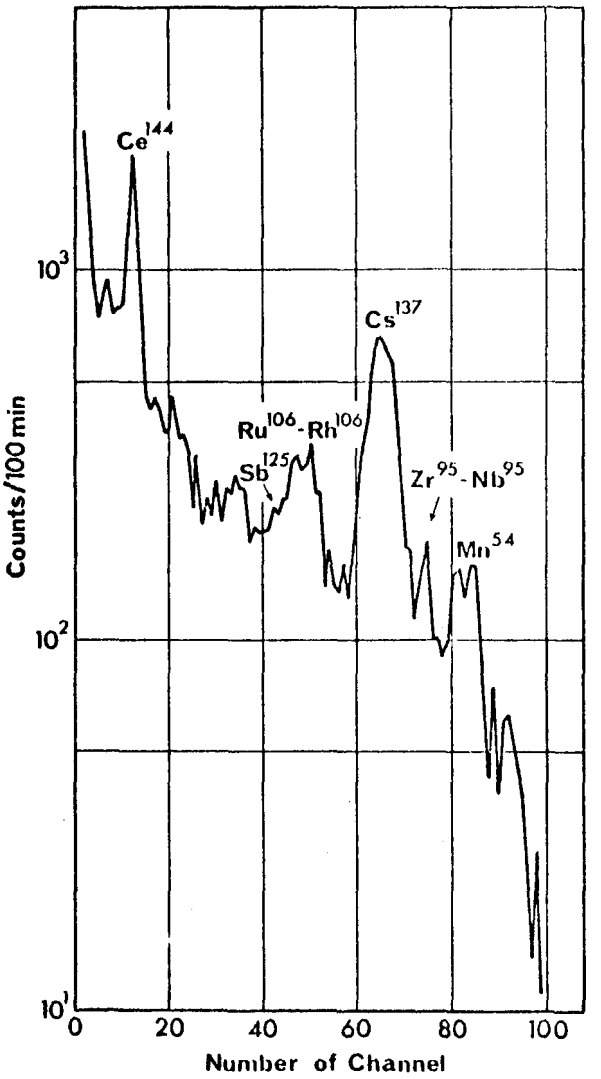


Fig.45

Gamma spectrum of a rain sample collected at the reactor site . The sample was counted 2 weeks after collection.

Sr^{90} and Cs^{137} Concentrations in Milk: Y. Prulov and M. Stiller

During 1965, about 70 milk samples from different parts of the country were analysed for Sr^{90} and Cs^{137}. The results are summarized in Table 29. During the first half of the year the average Sr^{90} concentration was about 5 pc/l, with values ranging from 1.0 to 10.9 pc/l. The average Cs^{137} concentration was about 30 pc/l, the values ranging from 10.6 to 73.0 pc/l. Most of the values were clustered around the mean values.

TABLE 29

Sr^{90} and Cs^{137} concentration in milk during 1965

Mean values

Period	Sr^{90} pc/l	Cs^{137} pc/l	Cs^{137}/Sr^{90}
Jan. - June 1965	4.9	30.9	6.3
July - Dec. 1965 (sheep excluded)	2.9	19.5	6.7

In the second half of the year there was a general decrease in the concentrations. Thus Sr^{90} averaged 3 pc/l and ranged between 1.0 - 6.5 pc/l, and Cs^{137} averaged 18 pc/l and ranged between 8.6 - 29.0 pc/l. Again most concentrations were near the mean values.

The significant difference in the concentrations of Sr^{90} and Cs^{137} during the first and second halves of 1965 may largely be explained by the methods of feeding the cattle. Thus during the first half of 1965 the main feed was green pasture, which contained higher concentrations of Sr^{90} and Cs^{137} due to washout of nuclear debris from the air. On the other hand, during the summer months stored feed, which is less contaminated, was used.

Milk in Israel contains lower concentrations of Sr^{90} and Cs^{137} than the milk in America and Europe (20-50 pc/l Sr^{90} and 100-250 pc/l Cs^{137} in Belgium[1] and about the same concentrations in Italy[2]). The average Sr^{90} and Cs^{137} concentrations were far below the maximum permissible concentrations for

the population at large. (The M.P.C. values for drinking water are 1,000 pc/l for Sr^{90} and 200,000 pc/l for Cs^{137} (3).)

References:

1. La Retombée Radioactive Mesurée à Mol - R - 2348, 1964
2. Data on Environmental Radioactivity in Italy - B10/08/64, 1964
3. National Bureau of Standards Handbook 69, U.S. Department of Commerce, 1959

Sr^{90} and Cs^{137} in Food: Y. Prulov and M. Stiller

During April-October 1965, over 100 food samples were analysed at the request of the Ministry of Health. The Ministry provided the samples, which consisted of packages containing representative daily food consumed by five adults. Each package was divided into seven components according to the type of food, and each sample was analysed separately for Sr^{90} and Cs^{137}. Foods which are usually consumed in small quantities, such as coffee, tea, etc., were not included in the packages but were analysed separately once every three months.

Table 30 gives the mean Sr^{90} and Cs^{137} contents found in the more common foods. From these values the total daily intake per adult was estimated to be 22 pc of Sr^{90}, and 92 pc of Cs^{137}.

TABLE 30

Mean Sr^{90} and Cs^{137} contents of the more common foods

Type of food	Concentration in pc/kg	
	Cs^{137}	Sr^{90}
Bread	45	16
Meat and eggs	52	4.6
Vegetables	6	6.4
Fats	15	3
Milk products	257	70
Fruits and jams	16	2.5
Miscellaneous	75	19
Cocoa	213	21
Coffee	142	44
Tea	388	375
Sugar	1.1	14
Salt	3.7	10

Sr^{90} in Soil: Y. Prulov and M. Stiller

Soil may be expected to accumulate Sr^{90} deposited from nuclear test debris. In fact the Sr^{90} content of soil can serve as a measure of the integrated Sr^{90} fallout, provided a location of minimum runoff is chosen and the sample is taken deep enough to include all the Sr^{90} in the soil.

The depth of penetration of Sr^{90} in soil depends on the type of soil and amount of rainfall. Thus heavy soils (high specific gravity and low permeability) retain most of the Sr^{90} in the upper 10-15 cm, while light soils allow deeper penetration. Soils having high exchangeable calcium values tend to retain Sr^{90} in the upper layers.

It has been observed and widely accepted that the total amount of Sr^{90} in soil at a particular site is very close to the total amount of it deposited by rain at that site. This is to be expected since rain is the principal mechanism by which Sr^{90} is deposited. Table 31 presents the expected amounts of Sr^{90} in soil at 7 sampling sites, and compares them with the observed values. These expected values were obtained by adding the amount of Sr^{90} in the soil in 1958[1] to the total amount deposited by rain since October 1958. The rain data were obtained from the Meteorological Service. Sr^{90} concentrations in rain were obtained from analyses of rain samples at Nahal Soreq and Tirat Yael. These two stations are representative for the major part of Israel (except the southernmost part).

There is close agreement between the expected and observed values of Sr^{90} in soil at Ruhama, Tirat Yael and Taoz. At Beit Guvrin and Mishmar Haemek the agreement is somewhat less close, and at Hanita and Regavim there are wide discrepancies which are probably due to insufficient depth of sampling.

Reference:

1. GAT, J. R., GILAT, J., Israel AEC Report IA-572 (1960)

TABLE 31

Expected and observed concentrations of Sr^{90} in soil

Rainy Season	Mean Seasonal Specific Activity mc Sr^{90}/km^2 / mm rain	Mishmar Haemek		Hanita		Regavim		Tirat Yael		Taoz		Beit Guvrin		Ruhama	
		$\frac{Sr^{90}}{km^2}$ (mc)	rain (mm)	$\frac{Sr^{90}}{km^2}$ (mc)	rain (mm)	$\frac{Sr^{90}}{km^2}$ (mc)	rain (mm)	$\frac{Sr^{90}}{km^2}$ (mc)	rain (mm)	$\frac{Sr^{90}}{km^2}$ (mc)	rain (mm)	$\frac{Sr^{90}}{km^2}$ (mc)	rain (mm)	$\frac{Sr^{90}}{km^2}$ (mc)	rain (mm)
Oct.1958 - Sept.1959	0.015	6.9	459.4	10.3	686.5	8.56	570.8	10.6	708.1	5.36	358.6	5.5	365.6	4.76	317.7
Oct.1959 - Sept.1960	0.015	7.05	470.0	9.3	619.1	6.75	449.5	13.1	877.5	2.35	156.7	2.67	178.5	2.39	159.5
Oct.1960 - Sept.1961	0.001	0.66	665.4	0.67	674.7	0.58	586.7	0.84	844.7	0.5	501.1	0.43	432.8	0.39	399.9
Oct.1961 - Sept.1962	0.022	17.6	801.0	13.3	606.6	16.9	769.4	23.6	1071.7	9.1	413.5	6.62	300.8	0.88	222.4
Oct.1962 - Sept.1963	0.022	12.0	546.6	15.8	719.7	12.7	567.7	22.2	1011.2	4.86	222.0	3.52	160.1	3.07	139.6
Oct.1963 - Sept.1964	0.022	17.1	776.6	16.9	766.6	15.9	724.4	23.8	1083.8	16.0	726.0	12.6	572.1	11.7	530.3
Subtotal		61.3		57.2		61.4		94.1		38.1		31.3		27.2	
From soil analyses till October 1958		5.6		12.1		13.6				22.5		14.6		4.4	
Total expected mc Sr^{90}/km^2		66.9		69.3		75.0		>94		61.6		45.9		31.6	
Observed mc Sr^{90}/km^2		41.5		31.4		23.5		89		62.0		36.8		31.4	

Fresh Fallout in Israel from the Second Chinese Nuclear Test : A. Donagi*, A. Eisenberg**, Y. Feige, Y. Prulov, E. Shalmon

Fallout from the Chinese nuclear test of May 14, 1965 was first detected in Israel in air samples taken on May 28, 1965. Gamma-spectrometric analysis showed the presence of I^{131} but no Ba^{140}-La^{140} or Zr^{95}-Nb^{95}. These appeared in air samples only three days later. This fractionation effect was probably due to differences in the transport mechanism of gaseous fission products as compared with particulate debris. During the week of 28.5.1965 to 3.6.1965 the I^{131} concentrations in surface air were 0.05 to 0.18 pc/m^3.

In milk samples, I^{131} was first detected about three weeks after its appearance in the atmosphere and could still be discerned as late as the second half of August. The mean concentration was about 10 pc/l. High levels of I^{131} activity were also found in the thyroid glands of sheep, and persisted for about 3 months. The highest activity observed was about 7 pc/g, in a sample collected in the early part of July.

Radioactivity of Wild Fruits in the Vicinity of the IRR-1 Reactor : A. Tal and E. Shalmon

Samples of wild fruits (grapes and figs) were collected at a distance of about 1 km from the reactor, and also near the waste disposal pit. The fruits were ashed at 400°C and the ashes analysed by gross beta counting and gamma spectrometric analysis. All the samples contained only traces of Cs^{137} and K^{40}. Their concentrations ranged from 3×10^{-5} to 9×10^{-5} µc/kg for Cs^{137} and 3×10^{-4} to 8×10^{-4} µc/kg for K^{40}. In the figs, a gamma peak was also observed at 0.75 MeV. This peak appears to be due to trace activity of Zr-Nb^{95}.

The trace activities of fission products observed in the fruits are far below the maximum permissible levels. From a comparison with controls

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it is concluded that the activities are due to deposition of fallout from nuclear detonations rather than to contamination from the IRR-1 reactor.

Evaluation of Some Procedures for Sizing Atmospheric Aerosols : E. Shalmon and A. Donagi*

The behaviour of an aerosol is largely determined by its particle size distribution. The commonly employed measurements of total airborne mass concentration of dust do not give reliable estimates of potential hazards, since they fail to make allowance for the retentions of the various portions of the respiratory system which are highly size dependent and vary over wide ranges. Accordingly, it has become accepted that the particle size distribution of an atmospheric aerosol must be evaluated before the potential hazard associated with its inhalation can be estimated.

A review of the literature on the size distribution of atmospheric dust reveals large discrepancies in the results reported by the different investigators. Some of these results are presented in Table 32.

TABLE 32

Particle size distribution characteristics reported in the literature

Location	Count median diameter (micron)	Mass or Volume median diameter (micron)	Standard geometric deviation	Refs.
14 U.S. cities (average)	0.54	0.97	1.56	3,4,5,6
Knolls Atomic Power Laboratory	0.028	1.12	3.05	7
University of Minnesota (indoor air)	0.46 - 0.95	1.8 - 7.9 (range for eight samples)	1.66-3.36	8
4 U.S. cities (40 samples)				
Range	up to 0.2	0.8 - 8	1.74-3.16	9
Average	0.03	3.56		

* Tel-Hashomer Hospital

Aerosol samples were collected on membrane filters, using a positive displacement pump as the air mover. Membrane filters were chosen because they have high surface retention and uniformly high efficiencies greater than 99% for particles larger than 0.01 micron in diameter[1]. Particles larger than 1 micron in diameter were sized by light microscopy, and sub-micron particles by electron microscopy. Photographs were made of the dust samples as viewed through the microscopes. Best results were generally obtained at 430 magnification with the light microscope, and between 2,000 and 10,000 with the electron microscope.

The micrographs were projected on a vertical screen and the sizing carried out on the projections. Each sizing involved about 5,000 dust particle. A log-normal distribution of particle sizes was expected[1] and the size intervals were selected accordingly.

The size data were converted to cumulative percentages, which were plotted on logarithmic probability paper as a function of the diameter corresponding to the upper limit of each size interval.

Surface area and volume distributions were plotted not from the direct measurements obtained with the light microscope, but from a plot of log frequency versus the square of the logarithm of the diameter of the particles.

Table 33 summarizes the results obtained for various dust samples. The following points were noted:

(i) The light and electron micrographs indicate no sharp cutoff in the sizes of particles retained by the filters. Particles down to about 0.001 micron were observed.

(ii) The reproducibility of the results by this method was good, as indicated by duplicate sizings of the same dust sample by different people. It was found that the use of a projected micrograph yielded more reproducible results than the commonly accepted technique of sizing directly through a microscope.

(iii) Sizing of dust particles by horizontal and by mean geometric diameters were found to give essentially the same distributions, and thus, the easier method of measuring only the horizontal projected diameter of the particles would be acceptable.

(iv) Almost all (above 99.9%) tropospheric aerosol particles are smaller than 1 micron in diameter.

(v) Almost all (over 97%) of the surface area and volume of tropospheric aerosols aerosols are associated with particles larger than 1 micron.

TABLE 33

Summary of count, surface area, and volume median diameters of various dust samples

Designation of Sample	Count median diameter (micron)	Standard geometric deviation	Surface area median diameter (micron)	Standard geometric deviation	Volume median diameter (micron)	Standard geometric deviation
TAS-A	0.045	3.56	5.4	2.08	9.0	1.86
TAS-C,D,E (combined)	-	-	-	-	6.5	1.96
TAS-A to F (combined)	-	-	3.8	2.21	7.4	1.92
TAS-A to F (combined)[a]	-	-	-	-	6.9	1.92
TAS-A to F (combined)[b]	-	-	-	-	7.6	1.91
T - 1	0.012	2.22	6.6	2.25	14.9	2.02
T - 2-4 (combined)	0.011	2.32	6.0	2.21	12.2	2.00
I - 1-5 (combined)	0.010	2.36	6.2	2.28	14.8	2.06

a - measured by observer A b - measured by observer B

References:

1. SHALMON, E., Deposition of Some Radionuclides on Tropospheric Aerosols, Thesis, University of Michigan, Ann Arbor, Michigan, 1964
2. AITCHISON, J. and BROWN, J.A.C., The Log-Normal Distribution, Cambridge University Press, 1957
3. BLATZ, H., ed., Radiation Hygiene Handbook, McGraw-Hill, 1959
4. FRIEDLANDER, S.K., et al., Handbook on Air Cleaning, AECD-3361, Harvard University, School of Public Health, 1952
5. IVES, J.E., et al., Atmospheric Pollution of American Cities for the Years 1931 to 1933, Pub. Health Bull., 224 U.S. Gvt. Print. Office, 1936.
6. MAGILL, P.L., HOLDEN, F.R. and ACKLEY, C., eds., Air Pollution Handbook, McGraw-Hill, 1956
7. FITZGERALD, J.J. and DETWILER, C.G., Am. Ind. Hyg. Assoc. Quart., 16 123, 1955
8. WHITBY, K.T., ALEGERN, A.B., and JORDAN, R.C., Size Distribution and Concentration of Airborne Dust, Presented at the Semi-Annual Meeting of the American Society of Heating and Air Conditioning Engineers, San Francisco, Calif., June 1955
9. WHITBY, K.T., et al., The ASHAE Airborne Dust Survey, Heating Piping and Air Conditioning, November 1957.

A Survey of the Operation of Dental X-Ray Apparatus in Israel : A. Donagi*, E. Shalmon and D. Fishel**

A survey was conducted to determine the safety of operation of dental X-ray machines in Israel, with a view to establishing routine country wide supervision of these machines. Unfortunately, a considerable number of the machines in use are relatively old and in bad condition, emitting excessive radiation which affects both patient and operator. It was found that radiation exposure from dental X-ray machines accounts for an appreciable fraction of the total population dose.

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A five percent random sample of dentists and dental practitioners was investigated. Details of the physical characteristics of the machines and the practices of the operators were recorded, according to the pattern adopted by the U.S. Public Health Service[1,2,3]. The following are the more important parameters investigated:

Make, model, age and usage of apparatus
Professional age of operator
Work load of the apparatus
Normal operating control settings
Presence of collimator and filtration
Diameter of central beam
Radiation output of central beam
Scattered radiation around the apparatus
Radiation shielding and protective devices
Type of film used and techniques of film developing

The findings of the survey are listed below:

(i) There are about 1,200 dental X-ray machines in Israel, corresponding to about 65% of all the practitioners.

(ii) The average professional age of the dentists is 25 years and of the dental practitioners 31 years. These professional ages are considerably higher than those in the U.S.A., and may account for the lack of awareness of radiation hazards and control which are revealed in this survey.

(iii) The professional age of practitioners is inversely related to the number of X-ray examinations performed by them.

(iv) The age of X-ray apparatus in Israel and the diversity of makes are considerably greater than those in the U.S.A. The mean age of foreign made machines, which account for about 69% of all machines, is 16.7 years, against 5.3 years for the Israeli makes.

(v) Although most of the X-ray machines have a connecting cable between timer and apparatus, in 77% of the cases this cable is too short, thus causing an unnecessary radiation exposure to the operator.

(vi) Only about 38% of all X-ray apparatus and 5% of the Israeli made machines have filtration. Such filtration considerably reduces the radiation exposure of the patient.

(vii) Only 46% of X-ray machines had collimators and 29% have central beams diameters of less than 7.6 cm factors which reduce the radiation dose to the patient.

(viii) The occupational radiation exposure of the operators is below the maximum permissible doses, but is high considering the low working load of the machines.

(iv) Radiation exposure of patients tends to be considerably higher than that found in other countries, and results mainly from scattered radiation.

References:

1. Physical Survey Manual - Dental X-Ray. U.S. Public Health Service, 1960.
2. YALE, S.H. and HAUPTFURER, J.D., J.A.D.A. 58, 49-54, April 1963.
3. Medical X-Ray Protection up to Three Million Volts, National Bureau of Standards Handbook 76, U.S. Department of Commerce, 1961.