Enviromental Radioactivity measurements in Northwerstern Greece

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ENVIRONMENTAL RADIOACTIVITY MEASUREMENTS IN NORTHWESTERN GREECE

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The Nuclear Physics Laboratory (NPL) of the University of Ioannina has for the last five years been conducting research with regard to the penetration of radioistopes into the ecosystem. Radioactivity measurements carried out during the summer of 1986, immediately after the Chernobyl accident and data obtained from controlled *ad hoc* experiments conducted thereafter, have been employed in this research. The areas covered by the research programme of the NPL include:

1. Modelling of processes involved in the transport of trace elements through ecosystems.
2. Measurement of rate parameters and transfer coefficients.
3. Calculation of doses received by the general population or selected segments of the population.
4. Countermeasures for the decontamination of foodstaffs.

Some of the results obtained to date are briefly presented in what follows.

RADIOCONTAMINATION TRANSPORT TO MILK

Environmental behaviour of ^{131}I following the Chernobyl accident

Atmospheric, grass and milk data, collected during May 1986 in northwestern Greece, were employed in order to investigate the propagation of ^{131}I via the air-grass-milk pathway (Assimakopoulos, *et al.*, 1988). The process was modelled by means of the three compartments shown in Fig. 1, which describe the time evolution of radioiodine concentration in the air A(t), grass G(t) and milk C(t) through a system of linear differential equations. The initial impulse of ^{131}I activity in the area was described by means of a first order γ-variate function

$$A(t) = A_0 t e^{-\lambda \cdot t} \qquad (1)$$

The model depicted in Fig. 1 depends on two transport (γ_{ag}, γ_{gm}) and three decay (λ_a, λ_E, λ_B) parameters. It also depends on three superficial amplitude parameters for the maximum specific activity observed in the atmosphere (A_0), grass (G_0) and milk (C_0). Calibration of the model with respect to these parameters, as well as overall validation, was performed by fitting solutions of the model (minimum χ^2 fit) to atmospheric, grass and milk data. The comparison of model predictions and experimental data is given in Fig. 2. Model parameter values are contained in Table 1. Potentially received doses to the thyroid gland of people living in northwestern Greece arising from these observations are given in Table 2.

Modelling of trace element transport from a ruminants diet to its milk

The model employed for the analysis of experiments involving the transport of radioactive substances from an animal's diet to its milk is depicted schematically in Fig. 3. In this model V_1 represents the volume of the whole animal and V_2 the volume of milk in the mammary gland. While the animal is being fed contaminated feed, a fraction γP of the daily intake P [Bq d^{-1}] of contamination is transferred to its body resulting in an average contamination concentration $x_1(t)$. Compartment 1 releases contaminant into excreta at a rate $\xi_1 x_1$ and into milk, accumulating in the mammary gland, at a rate $\lambda_2 x_1$. Some of the contaminant is returned from the mammary gland to the body at a rate $\mu_2 x_2$, where $x_2(t)$ is the contamination concentration of the milk at

time t.

During the short period between milkings of the lactating ruminant, the volume V_1 of the body may be considered as constant, while the volume V_2 of the milk accumulating in the mammary gland may be considered to increase linearly as

$$V_2(t) = \alpha + \beta t \qquad (2)$$

According to the last expression, a small amount of milk α (a few g) remains in the mammary gland immediately after milking (at $t = 0$), while at the next milking (at $t = T$) the volume of milk in the mammary gland has reached $V_2 = \alpha + \beta T$.

The system of linear differential equations which describes the temporal evolution of the functions $x_1(t)$ and $x_2(t)$ and the solution of these equations are given in Assimakopoulos *et al.* (1991). The model contains seven parameters (γ, ξ_1, λ_2, μ_2, V_1, α and β), whose values are generally unknown. In order to validate the model and calibrate its predictions with respect to its parameters, several controlled experiments were conducted.

Radiocaesium transport from a sheep's diet to its milk

In one experiment, ten adult lactating ewes were segregated from a herd at the Ioannina Agricultural Research Station and held in isolated pens. During an initial period of 20 days, the animals were offered a diet of radiocaesium contaminated hay (*medicaga sativa*), harvested in northwestern Greece

Figure 1. The three-compartment model employed in the analysis of the air-grass-milk pathway data.

during the summer of 1986, which subjected them to a daily ^{137}Cs activity intake of 832 Bq d^{-1}. The animals were then returned to uncontaminated feed and were further monitored for an additional 15 days. Milk samples were measured daily at the NPL for ^{137}Cs specific activity, with the results presented in Fig. 4. The continuous line through the data represents the best fit (minimum χ^2) of model predictions to the data by treating all seven transport parameters as free. The transfer coefficient for hay-to-milk radiocaesium transport was determined from this experiment as

$$f_m = 0.058 \pm 0.007 \ d\,L^{-1} \qquad (3)$$

The transfer coefficient from a sheep's diet to its milk was also measured in a detailed study of the decontamination of lactating ewes, which had been allowed to reach equilibrium with respect to ^{137}Cs intake. In this experiment, 15 adult ewes, which had been subjected to a heavily contaminated diet for a period of 50 days, were segregated in a pen at the Agricultural Research Station of Ioannina, where they were fed on uncontaminated herbage. Specific radiocaesium activity in the animals' milk was monitored daily for a period of 130 days. The data from this experiment are contained in Fig. 5. The value of the transfer coefficient obtained from these data was

$$f_m = 0.071 \pm 0.009 \ d\,L^{-1} \qquad (4)$$

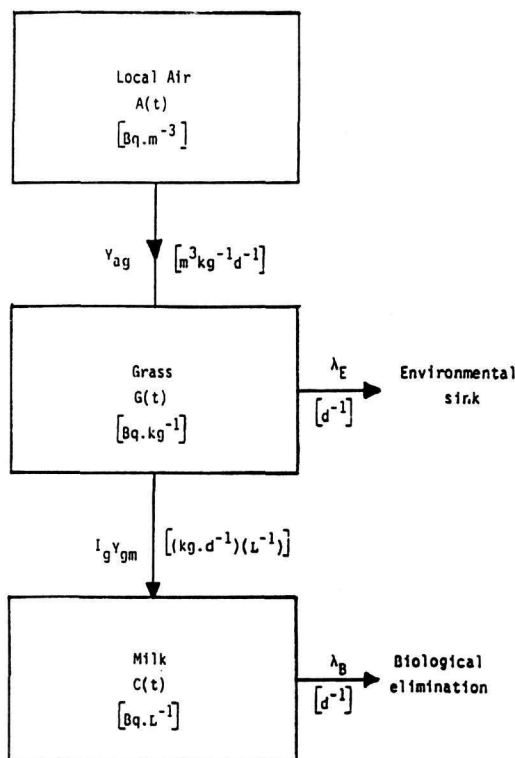which, within experimental error, coincides with the result in eqn (3).

Depencence of the radiocaesium diet-to-milk transfer coefficient on the stage of lactation

The f_m value in eqn (3) was the first measurement of this parameter reported in the scientific literature. Since then a number of investigations have reported f_m values ranging from 0.03 to 0.22 d L^{-1}. Several factors, such as the type of feed, the chemical form of caesium in the herbage or the stage of lactation of the ewes, could be responsible for this variability. In order to investigate the last effect an experiment was conducted during a complete lactation period. To this purpose one hundred and forty adult *boutsiko* ewes, which had given birth between 1 and 2 November, 1990, at the Ioannina Agricultural Research Station were used in the study.

Each week after the start of lactation a group of six ewes was separated from the flock and segregated into a separate pen for a period of three weeks, during which daily milk production and herbage intake of the group as a whole were measured. During the first "preparation week", the animals were fed on ground wheat. During the second week, the animals were fed on contaminated ground wheat, harvested in north western Greece during July 1986, which contained 1150 Bq/kg of radiocesium (^{137}Cs and ^{134}Cs). Daily milk production and food consumption of each group were monitored. Samples of the morning and evening milkings during this "contamination week" were bulked and the radiocesium activity concentration was measured at the Nuclear Physics Laboratory. The ewes were returned to uncontaminated ground wheat for a third "decontamination week", during which time the same parameters were monitored. After the end of the three-week period of study the animals were returned to the flock.

Transfer coefficients for each week of the lactation period, which lasted for 21 weeks, were extracted by using the model illustrated in Fig. 3. The temporal evolution of f_m values through the entire lactation period, contained in Fig. 6, shows a factor of three monotonic increase as the stage of lactation progresses. This indicates that the stage of lactation dependence of the transfer coefficient should be taken into account in models predicting radiocaesium burdens of the general population.
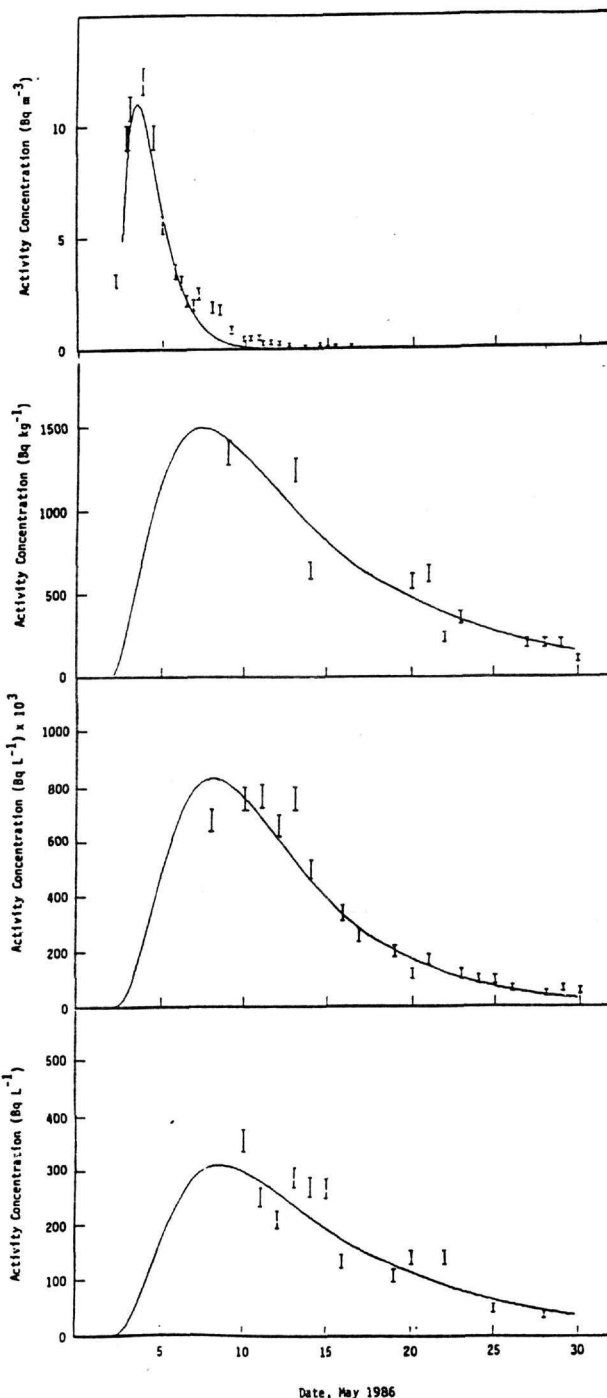

Figure 2. Specific activity data of ^{131}I in north western Greece during May 1986. (a) atmosphere, (b) grass, (c) ovine milk, (d) bovine milk.

Table 1. Numerical values of model parameters derived from independent fits to atmospheric, grass and milk data. The decay parameters for air λ_a, grass λ_g, milk λ_m and the transfer rate of the contaminant from grass to milk γ_{gm} are indicated in Fig. 1 and their physical significance explained following eqns (1) and (3); f_m is the grass to milk transfer coefficient.

| Data | Decay parameters | | | | Grass to milk transfer rate γ_{gm} (L^{-1}) | Transfer coefficient f_m (d L^{-1}) |
	λ_a (d^{-1})	λ_g (d^{-1})	λ_m (d^{-1})	Amplitude		
Atmosphere	0.65 ± 0.13					
Grass	0.64 ± 0.10	0.11 ± 0.07		980 ± 320		
Ovine Milk	0.69 ± 0.03	0.17 ± 0.02	0.74 ± 0.03	2861 ± 264	0.73 ± 0.25	0.94 ± 0.32
Bovine Milk	0.70 ± 0.04	0.11 ± 0.03	0.81 ± 0.09	202 ± 29	$(4.1 \pm 1.5) \times 10^{-3}$	$(5.1 \pm 1.9) \times 10^{-3}$

Table 2. Potentially received doses to the thyroid gland of people living in northwestern Greece for the period May 1986–July 1986.

| Exposure pathway | Dose equivalent (mSv) | | | |
	Infants	Children	Adolescents	Adults (>18 y)
Ovine milk consumption	0	58[a]	26[a]	4.9[b]
Bovine milk consumption	8.5[a]	5.5[a]	2.5[a]	0.48[b]
Leafy vegetable consumption	0	3.6[c]	2.9[c]	1.9[c]
Inhalation	0.56[d]	0.52[d]	0.39[d]	0.22[d]

[a] $Q_m = 0.5$ L d^{-1}.
[b] $Q_m = 0.25$ L d^{-1}.
[c] Q_g = Leafy vegetable consumption rate was assumed to be 0, 68, 123 and 219 g d^{-1} for the newborn, children, adolescents and adults respectively (see Soldat 1976).
[d] The dose equivalent was calculated using eqn (5) with the normalizing amplitude A_0 taken at the average value of 13 Bq m^{-3} (Greek AEC Report 1986).

Transport of radiocaesium from a ruminant's diet to its tissues

A general multiple compartment model, which describes the transport of trace elements through animals was investigated. This model considers a system of K interconnected compartments of volume V_k, k = 1,2,...,K, each containing, at a given time t, N_k molecules of a trace substance. A typical such compartment is depicted in Fig. 7. For purposes of generality we consider this compartment to be fed from the outside world at a constant rate P_k [molecules per day]. We also consider this compartment to release molecules to the outside world at a rate $\xi_k x_k$, where ξ_k is a constant and x_k [molecules per liter or molecules per kilogram] the concentration of trace molecules in the compartment. Compartment k is linked to every other compartment j = 1,2,...,K (j ≠ k) in the system and is thus fed at a rate $r_{jk} x_j$, where again x_j is the concentration of molecules in compartment j and r_{jk} is a constant characterizing the link between compartments j and k. Similarly compartment k feeds every other compartment in the system at a rate $r_{kj} x_k$. Then the equation, which describes the rate of change of molecules in compartment k, may be written concisely in matrix form as (Assimakopoulos, et al. 1991)

$$\frac{d(Vx)}{dt} = P + Rx \qquad (5)$$

where x and P are column vectors with elements x_k and P_k, respectively. V is a diagonal matrix with elements V_k, the volume of each compartment in the system, along the diagonal; R is the transpose of the matrix with elements r_{kj}. If the volume of each compartment remains constant, eqn (5) may be readily written as

$$V \frac{d(x)}{dt} = P + Rx \qquad (6)$$

with formal solutions (Assimakopoulos, et al. 1991)

$$x(t) = [\exp(V^{-1}Rt) - 1]P + \exp(V^{-1}Rt)x(0) \qquad (7)$$

in which the contamination concentration in the departments of the system at t = 0 is given by the x(0).

The general model described in the previous sections has been applied to the on-going investigation at the Nuclear Physics Laboratory of the University of Ioannina for radioactive caesium contamination and decontamination of sheep. In one experiment fifty adult ewes were subjected to a diet of wheat, harvested in northwestern Greece shortly after the Chernobyl accident, which provided a constant daily intake of approximately 5000 Bq. Half of the animals were sacrificed at regular intervals during this gradual contamination phase, which lasted for 60 days and samples of various "compartments" of the animals (blood, muscle, heart tissue, etc.) were measured for radiocaesium concentration. The remaining animals were subsequently returned to a contamination-free diet and radiocaesium concentration in the same compartments was measured through periodic slaughtering for an additional 60 days.

The compartment configuration considered for the analysis of the above experiment is contained in Fig. 8. According to this configuration, a fraction γP of the daily intake P [Bq d^{-1}] is transferred to the blood compartment, which is designated as compartment 1. The blood compartment acts as a vehicle for the transfer of contamination to every other compartment k of the animal at a rate $\lambda_k x_1$, while at the same time is constantly fed through recycling by each

Figure 3. A two-compartment model for the contamination of ruminants' milk.

compartment at a rate $\mu_k x_k$. For purposes of generality, each compartment of the animal, including the blood compartment, is considered to release contaminant to the outside world at a rate $\xi_k x_k$.

In terms of the parameters of the general model, the rate constants of the sheep model may be identified as

$$P_1 = \gamma P, \ P_k = 0, \ k = 2,3,...,K$$

$$r_{1k} = \lambda_k, \ k = 2,3,...,K$$

$$r_{k1} = \mu_k, \ k = 2,3,...,K$$

with all other elements $r_{kj} = 0, \ k,j \neq 1$.

Solutions of the sheep model just described (continuous curve) are compared to actual experimental data in Fig. 9. The model considered here involves four compartments of the animal (blood, muscle, fat and lung tissue). The animal is subjected to a constant intake of 5,000 Bq d^{-1} for an initial period of 60 d. It is subsequently returned to a contamination - free diet and the decontamination of the various compartments is followed for an additional 60 d. The rate parameters employed in the calculation are derived from a best (minimum χ^2) fit to the experimental data and are listed in Table 3. The same table contains the transfer coefficients to each compartment, computed from the rate parameters.

Radiocaesium transfer to sheep's milk as a result of soil ingestion

Plants growing on soil, contaminated by radioactive substances, lead to the contamination of herbivorous animals either from the amount of contaminant taken up by the roots or from soil adhering to the plants' surface. Root uptake of various radionuclides and the consequent radiocontamination of ruminants through consumption of the plants have been extensively studied in the past. However, it has also been recognized that direct soil ingestion may contribute significantly to overall plant and animal radiocontamination. Direct soil
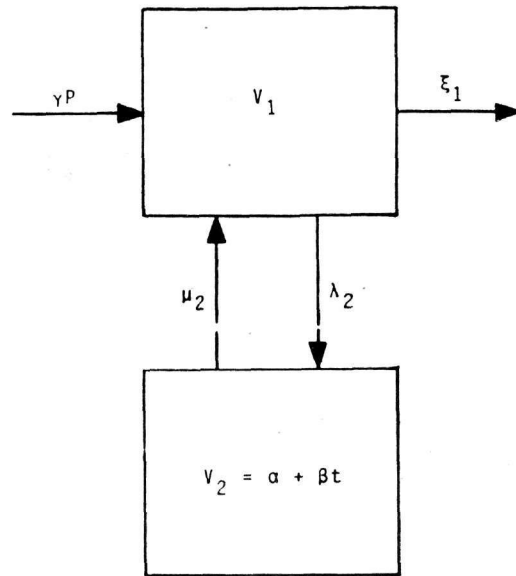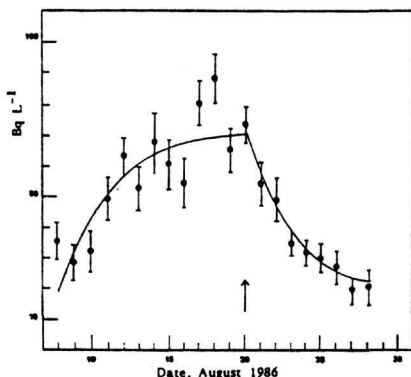
Figure 4. Total radiocaesium specific activity in sheep's milk during the contamination and decontamination periods.
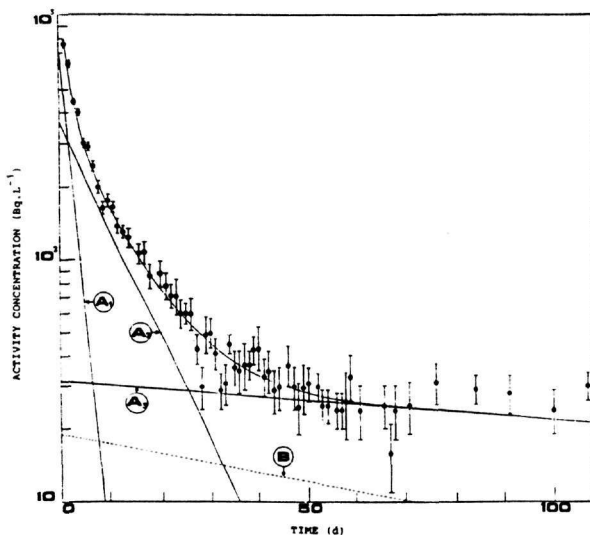

Figure 5. Total radiocaesium specific activity in sheep's milk during a long decontamination period.

adherence to plants' surfaces may reach soil mass loadings ranging from 100 to 500 mg soil per g of plant, depending on the biomass of the plant, weather conditions and soil disturbance from agricultural equipment. As expected, the amount of soil intake is reported higher for free-grazing animals, especially in arid or deteriorated pastures, where soil particles may be ingested directly from the ground surface, through the uprooting of plants or licking of snouts whilst grazing. Previous studies have found that in extreme cases soil ingestion can account for up to 18% and 30% of the daily food intake of cattle and sheep, respectively. Such amounts may greatly affect the overall radiocontamination of ruminants.

Even though direct soil ingestion has been recognized as a major pathway for the transport of radionuclides to ruminants, very little information exists in the scientific literature with regard to transport rates through this mechanism. An experiment was thus conducted in order to investigate the effects of soil ingestion with regard to radiocaesium contamination of sheep milk and measure the corresponding transfer coefficient. For this purpose eight adult ewes, which gave birth between 1 and 3 November 1990 at the Ioannina Agricultural Research Station, were used. Throughout the experiment, which lasted for two weeks (23 March to 4 April, 1991), the animals were individually housed in metabolism cages and fed daily on 500 g dry roughage (*medicaga sativa*), supplemented by 800 g of pelleted food concentrate. During the first week of the experiment, 50 g of radiocaesium contaminated soil, packed in 7 g gelatin capsules, were orally administered to the ewes every day. The contaminated soil employed in this experiment consisted of 1 cm sandy topsoil, collected 1 km SW of the village Bourakovka, within the 30 km zone of the heavily contaminated Chernobyl area. Activity of the soil in ^{137}Cs was measured as $36,700 \pm 700$ Bq kg^{-1}, thus resulting in a daily radiocaesium activity intake of the ewes of $1,835 \pm 35$ Bq d^{-1}. Herbage intake and daily milk production of each ewe in the group were monitored throughout the duration of the experiment. Urine and faeces from each metabolism cage were also collected and weighed daily. Milk from the morning and evening milkings was bulked daily and measured at the Nuclear Physics Laboratory for radiocaesium concentration. The activity concentration in the urine and faeces collected from the metabolism cages was also monitored on a daily basis.

Typical activity concentration data collected from one of the animals, are presented in Fig. 10. As expected, the data evince an increase in radiocaesium activity concentration in both the ewes milk and urine during the first seven days, whilst contaminated soil was being administered to the animals. This is followed by a gradual exponential decrease during the second week, when the animals were returned to

uncontaminated feed. In contrast, faeces specific activity remains practically constant through the contamination period and reduces sharply immediately after the animal is returned to uncontaminated feed. Similar results were obtained for all ewes involved in the study. The average value obtained for f_m in this study was

$$f_m = (2.6 \pm 0.6) \times 10^{-2} \ d \ kg$$

$$(8)$$

A similar analysis was carried out for the determination of radiocaesium transport to the animals' urine. The transfer coefficient f_u was determined from these parameters as
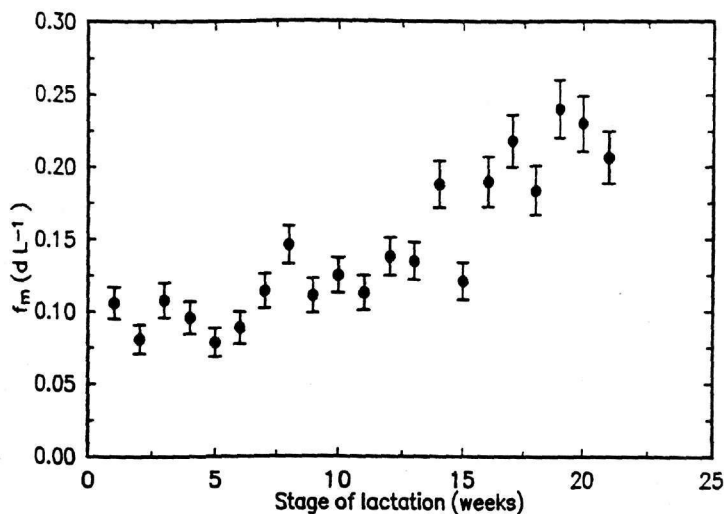

Figure 6. Transfer coefficients for radiocaesium transport from a sheep's diet to its milk measured during a complete lactation period.
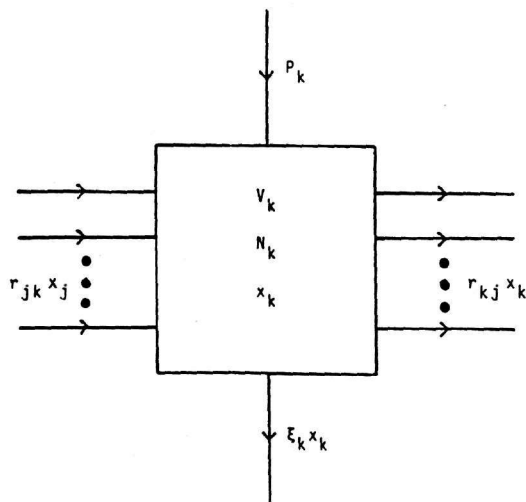
$$f_u = (5 \pm 2) \times 10^{-2} \ d \ kg^{-1} \qquad (9)$$

The soil-to-milk transfer coefficient f_m measured in this experiment is substantial. The value obtained here is by only a factor of three to five lower than f_m values for herbage-to-milk radiocaesium transfer. Thus soil ingestion may be a major source of milk radiocaesium contamination, especially for free-grazing animals.

Figure 7. Typical unit of a general K-compartment model.

RADIOCONTAMINATION OF HUMANS

Radiocaesium contamination of breast milk and infants

During the months of May and June 1986, samples of breast milk brought to the Nuclear Physics Laboratory at random (mainly by wives of concerned colleagues) showed no iodine or cesium contamination above the detection limits of the apparatus. As expected, it was soon established that pregnant women and new mothers, following government warnings and directions of their
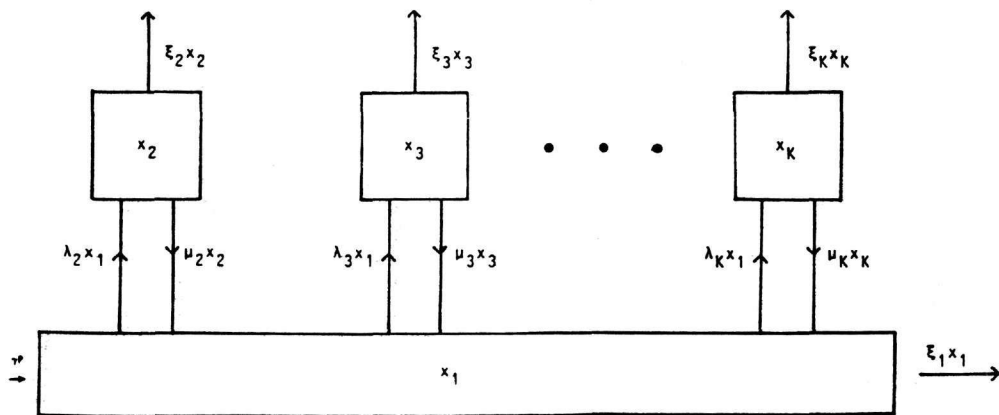
Figure 8. A multiple-compartment model for the study of Cs contamination of sheep.

physicians, were extremely careful to include only pre-Chernobyl products in their diet. These precautions, however, were dropped as a general practice towards the end of 1986. During the spring of 1987, when the research reported here was carried out, pregnant women and new mothers had returned to their regular dietary habits, while radiocesium contamination of foodstuffs in the area was still at measurable, albeit stabilized levels. It was, therefore, considered of interest to investigate the possible penetration of radiocesium into breast milk in this situation. On the other hand, the Nuclear Physics Laboratory has amassed a considerable amount of data from routine monitoring of foodstuffs, which lead to well-established average levels of food contamination in the area. It was hoped that these data could be used to correlate measured levels of radiocesium in breast milk with the diet of the mother and thus assess the relevant transfer coefficient.

Samples of milk from one hundred and two (102) new mothers were collected by the staff of the Department of Obstetrics and Gynaecology of the University of Ioannina during the months of February, March, April and May 1987. The mothers' age ranged from sixteen to thirty-five years. The samples were predominantly colostral milk, collected at the University of Ioannina Hospital during the first week after labor, with an average sampling time of 3.6 d following parturition. At the time of sampling each donor replied to a questionnaire pertaining to age, origin, education and social background . Special emphasis was given on the mother's diet during the last three months of pregnancy. In particular donors reported on the daily average consumption of the four most contaminated items in the area namely, bread, milk, red meat and fruit (apples).

During the period of the experiment, samples of the dietary items listed in the questionnaire filed by each donor, were measured routinely to establish any change in contamination levels. All food samples were obtained from large commercial outlets in the area and were measured in a standard 400 mL geometry with the same detector. Dairy samples were obtained from a large dairy plant in the city of Ioannina which collects daily most of the milk produced by individual farmers. Radiocesium contamination (± one standard deviation from the mean) measured in north western Greece for the four food items considered here are contained in Table 1.

The results of the measurements of total radiocesium contamination (both ^{134}Cs and ^{137}Cs) in the 102 samples of breast milk examined are presented in the histogram of Fig. 11. Since the background level for cesium was considerable, measurements of several samples resulted only in an upper limit ($\leq$ 10 Bq L-1) for contamination concentration. These results are contained in the lowest group of the distribution.

An attempt was made to establish a relation between the measured contamination level in milk and the corresponding diet of the mothers. The data were analysed by means of multiple regression and correlation techniques in order to establish the relation between quantities of radioactivity in the food and the resulting output in colostral milk. The value of the transfer coefficient, expressing the transfer of contamination from the mother's diet to her milk, as obtained from this correlation was

$$f_m = 0.06 \pm 0.03 \, dL^{-1} \qquad (10)$$

This may be compared to the values 0.0079 - 0.0186 d L^{-1} obtained for dairy cows and 0.058 d L-1 measured for lactating ewes.

The consumption of cesium-contaminated milk leads to radiation exposure of the infant. The resultant effective dose was estimated by assuming a daily ingestion of 0.5 L breast milk and a level of contamination of 4.7 Bq L-1 in ^{134}Cs and 11.7 Bq L-1 in ^{137}Cs. It was thus calculated that each day the infant receives an effective dose of 0.012 mrem. This value is an upper limit, applicable only during the initial phase of breast-feeding. A drop by 60% in Cs concentration in mature milk would lead to a daily dose of 0.005 mrem. Since this dose estimate is rather low, it was not recommended to the mothers to halt breast-feeding.

^{90}Sr concentrations in human teeth in south Ukraine, five years after the Chernobyl accident

Strontium-90 is considered one of the most dangerous radionuclides in nuclear fallout due to its relatively long lifetime and its propensity to accumulate in bones. Although human bone samples cannot be easily obtained, tooth contamination has been demonstrated in the past to be a reliable measure for the overall ^{90}Sr body burden. In the research reported here human teeth, collected in South Ukraine, approximately 1,500 km south of the nuclear accident site of 1986, were measured for ^{90}Sr concentration. An attempt was made to study differences of contamination levels among sex and age groups and investigate the factors which cause such differentiation.

Approximately 1000 human teeth were collected for the purposes of this study in South Ukraine, USSR, during the period of October 1990 to May 1991. Samples were collected in cooperation with dentists of the Central Children's Dental Clinic and several peripheral clinics in the greater Sevastopol area. The teeth were grouped into eighteen samples according to age and sex of the donors. No further particulars of the donors were recorded at the time of collection. All samples were ashed at a temperature of 450 - 500 °C and ground to fine powder. The final samples were formed by taking 20 g of ash from each group sample. The samples were further chemically treated in order to enhance strontium concentration. The final samples were measured for beta activity at the Nuclear Physics Laboratory of the University of Ioannina with a dual gas proportional detector assembly.

Strontium-90 concentration in the samples, expressed in mBq per g of ash, are contained in Fig. 12. Several features of these results are readily noted:
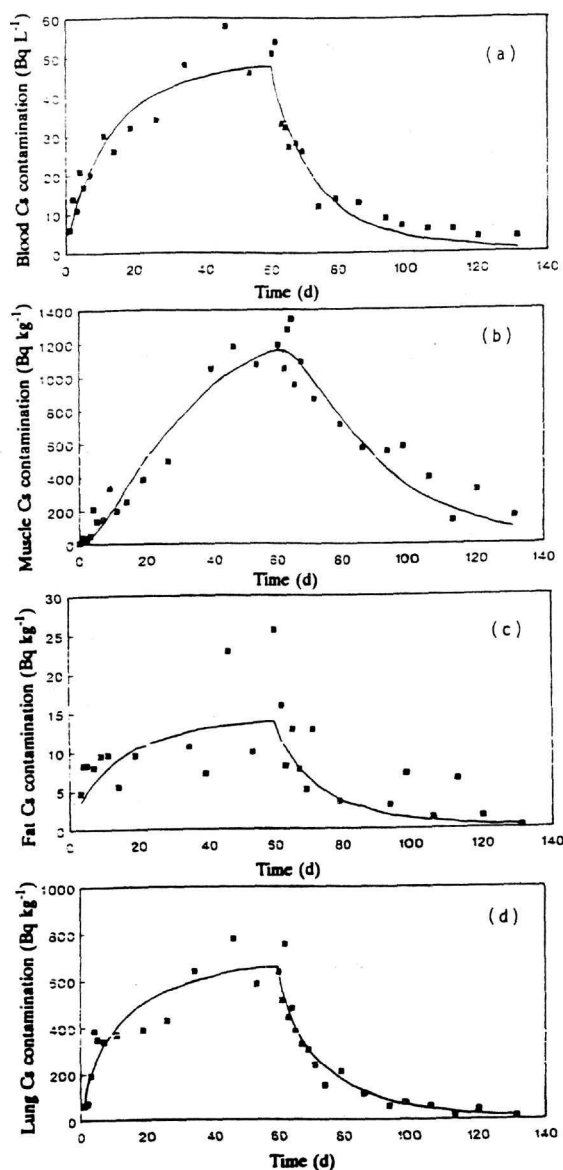

Figure 9. The time evolution of specific activity in the model of Fig. 8 for K = 4.

Compartment	Volume (kg)	λ (kg d⁻¹)	μ (kg d⁻¹)	Transfer coefficient (x 10⁻²) (d kg⁻¹)		
				Experimental	Model	Previous work
Blood	2.45	-	-	1.4 ± 0.3	1.1 ± 0.2	2[1]
Muscle	16.75	26 ± 4	1.1 ± 0.2	34 ± 7	33 ± 12	57[1], 8 - 50[2], 33[3]
Lung	0.50	5 ± 1	0.5 ± 0.1	17 ± 3	15 ± 5	17[1], 7[4]
Liver	0.85	17 ± 3	1.4 ± 0.2	18 ± 4	18 ± 6	33[1], 12[4]
Kidney	0.102	45 ± 13	1.7 ± 0.3	36 ± 6	37 ± 14	50[1], 9.6[4]
Spleen	0.095	45 ± 25	2.9 ± 0.5	23 ± 5	22 ± 14	24[1]
Heart	0.128	76 ± 14	6.1 ± 1.0	19 ± 4	18 ± 6	
Brain	0.085	0.11 ± 0.05	0.010 ± 0.003	15 ± 4	15 ± 8	
Rumen	1.56	19 ± 4	2.1 ± 0.3	13 ± 3	13 ± 4	
Intestines	1.60	5 ± 2	5 ± 1	1.4 ± 0.3	1.4 ± 0.7	
Fat	3.81	-	-	< 0.7	-	

1. Concentrations of ^{90}Sr in the teeth of the female child and teenage population exceeds by a factor of two or three concentrations in the corresponding male age groups. This may be due to physiological reasons or different dietary preferences (e.g. milk products) between the sexes of that age bracket.

2. For the population of both sexes, younger than 25 years of age, there seem to be two local maxima: ages 4 - 6 years and 10 - 19 years. The first group corresponds to babies born around the time of the Chernobyl accident and growing deciduous teeth shortly thereafter. The second group contains children, 5 - 14 years of age in 1986, developing permanent teeth during the post-accident period.

3. The overall trend of the data for the female population is a gradual decrease of ^{90}Sr concentration with age. This is in agreement with previous measurements. However, the data for the corresponding male population show a remarkable feature: ^{90}Sr concentration in teeth of the 25 - 45 year old group is three to four times higher than in samples from younger donors or women of the same age. A possible explanation for this anomaly is that this age group (20 - 40 years of age at the time of the Chernobyl accident) contains a significant number of men who, either as part of the military or civilian staff of engineering firms, were mobilized immediately after the accident for the extensive clean-up operations within the 30 km zone around the damaged nuclear power plant.

Figure 10. Typical specific activity data in the soil ingestion study.

4. Finally, a smaller maximum for the age group 20 - 50 years in the female population may be attributed to the period of fertility, when calcium deficiency appears in the female organism.

Although ^{90}Sr contamination of the population of South Ukraine inferred from these measurements is not substantial, a detectable growth of radiostrontium levels in human tissues is expected in the near future. This
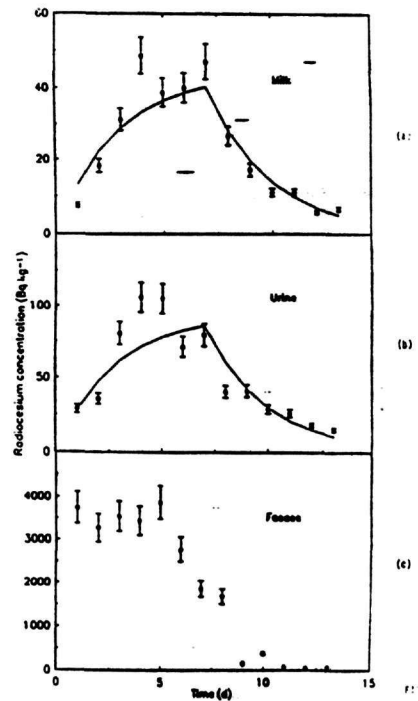
is due to a recent decision of local authorities to supply the Krimea with water from the river Dneper. An extensive program for monitoring ^{90}Sr transfer from the higly contaminated river Pripyat, a tributary of the Dneper, and through the cascade of Dneper's reservoirs to South Ukraine (Dneper estuary) is currently under way. Follow-up measurements of the nature reported here will also be conducted to assess this potential hazard.

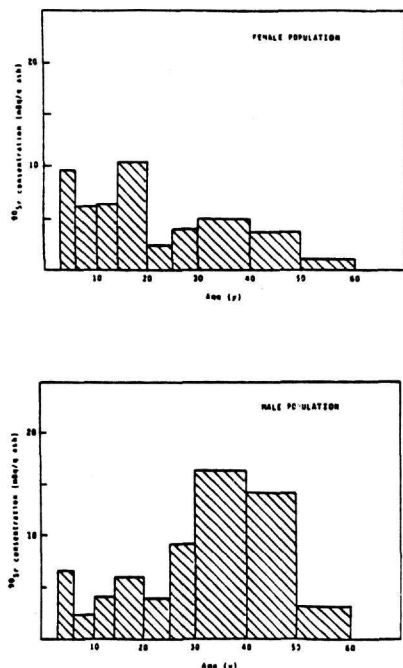Figure 11. Radiocaesium specific activity distribution measured in 102 breast milk samples.

Figure 12. Age dependence of ^{90}Sr concentration in human teeth in the male and female population of southern Ukraine.

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