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Transfer of radionuclides through the terrestrial environment to agricultural products including agrochemical practices

INSTITUTE OF
TERRESTRIAL
ECOLOGY
MERLEWOOD

ECP-2 project

Progress report for the period 1 November 1992 - 31 Augusti 1993

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Contents

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1. Distribution and solubility of strontium-90 in soil

Laboratory analyses on soil samples from the seven established experimental plots are under progress. According to the preliminary data from the present period of 1992/93, the radionuclides of ^{137}Cs and ^{90}Sr were found at all experimental sites. A relationship between ^{137}Cs and ^{90}Sr of 1:0.7 was observed inside the 30-km zone The corresponding figures on research plots outside the zone was varying between 1:0.2 and 1:0.01. These data reflect the differences in the deposition pattern.

Solubility analyses on undisturbed as well as on cultivated plots are under progress. To give an example, a mixed contaminated (fuel and condensed) podzolic soil profile (0-10 cm) was showing a considerable higher (3.4 times) solubility of ^{90}Sr compared to ^{137}Cs in water and weak acid treatments. The main parts of these radionuclides resisted and were collected by strong acids. The difference in solubility between cesium and strontium was also reflected in the vertical distribution of the radionuclides in the undisturbed soil profile of the same experimental site. The effects of pH on solubility of ^{90}Sr were performed in a minor lab-test of a mixed contaminated podzol soil and of a condensed contaminated peat soil. The laboratory experiment suggests a considerable increase in solubility at low pH.

2. Uptake of strontium-90 in plants

Laboratory analysis for strontium-90 in crop samples collected in 1992 from the seven experimental plots are under progress. The concentrations of radionuclides (cesium and strontium) were higher for raygrass than for other crops investigated (oat, barley, potato). An influence of soil type on the dynamic uptake of strontium-90 and cesium-137 over the growing season was observed.

Preliminary results show that transfer factors of cesium and strontium are highly influenced by soil type and the presence of fuel end core particles (Table 1).

Table 1. Transfer factors (Bq per kg dry biomass / Bq per kg dry soil) for raygrass

type of deposition	soil type			
	podzol		peat	
	Sr-90	Cs-137	Sr-90	Cs-137
fuel+condensed	0.7	0.2		
condensed	5.9	0.05	0.3	0.4

3. Countermeasures

A minor pilot field experiment of a countermeasure for ^{90}Sr was performed at two sites.

4. Intercalibration

SSI did prepare plant samples and executed a joint intercalibration on Sr and Cs for all CEC and CIS institutes participating in the ECP-2 project. In addition SSI did participate in an intercalibration of a joint sequential extraction procedure for Sr and Cs in soil samples. The later intercalibration was prepared by UIAR.

5. Meeting in Zelene Mys

In April 1993 a meeting was held in Zelene Mys with our CIS colleagues. During the meeting joint publications over Sr and Cs behaviour in the soil and transfer to plants were discussed. Our obtained results were in good agreement with those of our CIS and CEC colleagues. The current pilot field experiment of countermeasure for Sr was outlined and decided at this occasion.

K.U. LEUVEN
Cremers

As specified in our program of activities for the period 1992-93, the following topics have been covered.

1. Radiocaesium desorption from soils and solid phase speciation

Reversibility and desorption studies have been continued on a broad range of soils, samples in the various contaminated zones. New procedures have been developed for studying solid phase speciation of radiocaesium. It was shown that, for practically all soils, even peat soils of up to 60-70 % organic matter (such as Bragin and Komsomoletz), radiocaesium is quantitatively associated with the micaeceous frayed edge sites of the mineral fraction. Desorption behaviour of radiocaesium from these sites is quite erratic in that, sometimes very low, sometimes very high fractions are irreversibly retained within a very short time scale after contamination. So far, no link could be demonstrated with the ionic status of the soil.

2. Effect of calcium on radiocaesium fixation behaviour

A series of tests was made on the beneficial effect of calcium gifts on the fixation of radiocaesium in a range of soils. In some cases, the effect is quite significant whereas in other cases, the effect is quite small. These effects could so far not be rationalized or linked with other measurable soil properties.

3. Migration behaviour of radiocaesium in soils

In preparation of some model chromatographic transport studies of radiocaesium in soils, a podzol soil has been selected of very low cation exchange capacity which is typical for some of the contaminated zones in the CIS. This oils has been thoroughly characterized in terms of cation exchange capacity, ionic composition of the exchange complex and the soil solution, specific interception potential for radiocaesium in potassium and ammonium scenarios, field capacity, solid phase speciation of radiocaesium and fixation behaviour. On the basis of these characterizations, experimental protocols have been selected for carrying out chromatographic transport studies. These experiments are to be carried out at SCK-Mol.

4. Countermeasures

Laboratory procedures have been developed for quantitatively assessing the beneficial effect of countermeasure soil amendments for reducing the soil chemical availability of radiocaesium and radiostrontium. We have been able to demonstrate that the effect is quantitatively consistent with characterization of soils and soil amendments. On the basis of such tests, we are now in a position to make predictions on efficiency, required dose, and expected results.

5. Soil-plant transfer of radiocaesium

This specific issue was not itemized in our 1992-93 program but is a part of our contribution in the regular CEC terrestrial program. However, in view of the major importance of this process, some of the manpower, active in the present program has been engaged in this particular area. Moreover, it appears appropriate to report on this topic since it is proposed as a specific subproject for 1993-94. We have made some significant progress in the understanding of the factors affecting the plant uptake of radiocaesium. It appears that, in mechanistic terms, the uptake of radiocaesium can be rationalized on the basis of some preliminary adsorption process in the exchange complex of the plant root. On the basis of these insights, we have been able to demonstrate the dual nature of the effect of potassium on radiocaesium uptake. On the one hand, radiocaesium uptake is linearly related with the potassium saturation in the root exchange complex (which is dependent on the **relative** ion composition of the soil solution: K-Ca-Mg). On the other hand., radiocaesium uptake is inversely related to the K-concentration (Competitive effect in the soil solutions. On the basis of these findings, traditional fertilizer treatments, based on K amendment, may be quantitatively interpreted.

UNIVERSITY OF BARCELON
G Rauret

Summary

A) Intercalibration exercise for sequential extraction of ^{137}Cs and ^{90}Sr.

B) Evaluation the capacity of sequential extraction schemes for predicting radionuclide mobilization in different contaminates soil by condensed and fuel particles.

C) Evaluation of the radionuclides contamination in crops by near field resuspended soil particles, including rain-splash effect.

The scheme proposed and accepted as common scheme by all the participants in the ECP-2 sequential extraction scheme was applied to Zelene Myz soil for ^{137}Cs and ^{90}Sr. For radio-caesium the results (Bq/kg) are:

FRACTION 1	FRACTION 2	FRACTION 3	FRACTION 4	RESIDUAL
1.2 ± 2.3	18.2 ± 1.2	56.9 ± 4.3	19.7 ± 4.8	3.9 ± 0.7

The total activity of ^{90}Sr was 21.90 ± 2.38 Bq(kg (LID: 8.59 ± 2.13 Bq/kg). The first results (Bq(kg) of sequential extraction of ^{90}Sr are:

FRACTION 1	FRACTION 2	FRACTION 3	FRACTION 4
< 6.13	14.80 ± 2.03 (LID: 4.4)	< 8.33	< 5.81

To carry out an evaluation of the sequential extraction schemes as a tool for predicting radio-nuclide mobilization in contaminated soils, the first step is to apply this methodology to the soil samples collected in the studied zones. With this aim two sequential extraction schemes were applied. The first one a) especially designed by ECP-2 group for caesium and strontium. The second one b) especially designed to study the role of the organic matter in radionuclides retention in soils.

The first scheme was applied to four podzol soils coming from Poleskoe, Novosjolki, Novozibkov and Chistogalovka, and two peaty soils coming from Bragin and Komsomolets. All the soils contains condensed particles but Chistogalovka soil also contains fuel particles. In podzol soils the highest activity corresponds to the fraction extracted using HCl. In peaty soils the highest activity corresponds to the fraction extracted using HNO.

The second scheme was applied to two peaty soils coming from Bragin and Komsomolets containing condensed particles. No mobile radiocaesium was detected remaining more than a 90% of the activity in the residual fraction.

To carry out an evaluation of the radionuclides contamination in crops by near field resus-pended soil particles, including rain-splash effect two field experiments, similar to the one carried out last year, were designed. In these experiments both contaminated and non con-taminated straw were used to prevent soil particles resuspension. These experiments have been carried out in the 30 Km zone in close collaboration with the Ukrainian Institute of Radiology. Samples of soil and vegetation were collected by UIAR and soon will be picked up by the representative of the group of the UB.

In order to evaluate the significance of the radionuclides resuspension in the total uptake activity a sequential extraction scheme (water and chloroform: hexane 1:2) was applied to oat samples collected in the experiment performed during the period 1991-92. The mean results shows a high significant of resuspension, approximatively 50% which agrees with the conclusions obtained in the resuspension and rain splash experiment carried out by using a net to prevent resuspension.

CEN/SKC
C Vandecasteele

Data on transfer of radiocaesium and radiocobalt from soil to plants had been obtained in field plots (sandy soil with a texture similar to that of the soils encountered in the Chernobyl zone) installed at the CEN/SCK experimental farm. Twenty-four plots (2 x 2 m^2) were contaminated in 1982 with ionic forms of the radionuclides (12 plots for each nuclide). Maize was grown on one half of the plots while potatoes were planted in the other half. The crops were alternated on a two year rotation cycle. Samples of soil and plant organs were periodically collected (at sowing and harvest) for measurement of their radioactivity content. These data, gathered until 1991, were checked and submitted to a statistical analysis by non-linear regression using an exponential model with one or two compartments.

For radiocaesium, an important reduction of the bioavailability for plant uptake is observed with time as shown by the rapid decrease of the transfer coefficients in the three first years after the contamination (a half-time of approximately 1 year has been estimated for the first compartment representing about 90% of the deposit). Compared to that of caesium, the availability of radiocobalt is less affected by ageing in the soil.

The soil cores taken from undisturbed sites since 1986 were further analysed by gamma spectrometry, in 1 cm thick slices. The results obtained by the CEN/SCK are in good agreement with those provided (only caesium) by our Eastern colleagues and by SSI. Moreover, the samples from Chistogalovka and Kopachi were analysed for their strontium and transuranic elements content. Concerning strontium, the samples from one core taken at Chistogalovka (close to the reactor) were extracted by washing with nitric acid and treated with fluorhydric acid to solubilize the silicates and high refractory particles. Between 10 and 20% of the strontium activity was found in the refractory fraction. The contribution of this refractory fraction was higher in the top cm of the soil core and decreased with depth. The migration of strontium appeared higher than that of caesium and the comparison of vertical distribution at Chistogalovka and Kopachi revealed a faster movement at the later site that is located farer from the source. Most of the transuranic elements were still located in the three top centimetres. In these layer, the ratios $^{238/239\text{-}240}Pu$ were about 0.5, they dropped to lower values in the deeper layers. The ratio $^{241}Am/Pu$ was about 0.5.

The vegetation samples from Chistogalovka were measured by gamma spectrometry. The results are in rather good agreement with those provided by RIA Prypiat. The radiocaesium activity measured in grass harvested in September 1992 was higher than that found in the first cut in July maybe due to a better exploitation of the soil by the root system. The caesium contamination level was higher in the young grass (2nd cut) harvested in September than in the old cut for the first time on the same date. This observation was verified for the other gamma emitters detected in these samples. In oats, the radiocontamination in straw and husks were similar (lower than in grass). The mean contamination level in hulled grains was five time less and practically exclusively due to caesium. The corresponding soil radiocontent had to be measured by RIA Prypiat: as soon as these data will be provided, we will calculate the transfer factors.

In order to study the chromatographic behaviour of radionuclides in soil columns (disturbed as well as undisturbed soils) and the effect of countermeasures on their vertical migration, one system compatible with our coring device was designed. A prototype has been produced and texted successfully. A series of these columns are presently manufactured and will be available by the end of September.

AEA HARWELL
J Sandalls

CHECIR - ECP-2

Progress note for Period 14 July - 23 August 1993

Project title: Laboratory Studies with hot particles - ECP-2

Termination date: 1 November 1993

Funding from CEC: 20 K ECU

AEA Ref No: 18142006

Project Manager: John Sandalls
AEA Technology
Harwell Laboratory
Oxfordshire
UK

1. Introduction

The contract was received in mid-July 1993 and work began immediately.

The objective of the initial phase of this sub-project is to:

(i) isolate and characterise the hot particles, and
(ii) to study their leaching characteristics when subjected to the EPC-2 approved sequential extraction procedure (recommended by the project co-ordinator, Dr J Melin).

2. Procedure

2.1 Gamma-Ray Spectrometric Analysis of Soil Samples

Three samples of soil from the CIS were provided by the project co-ordinator. All these samples, as received, were analysed by gamma-ray spectrometry and the results are expressed (relative to ^{137}Cs) in Table 1.

Table 1
Gamma-ray Spectrometric Analysis of Soil

(i) as measured on 9 June 1993

Soil Sample	^{137}Cs	^{134}Cs	^{241}Am	^{155}Eu	^{154}Eu	^{144}Ce	^{125}Sb	^{106}Ru	^{60}Co
Chistokova	1000	52	7.2	8.8	11	39	10	33	26
Kopacti	1000	51	7.6	7.4	12	26	10	29	ND
Poleskoe 1	1000	55	ND	ND	ND	ND	ND	ND	ND

(ii) Decay-corrected to May 1986

Soil Sample	^{137}Cs	^{134}Cs	^{241}Am	^{155}Eu	^{154}Eu	^{144}Ce	^{125}Sb	^{106}Ru	^{60}Co
Chistokova	1172	553				2438		4125	
Kopacti	1172	542				1625		3500	

2.2 Characterisation by Microscopy

Using sub-sampling, a few grains of the Chistokova soil containing an elevated level of activity were isolated and dispersed over the surface of a piece of double sided adhesive tape. The particles on the tape were then examined under a low power binocular microscope. In one case it proved possible to identify a dark particle different from the others which were transparent.

This particle was picked up with tweezers and fixed on another piece of tape, sample 1. The remaining particles on the tape showed no activity above background.

An optical examination of a second set of particles dispersed on tape showed a number of potential fuel particles, but these were too small to be separated easily with tweezers. Both samples, the individual particle and the second set of particles, were left on the adhesive tape and carbon coated to provide electrical conductivity. They were then examined in an electron microprobe (a JEOL JXA 8600 Superprobe).

Sample 1

A conventional secondary electron, SEI, image of the µm in diameter. The lower image, Fig. 1 (b), was recorded using high energy, back-scattered electrons, BSI. This image mode is very sensitive to atomic number, the higher the atomic number the brighter the signal. We may deduce from this image that the particle is relatively homogeneous but that there are some small low atomic number particles adhering to the surface. Fig. 2 shows a similar pair of images at higher magnification.

Fig. 3 (a) shows the energy dispersive X-ray spectrum recorded with the beam rastered over a 50 µm area on the particles. The main peaks are due to uranium and zirconium. this spectrum was recorded using a 30 KeV primary beam in order to excite the higher energy U and Zr lines to confirm the identification of the lower energy peaks. Subsequent spectra were recorded with a 20 KeV primary beam. Fig 3(b) is the spectrum from a flat area of the specimen with no inclusions evident in the SEI image. The only significant peaks are from U and Zr. Oxygen is not detectable using this energy dispersive detector but measurements with one of the instrument's crystal spectrometers showed that the particle was an oxide. Fig. 3(c) is the spectrum from the small spherical particle appearing in bright contrast at the top of Fig. 2(a) but dark in 2(b) suggesting a low atomic number. This is confirmed by the X-ray spectrum.

EPMA is capable of good quantitative analysis on flat polished samples. Quantification is more difficult for rough particles. However, a number of measurements were made of the Zr to U ratio. This ratio was found to vary considerably across the particle surface, from 0.36 to 0.07 by weight.

Sample 2

In this sample the main problem was to identify the fuel particles. This was done using the BSI image. By adjusting contrast and brightness the high atomic number particles may be readily identified. (Fig. 4(a) shows the low magnification image used to locate fuel particle and Fig. 4(b) shows a high magnification image of the particle. Its general appearance is similar to sample 1 but it is an order or magnitude smaller. A second such sample is shown in Fig. 7(a). The X-ray spectra from these two particles are shown in Figs. 5 and 7(a). It is interesting to note that neither particle appears to contain any Zr.

In addition to the bright uranium rich particles seen in the BSI image, particles of intermediate contrast were observed. These particles were shown to contain Fe, Cr and Ni, Fig. 6

Discussion

Larger active particles may be relatively easily separated from soil samples and characterised by electron probe microanalysis, EPMA. Smaller fuel and other particles containing heavy elements may be identified for subsequent analysis from a dispersion of particles using the back-scattering contrast in the SEM or electron microprobe In the present investigation specimen charging degraded the quality of the images obtained. This problem may be overcome by the selection of a more suitable adhesive tape. It is possible to use the instruments computer to identify and classify particles automatically in the electron microprobe.

PAUL SCHERRER INSTITUTE, VILLIGEN, SWITZERLAND

T. Hinton

Subproject: Soil loading into plants and the foliar absorption of resuspended radionuclides

Subcontractor: Paul Scherrer Institute, Villigen, Switzerland

Principal Investigators: Thomas G. Hinton

Primary Collaborators: Yuri Invanon (Ukrainian Institute of Agricultural Radiology), Nickoli and Andre Arkhipov (Pripyat Research and Industrial Ass.).

I. Background and Objectives

Following the contamination of terrestrial environments, most radionuclides become sorbed to soil particles and can be subsequently transported by physical processes such as leaching, erosion and resuspension. Resuspension of contaminated soil increases man's exposure to radionuclides via the pathways of inhalation and ingestion. Because the concentration of radionuclides in soil is generally much higher than in plants, even small quantities of soil attached to vegetation can significantly contribute to the activity ingested. Ingestion of contaminated soil particles occurs when fruits or vegetables are inadequately washed, or inadvertently, when grazing animals consume soil-loaded vegetation. Our knowledge of resuspension, its importance in contaminating plants, and the biological availability of soil attached radionuclides is not adequate for predictive purposes. The data collected in this project will be used to determine if the foliar absorption of resuspended radionuclides is a relevant contributor to man's dose. We are testing the hypothesis that the foliar absorption of radionuclides attached to resuspended soil particles is **not** significant, and therefore, does not need to be considered as a relevant pathway to human contamination in radionuclide transport models.

II. Work Program

It was a challenge to try and design a field-experiment that would isolate the single pathway of plant contamination due to the foliar absorption of resuspended contamination. It was necessary to separate (1) endogenous contamination of the plant due to root uptake and (2) surficial contamination on the leaves of plants at the time of sampling.

Our approach was as follows. Cabbage and Kohlrabi seedlings were grown in uncontaminated soil within a clean greenhouse in Kiev. The seedlings and uncontaminated soil were placed in 3 l plastic bags and taken to two contaminated sites, Chistogalovka and Vladimirovka. Chistogalovka is within the 10 km zone and is dominated by fuel particle fallout, while Vladimirovka is an evacuated town outside the 30 km zone and is contaminated with the more soluble condensation-type fallout. The plastic bags were gathered at the top and loosely closed around the stems of the seedlings. The bag, containing the seedling in clean soil, was then buried in the contaminated soil so that the top of the plastic and the seedling was above the contaminated soil surface. The plastic isolated the roots of the seedlings in the clean soil and thus prevented root uptake of contaminants. The tops of the plants, however, were exposed to resuspension from wind and raindrop splash. The plants were watered with an uncontaminated source through the small hole at the gathering of the plastic top. The plants were placed in the field during the first field campaign of 31 May to 6 June 1993, and remained in the contaminated fields until the second campaign (2 - 11 July 1993). The leaves of each plant were than clipped, taken to the laboratory of Dr. Arkhipov, and thoroughly cleaned. Leaf surfaces were cleaned using a technique novel to the field of radioecology. Liquid plastic was applied to the surfaces, dried, and then pealed off. All surficial contaminants became embedded in the plastic and were removed when the plastic was pealed off. The thoroughness of this cleaning technique has been confirmed by scanning electron microscopy. Because root uptake was prevented, and all surfaces of the plants were thoroughly cleaned, any radionuclides that are now detected in the plants are assumed to have been absorbed through the leaf, and to have originated from radionuclides attached to soil particles and resuspended onto the leaf during the month-long field trial. Thus we hope to have an estimate of the foliar absorption of radionuclides from resuspended soil particles.

Applying, drying, and pealing the plastic from the leaves was a tedious process that required five workers (2 from Switzerland and 3 from the Ukraine) nine days to complete. The cleaned leaves have been returned to Switzerland and are now being analyzed for radionuclide content using state of the art Germanium systems. During the field experiment control plants remained in the Kiev greenhouse. Additionally, some seedling were transplanted directly into the contaminated soil of Chistogalovka and Vladimirovka so that root uptake of radionuclides could be compared.

In addition to the positive scientific collaboration between western and CIS scientists, numerous field and laboratory supplies were purchased in Switzerland and given to each of the CIS laboratories participating in the project.

INSTITUTE OF TERRESTRIAL ECOLOGY

B Howard

Interim Report

An initial discussion of possible approaches to studying radionuclide contamination of animals was discussed at the ECP-2 meeting in Barcelona. It was agreed that ITE collaboration within ECP-2 would primarily be in two subject areas:

1. Bioavailability of radiocaesium and radiostrontium from different sources for absorption in the ruminant gut:

a) *In-vivo* measurements of true absorption in cattle consuming contaminated pasture vegetation

Collaborators - UIAR, RIA Pripyat

* The various methods of measuring true absorption were discussed at a meeting in experiment to be carried out within the 10 km zone was agreed.
* The experiment was conducted at an experimental pasture site at Chistogalovka in July, with the involvement of 15 participant from each of RIA Pripyat and UIAR together with N.S. Beresford from ITE:
* The aim of the experiment was to measure the true absorption of radiocaesium and radiostrontium in dairy cattle.
* Two groups of experimental dairy cows were used; one group (n=8) were allowed to graze freely on the pasture the other group (n=6) were housed in an open stable and fed cropped vegetation.
* Initially solutions of ^{85}Sr and ^{134}Cs were infused into the cattle using peristaltic pumps attached to their backs. However, this arrangement proved ineffective and from the fourth day a twice daily injection of radioisotope was administered instead.
* herbage intake was measured throughout the experiment using alkane markers
* samples from the experiment of milk, urine, faeces and vegetation are currently being analysed; RIA Pripyat is responsible for gamma analysis. UIAR is responsible for ^{90}Sr analysis. ITE has also undertaken some analysis for intercomparison purposes.

b) *In-vitro* measurements of availability

Collaborators - BIAR, UIAR, RIAR, RIA Pripyat to prove samples for extractions BIAR carry out extractions

ITE and MLURI have developed an *in-vitro* CsCl extraction technique for predicting the availability of radiocaesium for absorption in the ruminant gut, mostly using sheep as the experimental animal. We hope to adopt a similar approach to radiostrontium and to validate it further with measurements of true absorption in cattle. Initially *in-vitro* extractions within the ECP-2 program were limited to radiocaesium and carried out on a range of contaminated sources which arè either routinely fed to, or ingested by grazing ruminants. Progress achieved so far includes:

* the collection of a variety of different forage sources and soils from contaminated areas
* bioavailability estimates were made for some of the sources, brought to ITE by Edvard Zurankov and extracted using the CsCl extraction technique. The proportion of radiocaesium extracted from samples of hay fed to cows at RIA Pripyat was surprisingly low.

* Further collections of pasture grasses and soils by BIAR during the true absorption experiment in the 10 km zone, these samples will be extracted with CsCl in Gomel.

2. Assessment of data previously obtained by CIS participants and preparation of papers for publication in the open literature

Collaborators - RIA Pripyat, UIAR, RIAR

CIS participants have summerized studies for further discussion or amendment for publication in English language journals. ITE has collaborated with the authors in preparing these documents for submission to journals. Two potential studies are currently being processed:

* RIA Pripyat have provided an English document summarizing studies conducted within the 30 km zone, ITE and RIA Pripyat have selected one study on which to concentrate and the second draft is in preparation.

* Astasheva et al. have been collaborating with ITE in producing an English version of a paper on the loss of radiocaesium from cattle and sheep. The paper has already been through two drafts.

A summary of Russian studies has also been provided to ITE by RIAR.

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The penetration of radionuclides in undisturbed soils was investigated and a model devised for its description.

Following the analysis of Kirk and Staunton[1], when root uptake and soil reactions are ignored, the equation governing trace element penetration into soil may be written as

$$(h_1+\theta)\,\frac{\partial C}{\partial t} = D \cdot \frac{\partial^2 C}{\partial z^2} - q\,\frac{\partial C}{\partial z} \qquad (1)$$

This may be written in terms of dimensionless variables as

$$\frac{\partial C}{\partial \tau} - \frac{\partial^2 C}{\partial \xi^2} + \frac{\partial C}{\partial \xi} = 0 \qquad (2)$$

in which

$$\xi = \frac{z}{z_o} \qquad \tau = \frac{t}{t_o}$$

and

$$z_o = \frac{D^*}{q} \qquad \tau_o = \frac{D^*(b_1+\theta)}{q^2}$$

Kirk and Staunton[1] solve this equation numerically, a procedure often leading to the introduction of numerical artifacts. We were able to give an analytical solution of this equation in the form

$$C = \frac{\xi}{\tau^{3/2}}\, e^{-\frac{(\xi-\tau)^2}{4\tau}} \qquad (3)$$

An experiment was carried out in order to verify the validity of eqn (3) with five different types of soils from the districts of Elia and Argolis in Greece. An amount of 2.5 μCl of ^{141}Ce was deposited on the surface of five undisturbed columns of these soils. For a period of two months enough water was added to the columns to keep them under a condition of saturation. The columns were then dried, sliced into 2 cm sections, and the cerium activity concentration of each section was measured. These data were used to fit eqn (3) above by using $D^{\bullet}$, q_1 b_1 and q as free parameters (an overall normalization amplitude was also used as a free parameter). The fit was performed by a modified version i MINUIT, the very powerful package of CERN.

The parameters obtained through the best fit of each set of data are as follows

Column	Amplitude	D• $cm^2\ s^{-1}$	q $cm^2\ s^{-1}$	b_1	q
1	0.022	6,47 x 10^{-6}	1.39 x 10^{6}	352	47
2	7.75 x 10-6	4.26 x 10^{-5}	2.85 x 10^{-6}	32	30
3	0.056	9.51 x 10^{-5}	2.28 x 10^{-6}	373	105
4	0.066	0.54 x 10^{-5}	2.39 x 10^{-6}	316	0.84
5	23	2.46 x 10^{-4}	1.34 x 10^{-4}	104	528

These are within the range of values expected for these types of soils. The model may thus be used with a high degree of confidence for the description of the penetration of trace elements into undisturbed soils, although validation with other radionuclides, such as Cs, which is more strongly trapped by clays, may be necessary.

Reference: G.J.D. Kirk and S. Staunton, On predicting the face of radioactive caesium in soil beneath grassland, Journal of Soil Sol. 40. (1989) 71-74.

Progress report ECP2
6. September 1992
Knut Hove and Hanne Solheim Hansen
Department of Animal Science, Agricultural University of Norway.

Background and objectives

CIS scientists have reported that use of countermeasures such as liming, fertilizing and ploughing affect the trace mineral content of pasture grass and the content of certain trace minerals in animal derived food products.
During the project period three activities were started:

1. An intercalibration study on the analysis of trace minerals in feeds and animal products (Atomic absorption spectrometry).

2. A field trial comparing the trace mineral contents of blood, milk and tissues in cattle grazing on, or fed roughages from, fields where countermeasures were undertaken during the first years after 1986 to fields where no countermeasures were done. Trace minerals in possible short supply are Zn, Co, Mn, Mo, I and Cu.

3. A litterature review of trace mineral concentrations in animal feeds, tissues and products was compiled.

Activities 1992-1993

Activities from the Norwegian party was started late in the project period due to a very slow funding. Funds were made available in August 1993.

A joint meeting was held in Zeleny Mys 26/4 to 30/4-93 together with the animal group from UK and scientists from Ukraine, Belarus and Russia. Protocols were agreed and field trials were started.

Intercalibration samples of dried milk powder, ground hay, ground straw and freezedried blood serum was prepared in Norway and transported to the CIS participants in early July 1993 by an ECP5 team.
Equipment required for sampling (Syringes, cooling boxes, blood sampling equipment, disposable equipment of different kinds) were brought to all 3 CIS collaborators.

Trace mineral content of animal products:

Ukraine

Farm at Polyeskoje. Ukranian Institute of Agricultural Radiology. Nadezda Astasheva.

Fields with soil ploughed and limed after Chernobyl accident.

Feed and blood samples were taken for analysis during the indoor feeding period in January, and in April before start of the pasture season. Liver biopsies and samples of milk, blood and feeds were collected at our visit on the farm. In addition samples were taken in July, and will be taken again at the end of the grazing season.

Farm Novochepelichy at RIA Pripyat. Nikolai Arkhipov. Permanent pasture. No countermeasures taken.
Start of experiment at our visit in April. Samples of milk, blood, liver and feeds taken. Sampling continued by RIA-Pripyat in July. Further samples to be taken at the end of the grazing season.

Belarus
Byelorussian Institute of Radiology. Slava Firsakova & Victor Averin.
During the meeting in Zeleny Mys it was made clear that the scientists from the Byelorussian Institute of Agricultural Radiology had several series of observations on trace mineral concentrations in animal feeds, organs and food products. The data should be compiled as their contribution to the study.

Russia
Russian Institute of Agricultural Radiology. Anatoly Vasilyev.
In an experiment starting at the time of the pasture season in 1993 5 cows will be grazed on a field where countermeasures were undertaken, and 5 cows on an unploughed field. Details of the progress is not known at present. The study will last for 1 full year ending in may 1994.

Results

Chemical analyses of the samples taken to Norway are in progress. Samples were only submitted to analysis in August due to the slow transfer of funds. Therefore no analytical results are ready at present. Samples which were to be analysed in the CIS may however be ready.

Continuing work

Analyses of the samples outlined in the protocol will be performed before the end of this year, but not within the time frame of the present ECP2 period ending September 1993. The Russian study will be continued for the 1993/94 indoor feeding season. We suggest that the trace mineral study should be continued within the proposed ECP9 program for at least 1 year in order to finish analyses and complete the study. A visit to the CIS collaborating institutions is planned for the end of the grazing season 1993 (late September/early October).