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PROGRESS REPORT

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ASSESSMENT OF METHODS TO REDUCE CS ACTIVITY IN SHEEP IN THE FIELD

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1 INTRODUCTION

The coincidence of locally heavy rainfall in the first week of May with an air mass containing radioactivity from the Chernobyl accident led to comparatively high fallout on northern areas of the United Kingdom, particularly in north Wales, west Cumbria and much of Scotland. The monitoring by the Ministry of Agriculture, Fisheries and Food of ^{134}Cs and ^{137}Cs activity in a variety of foodstuffs established that in certain upland areas some lambs contained greater than 1000 Bq^{-1} kg fresh weight in muscle; which is above the recommended limit for meat to be sold for consumption. Restrictions were placed on the movement of sheep in the affected areas, initially for 3 weeks.

It was expected that much of the initial deposit on vegetation would be washed off rapidly into the soil where it would be largely immobilized by adsorbtion onto soil minerals, especially clays. Over the first few weeks the activity of vegetation did decline, but on some areas of the west Cumbrian fells, ITE have found that the Cs activity of vegetation has not declined as much as expected. Therefore, contrary to expectations, some sheep were, and are, still eating grass with significant Cs activity and the levels in their tissues remains persistently high. A sampling policy by MAFF combining analyses of lamb tissue and external monitoring of live animals has made it possible to considerably reduce the restricted areas. However restrictions have had to remain in place on some of the more heavily contaminated fells.

Laboratory experiments in the 1970's (Van den Hoek 1976) have demonstrated the effectiveness of bentonite, a clay mineral, in preventing Cs absorbtion by sheep. The following experiment was conducted by ITE, for MAFF, to see whether bentonite could be used in a field situation to prevent uptake of Cs, and to compare its effectiveness with other possible methods in reducing the body burden of ^{134}Cs and ^{137}Cs in sheep.

This interim report presents a preliminary assessment of the data currently available.

2 STUDY SITES

An upland site was identified in west Cumbria where the ^{134}Cs and ^{137}Cs activity in lambs was known to be relatively high and where a group of ewes had grazed an enclosed pasture (National Grid Reference SD175961, altitude 246 m) since the Chernobyl fallout occurred. The pasture was divided into 5 paddocks (Figure 1, Plate 1) four of about 4000 sqm and one of about 6000 sqm which contained a large group of rocks.

Lowland grazing was obtained for some of the fell sheep, near Grange-over-Sands (National Grid Reference SD439901). The field contained considerably better quality grazing than that of the upland site.

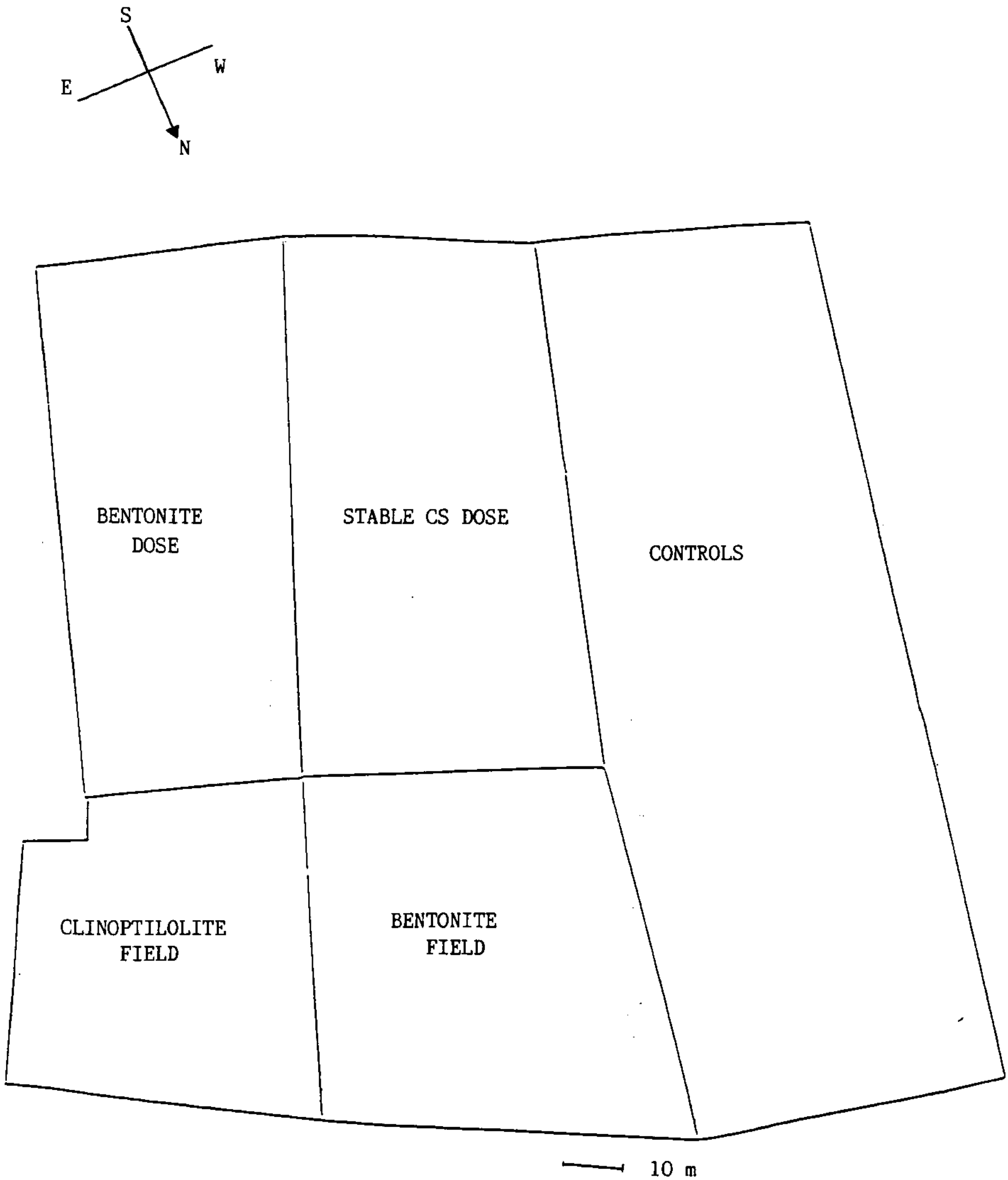


Figure 1. Map of the experimental field showing the division into 5 treatments. The photograph (Plate 1) was taken 100 m from the southern edge of the field.

Plate 1. View of the experimental field from the fell above. The control paddock with rocks is on the left of the field. The slope of the field gets steeper to the North so that the bottom mineral treated paddocks are only just visible.

3 MATERIALS AND METHODS

3.1 Treatments

35 ewes with 49 lambs were grazing the field. These were subdivided so that there were 5 or 6 ewes with their lambs allotted to each treatment. Initially 6 treatments were used:-

1 Controls

- the sheep were allowed to graze the paddock as normal.

2 Bentonite field

- the paddock was treated with Bentonite (a largely montmorillonite clay, $Al_4 Si_8O_{20}(OH)_4.nH_2O$ with $Mg^{2+} + Na^+$ or $Mg^2 + Ca^{2+}$ substituting some of the Al^{3+}) at the rate of approximately 37 g/m^2.

3 Clinoptilolite field

- the paddock was treated with clinoptilolite (a natural zeolite mineral $(Na_2,K_2, Ca, Ba) [(Al, Si)O_2)]n.xH_2O)$ which like bentonite has an affinity for Cs) at the rate of approximately 31 g/m^2.

4 Bentonite dose

- both the ewes and lambs were dosed orally on alternate days with a suspension of 10 g of bentonite in 0.05 l of water.

5 Stable Cs dose

- the ewes and lambs were dosed orally on alternate days with 0.4 g of stable Cs (as a chloride) in 0.025 l of water.

6 Lowland pasture (referred to hereafter as "Grange")

- the sheep were removed to lowland pasture where the ^{134}Cs and ^{137}Cs activity of the vegetation was much lower than that present on the original fell site. The treatment simulated the sale of store lambs for fattening on better pasture.

3.2 Experimental sequence

Day 0 Field subdivided into paddocks (Figure 1). At this stage the control paddock contained 11 ewes and 13 lambs.

Day 1 Initial whole body monitoring of flock. Milking of ewes. Dosing of sheep commenced. 5 ewes with their 5 lambs taken from the control paddock to lowland pasture in Grange. 1 ewe with twin lambs from control paddock killed for gamma analyses.

Day 2 Bentonite and Clinoptilolite spread on respective paddocks. Vegetation sampled from each treatment.

Day 15 Cs dose increased to twice the original dose. Bentonite dose increased to 20 g in 0.1 l of water.

Day 19 Two Cs dose ewes with their 3 lambs taken off treatment.

Day 23 One ewe with single lamb killed from each treatment.

Day 24 Intensive vegetation survey of field. Bentonite and clinoptilolite fields respread at a rate of 37 g/m^2.

Day 42 Intensive vegetation survey of field repeated.

Day 43 Experiment concluded. All sheep monitored. One ewe with twin lambs killed from each treatment (except Grange where one lamb was killed).

3.3 Whole body monitoring

On day 1 the whole body ^{134}Cs and ^{137}Cs content of all the lambs and 7 of the ewes was monitored by the NRPB (Northern Centre) using a portable partially shielded 6 by 5 inch NaI detector linked to a multichannel analyser. Subsequently one of the monitored ewes and its twin lambs were killed for gamma analysis to obtain a correlation between whole body and muscle ^{134}Cs and ^{137}Cs.

The live-monitoring was repeated at 6-8 day intervals, and it was possible to monitor 2 ewes from each treatment from day 9 onwards. On the last day (Day 43) all the ewes were monitored as well as the lambs.

3.4 Sampling

3.4.1 Milk

Milk was used as a bioindicator of Cs status of the ewes. Decisions could be made on the basis of Cs activity in milk on whether to repeat the mineral spread of paddocks or change doses.

Individual milk samples were taken, using a 0.2 ml oxytocin to induce milk let down, on each day that whole body monitoring occurred. Samples taken at other times were bulked for each treatment, because treatment with oxytocin was not possible.

3.4.2 Vegetation

A bulked vegetation sample cut 1 cm above ground level was collected along a transect, repeated at 20 m intervals, where there was evidence of recent grazing (fresh faeces, cropped vegetation, presence of sheep). This type of vegetation collection (a "sheep-walk") was carried out 3 days before the field was sub-divided and repeated at intervals throughout the experiment, at both sites.

Vegetation samples were also taken frequently using quadrats (1 m^2). In the latter stages of the experiment more intensive sampling of vegetation with quadrats was carried out, on days 24 and 42, using a random bearing and distance from the centre of each paddock.

3.5 Radiochemical analyses

All milk samples were counted in plastic containers (0.13 l) on Ge(Li) detectors. Vegetation samples were dried at 80° C, ground and counted in plastic containers on either a Ge(Li) detector or a NaI detector (PSR 6).

4 RESULTS

Initial results appeared to indicate that the 3 mineral treatments and removal to lowland pasture were effective in reducing Cs activities in both milk and tissues. Counting preference was at first given to milk samples, but as vegetation samples from each paddock were analysed, it became evident that the drop in activity in the sheep on mineral treatments was probably due to the relatively low Cs activity in these paddocks. Doses of bentonite and Cs were increased and the mineral treated paddocks were respread in the hope that an increase in the rate of loss of whole body and milk Cs activity would take place thereby indicating a treatment effect. It was possible to test whether the treatments were effective, by comparing whole body Cs activities with Cs activity of the vegetation in each paddock.

4.1 Whole body Cs activities

The figures shown are based on results from lambs that were retained throughout the experiment. Initial activities of ^{134}Cs + ^{137}Cs in the lambs varied from 256 to 883 Bq kg^{-1} whole body weight. The changes in Cs activity with time for each treatment are shown in Figure 2. After an initial rise the Cs activity in control lambs remained stable. The Cs treatments showed little effect, but, in the mineral treatment lambs, there was a loss of activity. The most rapid loss of activity occurred in the lambs taken to Grange and this is best demonstrated by comparing each individual measurement with that of day 1 (Figure 3). The limited data available on the ewes (Figure 4) follow similar trends to the lambs.

4.2 Cs activities in milk

The ^{137}Cs activity in milk (Figure 5) followed the trends shown by whole body activities. There was no indication of an increased rate of reduction of Cs activitiy following the respreading of the fields or the increase in dosing.

4.3 Cs activity of vegetation

The initial "sheep walk" samples indicated that the Cs activity of the upland vegetation was relatively high (^{134}Cs 1310 Bq kg^{-1} dry wt; ^{137}Cs 2819 Bq kg^{-1} dry wt). It was intended to use the Cs activity of vegetation samples obtained from the walks and occasional quadrats to look at changes with time, but it became apparent that the spatial variation in Cs activity of the vegetation was too great to compare timed samples without more intensive sampling. Nineteen samples in each of the smaller paddocks and 20 in the control were taken on day 24 and again on day 42 to show the extent of the variation in Cs activity and to test for a change in Cs activity of vegetation with time.

There was a considerable degree of variability in the Cs activity of the vegetation over the whole field, ranging from 250 to 6051 Bq kg^{-1} dry wt. However, most of the more heavily contaminated vegetation was present in the control paddock and in part of the Cs dose paddock. Vegetation from the 3 mineral treatments had less Cs activity (Table 1, Figure 6) and was less variable. The great range of Cs activity in the Cs dose paddock make the results from this treatment very difficult to interpret. There was no significant loss at the 5% level in the Cs activity with time (T-test).

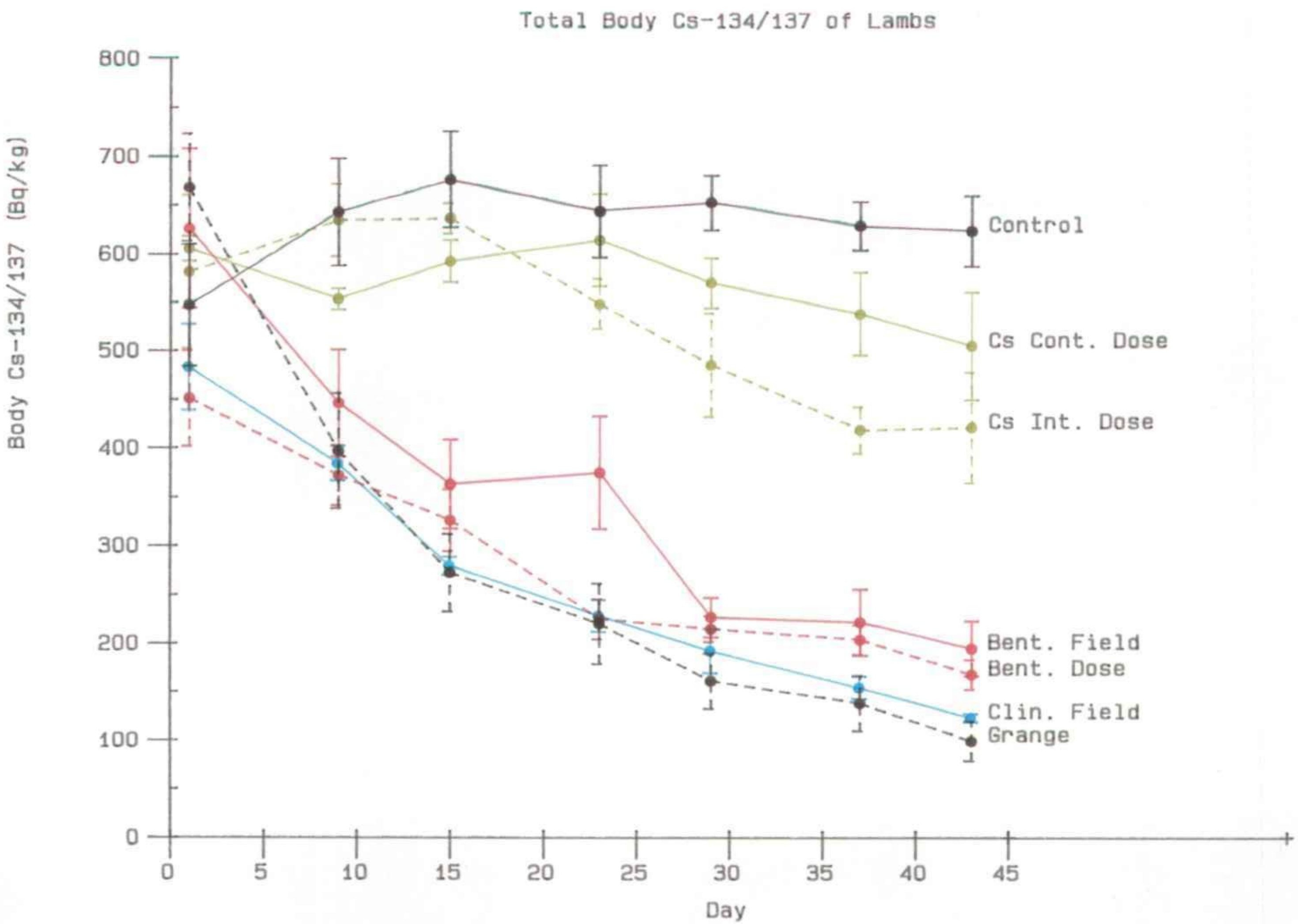


Figure 2. The change in whole in whole body $^{134}Cs + ^{137}Cs$ activity in lambs during the experiment ($x \pm SE$).

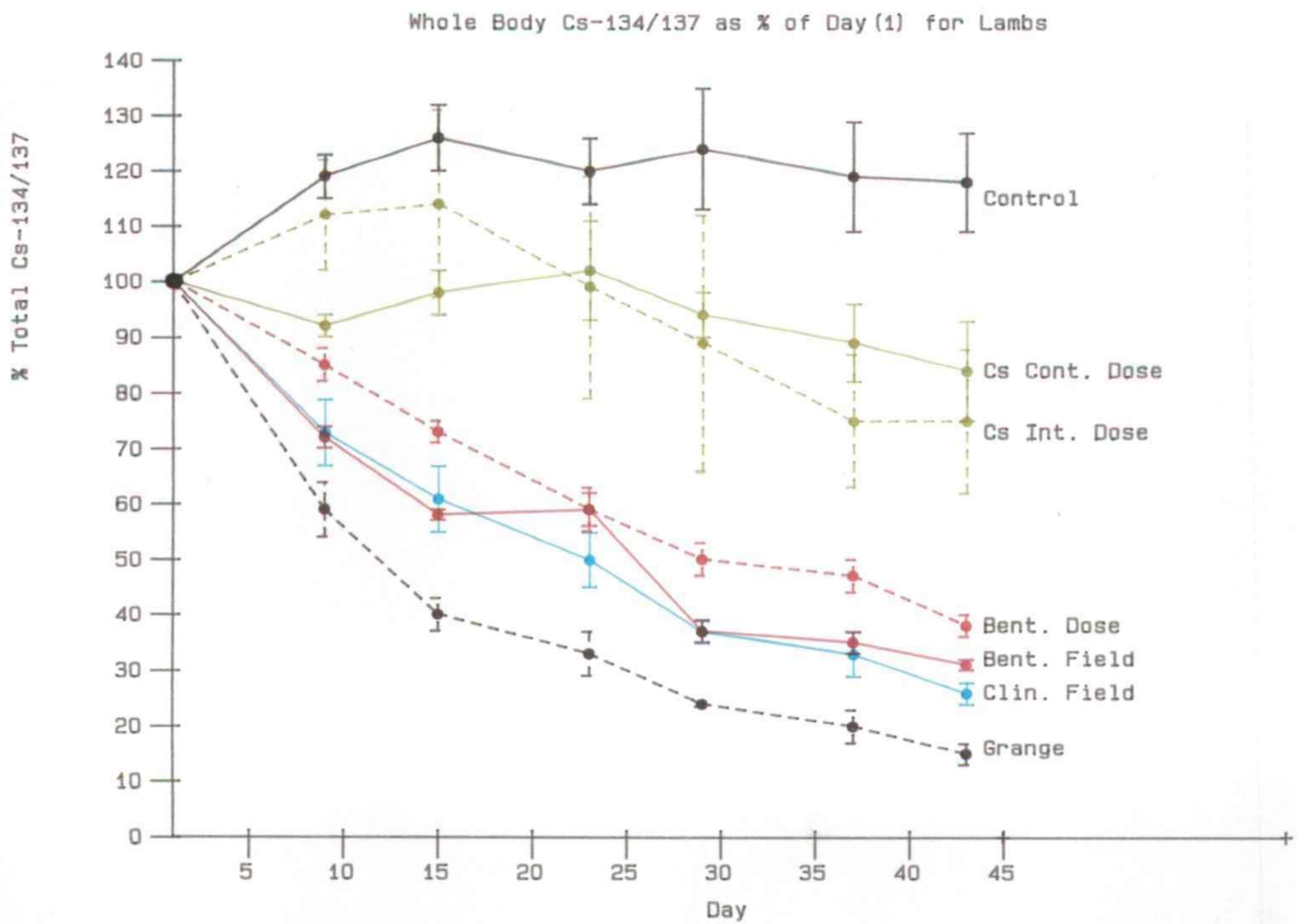


Figure 3. The change in whole body ^{134}Cs + ^{137}Cs activity in lambs expressed as a % of day 1 ($\bar{x} \pm$ SE).

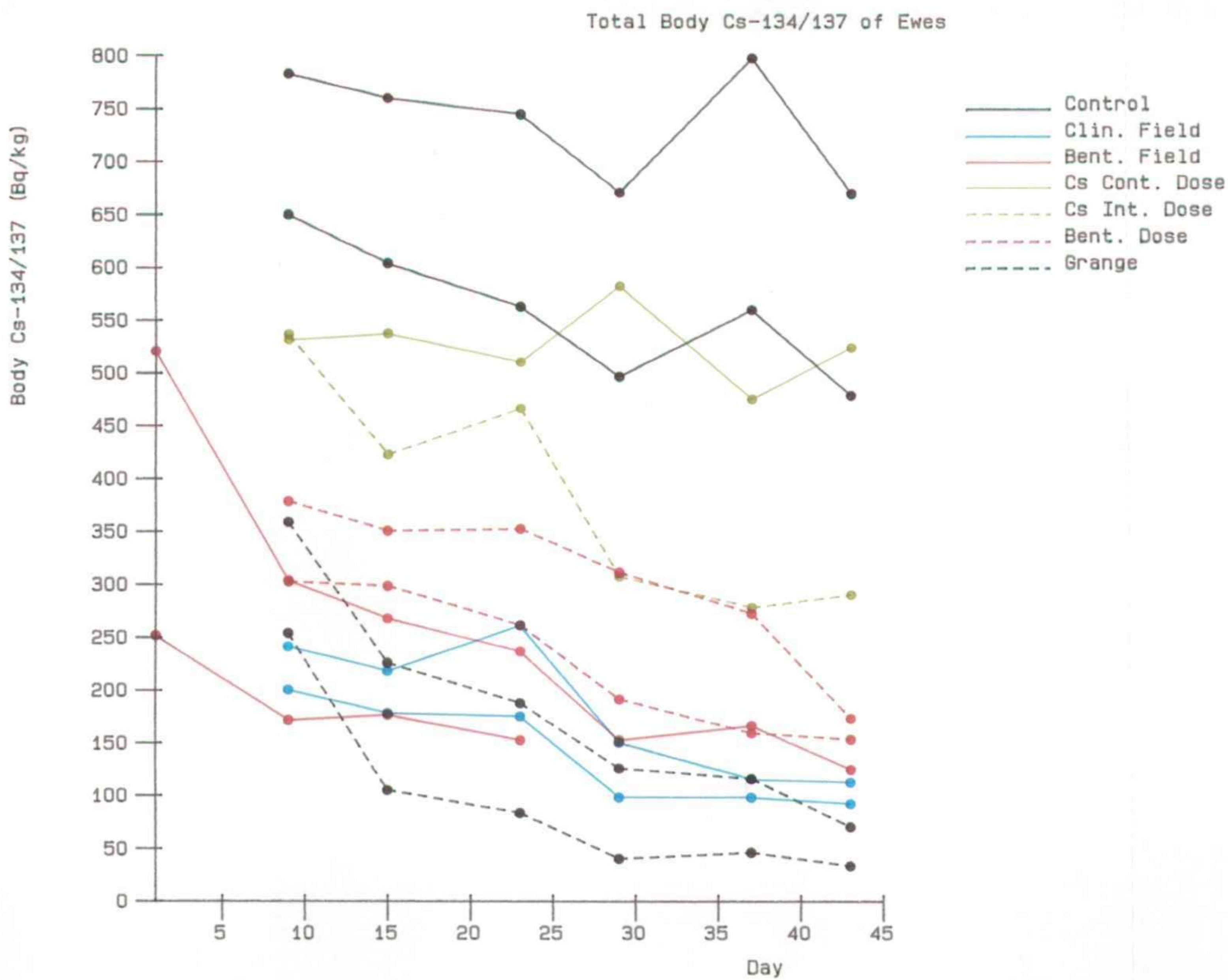


Figure 4. The change in whole body ^{134}Cs + ^{137}Cs activity in ewes during the experiment (x ± SE).

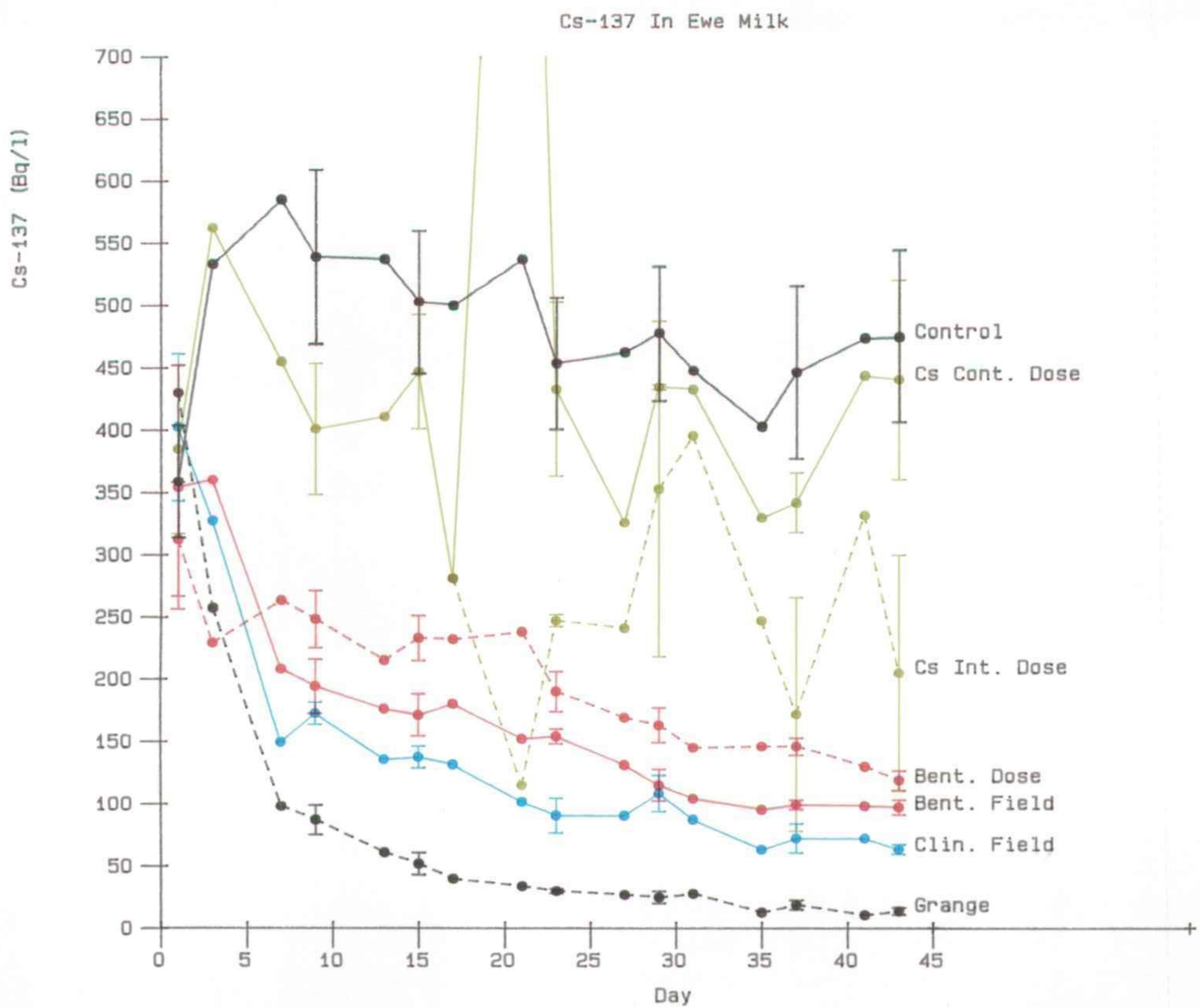
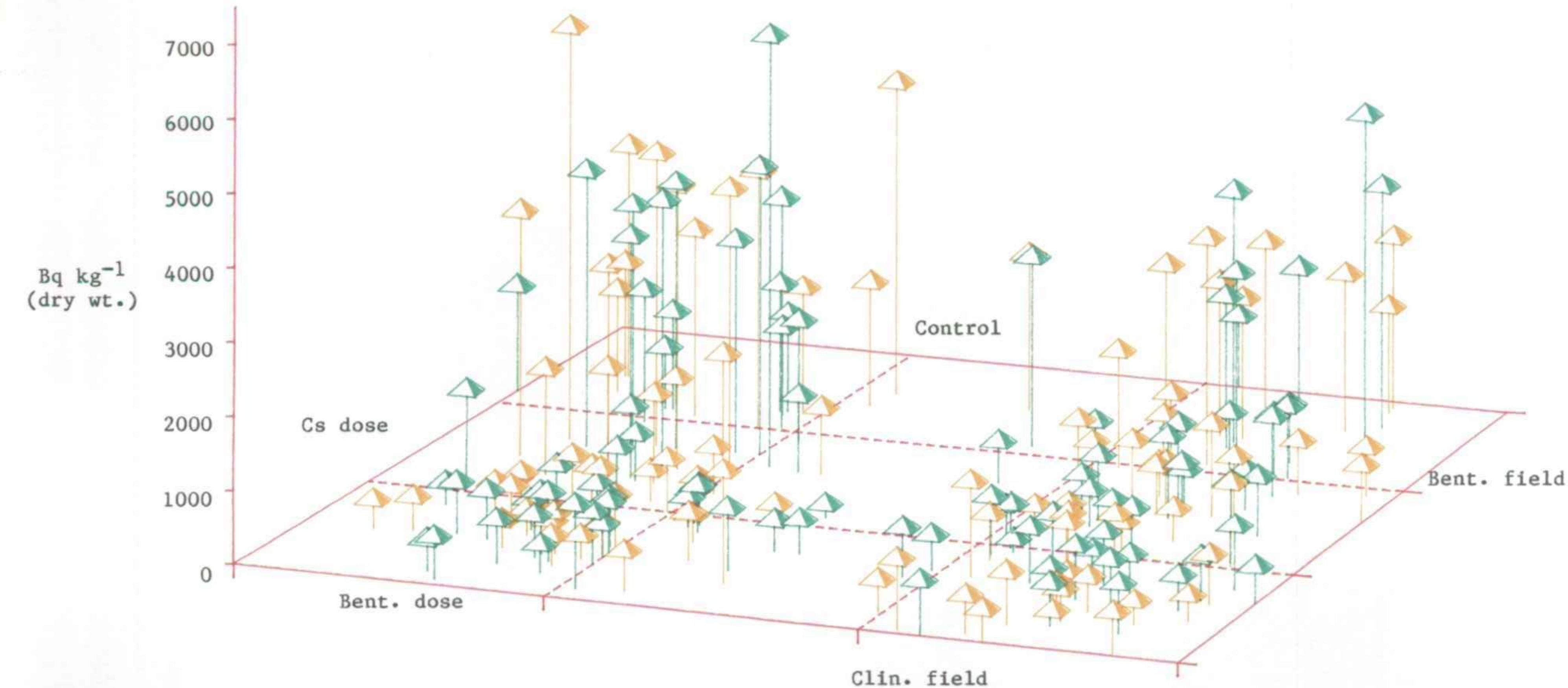


Figure 5. Changes in ^{137}Cs activity in ewe milk throughout the experiment. Standard errors are attached to the data when individual samples were taken.

Table 1. ^{137}Cs activity of vegetation in the different treatment paddocks. (n = 19, except for control plot where n = 20)

Treatment	^{137}Cs activity (Bq kg^{-1} dry wt) Day 24				Day 42			
	Mean	±	Standard Error	Range	Mean	±	Standard Error	Range
Cs dose	1892	±	408	250-6051	1630	±	309	281-4061
Bentonite dose	706	±	46	444-1192	587	±	66	350-1576
Bentonite field	824	±	56	482-1189	817	±	75	353-1696
Clinoptilolite field	665	±	38	255- 925	614	±	68	142-1346
Control	2117	±	239	628-4731	2454	±	274	436-4502

Figure 6. Cs137 variability in vegetation from the upland field



DATE: 23/08/86 in green
09/09/86 in orange

At the lowland pasture site at Grange the mean activity of the vegetation was 18.7 ± 2.3 Bq kg^{-1} dry wt for ^{137}Cs and 6.5 ± 1.1 Bq kg^{-1} dry wt for ^{134}Cs.

4.4 Concentration ratios

It was obviously necessary to compare whole body Cs activity with that of vegetation ingested in each paddock to test whether the treatments were having an effect. Transfer coefficients were inappropriate since they assume equilibrium has been reached and this does not appear to have occurred within the time scale of the experiment for any of the treatments except the controls. The concentration ratios calculated used the formula:

$$CR = \frac{^{134}Cs + {}^{137}Cs \text{ concentration in whole body (Bq kg}^{-1}\text{ fresh weight)}}{^{134}Cs + {}^{137}Cs \text{ concentration in vegetation}}$$

The data obtained from day 43 was used in the calculation (Table 2). Since the treated sheep have not equilibriated the concentration ratios would probably have declined further and therefore a slight effect may have been detected. However, a marked treatment effect is not evident.

Table 2. Concentration ratios (CR) for each treatment.

Treatment	CR Lamb Mean ± Standard error	CR Ewe Mean ± Standard error
Cs dose	0.22 ± 0.03	0.20 ± 0.03
Bentonite dose	0.18 ± 0.03	0.17 ± 0.03
Bentonite field	0.22 ± 0.04	0.17 ± 0.02
Clinoptilolite field	0.16 ± 0.01	0.15 ± 0.01
Control	0.23 ± 0.03	0.18 ± 0.03

5 DISCUSSION

There was no obvious effect of any of the treatments used at the upland site. Other difficulties would also render these treatments impractical. The frequent dosing with bentonite is labour intensive and the lambs were in a poor condition at the end of the experiment. All the sheep in this treatment were killed and analyses of metal concentrations of tissues is in progress. The minerals spread on the paddocks appeared to wash off rapidly, and there was no obvious change in the rate of decline in either milk or whole body activity following the repeated spreading of the 2 paddocks and the increased dosing.

The large variation in Cs activity of the vegetation in the field is being studied further. Soil descriptions and analyses are proceeding and the moisture patterns of the field are being investigated.

The rapid whole body loss in $^{134}Cs + ^{137}Cs$ activity of lambs removed to lowland pasture can be expressed by the equation:

$$\text{Whole body Cs activity} = 685.34 - 348.76 (\log_{10} \text{Time (days)})$$

The effective half life is 10.17 days.

The control lambs were restricted to a relatively contaminated area of the upland field. Their whole body Cs activity increased accordingly and appeared to stabilize. The likely changes in Cs activity in sheep in the affected upland areas in the coming months will depend on a variety of factors, including $^{134}Cs + ^{137}Cs$ levels in vegetation, the effect of greater grazing pressure on the vegetation species which are grazed and farm management practices.

6 ACKNOWLEDGMENTS

A large number of people were involved in this work and special thanks must go to John Barrows and Brian Cloughberry (MAFF), Peter Shaw and Lisa Burrow (NRPB, Northern Centre), Philip Leech (ITE), Stewart Lamb (HFRO), the fell farmer and his wife who kindly allowed us the use of the farm and the owner of the lowland pasture in Grange. Many of the staff at ITE Merlewood have helped in discussion and analysis of the data obtained; we are very grateful to them.

7 REFERENCE

VAN DEN HOEK, J. 1976. Caesium metabolism in sheep and the influence of orally ingested bentonite on caesium absorption and metabolism. Z. Tierphysiol. Tierernahrg. u. Futtermittelkde. **37**, 315-321.