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EFFECTS OF CLAY MINERAL TYPE AND ORGANIC MATTER ON THE UPTAKE OF RADIOCESIUM BY PASTURE PLANTS

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T.J. D'SOUZA [1], E. FAGNIART [2], R. KIRCHMANN [2]

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[1] Biology and Agriculture Division, Bhabha Atomic Research Centre, Trombay, Bombay 400085, India
[2] Department of Radiobiology, Centre d'Etude de l'Energie nucléaire, Mol, B-2400, Belgium

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Summary. - Studies were undertaken to examine the influence of interaction of clay minerals and organic matter on the uptake of radiocesium by two pasture plants, namely, ryegrass (**Lolium italicum** L.) and red clover (**Trifolium pratense** L.). The clay minerals used were bentonite (2:1 layer type) and kaolinite (1:1 layer type). Mixtures of clay and sand were prepared with 0, 5, 10, 20 and 40 per cent clay and treated with organic matter (forest turf) at 0, 5 and 10 per cent of the clay-sand mixtures. Results indicated that ^{134}Cs uptake by plants grown on the kaolinite-clay medium was greater than that on the bentonite-clay medium at a given organic matter level. Increasing the clay content of mixtures resulted in reduction in ^{134}Cs uptake by both plant species. The plant uptake of ^{134}Cs increased with additions of organic matter at a given clay content.

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Résumé. - Ce travail a été effectué dans le but d'étudier l'interaction entre des minéraux de l'argile (bentonite et Caolinite) et la matière organique, sur l'absorption du ^{134}Cs par les plantes **Lolium italicum** L. et **Trifolium pratense** L. Le sable a été mélangé avec l'argile (0, 5, 10, 20 et 40 % d'argile) et le mélange a été additionné de matière organique (tourbe) à 0, 5 et 10 %. Les résultats obtenus montrent que, pour le même pourcentage de matière organique, les plantes cultivées en présence de caolinite absorbent plus de ^{134}Cs que celles cultivées en présence de bentonite. La quantité de ^{134}Cs absorbée par les plantes diminue lorsqu'on augmente le taux d'argile. Par contre, la quantité de ^{134}cs absorbée augmente si l'on élève le taux de matière organique.

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Samenvatting. - Dit onderzoek werd uitgevoerd om de invloed van de wisselwerking tussen klei mineralen en organische stof op de opname van radiocesium door twee planten, te bestuderen. Deze planten zijn: Italiaans raygras (**Lolium italicum** L.) en rode klaver (**Trifolium pratense** L.). Als klei mineralen werden bentoniet (2:1 lagen type) en kaoliniet (1:1 lagen type) gebruikt. Klei en zand werden zodanig gemengd dat men mengsels verkreeg waarin 0, 5, 10, 20 en 40 % klei aanwezig was. Hieraan werd vervolgens organisch materiaal (bosturf) toegevoegd zodat dit laatste 0, 5 et 10 % uitmaakte van het oorspronkelijke klei-zandmengsel.

De resultaten hebben aangetoond dat bij een welbepaald gehalte organische stof, de opname van ^{134}Cs groter is bij planten gekweekt op een kaoliniet bodem dan op een bentoniet kleibodem. Een verhoging van de hoeveelheid klei in het mengsel heeft een vermindering van de ^{134}Cs tot gevolg, en dit voor beide plantsoorten. Bij een welbepaald kleigehalte, verhoogt de opname van ^{134}Cs bij een vermeerdering van organische stof.

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1 Biology and Agriculture Division, Bhabha Atomic Research Centre, Trombay, Bombay 400085, India, and

2 Department of Radiobiology, Centre d'Etude de l'Energie Nucléaire, Mol, B-2400, Belgium.

SUMMARY

Studies were undertaken to examine the influence of interaction of clay minerals and organic matter on the uptake of radiocesium by two pasture plants, namely, ryegrass (Lolium italicum L.) and red clover (Trifolium pratense L.). The clay minerals used were bentonite (2:1 layer type) and kaolinite (1:1 layer type). Mixtures of clay and sand were prepared with 0,5,10,20 and 40 per cent clay and treated with organic matter (forest turf) at 0,5 and 10 per cent of the clay-sand mixtures. Results indicated that ^{134}Cs uptake by plants grown on the kaolinite-clay medium was greater than that on the bentonite-clay medium at a given organic matter level. Increasing the clay content of mixtures resulted in reduction in ^{134}Cs uptake by both plant species. The plant uptake of ^{134}Cs increased with additions of organic matter at a given clay content.

RESUME

Ce travail a été effectué dans le but d'étudier l'interaction entre des minéraux de l'argile (bentonite et caolinite) et la matière organique, sur l'absorption du ^{134}Cs par les plantes *Lolium italicum* L. et *Trifolium pratense* L. Le sable a été mélangé avec l'argile (0, 5, 10, 20 et 40 % d'argile) et le mélange a été additionné de matière organique (tourbe) à 0, 5 et 10 %.

Les résultats obtenus montrent que, pour le même pourcentage de matière organique, les plantes cultivées en présence de caolinite absorbent plus de ^{134}Cs que celles cultivées en présence de bentonite. La quantité de ^{134}Cs absorbée par les plantes diminue lorsqu'on augmente le taux d'argile. Par contre, la quantité de ^{134}Cs absorbée augmente si l'on élève le taux de matière organique.

SAMENVATTING

Dit onderzoek werd uitgevoerd om de invloed van de wisselwerking tussen klei mineralen en organische stof op de opname van radiocesium door twee planten, te bestuderen. Deze planten zijn : Italiaans raygras (*Lolium italicum* L.) en rode klaver (*Trifolium pratense* L.). Als klei mineralen werden bentoniet (2:1 lagen type) en kaoliniet (1:1 lagen type) gebruikt. Klei en zand werden zodanig gemengd dat men mengsels verkreeg waarin 0, 5, 10, 20 en 40 % klei aanwezig was. Hieraan werd vervolgens organisch materiaal (bosturf) toegevoegd zodat dit laatste 0,5 % en 10 % uitmaakte van het oorspronkelijke klei-zandmengsel.

De resultaten hebben aangetoond dat bij een welbepaald gehalte organische stof, de opname van ^{134}Cs groter is bij planten gekweekt op een kaoliniet bodem dan op een bentoniet kleibodem. Een verhoging van de hoeveelheid klei in het mengsel heeft een vermindering van de ^{134}Cs opname tot gevolg, en dit voor beide plantsoorten. Bij een welbepaald kleigehalte, verhoogt de opname van ^{134}Cs bij een vermeerdering van organische stof.

INTRODUCTION

The absorption of radiocesium, a long-lived gamma-emitting fission product deposited in global fallout, by plants through their roots is mainly dependent upon the nature of the soil constituents. Clay minerals and organic matter present in the soil influence greatly the plant uptake of radiocesium. Soils can retain radiocesium in a fixed state which is relatively unavailable for plant absorption. This ability is largely attributed to clay minerals capable of forming a relatively stable collapsed structures when saturated with Cs^+ ions[9,10]. The quantity of these fixing minerals present in soils may be significantly related to the uptake of ^{137}Cs by plants.

It has been established that organic matter forms complexes with clays causing marked changes in their exchange capacity[6,7]. The total quantity of cesium sorbed by these complexes has been reported to be greater than that sorbed by pure clays and larger quantity of this element was in the readily exchangeable form in the complexes than in pure clays[12]. Laboratory and field experiments have demonstrated that the plant uptake of ^{137}Cs is influenced by the content of native organic matter in the soil, and increases with increasing content of such matter[3,4]. The present investigation was aimed at examining the interactions between organic matter and two clay mineral types in relation to their influence on the uptake of radiocesium by two pasture plant species. These pastures were representative of the north temperate regions where "soil-pasture grass-milk" pathway is the major route of transfer of radiocesium in the food chain.

MATERIALS and METHODS

Pure bentonite clay, a representative of the 2:1 montmorillonitic group having a cation exchange capacity of 73.8 meq 100 g were used for the experiments. Organic matter (forest litter mat) was dried and ground in a wiley mill. Pure quartz sand was washed, dried and passed through a two mm sieve. A few trial experiments were conducted to determine the feasibility of plant growth in the artificially prepared sand-clay-organic matter mixtures in different proportions. It was considered advisable to maintain constant volume rather than constant weight of the experimental pots since there were marked differences in volumes with constant weight of different mixtures.

Sand-clay mixtures were prepared so as to have clay comprising 0,5,10,20 and 40 per cent of the sand-clay mixture. Organic matter treatments were given at 0,5 and 10 per cent of the sand-clay mixture. Calculated amounts after giving suitable corrections for moisture, (Table 1), of sand, clay and organic matter were weighed and mixed in the dry state in an end over end shaker for half an hour. The dry mixture was then transferred to a basin and water was added in instalments and mixed mechanically to obtain a moisture level of 60 per cent. This mixture was than potted in black plastic pots having perforated bottom, and allowed to equilibrate for one week. Each treatment was replicated thrice.

A nutrient solution of 10 litres was prepared comprising 4.92 g $MgSO_4$ $7H_2O$ 5.90g $Ca(NO_3)_2 4H_2O$; 3.84g $Mg(NO_3)_2$ $6H_2O$; 4.04 g KNO_3; 1.16 g K_2HPO_4; 2.32 g KH_2PO_4 and the micronutrients B, Mn, and Cu (as sulphates), and E.D.T.A. NaFe. These quantities represent 7 meq Mg^{++}, 7 meq K^+, and 5 meq Ca^{++} per litre solution. Carrier free ^{134}Cs was mixed in this nutrient solution so that 25 ml of this solution gave an activity of 25 µCi ^{134}Cs. This 25 ml of labelled nutrient solution plus 10 ml of water was sprayed on the surface of all the pots. Five days after spraying, each of the pot mixture was again mechanically mixed in the wet state and repotted. The pots were now placed in plastic flats (70 cm by 100 cm) containing 20 litres of distilled water to obtain field capacity. After one week, 1.2 g seeds of ryegrass (Lolium italicum L.) and 0.8 g seeds of red clover (Trifolium pratense L.) were sown per pot. On germination the seeds were exposed to artificial light for 16 hours a day, the light intensity being 8000 to 9000 lux. The temperature of the greenhouse fluctuated between 18-25°C throughout the growth period and the relative humidity was 60%.

Ryegrass was harvested when it attained a height of 15-20cm (after 20 days growth) and red clover was harvested after a growth period of 4 weeks. The plant material was dried to constant weight at 70°C and wet ashed with concentrated nitric acid and hydrogen peroxide. The volume was made up to 100 ml and an aliquot of this extract was taken up for radioassay of ^{134}Cs through gamma-ray spectrometry using a well type 7.5 x 7.5 cm NaI (Tl) crystal integral line assembly and a Nuclear Data 512-channel pulse height analyzer attached to an oscilloscope and a computer readout typewriter.

RESULTS and DISCUSSION

1. Bentonite clay - organic matter mixtures.

Data on the effects of organic matter on the uptake of ^{134}Cs from varying sand-bentonite clay mixtures by ryegrass and red clover are shown in Table 2. Data indicate a reduction in the plant uptake of ^{134}Cs with increasing content of bentonite clay at any given organic matter level. This reduction in uptake is likely due to the greater fixation of ^{134}Cs in the bentonite, a 2:1 layer type mineral. Previous workers[2,5,9,11] have indicated high fixation of radiocesium in the 2:1 layer type of minerals and the present data indicate that the fixation of ^{134}Cs is greatly increased with increasing content of the clay mineral resulting in significant reduction in plant uptake. The data also indicate clear effects of organic matter content in the sand-clay mixtures; significant enhancement in plant uptake of ^{134}Cs was observed with increasing amounts of organic matter at any given clay content. The plant yields,in general, did not reflect any carbohydrate dilution effects on ^{134}Cs uptake by the two plant species. Earlier studies[1,6,7,12] have indicated that organic matter complexes with 1:1 and 2:1 layer lattice type clays and the complex formation enhances the quantity of readily exchangeable cesium[12]. Our present findings clearly demonstrate that organic matter is able to interact with clay, presumably by the formation of complexes thus releasing the ^{134}Cs bound in the clay with the corresponding increase in plant availability of the radionuclide.

It is also evident from Table 2 that plant species variation did not appear to influence the pattern of uptake of ^{134}Cs from mixtures involving bentonite clay and organic matter, though the absolute amounts of the radionuclide absorbed varied with the plant species.

2. Kaolinite clay-organic matter mixtures.

Data on the effects of organic matter on the uptake of ^{134}Cs from varying sand-kaolinite clay mixtures by ryegrass and red clover are presented in Table 3. Data indicate a pattern similar to that observed earlier for the uptake of ^{134}Cs by the two pasture plants from bentonite clay-organic matter mixtures (Table 2), namely, an enhancement in the plant uptake with decreasing clay content and increasing organic matter content. Comparing the ^{134}Cs uptake by the two plant species from the bentonite system (Table 2) with that from the kaolinite system (Table 3), it is evident that plants removed greater amounts of ^{134}Cs from the kaolinite system at all treatment levels. Earlier work[8] has shown that plants recovered more ^{137}Cs from kaolinitic soils than from montmorillonitic soils. Greater fixation of ^{137}Cs in soils containing minerals capable of forming relatively stable collapsed structures (2:1 layer type) when saturated with Cs^+ has been earlier demonstrated[9,11]. The present findings indicate conclusively that both the clay content and the clay mineral type influence in the absorption of radiocesium by the two pasture plants.

Data in Table 3 also indicate an increase in the plant uptake of ^{134}Cs with increasing levels of organic matter at any given clay content. In the case of red clover, though the organic matter level of 5% resulted in an increase in the plant uptake of ^{134}Cs, no further effects are observed at the higher (10%) organic matter level compared to the 5% level.

In conclusion, uptake of ^{134}Cs from sand-clay-organic matter mixtures by ryegrass and red clover was reduced with increasing bentonite clay and kaolinite clay contents over wide range of organic matter levels. Reduction in plant uptake of the radionuclide was more marked in the bentonite system at any given organic matter level. In the bentonite system, 58 to 70 per cent reduction in the ^{134}Cs uptake by ryegrass occurred at the 5% clay level. In the case of red clover, however, the reduction in ^{134}Cs uptake with increasing clay content was more gradual over the organic matter levels employed in the present studies. It was also evident that the plant uptake of ^{134}Cs increased with additions of organic matter at a given clay content.

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Table 1

Experimental design - Weight of soil mixture in g/pot

Treatment	Organic matter		
	0%	5%	10%
A. Sand	800	475	360
Clay 0%	-	-	-
Organic matter	-	25	40
Total	800	500	400
B. Sand	570	451	342
Clay 5%	30	24	18
Organic matter	-	25	40
Total	600	500	400
C. Sand	540	428	324
Clay 10%	60	47	36
Organic matter	-	25	40
Total	600	500	400
D. Sand	480	380	288
Clay 20%	120	95	72
Organic Matter	-	25	40
Total	600	500	400
E. Sand	360	285	216
Clay 40%	240	190	144
Organic matter	-	25	40
Total	600	500	400

Table 2

Effect of organic matter on the uptake of ^{134}Cs from varying sand bentonite clay mixtures by ryegrass and red clover

Duration of plant growth - ryegrass: 3 weeks
- red clover:4 weeks

Clay % / Organic matter %	^{134}Cs uptake (cpm/mg dry shoots)					
	0	5	10	20	40	LSD (p=0.05)
Ryegrass						
0	104.11	50.23	19.75	25.15	8.35	20.62
5	305.60	128.44	82.94	26.06	8.29	15.05
10	591.10	179.98	136.06	68.88	17.31	38.48
LSD (p=0.05)	39.84	25.28	14.22	11.34	3.92	-
Red clover						
0	194.13	60.85	22.80	14.81	9.03	29.50
5	459.42	384.16	137.86	31.96	10.68	94.13
10	366.60	477.54	296.02	53.43	20.74	131.85
LSD (p=0.05)	135.51	111.19	40.72	17.64	3.43	-

Table 3

Effect of organic matter on the uptake of ^{134}Cs from varying sand kaolinite clay mixtures by ryegrass and red clover

Duration of plant growth - ryegrass : 3 weeks
- red clover: 4 weeks

Organic matter % \ Clay %	^{134}Cs uptake (cpm/mg dry shoots)				
	0	10	20	40	LSD (p=0.05)
Ryegrass					
0	104.11	129.02	102.17	54.84	39.34
5	305.60	269.22	188.78	116.44	15.09
10	591.10	365.29	281.69	197.91	80.85
LSD (p=0.05)	39.84	81.49	21.93	25.62	
Red clover					
0	194.13	261.51	153.44	104.17	29.52
5	459.42	395.40	336.52	215.70	101.97
10	366.60	340.23	226.15	198.89	108.91
LSD (p=0.05)	135.51	51.88	61.47	34.67	

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