EFFECT OF COUNTERMEASURES ON RADIONUCLIDE UPTAKE BY GREEN PLANTS

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Summary

In the present paper results will be discussed in the field of countermeasures effectiveness on the radiocaesium and radiostrontium transfer to plants in relation to soil characteristics at the different sites investigated, as well as their influence on the crop yield.

1.Introduction

A reduction of root uptake by following a countermeasure strategy can be obtained by several means [Baes C.F.III, et al 1986]:

- removal of the contaminated soil surface layer;
- ploughing to reduce the contamination of the upper soil layers and subsequently reduce the uptake by shallow-rooted plans such as grass and legumes;
- addition of fertilisers: phosphorus to insolubilise strontium as phosphates (co-precipitation), calcium (lime) to compete with strontium for plant uptake, potassium (potash) to compete with caesium;
- addition of chelating agents to bind the radionuclides in a form unavailable for plant uptake or in soluble forms that will be leached below the rooting zone;
- cropping deep-rooted plants that exploit the soil below the contaminated layers;
- cropping plants used for grain production (grains generally exhibit lower transfer factors than other plant organs), seed production, fibre or oil production, for cattle feeding.
- use of agricultural lands for alternative purposes: planting forest for timber production.

2.Materials and methods

In 1996 and 1998 additional countermeasures were tested at already existing sites (Babchin and Vetka; Gomel region). At each site, experimental plots (16 m^2 each) were installed in the end of 1994 and cultivated in 1995 without application of countermeasures. In 1996 and 1998, alternative countermeasures (Table 1) were tested, individually or in combination, at different levels of application, on different crop species (Table2). The crops (4 plots per crop) were harvested at maturity. From each plot, the yield was recorded and representative samples of plant material and soil (plough layer) were collected and analysed for their ^{137}Cs and ^{90}Sr content. The radioactivity content in the different plant parts or harvests (Bq/kg dw) was related to the soil contamination level expressed on a surface area basis (Bq/m^2), referred to as the transfer factor.

Table1. Countermeasures tested at the different experimental sites between 1996 and1998.

1996		**1998**	
Babchin	**Vetka**	**Babchin**	**Vetka**
Bentonite		Bentonite	Bentonite
Clinoptilolite	Clinoptilolite	Clinoptilolite	
P	P		
K	K		
	Manure	Manure	Manure
			Sapropel

Table 2. Crop rotation at the experimental sites from 1996 until 1998.

1996		**1998**	
Babchin	**Vetka**	**Babchin**	**Vetka**
oat	oat	barley	oat
pea	pea		potato
rape	rape		winter rye
ryegrass	ryegrass		
	lupine		

3.Results and discussion

The relative yield and transfer factor for ^{137}Cs and ^{90}Sr, in precent of the value of the control, are reported in Table 3. The biomass production was significantly increased by fertilisers addition but fertilisation in fallow lands had an adverse effect on the ^{137}Cs contamination level in cereal grains which was increased by a factor 1.3 to 1.7 compared to the control; such an effect can be tentatively and partly explained by the conversion of nitrogen fertilisers to ammonium in poorly aerated peat soils.

Table 3. Effect of NPK fertilisation on the yield and ^{137}Cs and ^{90}Sr transfer factor to various plant organs at Vetka. The reported values are expressed in percent relative to the control on fallow land.

Year	Species	Organ	effect (% of control) on		
			Yield	Cs TF	Sr TF
1996	barley	grain	145**	166***	83*
	oat	grain	138*	170***	63**
	potato	grain	128**	86ns	68**
1998	oat	grain	nd	132**	77*
	winter rye	grain	nd	164***	73*

nd: not determined; ns: not significant at the 5% level; *, ** and *** are respectively significant at the 5,1 and 0.1% levels.

On field fertilised at normal rates for the site and crop, doubling the potash fertilisation generally tends to increase the crop yield. Spreading double K doses contributed to a reduction of the Cs uptake by a factor up to 2; Sr transfer to plants was not affected by supplementary K fertilisations. Combined double dosing of P_2O_5 and K_2O, were investigated on oat at Vetka and Babchin. This combined countermeasure failed to have any significant effect on crop yield but, in general, caused a decrease of the Cs transfer factor to plants (up to a factor 3). Comparing the doubling of K only and the combined addition of K and P showed that the key role is played by potassium.

Addition of farm manure was tested. The results obtained are summarised in Tadle 4.

In general, manure addition appeared to promote a significant increase of the crop yield. Sound conclusions about the influence of manure addition on Sr uptake by plants can not be made due to the limited set of available data. The observations do not show any effect on Sr accumulation by plants.

Sapropel as a countermeasure was applied in 1996 at Vetka (barley). The data obtained for yield, Cs and Sr transfer factors were not significantly different from those obtained on the non-amended controls, although this countermeasure has been reported to be the most effective [Prister et al 1993].

Application of clinoptiolotite at a rate of 30 or 50 t/ha, had no clear effect, on the crop yield (Table 5). Clinoptilolite addition tends to increase the Cs transfer to plants. This increase was significant for lupine, rape and oat grain, grown at Babchin and rape at Vetka. The strontium transfer to lupine and rape grown in Vetka was decreased to a certain extent, significantly for rape grains.

Table 4. Effect of farm manure additional on the yield and Cs and Sr transfer factors to various plant organs at different sites. The reported values are expressed in percent relative to the control.

Site	year	crop	organ	dose (t/ha)	effect (% of control) on		
					Yield	Cs TF	Sr TF
Vetka	1996	oat	grain	60	118 ns	121 ns	96 ns
			straw	60	101 ns	112 ns	114 ns
	1998	barley	grain	60	144 ns	105 ns	90 ns
			straw	60	nd	97 ns	99 ns
Babchin	1996	oat	grain	60	143 ***	55 ns	nd
			straw	60	117 ns	60*	nd
	1998	barley	grain	60	236***	77 ns	nd
			straw	60	144***	82 ns	nd

nd: not determined; ns: not significant at the 5% level; *,** and *** are respectively significant at the 5,1 and 0.1% levels.

Among the various contermeasures aiming on reduction the contamination of plants by root uptake, the application of extra quantities of potassium fertilisers reduces the the root absorption of Cs due to competition effect between these two analogs. The reduction is expected to be highest in poorly fertilised soil and less pronounced in well fertilised farm lands. This is the reason why a clear effect was generally observed on farmlands which had not been cultivated since the accident and why extra-addition of potash appeared to be less or not effective on soils on which high fertilisation dose had been applied (memory effect from previous fertilisations).

Phosphate fertilisers did not prove to be very effective in the conditions of our experiments. Phosphorus had no, or little effect, on the Cs transfer, but, on the contrary, showed adverse effects on the Sr transfer which was increased. The overall effect of organic matter (manure) additions on radionuclide transfer has not been clarified. Application of organic matter had a positive effect on the transfer of Cs, which was significantly reduced in some of the sites studies. To date, the reason for this behaviour is not clear. Surprisingly, for unexplained reasons, manure appeared in some cases to increase the Sr uptake by plant.

Table 5. Effect of clinoptilolite addition on the yield and Cs and Sr transfer factors to various plant organs at different sites. The reported values are expressed in percent relative to the control.

Site	year	crop	organ	dose (t/ha)	effect (% of control) on		
					Yield	Cs TF	Sr TF
Babchin	1996	oat	grain	30	160***	78 ns	nd
			straw	30	163***	75 ns	nd
		rape	green	30	nd	180***	nd
	1998	barley	grain	30	82 ns	183**	nd
			straw	30	94 ns	170***	nd
Vetka	1996	oat	grain	50	111 ns	162*	121 ns
			straw	50	88 ns	141 ns	148*
		rape	grain	50	nd	nd	57**
			green	50	111 ns	217*	92 ns
		lupine	grain	50	102 ns	104 ns	98 ns
			green	50	87 ns	143 ns	88 ns

nd: not determined; ns: not significant at the 5% level; *,** and *** are respectively significant at the 5,1 and 0.1% levels.

4.References

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