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Exposures from consumption of agricultural and semi-natural products

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Abstract. The importance of food from different production systems to the internal dose from radiocaesium, was investigated in selected study sites in Ukraine and Russia. Food products from semi-natural ecosystems are major contributors to the individual internal dose to rural population in areas affected by the Chernobyl accident. At the selected study sites it is estimated in 1995 that foods from private farms and forests contribute on average 35% to 60%, to the individual internal dose, variation relating to soil types and implemented countermeasures. The importance of food products from private farms and particularly forest products increases with time since ^{137}Cs concentration in some of the natural food products have longer ecological half life than food products from agricultural systems. A significant relationship was observed between consumption of mushrooms and whole body content of radiocaesium in rural people. The contribution to the collective dose of food products produced in the semi-natural ecosystems is less than the contribution to the individual internal dose for the local rural population.

1. Introduction

Ingestion pathways are important routes leading to radiation doses in man after deposition of radioactive fallout. Several factors will influence the extent of intake of radionuclides. The importance of semi-natural ecosystems, compared to agricultural systems, in determining dose to rural populations has been uncertain. Transfer of radiocaesium to food products in agricultural systems is usually lower than those from semi-natural ecosystems. In particular, some products such as certain mushroom species and game are known to contain relatively high amounts of radiocaesium in comparison with agricultural products. Therefore, it has been suggested that the comparative importance of different farming systems and ecosystems needs to be reassessed with regard to the transport of radionuclides to man.

Village residents have farming and dietary habits which potentially predispose them to higher rates of radiocaesium intake. On the private farms one reason for this is lack of mineral fertilises, which give potential for higher transfer of radiocaesium to both vegetation and animals. Furthermore, village residents have easy access to mushrooms and berries from the forest.

In contrast, the greater total quantity of food produced in agricultural systems needs to be considered when calculating overall collective dose, and compared to that from private farms and forests. Hence, it is important to know what proportion of people's diets which arises from

the various ecosystems and food production systems, and how this varies when calculating collective or individual dose. The differences in long term transfer of radiocaesium between food products from agricultural and semi-natural ecosystems may also change their comparative importance with time.

One of the prime objectives of EU funded ECP9-study was to make an initial assessment of the comparative importance of different food producing or collection systems in determining the individual internal dose for rural populations in a small number of selected settlements. In this paper we have extended the study to compare the collective internal dose received from consumption of foods produced in agricultural and semi-natural ecosystems.

Ecosystems where food are produced

The food production systems in the CIS country can be divided into two groups, the agricultural system, which include collective farms, and most of private farming. Whilst collective farms routinely use land rotation combined with ploughing and fertilisation to improve productivity, private farmers seldom apply artificial fertilisers, and tend to use animal manure for improving yields, particularly in their vegetable gardens.

Products from semi-natural ecosystems fall into two categories. Firstly there are the natural food products such as, mushrooms and berries which are used by people. In addition, clearings in forests and non improved pasture, are often used to provide fodder for the winter period, or as additional grazing land for animals.

Farming systems

Collective farms produce food through intensive management of the major soil and animal resources of their area, and provide labour opportunities for the rural population. Typically 2-5 villages are located within the area of a collective farm. Many village families are also allocated a plot of land in which to grow foodstuffs for their own use. Therefore within the village a subsistence farming economy operates, partly based on income from the collective farm and partly on exchange and sale of home grown vegetable and animal products. Traditionally, private farms have one or two cows, and milk is used for personal consumption as well as food for animals. Roughage for cattle is most often harvested from forest or scrubland. The grazing regime of privately owned cattle varies but to some extent relies on utilisation of marginal land that is not used by the collective. This includes the use of river banks, natural pastures and clearings in the forest. Sometimes they graze on fields which are lent to the farmers by the collective farm. The manure produced by the cattle is normally the only additional source of plant nutrients used for the private plots.

As the private farms utilise semi-natural ecosystems (e.g. grazing of domestic animals in natural pasture or in the forest) for milk production, this production has only been described as 'agricultural' when the pastures have been ploughed and/or fertilised. However it is sometimes necessary to differentiate further between private and collective farming systems, so in this study three different product groups are considered: Those from collective farming (intensive agricultural), from private farming (partly less intensive farming) and natural food products (e.g. food gathering). The use of countermeasures after the Chernobyl accident made these groups less well defined since in many areas, countermeasures (ploughing and fertilising) applied for reducing radionuclide transfer, made private farming less dependent on unimproved land.

Countermeasures

Countermeasures for reducing internal doses were applied to most contaminated areas, especially those area used intensively as part of the agricultural food producing system. Countermeasures used on the collective farm system included soil management, feeding regimes, radiocaesium binders, change of crops, and also the abandonment of some land used for food production. In the private farming system the more drastic countermeasures included restriction on the ownership of private cattle in the most heavily contaminated areas. Ploughing of natural pasture was also used widely, and private farmers given advices concerning soil management. Fewer countermeasures were available for reducing transfer of radioactivity to natural food products. However, the population were given information about change of diet and methods of food preparation to reduce radioactive content of foods.

2. Methods

The comparative importance from different sources of radiocaesium was considered for both individual doses for the rural population and collective doses from radiocaesium. Dietary survey and questioners about food production in the private farms were performed in the study sites. For both categories the time dependence and effect of countermeasures has been considered.

Detailed information was collected from selected study sites and combined with information about larger areas. Information on the following topics were collected.

- activity levels in food
- transfer to food products and variation over time
- dietary habits and dietary changes
- use of countermeasures
- quantity of food produced in the different production systems

3. Individual dose assessment from food consumption for rural populations in selected areas

Detailed studies were conducted in four different study sites where the influence of countermeasures, soil type and dietary changes were considered. The study areas selected for the detailed study of assessment of internal dose are shown in Table 1 [1]. The study site at Voronok was selected mainly for comparison with the Russian study site at Novozybkov. (Later "Russian site" indicates the Novozybkov area if Voronok is not spesified).

Table 1 Study areas in Russia and Ukraine

Country	Study areas	Deposition kBq m^{-2}
Russia	Novozybkov	700
	Voronok	50
Ukraine	Dubrovitsa	130

The volume of food products collected in the forest is small compared to that from agriculture (private or collective). However, the transfer of radiocaesium to natural products, such as mushrooms, wild berries, fish, and wild animals is often considerably higher than in the collective farming system. From the dietary survey [1] it was obvious that natural products are consumed by a significant proportion of the population. For all the study sites a considerable part of the population consume mushrooms (1/3 to 1/2). However, only a very few people (<1%) at the study sites consume meat from game. In addition to ranking use of natural foods the actual consumption of mushroom and forest berries (in kg d^{-1}) was estimated. In Table 2 the contribution of different food production systems is shown.

Table 2 Comparative importance (given in %) for the dose received from consumption of food contaminated with radiocaesium, from different ecosystems and food producing systems

Ecosystem	Food producing system	Ukrainian study site	Russian study site
Agricultural	Collective farming	17	17
	Private farming	48	22
Forest	Natural food	35	61

At the Ukrainian study site the agricultural system contributes on average about 65% of the radiocaesium intake, at the Russian site the agricultural system contributes about 40%. All the food products from private farming are, in this overview, attributed to the agricultural system. However, part of the milk production in the private system would been partly attributed to the semi-natural ecosystem because of private cows grazing natural and forest pastures which have not been fertilised or ploughed as a countermeasure. In the Russian study site natural food products are the main contributor to the internal individual dose from radiocaesium. In Ukraine food from the private farming system is a more important source.

For people who do not consume mushrooms we find that private farms in the Russian study site contribute 15% to radiocaesium intake, whilst 83% is due to intake of food produced in the collective farm. Among "non-mushroom-eaters" milk and meat contribute about 60% of the ^{137}Cs intake, while for mushroom eaters milk and meat contribute only about 20%; in this group about 70% of the ^{137}Cs dietary intake is due to mushroom consumption. The contribution of agricultural vegetable products is about 10%. In all cases, locally produced foods contributes more to the intake of ^{137}Cs than food bought from shops.

In Ukraine, among "non-mushroom-eaters" milk and meat contribute 60% of the ^{137}Cs intake. For those eating mushrooms, about 50% of their 137Cs intake come from mushrooms, and milk and meat supplies about 30% of the ^{137}Cs to this group. The contribution of agricultural vegetable products is about 10-15% for the different groups. As at the Russian site, products from private farms contribute more ^{137}Cs to the total diet than imported food sold in state shops. The private farming and natural food products contribute 83 % on average of the intake.

For all the study sites a strong, and consistent relationship exists between the extent of mushroom consumption and whole body radiocaesium content, as shown in Figure 1.

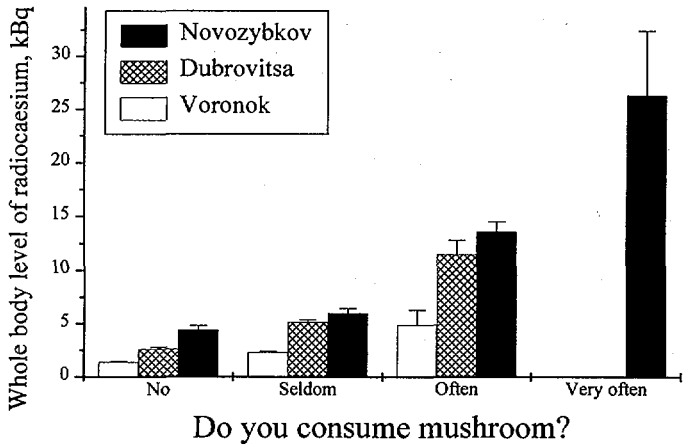

Figure 1 Relation between frequency of mushroom consumption and wholebody levels (kBq) of radiocaesium in 1994 and 1995.

Private farming is of little importance at the Russian study site because the private farming system no longer produces significant quantities of milk products. The consumption of milk from private production decreased following the Chernobyl accident to 1-3% of pre-1986 levels [4]. This dramatically reduced the intake of radiocaesium to man from the private farming system compared with the situation prior to 1986. In Russia changes in diet and agricultural practices adopted after the Chernobyl accident have given and still give, significantly reduced intake of radiocaesium to the population. From the information about milk consumption in another study site outside the controlled area (Voronok) where private cattle were not removed, it is possible to estimate the importance of the private farms' contribution to the dose at the Novozybkov site. The comparative importance between the groups for the Russian study site would then be as shown in Table 3.

Table 3 Estimated mean contribution (given in %) for the dose received from consumption of food contaminated with radiocaesium, from different ecosystems and food producing systems. Under traditional private farming practices.

Ecosystem	food producing system	Russia
Agricultural	Collective farming	5
	Private farming	50
Semi-natural/Forest	Natural food	45

This is similar to the results from the Ukrainian study site.

The agricultural system is in 1995 the major contributor to radiocaesium intake, contributing on average about 55%. However, again, the milk production in the private farming system is fully attributed to the agricultural ecosystem, mainly because of the intensive soil treatment countermeasures applied after the Chernobyl accident. Hypothetically, if this had not been the case the semi-natural ecosystem would have had a greater role. This is demonstrated in Table 4 where it is assumed that 50% of private milk production is associated with unimproved or forest pastures. To estimate the radiocaesium levels in private milk at the Novozybkov study site the present levels at the Voronok study site have been used with allowance made for the difference in deposition, between the two sites. For the Ukrainian study sites it was also assumed that 50% of private milk production is associated with unimproved or forest pasture. The result of this scenario is shown in Table 4.

Table 4 Comparative importance (given in %) for the dose received from consumption of food contaminated with radiocaesium, of different ecosystems and food producing systems, if countermeasures had been used in much lesser extent on natural pasture.

Ecosystem	Food producing system	Ukrainian study site	Russian study site
Agricultural	Collective farming	17	7
	Private farming	32	31
Semi-natural/Forest	Private farming	16	17
	Natural food	35	45

The agricultural system under such assumption is estimated to contribute on average 49% and 38% to the radiocaesium intake, respectively for the Ukraine and Russian study site.

It is clear that at present the collective production system is a comparatively unimportant source of radiocaesium for residents of villages in contaminated areas with similar characteristics to those included in this study and with continued traditional private farming. If individuals have a high intake of natural food products the radiocaesium intake is strongly influenced by consumption of these products. By introducing countermeasures in the private farming system the transfer of radiocaesium to man has been considerably reduced. However, that continued use in private production of semi-natural ecosystems, for which few countermeasures are available, maintains the importance of this production system.

Time dependence of the internal individual dose

The results given above describe the present situation concerning the importance of ecosystems and food producing systems for the radiocaesium intake to man. However, a clear difference has been demonstrated between the long term transfer in intensive agricultural systems and in semi-natural systems [2,3,4]. Therefore, the comparative importance of different food production systems will probably change with time.

To illustrate changes with time the intake of radiocaesium in the first year after fallout has been estimated by applying reported transfer factors for natural pasture in the area [1,4], and by using information about ecological half lives for different food products [5]. Fesenko et al [5] consider the reduction in the different food products to be dependent on three factors 1) natural biogeochemical processes, 2) countermeasures and 3) radioactive decay. By taking the relevant radiocaesium levels of food products or the ecological half life into account for the

products, the comparative importance for the different ecosystems and food producing systems can also be estimated at an early stage after an accident (e.g. one year after the accident, 1987). In the Bryansk region the effective half life for ^{137}Cs decrease in plant material varied between 1.4 and 1.9 year [5]. The long term behaviour of natural food products e.g. mushrooms, has been described by Shutov et al [3]; for mushrooms they found no significant reduction in radiocaesium levels in the Bryansk region. The comparative importance of the different system is shown in Table 5 for the Russian study site. Relevant information was not available from the Ukrainian study site.

Table 5 Comparative importance (given in %) for the dose received from consumption of food contaminated with radiocaesium, from different ecosystems and food producing system after one and nine year following the deposition.

Ecosystem	Food producing system	Russian study site 1987	Russian study site 1995
Agricultural	Collective farming	5	17
	Private farming	47	22
Semi-natural/Forest	Private farming	39	
	Natural food	8	61

At the Russian study site the intensive agricultural system contributed on average of 52%, to the internal dose one year after the accident compared to 39% at present. However the situation changed drastically concerning the importance of natural food products compared to the two other food producing systems. Natural food products contribute only about 8% in 1987 to the total intake of radiocaesium whilst in 1995 they contributed about 61%. For the Russian study site in 1987 the products from the private farming system would have been the main contributor to the intake of radiocaesium to man for the village residents.

4. Collective (total) internal dose estimation from consumption of total food production at the study sites

To dived the collective internal dose between different production systems at the study sites requests combination of knowledge of the total amount of food produced in each of the three food production systems. This includes products which are relevant for food consumption by either local people or by people outside the area. In Table 6 the amount of food, present radioactivity concentrations, and collective dose from different systems, estimated from productivity and dietary surveys performed in 1994 and 1995 of the local population is shown. The number of people living at the two study sites are 850 and 3000 respectively in the Russian and Ukrainian study sites. The yield of natural food products such as fungi and berries may be considerably underestimated since gathering by people from outside the area who also use the forests is not included.

Table 6 Total activity of radiocaesium in the food products produced at the two study sites.

		Russian study site			Ukrainian study site		
Food producing systems	**Food products**	**Quantity produced**	**Activity levels**	**Total activity**	**Quantity produced**	**Activity levels**	**Total activity**
		$t\ y^{-1}$	Bq/kg	kBq	$t\ y^{-1}$	Bq/kg	kBq
Collective	milk	1241	60	74460	1300	50	65000
	meat	155	273	42315	350	100	35000
	potatoes				813	20	16260
	vegetab						
	grain				1673	250	418250
	sub-total			116775			534510
Private	milk				543	140	76020
	meat	1	113	113	98	172	16856
	vegetab	95	11	1045	113	45	5085
	potatoes	217	11	2387	528	27	14256
	sub-total			3545			112217
Natural	mushrooms	4	10000	40000	49	1000	49000
	berries	1	403	403	30	210	6300
	sub-total			40403			55300
Total				**160723**			**702027**

The comparative importance for the different food producing systems for the collective dose from intake of radiocaesium by food produced at the study sites is shown in Table 7.

Table 7 Comparative importance (given in %) for the collective dose received in 1995 from consumption of food contaminated with radiocaesium, from different ecosystems and food producing systems at the study sites in Russia and Ukraine.

Ecosystem	Food producing system	Ukraine study site	Russian study site
Agricultural	Collective farming	76	74
	Private farming	16	2
Semi-natural	Natural food	8	25

Again at the Russian site private farming production is considerably affected by the removal of private cattle. If this was not done in 1986 the importance between the system would change from what shown in Table 7 to about 66%, 11% and 22%, respectively for the collective farming, private farming and natural food products at the Russian study site . The

semi-natural ecosystem would probably contribute to the internal dose on average with 13% and 26% respectively at the Russian and Ukrainian study sites if natural pasture were not improved. This shows that the semi-natural ecosystem is also important in relation to collective dose. However there is need for better knowledge about the consumption of natural food products both in the rural and specially for the urban population. Since the radioactivity concentration of radiocaesium in some natural food products has not significantly reduced during the years after the Chernobyl accident whilst the agricultural system have declined. The importance of agricultural systems for collective dose is therefore expected to decrease with time after an accident.

Relevance of the result for other affected areas in CIS

The study site in Novozybkov region has the soddy-podzolic soil which occurs in major part of the affected areas in Russia. The collective farms in the affected area are similar to the collective farm in the study sites with major food products being potatoes, milk and barley. The study site in Ukraine is representative for some areas in the Rovno region with specially high transfer of radiocaesium due to the soil type. Other affected areas in Ukraine are more similar to the Russian study site.

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