Commercial-in-Confidence NRPB-M336

Contract Report

Assessment of the Radiological Consequences of the Use of Contaminated Land at St Aubin, Essonne, France

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Abstract

A small area of land at l'Orme des Merisiers, St Aubin in the Essonne district of France has been found to be contaminated with a range of artificial radionuclides. Information was provided on the extent of the contaminated zones and the differing activity concentrations in soil within each zone. On the basis of this information, estimates have been made of the doses that adults, children and infants might receive as a result of using the area in its present form or following development for agricultural, recreational or residential purposes. Development for industry was not considered to be a likely option. The assessment took account of all appropriate exposure pathways and wherever possible was based on site-specific data. Cautious assumptions were made when such information was not available.

On the assumption that people would not preferentially spend time in those zones where activity concentrations are highest, doses to people frequenting the site in its present form would be a small fraction of the principal dose limit for members of the public of 1 mSv y^{-1} recommended by ICRP. The radionuclide of importance was caesium-137, which has a radioactive half-life of 30 y, and so doses will decrease with time.

Doses resulting from the development of the site for agricultural and recreational purposes were also based on activity concentrations typical of the whole area. Doses resulting from development for recreation were a fraction of the principal dose limit. Doses resulting from the use of the land for agriculture were somewhat higher but were still well within the dose limit. Doses that might result from development for residential purposes would be dependent upon the type of accommodation. Typical doses could range from 200—700 μSv y^{-1}. It is, however, conceivable that a house and/or garden could be situated within one of the areas where activity concentrations were highest. In this situation, the calculated doses exceeded the principal dose limit, whatever the type of accommodation, although these estimates could be refined if more information was available about external dose rates and the distribution of activity with depth in the soil.

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Environmental Assessments Department
National Radiological Protection Board
Chilton
Didcot
Oxon OX11 0RQ
United Kingdom

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1 Introduction

A small area of land at l'Orme des Merisiers, St Aubin in the Essonne District of France has been found to be contaminated with a range of artificial radionuclides. The site is presently owned by the French Atomic Energy Commission (CEA). Activity concentrations in soil have been determined by different organisations, and there has been considerable debate about the radiological impact of the contamination. As a result, a commission was set up by the Essonne District local authorities to carry out an independent assessment. The commission requested the National Radiological Protection Board to estimate the doses that might be received from the present use of the site and the potential doses that might result from development for agricultural, recreational or residential purposes. The commission considered that development for industrial purposes was not a likely option.

This report sets out the methodology on which the dose estimates were made, presents the results and discusses their interpretation. Both internal and external exposure pathways have been considered. Throughout the report, internal exposures represent the committed effective dose equivalents from intakes of radionuclides in a given year. Where appropriate, these have been added to the estimated annual external exposure to evaluate total annual committed doses. For simplicity, in the remainder of this report this quantity and its components will be referred to as dose and expressed in microsieverts (μSv). No European directive has yet been issued concerning the new recommendations of the International Commission on Radiological Protection, and so these have not been taken into account in this assessment.

2 Measurement data

A map delineating areas with different levels of contamination was provided by the Essonne District Commission, together with associated measurements of activity concentrations of strontium-90, caesium-137, plutonium-239, 240 and americium-241 in soil. The commission stated that other γ-ray emitting radionuclides such as cobalt-60, barium-133 and isotopes of europium had been detected, but that these radionuclides were confined to small areas and that activity concentrations were generally low (< 100 Bq kg^{-1}). The dose assessment that follows is based almost entirely on the information provided by the commission. Their measurements are reproduced in Table 1 and Figure 1. Activity concentrations in air were provided but were expressed only in terms of gross activity. Moreover, measured values on site did not differ significantly from those measured further away. These measurements have not therefore been used in the assessment of doses. Analytical data have been published by other organisations (eg, reference 1) but these refer to isolated samples and do not represent typical activity concentrations within given areas. For this reason, their use in assessments of the radiological consequences of land contamination is inappropriate.

3 Assessment methodology

The assessment took account of all appropriate exposure pathways, and whenever possible was based on site-specific data. Cautious assumptions were made when such information was not available. Consequently, the calculated doses are likely to be higher than those that might be received by an average individual, but are not considered to be extreme values.

3.1 Treatment of measurement data

Most of the measurements in soil related to a depth of 100 mm. However, one measurement gave an average value over 1.2 m depth and suggested that activity was present at depths greater than 100 mm. For this assessment, the measured activity concentrations to 100 mm depth were therefore cautiously assumed to persist

Doses resulting from the ingestion of foodstuffs were calculated for adults, children and infants, and both vegetable crops and animal produce were considered. The general crop classifications considered were root crops, green vegetables, cereals and fruit. Activity concentrations in the crops were calculated using published soil:plant transfer factors[8]. The animal produce considered was beef and veal, mutton, pork, offal, poultry, cows' milk and eggs. It was assumed that the animals' diet for the entire year was grown on the contaminated land. Activity concentrations in animal tissue were calculated using published values for plant:animal transfer coefficients[8,9].

To calculate intakes of activity it was cautiously assumed that foodstuffs were consumed at higher-than-average consumption rates. No information on consumption rates for different foodstuffs was received from the Essonne District commission. However, consumption rates that are typical of the whole of France have been published[8], and higher-than-average rates for use in this assessment have been derived using the quotients of higher-than-average and typical values that are applicable to the United Kingdom[2]. In the absence of any data concerning consumption of offal in France, higher-than-average values have been used that are appropriate for the United Kingdom[2]. All of the consumption rates for foodstuffs used in this assessment are given in Table 3. Doses resulting from the ingestion of radionuclides in foodstuffs were calculated using published data[5].

Children and infants might regard agricultural land as a play area, in which case the resultant doses can be inferred from those arising from the development of the area for residential accommodation. (see Section 3.4 below). For adults, the remaining pathways relate to people working on the land The total area of the contaminated land is about 6500 m^2. It was cautiously assumed that a person might spend 500 h y^{-1} working on this land, of which 10 h might involve mechanical operations such as harvesting and tillage. Occupancy values are summarised in Table 4. External exposure was estimated in the manner described in Section 3.2. For inhalation of resuspended material, it was assumed that a dust loading of 100 μg m^{-3} persisted for 490 h, but that during mechanical operations the dust loading increased to 10 mg m^{-3}. This higher value is typical of that found in dusty environments such as mines. For inadvertent ingestion of soil, an intake rate of 36.5 g y^{-1} (100 mg d^{-1}) was taken together with the assumption that all soil ingestion occurred during time spent outside. The estimation of the resultant doses was as described in Section 3.2.

Development for agriculture would not be confined to small areas, and so this part of the assessment considered the whole of the contaminated area only.

3.4 Doses resulting from development for recreation

If the developed area were to consist only of grassland, and ornamental gardens, then the following pathways require evaluation:

external irradiation;
inhalation of resuspended material;
inadvertent ingestion of soil.

If, however, the area was covered with a synthetic material, then external exposure would be the only pathway to consider.

Doses to all three age groups were estimated. It was cautiously assumed that adults and children might spend 1000 h y^{-1} (about 3 h d^{-1}) in the area, but for infants a value of 200 h y^{-1} was considered more appropriate (Table 4). External dose rate was calculated in the manner set out earlier. For inhalation of resuspended material, a dust loading of 100 μg m^{-3} was taken together with breathing rates appropriate to light activity. Intake rates for the inadvertent ingestion of soil were the same as those given in previous sections (i.e. 36.5 g y^{-1} for adults and children and 73 g y^{-1} for infants).

area of land have been published[12]. These suggest that in this case a person could attain self-sufficiency in grain, vegetables and fruit crops together with milk and milk products. It is also conceivable that enough grain could be produced to sustain poultry, although the incremental doses from this pathway are small. From Table 6, the overall dose from these foodstuffs for infants would be about 660 µSv y^{-1}. The corresponding doses for adults and children are about 540 µSv y^{-1} and 510 µSv y^{-1} respectively. In each case the consumption of fruit and green vegetables together contribute more than 50% of the overall dose. The radionuclides of importance are strontium-90 and, to a lesser extent, caesium-137. Both radionuclides have half-lives of about 30 y, and so doses will decrease slowly with time.

The area is not large enough to accommodate sufficient numbers of beef cattle, pigs and sheep to sustain a person at the consumption rates assumed here. Such animals might use the area as part of their grazing, but the resultant doses would be lower than those given in Table 6. Doses arising from the consumption of these foodstuffs would then be much less than those that would arise if the land were used to grow crops.

Doses that might be received by adults working on the land would be about 60 µSv y^{-1}, most of which would result from external irradiation. Since the radionuclide of importance for this pathway is caesium-137, doses will decrease with time. The total dose that might be received by an adult who worked on the land and also consumed its produce would therefore be about 600 µSv y^{-1}. Incremental doses to children and infants from the use of agricultural land as a play area would be 120 µSv y^{-1} or less.

For all age groups transfer through foodchains is the most important exposure pathway, and although the relatively small area of the contaminated land has been taken into account, the estimates of overall doses still contain cautious assumptions. In practice, it is unlikely that one person would consume all foodstuffs at the higher-than-average rates assumed here, and so actual doses would be lower than the estimated values. Furthermore, transfer of radionuclides from soil to plant were based on the assumption that the measured activity concentrations persisted to a depth of 300 mm in the soil. These dose estimates could therefore be refined if more information was available on the distribution of radionuclides with depth in soil.

Doses that could result from the development of the site for recreation are given in Table 7. If the area were covered with a synthetic material, external irradiation would be the only exposure pathway to consider and doses would be very low, 10 µSv y^{-1} or less for all age-groups. If the area were grass-covered, doses to adults and children would be about 120 µSv y^{-1} from all pathways. Infants, for whom a lower occupancy factor was assumed, would receive doses of about 30 µSv y^{-1}. In each case, external irradiation was the pathway of greatest importance, and so these doses would decrease with time. Moreover, doses to adults and children have been based on high occupancy factors of 1000 h y^{-1}, or about 3 h d^{-1}. Lower occupancy times would reduce the estimated doses even further.

Typical doses that might be received if the site were developed for residential use are given in Table 8. For houses with purely ornamental gardens that are not used for food production, infants would receive doses of around 200 µSv y^{-1}, values for other age-groups being slightly lower. The most important pathway is external irradiation, which in all cases contributes more than 85% of the overall dose, and for which caesium-137 is the dominant radionuclide. Again, these doses will decrease with time as caesium-137 decays. For houses with large gardens, it is conceivable that people would be self-sufficient at least in root-crops and green vegetables and possibly fruit. The incremental dose from foodchain pathways for infants could then approach 500 µSv y^{-1}, values for other age-groups being less than 400 µSv y^{-1}. Overall doses for infants would then be about 700 µSv y^{-1}, while those for adults and children would approach 500 µSv y^{-1}. As noted earlier, it is unlikely that one person would consume more than one foodstuff at higher than average rates, and so actual doses would be less than those given here.

Table 9 gives doses that might be received if a house and/or garden were situated in zone UK4, the largest of the areas where activity concentrations were highest. For a house with an ornamental garden not used

5 Conclusions

On the assumption that people would not preferentially spend time in those zones where activity concentrations are highest, doses to people frequenting the site in its present form would be a small fraction of the principal dose limit for members of the public recommended by ICRP. Doses in the future will be less than present-day values because the radionuclide of importance is caesium-137, which has a radioactive half-life of about 30 y.

Doses resulting from the development of the site for agricultural and recreational purposes were based on activity concentrations that are typical of the whole contaminated area. Development for recreation would then result in doses to all age groups that are a fraction of the principal dose limit even if people spent about 3 h d^{-1} in the area. For children and infants, doses resulting from development for agriculture would be dominated by the foodchain pathway, even if the land was also used as a play area. Doses from the foodchain could reach about 660 µSv y^{-1} for infants, whereas doses to children could be about 510 µSv y^{-1}. The incremental dose from the use of the land as a play area would be about 120 µSv y^{-1}. Doses to adults from the foodchain pathway could reach about 540 µSv y^{-1}, the incremental dose for those who worked on the land being about 60 µSv y^{-1}. Dose estimates for the foodchain pathway are considered to be cautious since it is unlikely that one person would consume more than one foodstuff at the higher-than-average rates assumed in this assessment. These dose estimates could also be refined if more information was available on the distribution of activity concentrations with depth in the soil. Nevertheless the present overall dose estimates are within the principal dose limit for members of the public, which is 1 mSv (1000 µSv in a year).

Doses that might result from development for residential purposes would be dependent upon the type of accommodation. For houses with purely ornamental gardens, typical doses to all age groups would be 200 µSv y^{-1} or less. For houses with vegetable and fruit gardens, the incremental dose from the foodchain pathway could approach 500 µSv y^{-1} for infants, the corresponding value for other age groups being less than 400 µSv y^{-1}.

It is conceivable that a house and/or garden could be situated within one of the areas where activity concentrations are highest. Again, overall doses are dependent on the type of accommodation, but taking all age-groups and all types of accommodation into account, doses could be in the range 1700-3800 µSv y^{-1}. The entire range of values exceeds the principal dose limit for members of the public but is comparable with the dose that everyone inevitably receives from natural background radiation. The dose estimates could be improved if measurements of external dose rate were made and more information was available about the distribution of activity with depth in the soil.

For all of the development options considered, the radionuclides that contributed most of the overall doses were strontium-90 and/or caesium-137. Both of these radionuclides have a half-life of about 30 y, so that these doses will decrease slowly with time.

6 References

1 Pollutions radioactives à Saint Aubin. Le Cri du Rad No 12/13. Automne 1990.

2 Revised Generalised Derived Limits for radioisotopes of strontium, iodine, caesium, plutonium, americium and curium. National Radiological Protection Board NRPB-GS8 (1987).

3 NRPB, unpublished results.

4 International Commission on Radiological Protection, Report of the Task Group on Reference Man. ICRP Publication 23.

TABLE 1 Extent of contamination and activity concentrations in soil at l'Orme des Merisiers

Zone[(1)]	Surface area (m^2)	Depth of soil sampled (m)	Activity concentration in soil, Bq kg^{-1} [(2)]			
			Sr-90	Cs-137	Pu-239, 240	Am-241
1JK4 (red)	500	0.1	$5\ 10^2$	10^4	$2\ 10^3$	$6\ 10^2$
0-2/3 (red)	40	0.1	$5\ 10^2$	$2\ 10^4$	10^3	10^2
MN-3 (red)	40	0.1	$5\ 10^2$	$3\ 10^4$	10^3	$5\ 10^1$
HI-6, Q-2,3,MN-5 (yellow)	500	0.1	$1.7\ 10^2$[(3)]	$4\ 10^3$	$5\ 10^2$	$5\ 10^1$
FL3-FL9	6500	0.1	$3\ 10^1$[(3)]	$2\ 10^1$	10^2	10[(4)]
TU-3/3	250	1.2	$5\ 10^1$	$2\ 10^3$	$2\ 10^2$	$5\ 10^1$

Notes

1 The zones relate to the grid squares in Figure 1, each square representing an area of 20 m x 20 m.

2 The soil density was $2\ 10^3$ kg m^3. These activity concentrations have been assumed to be on a dry weight basis.

3 These values were estimated by NRPB from the Sr-90:Cs-137 ratios in other zones.

4 This value was estimated by NRPB from the Pu-239:Am-241 ratios in other zones.

TABLE 2 Activity concentrations in soil that are typical of the largest zone of contamination[(1)]

Radionuclide	Activity concentration, Bq kg^{-1} dry soil
Sr-90	$8\ 10^1$
Cs-137	$1.1\ 10^3$
Pu-238[2]	$1.5\ 10^1$
Pu-239, 240	3.10^2
Am-241	6.10^1

Note

1 These values represented weighted averages for the zone bounded by coordinates F3, F9 and L3, L9 (Figure 1).

2 This value was estimated from the Pu-238:Pu-239, 240 ratio in reference 1.

TABLE 5 Doses that might be received while the site remains undeveloped

Pathway	Dominant Radionuclide for pathway	Dose, μSv y^{-1} Adult	Child	Infant
External irradiation	Cs-137	10	20	10
Inadvertent ingestion	Pu-239, 240	0.8	2	3
Inhalation of resuspended material	Pu-239,240	0.5	1	0.2
Total		11	23	13

TABLE 6 Doses that might be received if the site was developed for agriculture

Pathway	Radionuclide of importance	Dose, μSv y^{-1} Adult	Child	Infant
Occupancy*:				
External irradiation	Cs-137	50	90	90
Inadvertent ingestion	Pu-239, 240	4	9	30
Inhalation of resuspended material	Pu-239, 240	7	4	2
Total due to occupancy		6.1	103	122
Transfer through foodchains:‡				
Root crops	Sr-90, Cs-137	85	70	75
Green vegetables+	Sr-90, Cs-137	140	145	225
Grain	Sr-90, Cs-137	100	90	105
Fruit	Sr-90, Cs-137	160	150	180
Milk	Cs-137, Sr-90	20	20	30
Milk products	Cs-137, Sr-90	40	40	50
Beef	Cs-137	80	50	20
Beef offal	Cs-137	15	12	2
Mutton	Cs-137	30	20	8
Sheep offal	Cs-137	30	20	3
Pork	Cs-137	10	6	3
Chicken meat	Cs-137	7	5	2
Eggs	Cs-137	2	2	3

Notes

* For adults, doses arising from occupancy are the result of working on the contaminated land. For children and infants, these doses result from the use of the land for recreational purposes.

\+ Green vegetables include fruiting vegetables such as tomatoes and courgettes.

‡ Because of the limited extent of the contamination, simple addition of doses from different parts of the foodchain is unjustified (see text).

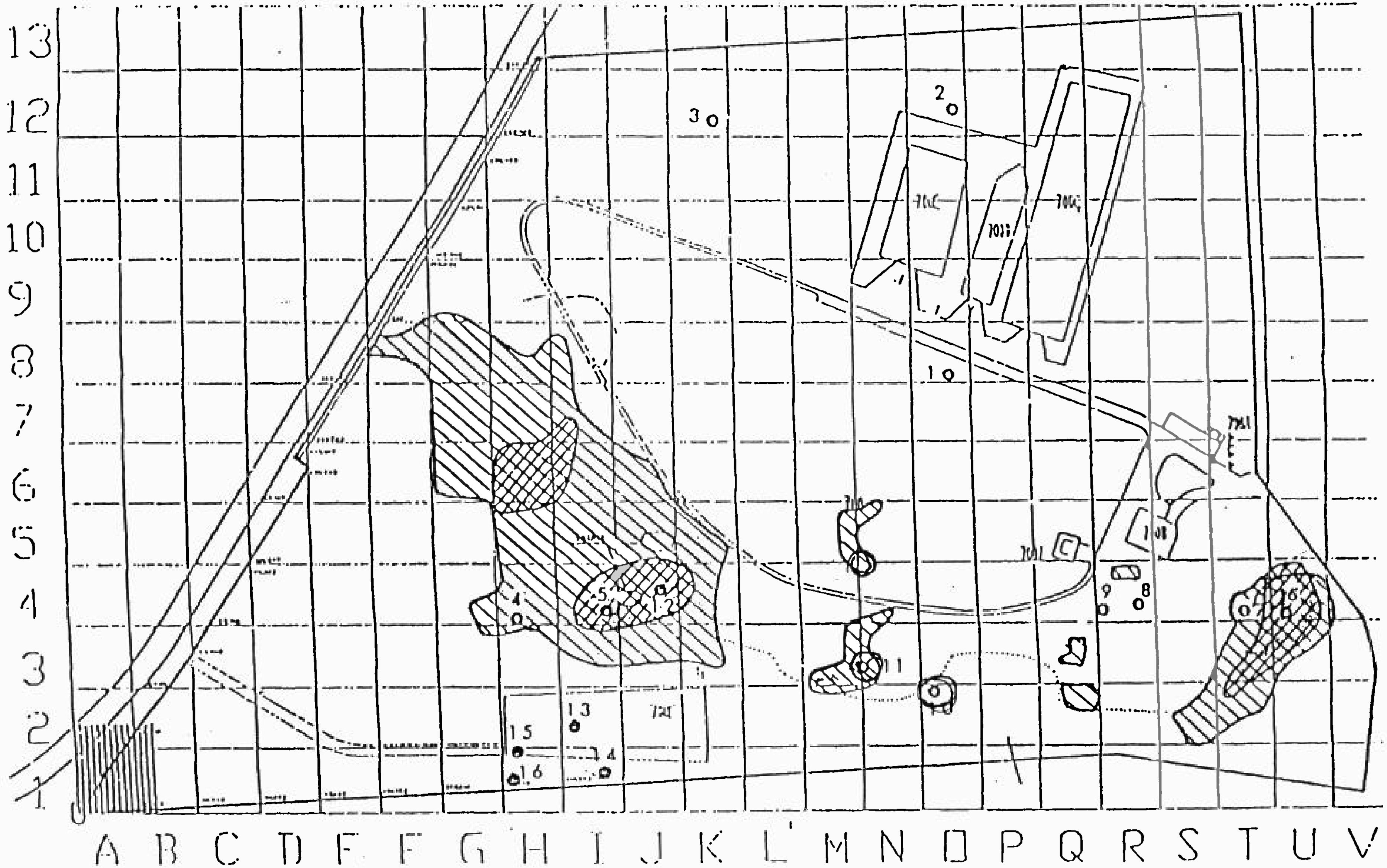
TABLE 9 Doses that might be received if a house was situated in a zone where contamination levels were highest

Pathway	Radionuclide of importance	Dose, μSv y^{-1}		
		Adult	Child	Infant
External irradiation	Cs-137	1600	1600	1600
Inadvertent ingestion	Pu-239	55	65	220
Inhalation of resuspended material	Pu-239	75	65	35
Total due to occupancy		1730	1730	1850
Transfer through foodchains*				
Root vegetables	Sr-90, Cs-137	580	495	475
Green vegetables	Sr-90, Cs-137	900	930	1400
Fruit	Sr-90, Cs-137	1000	970	1100

For total doses, see text.

* Likely doses from foodchains are dependent upon the proportion of the zone under cultivation, and so are not necessarily additive (see text).

FIGURE 1 The contaminated land at l'Orme des Merisiers



Note

1 For activity concentrations in different zones, see Table 1.