Possibilities for the rehabilitation of settlements affected by large scale radioactive contamination

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Abstract. With the support of the IAEA, a decontamination exercise was conducted in the highly contaminated area of Masany, Belarus. The aim of the work was to determine the effectiveness of decontamination methods. On the roof two different methods were used: a special roof-cleaning trolley, that can safely decontaminate asbestos type roofs, and a high pressure hot water jet, using either clean water or water with a detergent added. The decontamination factors, DF's were of the order of 0,2-0,3 for both methods. The walls were decontaminated by high-pressure hot water jet, planing of wooden walls, and industrial vacuum cleaning resulting in DF's 0,1-0,5. The upper layer of the surrounding soil areas was removed to a depth of about 10-cm, giving dose rate reduction factors, DRF's of 0,1-0,3. Inside the house, vacuum cleaning was performed with very little effect. In the kitchen garden three different methods were used: removal of the upper 10-cm soil layer (DRF of 0,25), triple digging (DRF of 0,3), and normal digging (DRF of 0,5). In conclusion, it was demonstrated that it is still possible, more than a decade after the Chernobyl accident, to substantially reduce the external dose rate in and outside a dwelling by forced clean up.

1. INTRODUCTION

Rehabilitation of contaminated settlements is an important issue in planning nuclear emergency management. The decisions must be based on the calculation of the dose avertable by certain decontamination methods and on the optimisation of the reclamation strategy applying the best of these techniques, with the full consideration of all possible aspects. The optimisation procedure requires the knowledge of the efficiency of different techniques, in terms of dose rate reductions, reduction in contamination levels, costs, public acceptance, feasibility etc.

Considerable efforts have already been invested in finding the most efficient ways of decontamination. Polessye Enterprise has accumulated practical experience in handling contaminated villages. EU has also provided financial, technical and expertise support to the affected counties within its framework programs during the 90's, the Nordic collaboration with the CIS countries, and the Danish East Aid. The latter has resulted in to test described in ref. 1 and 2. More recently the IAEA initiated a decontamination study which was performed in the highly contaminated area of Masany, Belarus, an abandoned settlement in the exclusion zone, close to the Ukrainian border and only a few kilometres away from the Chernobyl NPP. The study was conducted in and around a village house, trying several traditional and new techniques to reduce the external indoor and outdoor dose rate.

As part of its technical assistance and co-operation program the IAEA provided instrumentation, machinery, training and expert assistance to the Belarussian counterpart institutions (Ministry of Emergencies and State Enterprise POLESSYE) to conduct a pilot project for the demonstration of different decontamination techniques applicable to the Chernobyl affected territories. The multi-step decontamination study was successfully completed on a plot selected in the village of Masany (an evacuated settlement within the Chernobyl Radioecological Reserve), during the period 31 August – 10 September 1999. A house and its close environment (orchard, backyard) were cleaned with different techniques normally applied by the POLESSYE Company and/or others methods demonstrated by the experts. Radiological surveys were performed before and after the decontamination procedures were applied, to determine the efficiency of the individual steps and of the overall dose reduction effect of the combined efforts.

Article published by EDP Sciences and available at http://www.radioprotection.org or http://dx.doi.org/10.1051/radiopro/2002132

2. EQUIPMENT AND METHODS USED FOR THE STUDY

A number of ordinary tools (shovel, spade, lorries, etc.) as well as specialised equipment (bobcats, skim-and-burial plough, high pressure hot water jet, high power vacuum cleaner etc.) were used for the different steps of decontamination. The work was thoroughly followed by regular radiological measurements, using the following equipment.

- Portable dose rate meters (FH40G-L-10, EL-1117, DRG-01T1),
- Hand-held NaI spectrometer (Exploranium, GR-130),
- Contamination monitor (CONTAMAT)
- High Pressure Ionization Chamber (Reuter-Stokes RSS-112,)
- Electronic dose meters for personal use (Stephen)
- TLD dosimeters for personal use (by IAEA and by Polessye)
- Radiometer for on site sample analysis (RKG-01A)

3. RESULTS AND DISCUSSION

3.1 The site

In order to have a better demonstration of the decontamination efficiency and also not to interfere with the local population an abandoned house and the connecting land property (orchard, backyard, court) was chosen in Masany, an evacuated village within the exclusion zone (Chernobyl Radioecological Reserve), close to the Ukrainian-Belorussian border. The selected house was near the Perstok lake, on an about 70mx70m piece of land, separated from the lake by the dirt road and a dam (approx. 2m high), situated between two similar plots. The house was built of wood and clay, covered by corrugated asbestos roof plates. The ground plan of the house is rectangular with a wood-and-glass extension (veranda) on the right side (looking from the road).

3.2 Dose reduction outdoors

Three smaller (10mx10m) plots were prepared and used for testing the dose reduction efficiency of different decontamination techniques applicable in the vicinity of the houses (gardens, courts, backyards etc.). Another area (about 200m from the experimental area) was selected to study the effect of depositing the topsoil removed from the gardens. Special attention was paid to the effect of the drip-line decontamination.

For the characterisation of dose rate reduction factor (DRF) was used. This is the ratio of dose rates measured after and before the operation. Measurements were performed on the edges and in the middle of the experimental plots.

The following studies were carried out:

- triple digging (Plot 1)
- normal digging (Plot 2)
- removal of topsoil (Plot 3)
- covering contaminated areas with the removed topsoil
- the effects of the drip-line contamination
- soil core sampling and depth profile measurements
- horizontal and vertical profiles of the dose rate.

3.2.1 Triple digging (Plot 1)

This technique was proposed and demonstrated is described in detail in ref.3. The idea is to bury the topsoil in a depth between 30 and 45 cm without inventing the intermediate layer. With a proper sequential digging of three underlying soil layers (0-15cm, 15-30cm, 30-45cm) it can be achieved that the top layer is buried under the next two.

This technique has several advantages:

- It can be done by the owner/user of the plot
- It can be done with simple tools with no need for heavy machinery
- The contaminated soil remains at the place, there is no need to transport and deposit it somewhere else
- The contaminated soil will not be brought up later by normal digging
- This technique seems to effect soil fertility less than the topsoil removal
- The dose reduction factor (DRF) in the middle of Plot 1 was found to be 0.32, the best among the three methods applied.
- Shallow rooted plant will take up less radiocaesium than with normal digging.

Some of the disadvantages and concerns in connection with tripple digging:

- It requires more human effort than normal digging
- The contamination remains in the soil and its later removal (if required) is very difficult
- Not only the nutrients of the soil but also the radionuclides may become available for the root uptake

3.2.2 Normal digging (Plot 2)

This is the method most farmers apply when gardening: with the use of a shovel the top 15-20cm of the soil is turned. The advantages of the normal digging are:

- This is the simplest method and it can be done easily by the owner/user of the plot
- The contaminated soil remains at the place, there is no need to transport and deposit it somewhere else
- This technique seems to effect soil fertility the least, as compared with the other two methods applied

The main disadvantages are:

- The dose reduction factor (DRF) in the middle of Plot 2 was found to be 0.80, the worst among the three methods applied
- The contaminated soil will be brought up later by normal digging
- The radionuclides will easily be available for the root uptake

3.2.3 Topsoil removal (Plot 3)

This method was and is being efficiently used for decontamination of larger areas. The top 10-30cm soil layer is removed normally by agricultural machinery, the removed soil is transported to a distant place and deposited (often buried in trenches).

There are clear advantages of this technique:

- This method requires the least human effort, done quickly and efficiently, if machines are available
- The contaminated soil is removed 'forever', no more concern about radioactivity around the house

- The dose reduction factor (DRF) is 0.34, just as good as in case of the tripple digging

The main disadvantages are:

- The application of heavy machinery in a garden around the house can destroy the garden itself, smaller machines (like bobcats) are required, but they are not always available
- The removed contaminated soil has to be transported and deposited somewhere, an additional problem to be solved
- With the radionuclides all nutrients of the fertile topsoil are removed

3.2.4 The effects of the dripline contamination

Dose rate measurements were performed around the house, following the dripline (the line approx. 20-30cm from the outside wall, where radioactivity washed down from the roof by the rain is accumulated).

The range of variation of the dose rate above the dripline exceeded that of the values obtained elsewhere. The dose rate height dependence was also much more pronounced, in accordance with the inhomogeneity of the contamination. There was a place where Exploranium showed 60 μSv/h on the ground, as compared to 11 μSv/h measured 1m above the surface.

The average dose reduction factor was 0.31 but a more substantial reduction was obtained on the highest initial value point (DRF=0.19).

Dose rate reduction factors obtained **during** different decontamination operations are shown in Fig 1.

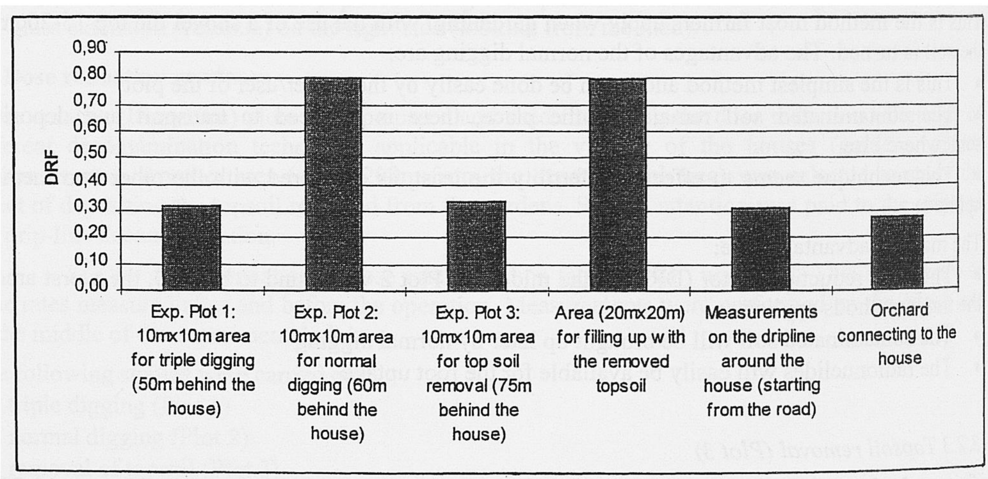

Figure 1: Outdoor DRF values obtained during different decontamination operations

3.3 Dose reduction indoors

People spend more time in houses then outdoors – even in rural areas. It is, therefore, important to know how indoors exposure can be diminished by the different decontamination techniques. Some of these methods are those applied for the reduction of outdoors radiation around the house because a great part of the exposure originate from the contaminated ground surfaces outside. The other group of indoor dose reduction techniques is specially associated with the buildings: cleaning and/or changing internal and external surfaces. In connection with the indoor dose reduction the followings were studied:

- removal of topsoil outdoors
- removal of dripline contamination
- cleaning the rooms with high power vacuum cleaner
- cleaning the attic with high power vacuum cleaner
- cleaning the outside surfaces (roof and walls) with high-pressure steam/waterjet washer

It is worth noting that the indoor exposure was not reduced so drastically as in case of the outdoor radiation levels. It is also interesting to see that effect of the outdoor decontamination operation had about the same effect than the intensive cleaning efforts in/on the house (vacuum cleaning, washing roof and walls). The overall DRF was in average 0.43, ranging 0.30-0.58.

The efficiency of the different clean up operations on the dose rate measured indoors can be seen in Fig. 2.

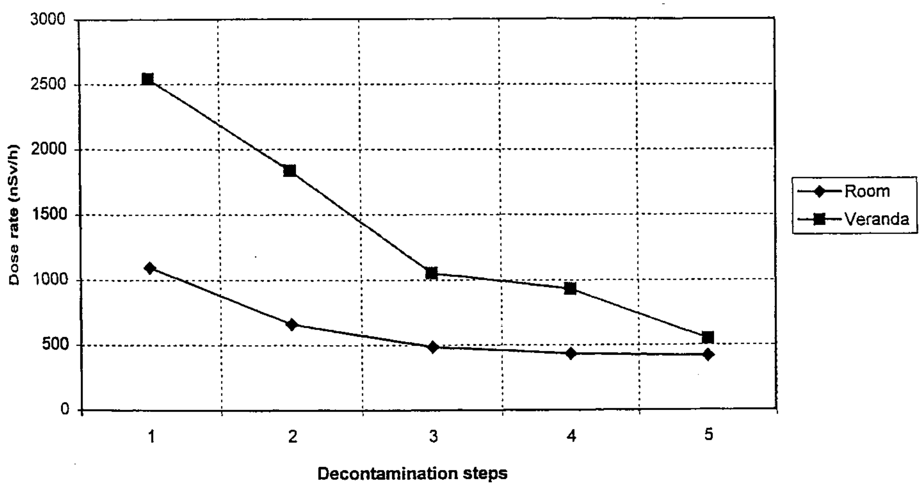

Figure 2: Dose rate reduction by different decontamination operations indoors

Decontamination steps:

1 before the beginning of the work
2 after the removal of the topsoil around the house (except the 1m dripline strip)
3 after the removal of the topsoil from the 1m dripline strip around the house
4 after vacuum cleaning inside the house
5 after finishing all the decontamination work (roof, ground, walls).

Decontamination of hard surfaces:

Decontamination factors (DFs) for different hard surfaces

Place of the measurement	Roof	Outside wall surfaces	Inside wall surfaces	Floor
Tool				
Special roof-cleaning trolley	0,2-0,5	0,3		
High pressure hot water jet	0,2-0,5	0,3		
Planing		0,2		
Industrial vacuum cleaning		0,5	0,3	0,2

4. CONCLUSION

The test has shown that even 14 years after a serious accident it is possible considerably to reduce the dose rate originating from deposited gamma emitting particles by simple methods: Inside the house by a factor of 2-3 and outside by a factor of 3-5. This reduction could be enhanced to more than 3 inside and more than 5 outside if a full section of a village were decontaminated, as the influence of the surrounding non decontaminated areas would then be reduced. Further some of the methods will also reduce the root uptake, and thereby the internal dose. This however is not yet investigated, but the effect should be looked upon in the near future, so that it would be possible to quantify the effect.

References

[1] *Guide on decontamination of rural settlements in the late period after radioactive contamination with long-lived radionuclides.* IAEA Working Document: TC Project RER/9/059, (2001).