DECONTAMINATION STRATEGIES IN CONTAMINATED SETTLEMENT.

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INTRODUCTION

Six years after the Chernobyl accident, decontamination actions had been completed in many places, the contamination could be considered as fixed, especially on urban surfaces and the social situation was felt to be stabilized. Under those conditions the efficiency of the « classical » decontamination techniques was under question, it was worthwhile to look at new specific techniques. Besides it was necessary to discuss the interest of new decontamination actions in settlements.
The European Union (EU) sponsored a project ECP 4 in order to look at the opportunities for further dose reduction actions in the contaminated territories of the three republics affected by the accident. The objective was to provide a local decision maker, faced with many alternatives for decontamination, with all the elements for determining what to do according to the various objectives he might pursue. The main results are presented here.

DOCUMENTING DECONTAMINATION TECHNIQUES

The project had a very broad objective. It surveyed usual techniques, techniques that had been designed within the framework of ECP4 (under assumption that they can be made effective at a full scale level), techniques that had been developed or examined by other Programmes, and the « do nothing » option. Exhaustivity was searched for. Actions dealing with all the sources and pathways were considered ; decontamination of urban environment (walls, roofs, yards, roads...), soil decontamination (arable soils and pastures) with chemical and physical approaches, decontamination of forests, protection and decontamination of machines and the decontamination of domestic and industrial food. Laboratory and field experiments have shown that it is still possible to decontaminate walls and roofs on which Caesium remained almost 10 years (for example using water under pressure), or fields in which the fertile layer is too thin for ploughing (e.g. turf harvester), and that modification of cheese making processes can achieve significant decontamination factors (e.g. the Phoenix cheese).
Effectiveness of decontamination has been estimated for about 60 techniques. Figures apply to Caesium, several years after an accident. Some typical results on decontamination factors (Df) are presented here (Table 1).

Table 1: Decontamination yields of Techniques applying to urban objects

Technique	Target	D_f	Constraints	Comments
Turning flagstones manually	Flagstones	6	No	-
Set of tools for dismantling	Houses	∞	No	Need to build a new house
Fire hosing	Roads	1.10	No	Water rinsing
Vacuum sweeping	Roads	1.4	No	Dust close to operator
Roof washer	Roof	2	No	Rot. brush, air compressor
Electric drill, steel wool or sand-paper	Roof (iron), wall (painted)	2-2.3	Possibly scaffolding	Grinding
High pressure turbo nozzle OM-22616	Roof, Wall, Asphalt & Concrete surface	1.3-2.2, 1.7-2.2	No	High pressure water hosing 120 bar
Detached polymer paste	Surfaces (smooth)	4-30	T > +5°C	Transports. Manual work
Sandblasting (dry or wet)	Wall	4 (dry) 5 (wet)	Scaffolding preferable	High-pressure with sand, Whole-body protect/air supply
Polymer coatings	Walls (not wooden)	4-5	T=20-30°C	Humidity <80%
Manual electric cutting machine	Wooden wall	5	Residual nail remove	Upper layer mechanically removed (dust)

Front loader / Bulldozer	Soil	28 / 10-100	No	Scraping top soil (10-30cm) Removes fertile soil layer
Shovel	Garden soil	6	Virgin soil	Digging to about 30 cm depth
Turf harvester (small)	Undisturb. grass. soils,	3-20	No or few stones	Removes the 3-5 cm top soil.
Ordinary plough and tractor	Arable soils	9-12(ext.)	Virgin land	Ploughing to 25-45 cm depth
Deep ploughing	Arable soils	2-4(crop)	Virgin land	Plough soil layer (25-35cm)
Skim-and-burial plough	Arable soils	10-20	Virgin land	5 cm topsoil buried at 45 cm
Liming (special trucks for spreading)	Acid arabic land	1.3-3	Soil pH = 4.5-5.5	Requires K addition, Persistent effect during 4-5 y.
Addition of potassium	Arable lands	1.3-3	No	K addition needed
Organic amendment of soil	Arable soils	1.3	-	Yield and quantity increase
Radical improvement of Pasture (draining, cleaning, disking 3 times...)	Pastures	4-16(peat) 4-9 (podzol)	No	Yield increase
Liming and fertilising	Forest pastures	1.5	Manual	Poor soils enriched by Ca, K
Ferrasin bol or Prussian blue	Cow	2-3	3 bolus/3 m.	Where Cs level > 1000 $Bq.l^{-1}$
Clean fodder to animals before slaughter	Cow	2-3 on meat	2 m. before slaughter	Organisation of special animal feed before slaughter
Phytodecontamination	Soils (mixed)	1.1-1.3.y^{-1}	7 procedures	
Ferrasin filters for milk	Milk	ca. 10	Private farm	If milk contamination> 400 $Bq.l^{-1}$

Other techniques concerning the rehabilitation of forests were examined, as well as techniques for food processing (e.g. alteration of the traditional Tvorog cheese production with a Df of 5).
Techniques have been also documented according the needs of optimisation. Components of the costs were depicted in physical terms: direct manpower and overheads, skill requirements for workers, and needs in education for the public, transportation, consumables, loss of value for products, generation of wastes (solid and liquid volumes, activity and toxicity). Prices were necessary in order to assess costs. A short synthesis was made in order to know the prices of manpower (from 70 to 100 ECUs per month), consumables (e.g. 0.15 to 0.3 ECU per liter for gasoline) and products (e.g. 0.25 to 0.4 ECU per liter for milk). Prices are indeed fluctuant at the local scale but this task was necessary to provide default values and standard values when comparing case studies.

IMPLEMENTATION OF CASE STUDIES

Case studies have been implemented in 4 settlements in order to illustrate a methodology for decision, and to look at cost effectiveness of countermeasures under different conditions (Table 2).

Table 2 : Some features of the case studies.

Cases	Reference Soil contamination ($Ci.km^{-2}$)	Present population	% of pre-accident population	Dominant pathway	Previous actions
Zaborie	66	180	20%	External	Extensive
Kirov	30	500	40%	External	Extensive
Savichi	10	160	20%	External	Limited
Millyachi	5	3200	100%	Internal	Numerous

When dealing with the settlements, no cases were found in which decontamination was desired in order to meet one unique target. The global idea is a desire for a return to a normal life style, by suppressions of interdictions in the formally "evacuated" areas (Savichi, Zaborie) or by alleviation of restrictions in villages in the other areas (Kirov, Millyachi). The need to be less dependent on the restrictions to life style is not a quantified criterion but it is a clearly expressed goal.
Individual doses are a matter of concern that was put forward in the four case studies, but not with reference to the same criteria. Average population dose is a criterion in Zaborie, to be compared with 5 mSv per year. Critical groups of workers have been identified in Zaborie, Kirov, Millyachi, whose doses are still to be compared with 5 mSv (e.g. forestworkers, cowboys,...). Reference to 1 mSv for the average population is also quoted (e.g. Belarus "Passports" on settlements).
It has been said that population stayed or came back in evacuated territories. Direct observations also shown that prohibited land was used either by the people from the settlement or by neighbours.
No objectives were assessed in terms of collective dose. Nevertheless, the gain in collective dose was considered as a good criterion to assess the efficiency of a countermeasure. Cost effectiveness was measured by the « cost of averted Man Sievert ». It was admitted that the most cost effective measure should be applied first in the strategy.
In Zaborie, application of countermeasures was limited by the fact that extensive decontamination took place so that options like ploughing were pointless. However, calculated doses being only slightly higher than 5 mSv (while measured doses are lower), many countermeasures would allow to go below this figure ; cleaning yards, education on mushroom consumption, but combination of agricultural countermeasures. Looking at cost efficiency, actions dealing with yards (Front loader or Bulldozer) or educational programmes yield to a cost of averted Man Sievert below 2000 ECUs, and they would be used first in applying a strategy. The most effective action was the cleaning of the yards surrounding the houses, provided that a local solution for waste disposal is accepted, as was done in the neighbouring settlement of Yalovka. Should generic costs be applied it would be 50 times less effective. Education on mushroom was priced on the basis of one visit per year to each family. Liming, in spite of a poor global impact, has a good cost-efficiency ratio and deserves to be included in the strategy. Both would go along better with a rehabilitation programme. Other options still have interest. Some options yield very high costs for averted Man Sievert, others are limited in their scale of application, because areas fitted for them are limited (e.g. Turf harvester).
Situation in Savichi is such that the effectiveness of countermeasures is usually lower, simply because the contamination levels are lower. Most countermeasures yielded cost of avoided ManSievert higher than 8000 ECUs. Turf harvester and ploughing achieved a cost lower than 1000 ECUs (actually less than 200 ECUs), because there was still room for such countermeasures, so that improving meadows and pastures can be proposed. Cleaning yards remains the most cost effective of the measures dealing with housing. In parallel with the cost benefit analysis, classification of Savichi as a prohibited settlement was reconsidered.
In Millyachi, the importance of internal dose and the high transfer coefficients increase the respective efficiency of agricultural countermeasures. Education for the mushroom consumption remains highly efficient. Many agricultural measures have cost efficiency around 1000 ECU per averted ManSievert, but cleaning yards still remains effective.
Almost in all cases there are actions with a reasonably low cost for averted dose. Should ManSievert be valuated to 5000 ECUs or even 2000, there are indications for application of countermeasures. Besides, it remains true that actions on non disturbed land are among the most efficient and that they are limited in the present case studies.

CONCLUSION

The necessity to undertake new decontamination actions or other dose reduction actions almost one decade after the Chernobyl accident raised serious doubts when the programme was launched. Today, decontamination of all the contaminated territories is still out of reach, but the studies that were undertaken have shown that there are clear indications for action in practical cases. It is believed that this feeling is shared by the local authorities that were involved in the case studies.

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