CEC-CHECIR ECP-4
OPTIMIZATION OF INTERVENTION STRATEGIES FOR THE RECOVERY OF RADIOACTIVE CONTAMINATED ENVIRONMENTS.

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Abstract. The goal of this work is to evaluate different options of intervention for the recovery of contaminated environments. It will consider not only the efficiency of the countermeasures in terms of dose reduction, but also in terms of costs, wastes and other possible secondary consequences, in order to obtain the best possible strategy for each particular circumstance. This paper summarizes the methodology of optimization of intervention, which has been carried out in the framework of CEC-CHECIR ECP-4 Project.

1. Introduction

Following a nuclear accident with environmental consequences, intervention, leading to the recovery of the contaminated environment to as close to normality as possible with the lowest social cost, could be necessary. The reduction of the damage from the existing contamination should be justified and optimized. This means that the best strategy for applying recovery actions must be selected from a set of potential alternatives, analyzing the positive and negative effects related with their applicability.

2. Methodology

Two main branches of activity on which the strategy analysis is based are identified. The first one deals with the scenario of intervention which requires actions leading to its characterization, its classification and the evaluation of its radiological impact. The second one is related with the different decontamination procedures, and their relationship with the scenario. Both of them will converge in an evaluation process under different criteria. Figure 1 shows the relationship between the two branches and the general sequence of operations involved.

The characterization of the scenario consists in a complete physical, radio ecological and socioeconomic description. This will allow its classification in different intervention elements (IE), defined as class elements of any scenario where similar activity concentrations lead to similar radiological risks and similar response to the same recovery actions. Once classified, it is possible to calculate the normalized (per unit of deposited activity) radiological impact in terms of dose rates and integrated doses derived from each IE.

The analysis of the decontamination procedures consists of an assessment of their performance and applicability for the different identified IEs. The *performance* represent its radiological and economic behaviour on each IE (in relation to each specific radionuclide). The cost will include the operation costs and the costs concerning the waste management and

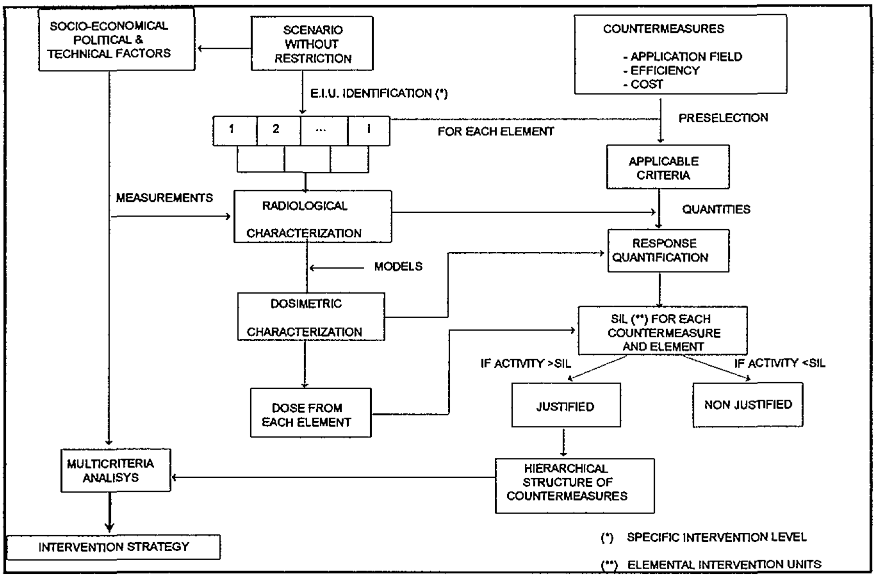

Figure 1. Schematic diagram of the methodology for strategy analysis.

disposal as a consequence of the intervention. The *applicability* incorporates other factors such as the availability of resources, effort involved in the implementation, and all other possible constrains related with the scenario. Both performance and applicability will determine their *practicability* for the real case under analysis.

Several categories of Intervention Scenarios can be immediately envisaged, but this work deals only with two of them:

1. Urban scenarios: dealing with all the environments where people normally live. The radiological risk will be evaluated only through the external irradiation from the different locations of deposition. Typical IEs in these scenarios are gardens, yards, streets, roofs, walls.
2. Agricultural scenarios: where the most significant risk contribution will come through the food chain, directly from crops, or through cattle, mainly through milk, but also external doses to the farmers are evaluated. Typical IEs are soils used for pastures, haylands, and arable lands.

A data base of countermeasures developed in the frame of ECP4 Project and others, usually applied to recover Chernobyl scenarios, has been prepared. For each countermeasure, radionuclide and IE, the following factors of performance have been included: frequency of application; decontamination factor (in terms of transfer factor to certain crops and/or in terms of external dose); man power; depreciation of equipment; consumables; overheads; secondary effects on the IE, such as changes in productivity or quality; restriction time after intervention and amount and activity of wastes.

Factors determining the applicability are: scale of application; number of operators; equipment and consumables and constrains, if any.

Using adequate radio ecological and dosimetric models, the following items are evaluated: radiological risk from each IE in terms of collective and individual doses and length of restriction, if legal levels are applicable. The data base of countermeasures make it possible to calculate: the averted and residual collective dose from each IE after applying each countermeasure; the cost of application using all cost factors, included wastes and secondary consequences and the volume, specific activity and management cost of the generated wastes.

The developed procedure, using the evaluated dosimetric and cost factors, can make possible a cost effectiveness analysis or a complete cost benefit analysis, if a preestablished value for the collective dose is introduced; in this case a specific intervention level (SIL) is calculated for each countermeasure on each IE, below wich the procedure would not be justified. According to the type of analysis and taking into account external restrictions such as available budget, machinery, man power..., it is possible to decide the final strategy of intervention.

3. Case study

As a demonstration of the usefulness of the proposed methodology, a case-study concerning a local strategy of intervention is exemplified on Savichy, a large rural settlement in the Southern-Eastern part of Belarus. After Chernobyl accident all the population was evacuated but in 1987 part of it came back without permission. The objective is to analyze the radiological situation of the population, at present and in future, supposing that the settlement would recover the former population ("shadow population") and to provide criteria to decide about the possibility of applying some decontamination to improve the situation. For both, urban and agricultural scenarios, the impact evaluation and the applicable countermeasure's behaviour have been analyzed using the two branches defined in the methodology. This paper only shows the result of the urban analysis.

Figure 2 shows the external dose distribution on different locations from all IE, calculated using models where the inputs are the dose rate on undisturbed land (33 μR h^{-1}), the relative distribution of activity on the different urban elements and the permanence factors for the population. The total yearly individual dose rate was 1,05mSv. The contribution of the different urban IEs to the dose in each collective farm is shown in Figure 3 for wooden wall houses.

The results obtained for the "shadow population" are very similar.

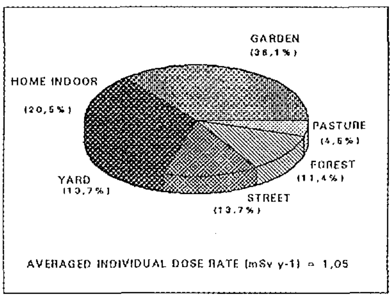

Figure 2. External dose distribution on different locations from all IEs.

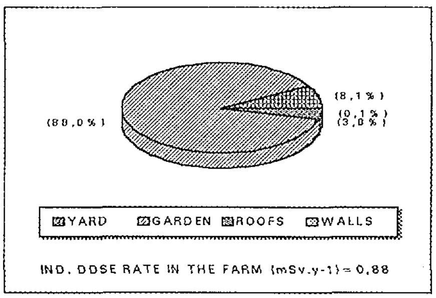

Figure 3. Wooden houses: contribution of the different urban IEs to the total dose.

The response of the different countermeasures applicable to farms with brick and wood walls under three different criteria is shown on Table 1 and 2. For the cost-benefit analysis the preestablished value for the collective dose used was 15.000 ECU Sv^{-1}.

Both the cost-benefit and the cost efectiveness analysis give as best decontamination procedure the spade on yard. The countermeasure which avoids a higher value of the collective dose is the spade on garden.

Table 1. Decontamination of farms with brick homes.

INTEGRATION TIME (y)			50				
DOSE RATE INDOORS (nGy/h)			40,3556				
DOSE RATE OUTDOORS (nGy/h)			281				
OPTIONS OF DECONTAMINATION	Decontam. factor	Individual dose from the IE doing nothing Sv/y	Resi.Ind.dose from the IE after decont Sv/y	Collective averted dose per home man.Sv/home	SIL micro R/h	Cost Effectiv. ECU/Sv	Proc. cost/ waste cost ECU/home
SPADE/YARD	6	1,2E-05	2,0E-06	2,0E-03	16	7209	14
SPADE/GARDEN	6	1,3E-04	2,2E-05	2,2E-02	19	8631	188
SPECIAL DIGGING/YARD	13	1,2E-05	9,2E-07	2,2E-03	30	13973	31
SPECIAL DIGGING/GARDEN	13	1,3E-04	1,0E-05	2,4E-02	36	16728	404
ARS-14/ROOF	1,9	4,7E-06	2,5E-06	4,5E-04	143	65742	29
SET OF TOOLS/ROOF	total	4,7E-06	0,0E+00	9,5E-04	445	204303	193
HAMMER NAIL-TAKER/ROOF	total	4,7E-06	0,0E+00	9,5E-04	563	258367	244
SANDBLASTING DRY/WALLS	4	1,2E-07	3,0E-08	1,8E-05	2207	1012505	18
ROOF WASHER	2	4,7E-06	2,4E-06	4,7E-04	2836	1301073	615
TURBO NOZZLE HP/ROOF	2,2	4,7E-06	2,1E-06	5,2E-04	3910	1793602	925
POLYMER COATINGS/WALL	4,5	1,2E-07	2,7E-08	1,9E-05	4132	1895399	35
ARS-14/WALL	2,4	1,2E-07	5,0E-08	1,4E-05	6349	2912547	41
AMMONIUM NITRATE SPRAY/wall	1,3	1,2E-07	9,2E-08	5,5E-06	139790	64123943	356
SANDBLASTING WET/walls	5	1,2E-07	2,4E-08	1,9E-05	329280	151046062	2906
TURBO NOZZLE HP/walls	1,3	1,2E-07	9,2E-08	5,5E-06	411348	188691552	1047

Table 2. Decontamination of farms with wood homes.

INTEGRATION TIME (y)			25				
DOSE RATE INDOORS (nGy/h)			75				
DOSE RATE OUTDOORS (nGy/h)			309				
OPTIONS OF DECONTAMINATION	Decontam. factor	Individual dose from the IE doing nothing Sv/y	Resi.Ind.dose from the IE after decont Sv/y	Collective averted dose per home man.Sv/home	SIL micro R/h	Cost Effectiv. ECU/Sv	Proc. cost/ waste cost ECU/home
SPADE /YARD	6	5,9E-05	9,8E-06	1,7E-03	18	8437	14
SPADE /GARDEN	6	6,4E-04	1,1E-04	1,9E-02	22	10122	188
SPEC DIGGING/GARD.	13	6,4E-04	4,9E-05	2,1E-02	43	19618	404
ARS-14 /ROOFS	1,9	2,7E-05	1,4E-05	4,5E-04	143	65386	29
SPECIAL DIGGING/YARD	13	5,9E-05	4,5E-06	1,9E-03	36	106022	31
SET OF TOOLS/ROOF	total	2,7E-05	0,0E+00	9,5E-04	443	203196	193
HAMMER NAIL-TAKER/ROOF	total	2,7E-05	0,0E+00	9,5E-04	560	256968	244
ROOF WASHER/ROOF	2	2,7E-05	1,4E-05	4,8E-04	2821	1294024	615
TURBO NOZZLE HP/ROOF	2,2	2,7E-05	1,2E-05	5,2E-04	3889	1783685	925
MANUAL ELECTRIC CUTT/WALLS	5	8,0E-07	1,6E-07	2,2E-05	12667	5810531	130

References

[1] C. Vázquez, J. Gutiérrez, R. Guardans, B. Robles and M. Savkin, ECP4 1993 Annual Progress Report, "Optimization of Intervention Strategies for the Recovery of Radioactively Contaminated Environments. Application to a Case-Study: Kirov (Belarus)." CIEMAT/IMA/UGIA/M5A12/01-93. December 1993.

[2] C. Vázquez, and C. Trueba, ECP4 1994 Annual Progress Report, "Optimization of Intervention Strategies for the Recovery of Radioactively Contaminated Environments. Application to a Case-Study: Kirov (Belarus)." 2 nd Version CIEMAT/IMA/UGIA/M5A22/02-94. December 1994.

[3] C. Vázquez, C. Trueba and N. Rodríguez, CHECIR ECP4 Subproject 6: Modelling and Cost-Benefit Analysis. January-August 1995 Progress Report. CIEMAT/IMA/52F21/02-95. August 1995.