INTERVENTION STRATEGIES FOR THE RECOVERY OF RADIOACTIVE-CONTAMINATED ENVIRONMENTS

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Abstract

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Following an accident with environmental consequences, intervention may be necessary. The type of remedial actions and the strategy required will be dependent upon, inter alia, the phase and conditions within the contaminated scenario. Leaving aside the basic countermeasures (such as confinement, evacuation), which are based on internationally agreed Generic Intervention Levels (GIL's), the paper deals with intervention strategies leading to a return of the contaminated site to as close to normality as possible with the lowest social cost. The reduction of the damage from the existing contamination must be justified and optimised; the best strategy for applying recovery actions must be selected from a set of potential alternatives. A methodology for intervention strategies analysis, developed in the framework of CEC–CHECIR ECP–4 "Decontamination Strategies", is presented together with some examples of application.

1. INTRODUCTION

This paper explains the Centro de Investigaciones Energeticas Medioambientales y Tecnologicas (CIEMAT) design for optimising decontamination strategies for the recovery of contaminated scenarios using cost benefit analysis. The work has been developed as a part of the CEC/CHECIR ECP–4.

The scope of the proposed methodology is only radiological, trying to minimise the radiological risk of the population with the lowest possible social cost, taking into account all the subsidiary factors that can be expressed in monetary terms.

The procedure starts with the characterisation of the scenario, classifying it into elemental intervention units (EIU) and with the identification of the available intervention procedures or countermeasures. Then, the criteria or factors of influence for the countermeasure's response are defined and the behaviour of each procedure over the different EIUs is quantified according with the selected criteria. A Specific Intervention Level (SIL) can be calculated for each procedure over each EIU where the countermeasure applies. This makes it possible to classify the different intervention options according to the net benefit obtained. Finally, the available budget and other social and political aspects will determine the extent of the intervention, and therefore, the intervention strategy.

This method of analysis can be implemented on a simple PC support. Default values are supplied for the different criteria considered in the analysis, but also input capability is provided for the introduction of alternative values. This software must be updated periodically as the technological capabilities in decontamination procedures are evolving and economical values changing.

It would be useful that this methodology would be available "a priori", before the occurrence of any accident for several different representative environments of the different countries.

As a part of the CEC/CHECIR ECP–4 a case-study (Kirov-Byelorussia) has been analysed by the application of the proposed methodology.

2. MATERIAL AND METHODS

2.1. Description of the methodology

The proposed framework identifies two main branches of activity on which the strategy analysis should be based. The first one is related to the scenario of intervention requiring actions aimed at its characterisation, classification and evaluation of radiological impact. The second one deals with the decontamination procedures and their relationship with the scenario including, in addition to the assessment of their applicability and effects (positives and negatives), the calculation of Specific Intervention Levels (SIL's) for each selected countermeasure. In this context intervention scenario means the spatial and temporal unit over which an intervention can be envisaged without significant interference from the outside.

The characterisation will consist of identifying, collecting and structuring information leading to a complete description (physical, radiological, socio-economic...) of the contaminated scenario. This must allow the differentiation of the scenario in intervention units (IU's) defined as class elements of any scenario where similar activity concentrations lead to similar radiological risks and have similar response to the same countermeasure.

TABLE IA. SOFTWARE DESIGN

IU's MODULE		
OPTION:	TO CREATE TO MODIFY	
	INPUT	Identification Code Pathways (Secondary IU's), Radionuclides, Models, Parameters
	OUTPUT	New element in IU's file
	Options	Return Go to Countermeasure Submodule (Option To Create)
OPTION:	TO SELECT	
	INPUT	Calculation criteria: Integration period, Discount factor, value IU's to be selected (code)
	OUTPUT	Dosimetric and economic impact (unitary)
	Options	Return Go to Countermeasure Submodule Go to Scenario Submodule
COUNTERMEASURE SUBMODULE		
OPTION:	TO CREATE OR TO MODIFY	
	INPUT	Identification Code Parameters for the assessment of the performance (radiological and economic)
	OUTPUT	New element in Countermeasure file
	Return	
OPTION:	TO SELECT	
	INPUT	Countermeasures on each IU to be analysed Restrictions
	OUTPUT	SIL's
	Return	
SCENARIO SUBMODULE		
	INPUT	Ranges of activity for primary IU's Number of IU's into each range Restrictions on IU's
	OUTPUT	Radiological Impact from IU's in each range Countermeasures justified from IU's in each range Net Benefit, Residual Dosimetric Impact Residual Specific Activity and Dose Rates
	Options	Return Go to Strategy Submodule
STRATEGY SUBMODULE		
	INPUT	Values for restrictions on Countermeasures and IU's Available Budget
	OUTPUT	Selected strategy for the available budget Note 1: Restrictions, where they exist, must be always observed Note 2: The relative net benefit is the unit used in comparing countermeasures

TABLE 1. EXAMPLE OF APPLICATION

IU MODULE

INPUT	IU	PATHWAYS	PARAMETERS	CRITERIA
	Hay-land		In-Ocupancy factor 0.4	Integration period: infinite
	Milk	Ingestion	Out-Ocupancy factor 0.2	Discount factor 0.04
	Cheese	Ingestion	House occupants 4	α value($ / man-Sv) : 8000
	Rooves	Ext. irradiation		Radionuclides: Cs 137, Sr 90
	Walls	Ext. irradiation		Dry deposition
	Yard	Ext. irradiation		

OUTPUT (Impact per Bq/m^2)	Activity		Dosimetric Impact (Man-Sv/ha)		Economic Impact ($/ha)	
	Cs	Sr	Cs	Sr	Cs	Sr
Hayland (Bq/ha)	10000	10000				
Milk (Bq/l)	1.5E-3	3.7E-4	3.0E-6	2.0E-6	0.024	0.016
Cheese (Bq/Kg)	2.2E-5	2.1E-4	4.5E-8	1.1E-6	3.6E-4	8.9E-3
	Ind. Dose rate		(Man-Sv/house)		($/house)	
	In	Out	Cs	Sr	Cs	Sr
Rooves (μSv/d)	4.0E-3	8.8E-5	4.9E-5		0.393	
Walls (μSv/d)	2.9E-4	1.6E-3	2.3E-5		0.0108	
Yard (μSv/d)	8.0E-3	8.7E-2	1.1E-3		9.15	

COUNTERMEASURES SUBMODULE

INPUT	Countermeasure	Decont. Factor		Cost	OUTPUT	SIL's (KBq/m^2)
		Cs	Sr			
	Turf harvester (Hayland)	20	3	2025 ($/ha)		186
	Deep ploughing (Hayland)	20	3	825 ($/ha)		76
	Cheese (option 1)(Milk)	0.75	3.72	2.5E-4 ($/l)		2.5 (Bq/l)
	H.P. water (Rooves)	1.7		1 ($/m^2)		3500
	H.P. water (Walls)	1.8		0.2 ($/m^2)		3200
	Digging (Yard)	3.8		1 ($/m^2)		2050

TABLA 1. EXAMPLE OF APPLICATION (CONT.)

SCENARIO SUBMODULE

INPUT			OUTPUT (Hayland)				
Range of deposition (central value) (Bq/m2)		Hayland (ha) / Houses (number)	Economic value of the dosimetric impact ($)		Justified countermeasures (net benefit $)		
Cs	Sr		By milk	By cheese	Turf (milk)	Plough (milk)	Cheese
7.5E3	7.5E2	10 / 3	1942	95			16
3.0E4	3.0E3	20 / 4	15534	762			274
7.5E4	7.5E3	20 / 6	38834.	1905		19698	761
3.0E5	3.0E4	12 / 3	93202.	4571	62838	76976	1917
7.5E5	7.5E4	8 / 2	155337	7618	129029	138193	3224
3.0E6	3.0E5	4 / 1	262162	14512	236127	240200	6725
7.5E6	7.5E5	2 / 1	388342	19045	359023	360331	8106

INPUT		OUTPUT (Houses)					
Range of deposition (central value Bq/m2)		Economic value of the dosimetric impact ($)			Justified countermeasures (net benefit $)		
Cs	Sr	Walls	Rooves	Yard	H.P. water (walls)	H.P. water (Rooves)	Digging (Yard)
7.5E3	7.5E2	0.2	0.9	11.2			
3.0E4	3.0E3	1.0	4.7	59.5			
7.5E4	7.5E3	3.9	17.5	223.1			
3.0E5	3.0E4	7.8	34.9	446.2			
7.5E5	7.5E4	12.9	58.3	743.7			
3.0E6	3.0E5	25.9	116.5	11487.5			347.7
7.5E6	7.5E5	64.8	291.3	33718.7	13.5	65.4	1994.2

STRATEGY SUBMODULE

INPUT Maximum milk production to make cheese: 80000 l/y
GIL for permanent resettlement : 1 Sv/lifetime
DIL for Sr-90 in milk : 0.1kBq/l
GIL for relocation : 30 mSv/month
DIL for Cs-137 in milk : 1 kBq/l
Budget available : 25000 $

OUTPUT : Classification of compatible cost effective countermeasures taking into account input restrictions

Range (Bq/m^2)	Rel. ben.	IU / count.	Inversion ($)	Accum. ($)	Range (Bq/m^2)	Rel. ben.	IU / count.	Inversion ($)	Accum ($)
7.5E6	**218**	**plough+ cheese**	**1655**	**1655**	**7.5E6**	**2.7**	**digging**	**750**	**22215**
3.0E6	**73**	**plough+ cheese**	**3310**	**4965**	7.5E4	1.2	plough	16500	38715
7.5E5	**21**	**plough**	**6600**	**11565**	7.5E6	1.1	HPwat. R	58	38773
3.0E5	**8**	**plough**	**9900**	**21465**	7.5E6	1.0	HPwat.	13	38786

Typical IU's for urban environments are paved streets, public gardens, walls, roofs and gardens of buildings, etc.; the different building materials and type of buildings (multi-storied/single, public/private) can result in different IU's. Concerning agricultural environments the aspects which influence the radiological impact such as soil texture, pH, organic matter, irrigated or dry farming, destination of production, etc. must be taken into account in obtaining IU's. Lands where rotation of crops is a common practice, haylands and fruit orchards are typical examples. In natural or seminatural environments, forest, scrubs and pasture lands will be IU's in most cases.

The above examples of IU's can be considered as primary IU's because they are elements where the contamination is directly deposited. Other secondary IU's where the contamination is the result of activity transfers through different pathways (foods, wood, underground water, etc.) could also be identified. Almost all of the attributes characterising IU's would be suitable to be known before an accident occurs.

One of these attributes is the set of parameters influencing the future behaviour of the deposited activity on the IU. For example if the IU is the ceramic file roof in single family homes, the models for geometry, building material and occupancy factor need to be previously defined. In the case of haylands the soil factors (texture, pH, CEC) and information on practices and production rates will be the typical parameters.

Another IU attribute is the radiological impact that it will produce. It is possible to calculate a normalised (per unit of deposited activity) impact in terms of dose rates and integrated doses (infinite) for each IU identified. Relevant tasks to achieve this will be the identification of exposure pathways from each primary IU and the assessment of radioactivity transfer along the components (secondary IU's potentially to be cleaned-up as an alternative to the clean-up of the primary ones) of the pathway.

The geographical distribution of potential IU's in the scenario is also an attribute suitable for prior evaluation. Since the preparedness for emergency will use GIS representing the measured or estimated activity distribution on the contaminated scenario, the range of contamination over each IU, after the accident occurs, can be obtained by overlapping both maps. A few ranges of activities must be set up for each IU and radionuclide. Then the amount of IU components belonging to each range will be evaluated in order to obtain criteria in deciding the application of countermeasures.

Analysing decontamination procedures will consist of an assessment of their performance, applicability and adaptability when applied to IU's. The performance criteria characterising the radiological and economic behaviour of each technique on each IU (and for one specific radionuclide) must therefore be identified.

The radiological efficiency of a decontamination procedure will be evaluated in terms of a decontamination factor, averted dose and added risk to the workers. Factors influencing the efficiency must be taken into account.

The economic impact will include the operation costs and the costs concerning waste management and disposal as a consequence of the intervention. The assessment of indirect consequences (negative and positive) produced by the clean-up technique, such as secondary contamination, ecological damage, changes in productivity and/or quality of foods, indirect health effects, etc., will also be made in monetary terms.

The above parameters will make it possible to calculate the SIL of the countermeasure. In this context SIL means the minimum value of the activity concentration on the IU that would justify the application of the countermeasure.

2.2. Software Design

Given the need to have available a tool for rapid analysis, the above methodology is being implemented as a PC software the structure of which is shown in the Table IA.

3. RESULTS

Applying the proposed framework, Table I shows the results obtained in the analysis of a hypothetical case study. The example consist of a dry deposition of Cs and Sr over a rural settlement with single family brick houses of 50 m^2 and having a surrounding yard of 800 m^2 each. The settlement has 76 ha of haylands for milk (10000 l/ha) and Brynza cheese (from the 10% of produced milk) production. Data on contamination, IU's, pathways, countermeasures, parameters and criteria considered for calculation are also shown in Table I. Although the values used are as real as possible the results must only be interpreted as a positive test for the proposed methodology and not as a judgement of the involved countermeasures.