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MULTI-CRITERIA MODEL TO SUPPORT DECISION-MAKING FOR THE REMEDIATION OF URBAN AREAS

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ABSTRACT

Under the environmental modeling Project of radioecology research area of IRD (CNEN), several tools have been developed to support post-emergency activities. Currently, a multi-criteria model is in development with the aim of supporting decision-making processes under the radiological protection point of view. At this stage, we are focusing on the decontamination of urban areas. The model includes five calculation modules: (i) averted doses to the public due to remediation procedures; (ii) occupational exposure of remediation workers; (iii) properties of the wastes generated by a remediation procedure; (iv) classification of each procedure for a specific urban scenario based on previously calculated quantities; and, (v) multi-criteria rank calculation. The classification of procedures is based on two types of criteria previously defined, both also included as input data of the model. The first type, called Subjective Criteria, is based on experts' opinions collected through questionnaires. The second type, called Technical Criteria, is calculated according to the outputs of the three first modules of the program. The output of the model is a rank order list indicating the priority of procedures to use for each different type of urban environment. The use of results based on criteria and methods developed previously to the occurrence of a contamination event intends not only to provide an input to decision-making processes but also to improve public confidence on authorities responsible for the remediation decisions.

1. INTRODUCTION

The various accidents and the performance of the teams in charge of the radiation protection of the public highlighted the relevance of existing a prior planning for the assessment of public exposure and for the implementation of protection and remediation measures [1, 2, 3, 4, 5].

In Brazil, since the accident in Goiânia, in 1987 [2], decision-making supporting tools have been developed within an environmental modeling project. The project began with the development of CORAL code, based on the German model ECOSYS [6], to evaluate the consequences of a possible accidental contamination of rural areas in the short, medium and long term. Then the PARATI model, based on information obtained after the Goiania and Chernobyl accidents was developed, focused on the evaluation of public exposure due to Cs-137 contamination in urban areas [7]. This model already includes the possibility to simulate the application of protective measures and evaluating their effectiveness in reducing doses to the public.

It was then developed the SIEM code - Integrated Emergency System [8] which includes the German model ECOSYS, the Brazilian model PARATI and generic models developed by the International Atomic Energy Agency [9]. The SIEM also incorporated standardized data on the physical behavior of radionuclides and dose conversion factors.

Later, it was developed a remediation procedures catalog that includes their main features to be considered in a decision-making process, from the point of view of radiological protection, considering technical and effectiveness aspects, material, equipment and labor requirements, and wastes generated by each different clean-up procedure.

The approach of multi-criteria analysis has been widely used in several areas of knowledge such as Economics, Transport, Industry, Production, among others [10, 11]. It allows performing an optimization study, taking into account several factors, related to benefits and detriments, appropriate to support a decision-making process. This method was previously used in Switzerland, together with the ECOSYS model, for evaluation and selection of protective measures to be applied after an accidental release of radioactivity into the environment [12].

With the multi-criteria analysis (MCA) tool, the criteria can be established a priori, leading to the selection of technically justified options, making the process more transparent and reliable, aiming to increase public acceptance of the decisions taken and on protective measures adopted.

The methodology selected uses two types of criteria, here denominated as “subjective” and “technical” criteria. To derive values for the subjective criteria, a software-based on a scripting language hypertext preprocessor (PHP), was then developed [13]. The criteria were established by interviewing experts on remediation after accidents. The data were analyzed by the fuzzy logic method to feed the a multi-criteria model designed to support decision-making processes to be applied in the remediation phase after a nuclear or radiological accident [14].

At this stage, it was observed that many relevant aspects were not being covered by SIEM software, highlighting the need to expand it in order to make it more flexible and allow quantitative assessment of occupational exposures and the generation of wastes by various procedures.

The objective of this work is to build a specific integrated model for urban areas, including:

- the long-term behavior of Cs-137 in urban areas;
- dose calculation for residents and visitors of urban environments;
- simulation of remediation procedures;
- doses received by the remediation workers;
- wastes generated during the clean-up procedures;
- classification of these procedures, according to the results obtained in specific scenarios, within pre-established criteria; and,
- establishment of priorities by a multi-criteria model to support decision-making processes by considering the relevant aspects of radiation protection.

It is important to have a study on the feasibility of implementing protection measures for members of the public due to its effectiveness in reducing doses, adapted to the national situation in relation to exposure scenarios and to factors associated with climate and social aspects. To accomplish this objective it is important to consider detriments and benefits, difficulties and limitations of procedures, effectiveness in reducing doses to the public, while not unnecessarily exposing workers, among other aspects, in order to guide a decision-making processes.

2. METHODOLOGY

In this work only urban scenarios were considered. Also, only those aspects that are relevant for radiological protection were included. Social aspects, costs, legal aspects and public acceptance aspects were not considered as these are not under the scope of support provided by the IRD.

The study area comprises all municipalities that are partly or fully included within the radius of 50 km from the nuclear power plant of Angra dos Reis. This includes 16 Counties, 9 in the State of Rio de Janeiro and 7 in the State of São Paulo.

The main urban characteristics of the study area were observed through images of the Google Earth system and Counties' webpages. Population data were obtained from the 2010 IBGE census [15].

Data for description of the scenario were normalized to 1km^2 of the specified scenario. Each scenario includes different types of environments, such as buildings and streets, and parameters quantified were number of residential units, number of trees and bushes, area covered by lawn, paved surfaces and roofs. These parameters are relevant for the evaluation of the local averted dose for residents, the doses received by the clean-up workers and the type, amount and activity of the generated wastes from each clean-up procedure.

The technical criteria comprises a set of factors developed to allow quantitation of various technical aspects related to the each subjective criteria. These technical criteria does not depend on the opinion of experts, but on the effects of the application of each remediaiton procedure. Subjective criteria and corresponding technical criteria considered in this work are shown in Table 1.

Table 1. Relationship between subjective criteria and technical criteria

Subjective Criteria	***Technical Criteria***
Short term concentration	Effect of procedure on first month concentration
	Relevance of surface to dose
Short term dose (1 month)	First month dose reduction
	Relevance to lifetime dose
First year dose	First year dose reduction
	Relevance to lifetime dose
Lifetime dose	Lifetime dose reduction
Delays	Effect of delay on first year dose
	Effect of delay on lifetime dose
Infrastructure	Availability of equipment
	Availability of materials
	Personal protection equipment
Waste	Type
	Amount
	Concentration
Work force	Availability
	Needs for training
Leadership	Availability
Occupational dose	Ratio to averted dose to the public

As already described, it was decided to build an independent program, based on PARATI model, using the Excel program [7]. At this stage, the developed program is restricted to a contamination with Cs-137. Also, in this work, only adults are considered.

3. RESULTS

The conceptual model is presented in Figure 1. It comprises 3 calculation modules:

- Module 1: environments and doses to the public
- Module 2: occupational doses, wastes and technical criteria
- Module 3: multi-criteria assessment

Input data to module 1 are the initial deposition on a lawn surface; properties of Cs-137 retention and weathering from urban surfaces; the contribution of surfaces to urban environments external dose rates; dose coefficients; population occupancy habits; and, the effect of the cleanup procedures over urban surfaces concentrations.

Surfaces included are the same as those from PARATI and SIEM [7, 8] and includes lawn, bare soil, paved horizontal surfaces, walls, windows, trees and roofs. New surfaces may however be included in the model.

Urban environments simulated are indoors and outdoors compartments of high shielding houses, medium shielding houses, low shielding houses and multistory buildings; streets; and,

park areas. The program allows the inclusion of new environments according to the modelers needs.

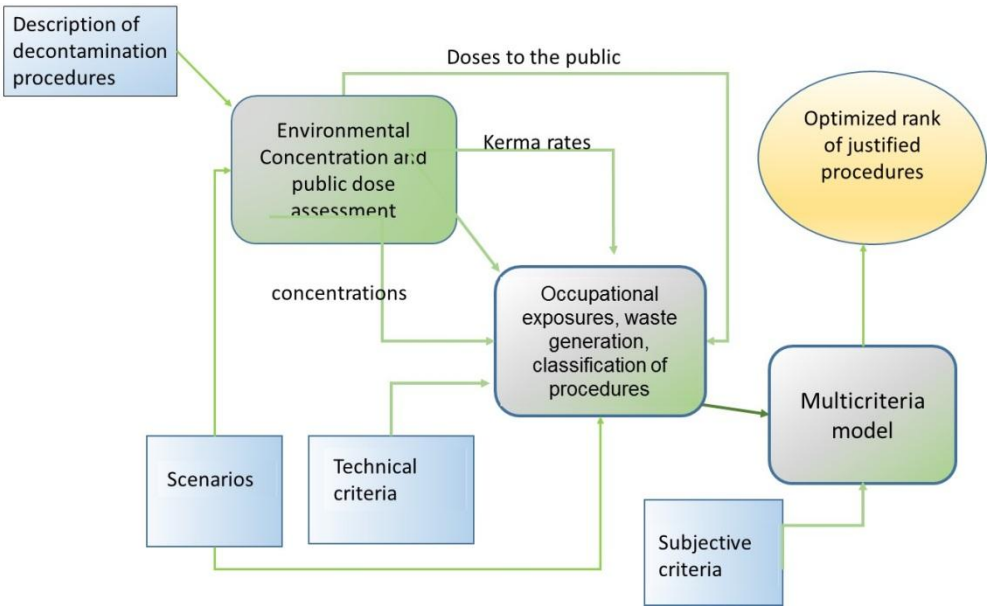

Figure 1. Squematic representation of the software

Remediation procedures considered are listed in Table 2. Additional procedures may, however, be included by the user.

Outputs from module 1 are:

- Concentration of urban surfaces and air concentration, as a function of time after the deposition resulting from an accident;
- External dose rates in each compartment of the urban environments;
- Inhalation rates;
- Integrated effective dose to individuals, groups of individuals and the population as a whole.
- Surfaces concentration with and without the use of cleanup procedures, as a function of time after the initial deposition and with the moment when the procedure is applied; and,
- Averted doses to the public due to cleanup procedures.

All results from Module 1 are used as input data to module 2. Besides those, scenarios descriptions are also input to module 2. The description considers an area of 1 km^2 composed of a specific type of building, streets and vegetation. All surfaces were quantified using Google maps images [16].

Module 2 calculates all values for the technical criteria. To achieve that, it also estimates occupational exposures for the cleanup workers and the properties of wastes generated by each cleanup procedure.

Inputs to model 3 are the subjective and technical criteria. The output is a rank order for the procedures being compared for a specified scenario.

Table 2. Countermeasures simulated by the program

Procedure	***Urban Surface***
Water hosing	Wall
	Roof
	Paved surfaces
Chemical washing	Wall
	Roof
	Paved surfaces
Scraping	Wall
	Paved surfaces
Mixing layer	Soil
Removal	Grass
	Soil surface
	Paved surface
	Roof tile
Cutting	Grass
Pruning	Trees
Covering	Soil
	Lawn
	Paved surface
	Wall

4. CONCLUSIONS

At this time the model is being verified and quality checks are being performed. Next steps includes the organization of output reports and user manual development. Some case studies shall also be performed to check for consistent results based on those cited in the scientific literature, for accidents such as the Chernobyl, Tomsk and Fukushima accidents.

In the longer term, similar procedures are planned to be developed for use on agricultural areas. Although preliminary studies have already been done, more work is needed due to the complexity in dealing with a highly seasonal dependent problem.

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