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ASSESSMENT OF RADIOLOGICAL PROPERTIES OF WASTES FROM URBAN DECONTAMINATION PROCEDURES

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ABSTRACT

One important activity associated to urban areas contaminated from accidental releases to the atmosphere of nuclear power plants is the management of radioactive wastes generated from decontamination procedures. This include the collection, conditioning, packing, transport and temporary/final disposition. The final destination is defined usually through a political decision. Thus, transport of packed radioactive wastes shall depend on decisions not just under the scope of radiological protection issues. However, the simulations performed to assess doses for the public and decontamination workers allows the estimate of radiological aspects related to the waste generated and these characteristics may be included in a multi-criteria decision tool aiming to support, under the radiological protection point of view, the decision-making process on post-emergency procedures. Important information to decision makers are the type, amount and activity concentration of wastes. This work describes the procedures to be included in the urban area model to account for the assessment of qualitative and quantitative description of wastes. The results will allow the classification of different procedures according to predefined criteria that shall then feed the multi-criteria assessment tool, currently under development, considering basic radiological protection aspects of wastes generated by the different available cleanup procedures on typical tropical urban environments.

1. INTRODUCTION

After the Chernobyl nuclear accident in 1986, caused by the explosion of a nuclear power plant in Ukraine, followed by the fire of the reactor, several European countries have been working to raise the effectiveness of protective measures in order to reduce doses in public [1, 2, 3].

Although there was already preparedness for the emergency phase, the Goiânia accident, in 1987, has also shown the need for pre-planning in relation to recovery measures. The Goiânia experience has shown that the introduction of criteria and methodologies after the accident was a difficult task under the point of view of the acceptance by the public and their representatives [4, 5, 6].

The Tomsk accident, in 1993, showed that several of the protection/remediation measures, applied in a time of great popular pressure and concern, were ineffective in reducing doses to

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the public while leading to unnecessary exposure to workforce involved in decontamination processes [7].

Considering the large amount of data available in the literature containing the description of protection and remediation measures, projects have been developed with the goal of creating a database to be used after an event leading to the environmental contamination in order to support decision-making processes based on multi-criteria methods.

Thus, the aim of this research is to describe criteria, models and parameters to be used to classify wastes from decontamination procedures in order to include this aspect in a multi-criteria analysis aiming to support, under the aspects of radiological protection, the decision-making process at the recovery phase after an accidental contamination of tropical urban areas.

2. METHODOLOGY

After the development of a database describing the main characteristics of 25 remediation procedures that can be used in the clean-up of tropical urban environments [8], criteria for the classification of wastes generated by these procedures have been developed (Table 1) [9]. These criteria are needed as input to the multi-criteria decision tool under development [10] in order to account for wastes generation in the decision-making process.

However, the procedures considered in this study are those that generate solid wastes such as asphalt, concrete, roof tiles, gravels, soil, soil with grass, pasture, twigs and leaves, pieces of removed floors and air conditioning filters; the relevance on amount and activity relates to packing and transporting operations and the corresponding occupational exposures.

Mixed wastes, resulting from washing operations, consisting of residues diluted in water or chemical solutions, are not always easy to collect. They can also cause secondary contamination of other surfaces; they can infiltrate in soil, and have the potential to transfer the contamination to other locations such as street drains, rivers and sewerage treatment plants. The relative amount and concentration of wastes shall than depend on the amount of water or chemical solution used in decontamination, the procedures introduced to collect residues and post-treatment for reducing volume for disposal or dilution for discard.

Some procedures, such as scrapping and pruning, also produce dust that may be transported and re-deposited on other surfaces. Furthermore, they may increase inhalation risks for workers. These properties are considered under the first factor on Table 1, while the calculations related to the other factors follow the methodology developed in this work.

The properties of the wastes depend on the urban scenario, the moment when the clean-up is performed, and on the procedure used. Different scenarios were defined mainly based on the characteristics of urban areas located within 50 km from the Brazilian nuclear power plants. The description of these scenarios has been presented elsewhere [11]. Data from these scenarios shall be used to estimate the amount of wastes generated by each procedure.

The model SIEM [12] shall be used to determine the concentration of the surfaces being cleaned-up before and after the moment when the procedure is applied. The most relevant materials property needed for classifying solid wastes is the density. Values considered here were taken from Salinas and collaborators [13] and other technical references.

Table 1. Criteria for classifying different types of waste [9]

Criteria	Factor	Options	Value
Waste generation	Type of waste	liquid wastes or other types that are difficult to be collected	1
		fine solid material with potential to spread over nearby surfaces	2
		easily collectable solid waste	3
		no waste but future exposures cannot be discarded	4
		no wastes are produced during the procedure	5
	Relative amount	More than 100 kg/m^2 of contaminated area	1
		10 to 100 kg/m^2 of contaminated area	2
		1 to 10 kg/m^2 of contaminated area	3
		0.1 to 1 kg/m^2 of contaminated area	4
		Less than 0.1 kg/m^2 of contaminated area	5
	Relative contamination	More than 1,000 Bq/m^3 per Bq/m^2 of contaminated area	1
		100 to 1,000 Bq/m^3 per Bq/m^2 of contaminated area	2
		10 to 100 Bq/m^3 per Bq/m^2 of contaminated area	3
		1 to 10 Bq/m^3 per Bq/m^2 of contaminated area	4
		Less than 1 Bq/m^3 per Bq/m^2 of contaminated area	5

3. RESULTS AND DISCUSSION

Although the main objective of SIEM [11] is to calculate doses to the public as a function of time after an environmental contamination, it was also designed to provide the effectiveness of countermeasures on these doses. As so, the module PARATI [14] allows the assessment of the concentration of the contamination before and after the use of clean-up procedures. From these data, the amount of activity removed by unit area of the surface being clean-up can be estimated. Then, if the procedure is to be applied at time **t** after the initial contamination event, the concentration on wastes can be estimated by:

$$Cw = Cs(t) - Cs(t+1) \tag{1}$$

Where Cw refers to the concentration of the solid waste (Bq/m^2 of the original surface) and Cs refers to the concentration of the surface being treated by the procedure at time **t** and after the treatment (at time t+1).

Volume and weight quantities depend on the scenarios. As so, standard scenarios were developed and described in relation to amount of surfaces (m^2) present per km^2 of area [11]. For trees and bushes, description relates the number of units per unit area. To assess the area and volume occupied by such surfaces, the canopies are considered as a 5 m diameter sphere and bushes a 2 m diameter sphere:

$$S_{tree} = N_{tree} \times s_{tree} \tag{2}$$

S_{tree} is the total area occupied by trees for each scenario (m^2/km^2); N_{tree} is the number of trees estimated for each scenario [11] and s_{tree} is the horizontal projected area of a reference tree (20m^2) or bush (3 m^2). Total removed activity related to trees (R_{tree} (Bq/km^2)) is estimated by:

$$R_{tree} = Cw_{tree} \times S_{tree} \tag{3}$$

The volumetric concentration Cv_{tree}, in Bq/m^3, can then be estimated by:

$$Cv_{tree} = \frac{R_{tree}}{V_{tree} \times N_{tree}} \tag{4}$$

Where V_{tree} is the volume of a tree (65.5 m^3) or of a bush (4.2 m^3). The ratio between Cv_{tree} and $A_{ref,}$ the initial deposition at the reference area (horizontal lawn surface) [14] defines the factor on relative contamination.

The average relative amount of the waste generated from pruning trees and bushes per unit area, W_{tree}, in kg/m^2, is then estimated by:

$$W_{tree} = \frac{V_{tree} \times \rho_{tree} \times N_{tree}}{10^6} \tag{5}$$

Where ρ_{tree} is the density of the removed material (Table 2) and the factor 10^6 refers to the conversion of units for the reference area from 1 km^2 to 1 m^2. Wt_{ree} is then used to classify the procedure on that specific urban environment according to the criteria factor on relative amount of waste generated by the clean-up procedure.

For other surfaces, the depth affected by the procedure is taken into account to estimate the volume of removed material. Scrapping is considered to remove about 0.5 cm of the surface while removal of pavement is considered to remove 20 cm for concrete and asphalt and 5 cm for stone. For lawn, a 3 cm layer is considered for cutting grass and 5 cm plus 1 cm of soil surface are considered to be remove by weeding or turf harvesting. Total removed activity from surface s, Cv_s (Bq/m^3) is calculated by:

$$Cv_s = \frac{Cw_s}{d_s} \tag{6}$$

Where Cw_s is the concentration removed from the surface (Bq/m^2) and d_s is the depth of the layer being removed by the procedure (m).

With the total activity removed and the total corresponding volume of waste created, the third factor can be estimated for each decontamination procedure in each scenario. The total volume removed and the respective densities are used to estimate the quantity needed to describe the second factor (relative amount of wastes):

$$W_s = \frac{S_s \times d_s}{10^6} \times \rho_s \tag{7}$$

Where S_s is the total area of surface *s* per km^2 of contaminated area, 10^6 is the unit conversion for the contaminated area and ρ_s is the density of the material of the surface. Densities of relevant materials are presented on Table 2.

Table 2. Reference density of the materials used in the study

Material	Density (kg/m^3)	Reference
Soil (50 cm top layer)	1,800	[13]
Concrete	2,400	[13]
Asphalt	2,300	[13]
Granite slab	2,650	[15]
Glass	2,530	[13]
Clay	712	[13]
Wood	790	[13]
Brick	1,900	[13]
Wall finishing material	1,200	[13]
Lawn	780	[13]
Ceramic tile	1,880	[16]
Fiber cement tile	1,600	[17]

When considering measures that involve chemical washing or water in houses or on paved areas, the waste generated is water itself, and may contain ammonia or other chemicals. For these cases, it was adopted a liquid density of 1,000 kg/m^3. The amount of water used in the procedures may have large variations, but reference values for water hosing are of 0.02 m^3 of water by m^2 of surface for the washing walls and roof and about 0.250 m^3 of water by m^2 of surface for the washing of streets [2].

4. CONCLUSIONS

In this work, the objective was to describe the general aspects and parameters needed to classify clean-up procedures according to the type, quantity and quality of wastes generated. The values for these criteria factors shall be included in the multi-criteria decision tool, that currently under development, to support decision-making process at the recovery phase after a nuclear and/or radiological accident. The three criteria factors were considered enough to classify the wastes generated by clean up procedure, considering the aspects related to occupational exposures from packing, transporting and disposing the wastes and also the costs related to these activities.

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