APPROACHES FOR OCCUPATIONAL EXPOSURES DURING THE DECONTAMINATION OF URBAN AREAS

Silva, D.N.G.[*1]; Rochedo, E.R.R.[2]; Guimarães, J.R.D.[1], De Luca, C.[3]

[1] Instituto de Biofísica Carlos Chagas Filho, Universidade Federal do Rio de Janeiro, Av. Carlos Chagas Filho, 373, bloco G, 21941-902, Rio de Janeiro-RJ, Brasil
[2] Instituto de Radioproteção e Dosimetria, Comissão Nacional de Energia Nuclear, Av. Salvador Allende s/no., 22780-160, Rio de Janeiro-RJ, Brasil
[3] COPPE, Programa de Engenharia Nuclear, Universidade Federal do Rio de Janeiro, Av. Horácio Macedo, 2030, bloco G, 21941-914, Rio de Janeiro-RJ, Brasil

ABSTRACT

The occurrence of various accidents involving radioactive material and the performance of the staff responsible for the radiological protection of the public have highlighted the need for prior planning for the assessment of public exposure and pre-defined guidelines for the application of more appropriate protective and remediation measures. This work is part of a project that aims to develop a multi-criteria tool to support decision-making processes in cases of nuclear or radiological accidents in Brazil. It describes the development of a model to assess occupational exposure related to decontamination procedures for the remediation of urban areas. Numerical values for model parameters were mainly based on previous developed works within the same project that includes a database describing main features of different procedures that may be used during the remediation phase after accidents and the definition of standard scenarios to perform simulations of accident consequences focusing members of the public doses. The model defined for estimation of occupational doses due to decontamination procedures shall be included in the multi-criteria tool under development in order to assess the effects of application of decontamination procedures in occupational exposure as compared to the averted doses to members of the public due to the same procedure.

1. INTRODUCTION

The occurrence of various accidents involving radioactive material and the performance of the staff responsible for the radiological protection of the public have highlighted the need for prior planning for the assessment of public exposure and pre-defined guidelines for the application of more appropriate protective and remediation measures [1, 2, 3]. Countries that use nuclear energy for the generation of electricity have been concerned not only with the technological development of safety systems but also with the prevention and remediation of the consequences of accidents that lead to the contamination of the environment and the consequent exposure of members of the public.

Several countries have been working on increasing the efficiency of protective and remediation procedures to decrease public doses. In Brazil, the Goiânia accident, in 1987 [1] raised the need for previous planning regarding protective and remediation measures in urban areas [4]. Goiânia experience has shown that introducing numerical criteria and

[1] Author's E-mail. dneves@biof.ufrj.br

methodologies after an accident was a difficult task under the point of view of public acceptance [5, 6, 7].
An environmental modeling project was set aiming to develop a tool to supportdecision-making processes after a nuclear or radiological accident for the protection of the public and of the workers exposed while implementing decontamination and remediation procedures.

The use of computer models for assessment of urban contamination situations and remediation options enables the evaluation of a variety of situations or alternative remediation strategies in contexts of preparedness or decision-making [8].

The main goal of this work is to describe the development of the mathematical models proposed for the assessment of doses to workers applying decontamination and remediation procedures in urban areas, based on results of environmental concentrations and dose rates at different compartments of an urban area. The results shall be included in a multi-criteria decision tool as a criterion to be considered along with other criteria such as the averted dose to the public, the characteristics of the generated waste, the feasibility for the use of each procedure in specific environments, among others [9].

2. METHODOLOGY

In a first step, a database describing the main characteristics of decontamination procedures applicable to urban tropical areas was developed. The description includes technical, radiological, political, social and economic aspects, for 23 remediation procedures [9, 10]. The structure of the database is as follows:

(a) General aspects: name, surface to apply the procedure (soil, paved surfaces, wall, roof, trees), type of procedure (washing, removal of contamination, covering, among others), short description of the procedure, radionuclides for which it is recommended and scale of application;
(b) Technical aspects: exposure pathways, efficiency, technical restrictions, factors that may affect averted doses and additional doses, such as doses to workers;
(c) Infrastructure: special needs for material, equipment, personnel ability, training, and safety features;
(d) Waste: type, amount and concentration; and,
(e) Other aspects: other impacts, practical experience and references.

In order to estimate doses to the public (individual and collective) and dose to remediation workers, it was necessary to derive reference scenarios [11]. The doses for the workers are assessed and compared with the averted doses to the public, for each procedure at each reference scenario.

The number of workers and the spent time for each procedure were derived from literature data and from actual observation for usual daily cleaning activities of urban areas. From the database on remediation procedures the information described on the section of infrastructure requirements was taken, complemented by data raised for the Rio de Janeiro Prefecture, regarding the usual execution of urban activities such as the pruning of trees, the cleaning of streets and small civil constructions, done either manually or with machinery support.

Only collective doses are considered in the comparative assessment between the doses to the workforce and the averted doses to the public. It is considered that each worker has its exposure controlled under the directives for routine occupational exposures at the post-accident remediation phase.

3. RESULTS AND DISCUSSIONS

During the application of decontamination procedures, workers may be exposed by several pathways such as external exposure to contaminated surfaces and inhalation of resuspended dust. External exposure occurs at the specific environment being decontaminated and, according to the scenario, also enhanced exposure may occur due to the proximity of specific surfaces such as trees and roofs. Procedures that use water for cleaning surfaces usually don't resuspend dust and thus have small contribution to worker's inhalation. However, for procedures involving demolition, digging or scrapping, generated dust and inhalation doses to workers are to be assessed and may demand the use of personal protective equipment such as filter masks. In this work, the use of personal protective equipment was not considered and inhalation doses were estimated using a resuspension factor of 10^{-6} m^{-1}.

Doses to workers were assessed based on activity concentration in surfaces and on kerma rates estimated for the different urban compartments, considering the number of workers and time needed for each procedure per unit of area (km^2).

The general equation used to assess doses to workers is:

$$D = N_T \times T_T \times (k_{amb} \times DC_{ext} + C_{sur} \times Q_{sur} \times DC_j + C_{air} \times DC_{inh} \times T_I)$$

Where D is the collective dose received by workers at the decontamination procedure per km^2 of contaminated area and:

N_T = Number of workers needed to work simultaneously at the procedure
T_T = Time needed to execute the procedure (h/km^2 or h/unit)
k_{amb} = kerma rate at the location being decontaminated (Gy/h)
DC_{ext} = External dose coefficient (Sv/Gy)
C_{sup} = Concentration of the surface being decontaminated (Bq/kg or Bq/m^2)
Q_{sup} = Amount of surface being decontaminated (kg/km^2 or $units/km^2$)
DC_j = External dose coefficient per unit activity for the specific geometry of exposure ($(Sv/h)/(Bq/m^2)$)
C_{air} = Air concentration at the location being decontaminated, considering the specific resuspension coeficient that is adequate to the kind of procedure being used (Bq/m^3)
DC_{inh} = Inhalation dose coefficient (Sv/Bq)
T_I = Inhalation rate adequate to comply with the type of procedure being developed (m^3/h)

Calculations are performed for each procedure according to different types of environments where each procedure is applied. Parameters values needed for the calculations are summarized on Table 2, for house environments, and on Table 3 for public area environments.

Table 2. Main properties of decontamination procedures for urban areas – residential environments

Procedure	*External exposure (environment)*	*External exposure (surface)*	*Inhalation*	*Exposure time unit**[1]	*No. of workers on each team N_T*
Procedures in residential areas					
Pruning trees	Outdoors residences	Trees	Resuspension	3 h/tree	3
Pruning bushes	Outdoors residences	Bushes	Resuspension	1 h/bush	2
Cutting lawn	Outdoors residences	—	Resuspension	0,005 h/m^2	2
Soil removal - 1 cm	Outdoors residences	—	Resuspension	0,0075 h/m^2	2
Soil removal - 5 cm (manual)	Outdoors residences	—	Resuspension	0,0075 h/m^2	2
Digging gardens	Outdoors residences		Resuspension	0,01 h/m^2	1
Washing walls with water	Outdoors residences	Walls	—	0,033 h/m^2	2
Chemical washing of walls	Outdoors residences	Walls	—	0,033 h/m^2	2
Scrapping walls	Outdoors residences	Walls	Resuspension	0,5 h/m^2	2
Washing roofs with water	Outdoors residences	Roof	—	0,1 h/m^2	2
Chemical washing of roofs	Outdoors residences	Roof	—	0,1 h/m^2	2
Scrapping tiles	Outdoors residences	Roof	Resuspension	0,067 h/m^2	2
Changing roof tiles	Outdoors residences	Roof	—	0,4 h/m^2	2
Demolition	Outdoors residences	Walls and roof	Resuspension	*[2]	2

*[1] the amount of area or units being decontaminated are dependent on the scenario; values in equations are to be multiplied by the number of unit of trees or bushes per km^2 or by 10^6 m^2/km^2
*[2] it depends on the scenario

For the comparative assessment between doses to workers and averted doses to the public, values for the public occupancy of urban environments are summarized on Table 4. The number of people living on each type of urban environment depends on the scenarios and is described elsewhere [11].

Table 3. Main properties of decontamination procedures for urban areas – public environments

Procedure	*External exposure (environment)*	*External exposure (surface)*	*Inhalation*	*Exposure time unit**	*No. of workers on each team N_T*
Procedures in public areas – parks and squares					
Pruning trees and bushes	Outdoors	Trees	Resuspension	3 h/tree	3
Soil removal - 1 cm	Outdoors	—	Resuspension	0,0075 h/m^2	2
Soil removal - 5 cm	Outdoors	—	Resuspension	0,0075 h/m^2	2
Cutting grass	Outdoors	—	Resuspension	0,005 h/m^2	2
Cutting grass without vehicle	Outdoors	—	Resuspension	0,05 h/m^2	2
Procedures in public areas – streets and sidewalks					
Street hosing	Street	—	—	0,0015 h/m^2	2
Washing with truck	Streets – shielding by truck	—	—	0,0015 h/m^2	3
Scrapping pavement	Street	—	Resuspension	0,01 h/m^2	4
Scrap with vehicle	Streets – shielding by truck	—	—	0,001 h/m^2	4
Remove pavement	Street	—	Resuspension	0,04 h/m^2	2
Remove with vehicle	Streets – shielding by truck	—	—	0,004 h/m^2	2

* the amount of area or units being decontaminated are dependent on the scenario; values in equations are to be multiplied by the number of unit of trees or bushes per km^2 or by 10^6 m^2/km^2

It is important to say that both the scenarios and occupancy rates are input data to the model and can be changed by the user, to allow adapting them to actual situations observed in case of an accident. Values used in this work are considered as default for the classification of decontamination procedures related to previously defined criteria considering averted doses to the public, efficiency of the procedure as a function of the moment after the accident when it is applied, dose received by workers while applying the procedures and waste generated by each procedure [12].

For public areas, the number of visitors and permanency time were based on data collected together with two important park areas in Rio de Janeiro; (i) the Botanic Garden, a very wooded park with 140 hectares of preserved natural vegetation and forest areas, open for public and touristic visitation [13]; and, (ii) the Zoological Garden.

Occupancy rates on paved areas such as streets and sidewalks comprise two types of people: (i) 1 hour per day for resident members of the public while in transit at these areas; and, (ii) different types of workers, such as municipal and state guards, police members, street cleaning people, and others, for which an occupancy rate of 40 hours per week was considered.

Table 4. Occupancy rates used for assessing averted doses to members of the public.

Number	Type of procedure	Type of public and occupancy rates
1	Procedures on residential areas	Adult 24 h/d at the residence
2	Procedures on open park areas	2000 visiting adults for 4 h/d at the park area + 12 park workers per km^2 of park area for 8 h/d
3	Procedures on streets and sidewalks	Resident adults 1 h/d at street + 5 persons per km^2 of the area working for 8 h/d at the street

4. CONCLUSIONS

This paper describes the steps for developing the model to consider occupational exposures related to the applying of decontamination procedures in urban areas. Parameter values were taken from literature or from actual observation. Only collective doses shall be compared with collective averted dose to the public living in the same area. Individual occupational doses are controlled in an independent way and thus not included in this comparison. However, it is considered that several teams may be needed to comply with a singular task.

The ratio between the occupational dose and the dose averted to the public shall be used to define the viability of a procedure. If doses to workers are higher than the dose averted to the exposed public, the procedure shall not be recommended.

5. REFERENCES

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