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DEFINING CRITERIA RELATED TO WASTES FOR USE IN MULTI-CRITERIA DECISION TOOL FOR NUCLEAR ACCIDENTS

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ABSTRACT

The selection of protective measures and strategies for remediation of contaminated areas after a nuclear accident must be based on previously established criteria in order to prevent stress of the population and the unnecessary exposure of workers. After a nuclear accident resulting in environmental contamination, decisions on remediation of areas is complex due to the large numbers of factors involved in decontamination processes. This work is part of a project which aims to develop a multi-criteria tool to support a decision-making process in cases of a radiological or a nuclear accident in Brazil. First, a database of remediation strategies for contaminated areas was created. In this process, the most relevant aspects for the implementation of these strategies were considered, including technical criteria regarding aspects related to the generation of wastes in a reference urban area, which are discussed in this paper. The specific objective of this study is to define criteria for the aspects of radioactive wastes, resulted by the implementation of some urban measures, in order to be incorporated in a multi-criteria decision tool. Main aspects considered were the type, the amount and the type of treatment necessary for each procedure. The decontamination procedures are then classified according to the selected criteria in order to feed the multi-criteria decision tool. This paper describes the steps for the establishment of these criteria and evaluates the potential for future applications in order to improve predictions and to support the decisions to be made.

1. INTRODUCTION

After a nuclear or a radiological accident resulting in dispersion of the radioactive material in the environment, it's usually necessary to implement remediation strategies in order to

decontaminate the affected areas, reducing doses to the public. The selection of the most efficient measures must be based on previously established criteria to prevent excessive stress to the population and avoid that measures that are not effective in reducing doses to the public are performed leading to the exposure of the workforce [1].

In these circumstances, the decision-making process is complex due to the large numbers of factor involved in decontamination measures. In emergency preparedness, some countries have carried out researches to develop computational models to simulate the environmental behavior of radionuclides dispersed in the environment after an accident and the consequent doses received by population. Some models also allow the evaluation of protective measures by estimating the dose reduction to members of public due to the remediation procedures [2, 3, 4, 5].

In Brazil, the development of tools to support a decision-making process in these cases was started after the radiological accident of Goiânia, in 1987. The Goiânia experience showed that the insertion of criteria and methodologies after the occurrence of an accident was very difficult due to problems with acceptance by the public and their representatives [6, 7].

Multi-criteria analyses proceedures have been widely used to support decision-making processes in the most diverse areas of the knowledge, such as Economy, Transport, Industry, Production, among others [8]. It is based on the comparison of alternatives, leading to the recommendation of optimized actions to help authorities in situations of important decisions. The approach by multi-criteria analysis has been cited as an adequate tool to use as support to the decision-making process after an accident. With this method, the criteria may be previously defined, leading to a selection of options that are technically justified, making the decision process more reliable and transparent. These aspects are relevant for public acceptance of adopted decisions on remediation procedures [9, 10].

Under this project, the first step was the development of a computer system to assess doses to members of the public after accidental environmental contamination, including the assessment of the effect of remediation procedures in reducing such doses [3]. Then, a database describing remediation measures which can be implemented in cases of nuclear or radiological accident in Brazil was developed. The measures are separated in the database according to the type of area (urban, rural and aquatic) to which they may be applied [11].

The objective of this work is to discuss the definition of criteria related to radioactive wastes resulting from the implementation of remediation of urban areas, in order to be incorporated in the multi-criteria decision tool, currently under development.

The complete multi-criteria analysis is to be performed by various agencies and must take into account the actual situation at the moment of decision. Thus, at this stage, only the technical aspects are being considered.

2. METHODOLOGY

The database includes 22 possible protective and remediation measures that may be applied to urban environments [11]. For this type of area, the measures were subdivided according to

the type of procedure involved and their main characteristics, which correlate with the generation of waste [12]:

(i) Physical removal of contamination: road planning, cutting grass, turf harvesting, pruning trees and brushes, top soil removal with coating material, manual or mechanically and removal of roof tiles.

(ii) Cleaning or Washing the contaminated surface: vacuum sweeping roads and walkways, fire hosing roads and walkways, high pressure washing of walls, treatment of walls with chemical products, mechanical abrasion of walls, sandblasting of walls, washing roofs with high pressure water, cleaning devices or chemical solutions, and cleaning of internal surfaces.

(iii) Covering the contaminated surface: turning flagstones and covering areas with soil, sand, asphalt or concrete.

(iv) Diluting the contamination: digging (gardens, surface or deep triple digging).

The general structure of the database is presented below:

(i) General Aspects: Name of measure, surface where the measure is to be applied, type of measure, description of the procedure, applicable radionuclides and scale of application.

(ii) Technical Aspects: Exposure pathways, moment of application, technical restrictions, effectiveness of the measure, factor affecting averted doses to the public and additional doses (e.g., dose to workers).

(iii) Infrastructure: Factors that may influence the efficiency, the need for specific equipments and/or materials, the need of skilled people and/or training, safety considerations and factors affecting costs.

(iv) Wastes: Type and amount.

(v) Other Aspects: Other impacts, actual experience, references and comments.

The definition of criteria for feeding the multi-criteria decision-making model follows the approach used within the fuzzy logic methodology, which has been cited to be adequate to deal with subjective factors, provided that the alternatives can be related to different levels that follow an increasing or decreasing order [13]. This order allows the classification of each remediation procedure for comparative purposes. The criteria and scaling order were selected based on the information in the database.

3. RESULTS AND DISCUSSION

The discussion on waste generation is complex. Some measures do not generate waste. However, some of them, as in the case of those involving dilution, leave residual activity, while others, such as those involving coating, may lead to exposure in the future, due to the loss of memory loss associated with these activities. This fact has been observed in Goiânia,

where an area covered at the time of accident was subsequently abandoned and has been occupied and the excavation for building brought back to the surface a quantity of material that was then deposited on the ground surface. Another example was the excavation of a street to exchange public sewage pipe where urban maintenance activities has also brought back to the surface material that had been previously isolated [7].

Although these two examples were related to a small amount of material and the resulting exposures were low, in case of accidents with severe contamination of large areas, these two types of measures must be differently described according to the potential for exposure in the future, even though both do not generate waste. While in the case of dilution, future exposures are considered in decision-making process through the radiological criteria related to residual doses, but when the coating measures are implemented, it would be also important to consider the potential future exposures, which is not usually done.

For urban areas, the various types of waste that may be generated due to the application of protective measures include:

(i) solid wastes resulting from physical removal of contamination, such as asphalt, dust, broken stones, soil, soil with turf, grass, twigs and leaves, tiles, waste scraping pieces of flooring removed and air conditioning filters; and,

(ii) mixed waste resulting from cleaning operations, composed by residues or sand in water or chemical solutions, which are not always easy to be collected, and may lead to the contamination of other surfaces, infiltration into the soil, or with the potential to transfer contamination to other locations such as rivers and sewage treatment plant.

The volume of wastes will be a function not only of the remediation measure itself, but also of the size of the contaminated area. Thus, comparison of criteria must be made considering the unit of originally contaminated area. Besides the quantity, other criteria to be included in the analysis were the possibility of reducing volume and the concentration of radioactive material per unit concentration in the initially contaminated area.

Regarding the expected contamination of the wastes, this will depend on the initial contamination area and on the decontamination method used. Thus, classification criteria are also only relative, since the effective classification of the wastes can be made only for defined contamination scenario. Furthermore, this must be considered together with the need for treatment, for example, solid-liquid separation, or volume reduction, which can lead to increased contamination of the waste directly generated from the decontamination procedure.

Another important aspect to be considered in relation to the generation of waste is associated with occupational doses resulting from the handling, processing, packaging and transportation. This however will be addressed at another work within the discussion of occupational doses. Aspects of cost associated with wastes, including the construction of repositories, as aforesaid, are not addressed in this phase of work, which is restricted to technical and radiological aspects.

With these considerations, and also based on the description of the procedures at the countermeasure database, the following criteria are proposed to be used for the classification

of waste generated due to remediation of contaminated areas after accidents, for comparative assessment purposes:

(i) Type of waste:
a. No waste is created and exposures are already considered in the radiological criteria already established.
b. No waste is created by the procedure, but there is a possibility of exposures in the future because the contamination was not physically removed or permanently diluted in the environment.
c. Solid waste which do not spread easily or mixed liquids that can be easily collected.
d. Fine solids wastes, with potential to be spread to other neighbors surfaces.
e. Liquid or mixed wastes difficult to be collected, with the potential to create hot spots or contamination in remote areas as urban rainwater drainage systems, rivers and water or sewage treatment plants.

(ii) Relative amount:
a. Up to 0.1 kg per m^2 of decontaminated area.
b. Up to 1 kg per m^2 of decontaminated area.
c. Up to 10 kg per m^2 of decontaminated area.
d. Up to 100 kg per m^2 of decontaminated area.
e. More than 100 kg per m^2 of decontaminated area.
Note: the relative amount must refer to the final waste to be discarded or disposed.

(iii) Relative contamination:
a. Up to 1 Bq/m^3 Bq/m^2 by the contaminated area.
b. Up to 10 Bq/m^3 for Bq/m^2 by the contaminated area.
c. Up to 100 Bq/m^3 by Bq/m^2 by the contaminated area.
d. Up to 1,000 Bq/m^3 for Bq/m^2 by the contaminated area.
e. Up to 10,000 Bq/m^3 Bq/m^2 by the contaminated area.

4. CONCLUSIONS

In this work, the criteria related to the generation of wastes in an urban area were discussed, and a set of classification criteria was proposed to be applied to remediation procedures as input data to a multi-criteria decision-making tool.

At this stage, however, criteria are related only to technical and radiological aspects related to public exposure. Legal aspects, costs and public acceptance are not within the scope of this project. Also, occupational doses received by workers responsible for the decontamination procedures and disposal of the waste generated are also under development.

The proposed criteria are then related to the type and amount of waste produced by each decontamination procedure and the expected contamination level in a relative basis.

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REFERENCES

1. IAEA, "The radiological accident in the reprocessing plant at Tomsk", *Accident Response Series*, International Atomic Energy Agency, Vienna (1998).
2. A. Nisbet, A. Jones, J. Brown, K. Mortimer, G. Roberts, S. Mobbs, "UK Recovery Handbook for Radiation Incidents", *HPA-RPD-042* – Health Protection Agengy, UK (2008).
3. L. F. C. Conti, E. R. R. Rochedo, E. C. S. Amaral, "Desenvolvimento de um sistema integrado para avaliação de impacto radiológico ambiental em situações de emergência", *Rev. Bras. Pesq. Des*. **4(3)**, 872-879 (2002).
4. E. R. R. Rochedo, "The radiological accident in Goiânia: environmental aspects in restoration of environments with radioactive residues", *International Atomic Energy Agency*, Proceeding Series, IAEA, Vienna, 365-384 (2000).
5. H. Müller, G. Pröhl, "ECOSYS-87: a dynamic model for assessing radiological consequences of nuclear accidents", *Health Physics*, **64(3)**, 232-252 (1993).
6. IAEA, "Assessment of radiological consequences and evaluation of protective measures", *The International Chernobyl Project*, Technical Report, International Atomic Energy Agency, Vienna (1991).
7. IAEA, "The radiological accident in Goiania", International Atomic Energy Agency, Vienna (1988).
8. J. O. R. Menezes, *Produção regional de aço: responsabilidade corporativa e contribuições do capital social para o desenvolvimento regional*, PhD thesis, Escola de Química, UFRJ, Rio de Janeiro (2008).
9. T. Zeevaert, A. Bousher, V. Brendler, P. H. Jensen, S. Nordlinder, "Evaluation and ranking of restoration strategies for radioactively contaminated sites", *Journal of Environmental Radioactivity*, **56(1-2)**, 33-50 (2001).
10. A. Schenker-Wicki, "The use of multi-criteria analysis (MCA) for evaluating feasible countermeasures after an accidental release of radioactivity", *IVth International Symposium of Radioecology*, Cadarache, France (1988).
11. D. N. G. Silva, E. R. R. Rochedo, M. A. V. Wasserman, "Remediation strategies after nuclear or radiological accidents", *Proceedings of the International Nuclear Atlantic Conference*, Rio de Janeiro, September 27 – October 2nd (2009).
12. RESTRAT-TD 14, "Manual on restoration strategies for radioactive contaminated sites", *Restoration strategies for radioactively contaminated sites and their close surroundings*, Project FI4P-CT95-0021a (PL 950128), **v.1** (1999).
13. L. Chwif, "Questionários para avaliação institucional baseados na lógica Fuzzy", *Ensaio: Aval. Pol. Públ. Educ*., **10(37)**, 457-478 (2002).