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REMEDIATION STRATEGIES AFTER NUCLEAR OR RADIOLOGICAL ACCIDENTS: PART 1 – DATABASE DEVELOPMENT

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ABSTRACT

The selection of protective measures and of remediation strategies of areas after a nuclear or radiological accident needs to be based on previously established criteria, in way to minimize the public's emotional stress and the exposure to workers involved in cleanup operations due to the implementation of procedures that are not effective in reducing doses to the public. Thus this work intended to develop a database which allows supporting the decision-making process after these accidents, by describing the foreseen strategies according to the type of accident and the type of affected environment, in order to be used in a multi-criteria selective process. To achieve that, in this first stage, the database has been developed including the following aspects: type of environment (urban, rural or aquatic); their contamination removal efficiency, as function of the time elapsed since the contamination event; the type and the amount of waste generated in the application of the strategy; the expected doses to the work team and basic needs such as specific materials, equipments, training, IPE, among others. The protection measures are usually described in literature considering their activity removal efficiency of a certain surface or environment. In order to determine their efficiency in the reduction of doses, a second stage is foreseen, involving the simulation of the implementation of the measures in different moments after the contamination, based on pre-defined accidents and scenarios, with focus on the surroundings of the Brazilian Nuclear Power Plants in Angra dos Reis.

1. INTRODUCTION

One of the current concerns in the international scenery is the study of the consequences of accidents and other events that lead to the contamination of the environment and the public's exposure. Since the Goiânia accident, in 1987 [1, 2], the IRD (Institute of Radiological Protection and Dosimetry) of CNEN (National Nuclear Energy Commission) has been developing tools to support decision-making processes after nuclear and radiological accidents, seeking the protection of the public. As part of the environmental modeling project, it was elaborated the code SIEM – Integrated System of Emergency [3], that includes mainly two models: CORAL, used to evaluate the long-term consequences of a contamination of

rural areas, developed after the German model ECOSYS [4], and PARATI [5], developed to assess the consequences of a contamination in urban areas. Several works were conducted simultaneously with the objective of gathering data to improve the output of these models, considering typical Brazilian characteristics related to climate, soil type, type of construction material, diet, among others [6, 7, 8, 9, 10, 11, 12, 13, 14].

The selection of protective measures and remediation strategies for contaminated areas after an accident needs to be based on previously established criteria, in order to minimize both the emotional stress of residents, workers and users of the area and the radiological exposure of workers involved in the application of such measures.

After the Tomsk accident, in 1987, an assessment of the protective and remediation measures applied in the heat of public concern was shown to be ineffective in reducing doses to public while leading to exposure of the workforce involved in the activities of remediation [15].

To avoid repeating such experience and considering the large database described in literature on protective and remediation measures, several countries are now working in the building of databases to be used after an event leading to environmental contamination in a way to support decision-making processes based in a multi-criteria decision supporting tool [16, 17].

As most of the described decontamination strategies have been developed for specific accident and environmental conditions, there was the need to adapt such strategies to fit specific characteristics of tropical climate areas and to habits and uses of areas in Brazil. The objective of this work was then the development of a database on remediation strategies for accidentally contaminated areas adequate to tropical climate areas, as a first step on the development of a multi-criteria support tool for a decision-making process.

2. METHODOLOGY

The database on protective and remediation measures was elaborated and developed mainly based on literature data [18, 19, 20, 21, 22]. Information on each specific measure was organized in order to fulfill the basic technical information needed for a multi-criteria approach to support a decision-making process after an accident.

For each measure, its adequacy to tropical environments has been analyzed. As so, those that are to be applied in relation to ice and snow have been removed; comments were included for those that need specific materials and/or equipments that may not be easily available and also to those that don’t consider the possibility of changes on the use of the area in medium to large terms.

For each type of environment, the measures have been divided according to their main characteristics. There may also be subdivision according to the type of surface to which the measure may be applied. The description of the measures includes 5 main groups of information, named “General Aspects”, “Technical Aspects”, “Infrastructure”, “Wastes” and “Other Aspects”. Each of these main groups is subdivided into fields as described below:

- Under the fields described in General Aspects, there are described the type of area involved, e.g., urban, rural or aquatic environments, the goal of applying the measure, its main characteristics, the main features of how it is to be applied in order to effectively reduce public exposure, the type of exposure that will be changed, the surfaces that will be the target of the procedures, and the radionuclides for which is may be useful in reducing exposures. An additional field describes also the scale of application, e.g., if the measure is feasible to be applied for large contaminated areas or for individual houses and buildings;

- Technical Aspects fields includes a description of exposure pathways and main processes to be affected to reduce exposure, the measure effectiveness in reducing doses and the best period to apply it in order to get the highest benefit; under technical restrictions, there are specific characteristics of the target surface that may affect the effect of the measure, such as finishing material, type of crop, type of building, and so on; factors affecting averted doses to the public may include aspects such as demographic density and population habits and a specific field describes expected dose to workers involved in the cleanup operation;

- Fields included under the title of Infrastructure are mainly related to the feasibility of the use of the measure and main aspects related to the cost of its application. As so, it includes the need for specific equipments and materials, the need for skilled people or the need for training people to operate machines or equipment, safety aspects related to both workers and the public and the need for precautionary side actions, and other aspects that may affect the cost of implementing the area such as size of the area or layout complexity of the area to be cleaned;

- An important aspect that will also influence costs and exposures is the type and amount of wastes generated in the operations; the waste management, however, is not assessed in the database, and only the wastes main characteristics are described; and,

- Under the fields “Others Aspects”, there are described other impacts foreseen by the application of each specific measure, the practical experience with the measure worldwide, references, and other aspects that may need to be considered in a decision-making process, such as the need for long-term control of the area, or optional variability on the main procedure according to specific characteristics of the area.

Psychological and other aspects related to public acceptance have also not been included as cultural differences are significant between Brazil and those countries where practical experience from Chernobyl accident are described in current literature. Also, the economic aspects are to be developed in a separate detailed work, mainly due to the large diversity of available resources depending on the type and the location of the affected area.

The overall structure of the database is described in Table 1.

Table 1: Structure of the database

General Aspects	Name of measure
	Surface where the measure is to be applied
	Type of measure
	Description
	Target
	Radionuclides for which the measure is effective
	Scale of application
Technical Aspects	Exposure pathways – processes affected that reduce exposure
	Moment of application (efficiency)
	Technical restrictions
	Effectiveness of the measure
	Factors affecting averted doses to the public
	Additional doses (e.g., dose to workers)
Infrastructure	Factors that may influence the efficiency
	Need for specific equipments
	Need for materials
	Need of skilled people and/or training
	Safety considerations
	Factors affecting costs
Wastes	Type
	Amount
Other Aspects	Other impacts
	Actual experience
	References
	Comments

3. RESULTS

The database contemplates 75 possible protective and remediation measures that may be applied to urban, rural and aquatic environments. The measures selected to be included in the database are described on Tables 2, 3 and 4. An example page of the database is presented on Table 5.

Table 2: Measures described for urban environments

Type of measure	Name of measure
1. Physical removal	Road planning
	Cutting grass
	Turf harvesting
	Pruning or removing trees and bushes.
	Top soil removal with coating material
	Top soil removal (manual)
	Top soil removal (mechanical)
	Removal of pavement stones and tiles
	Removal of roof tiles
2. Cleaning/Washing	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
	Washing roofs with high pressure water
	Cleaning of roofs with special cleaning devices
	Internal surfaces cleaning
3. Covering	Turning flagstones
	Covering areas with sand or soil
	Covering areas with cement or asphalt
	Triple digging
4. Diluting	Garden digging

Table 3: Measures described for aquatic environments

Type of measure	Name of the measure
Water	Provide alternative water source
	Treatment of the water
	Change of the water caption regime
	Controlled mix of the water
Fish	Prohibit fishing
	Limitation of the types and of the amounts of consumed fish
	Processing of the fish
	Provide uncontaminated pelleted feed
	Treat water and/or sediment
	Drainage of lakes and removal of top sediment layer

Table 4: Measures described for rural environments

Type of measure	Name of measure
Avoid contamination – Vegetables	Avoid direct contamination of agricultural products
	Harvest crops before contamination
	Cover cultivated areas with water impermeable sheeting
Avoid contamination – Animals	Prevent the ingestion of contaminated herbage by grazing animals
	Prevent animals eating highly contaminated feeds
Dilution	Normal ploughing; Deep ploughing
Removal of the Contamination	Removal of top soil layer
	Destroy animal products
	Prohibit of hunting and fishing; Consumption of vegetables; Water
Covering the contamination	Skim and bury
	Stabilization of soil surface to prevent resuspension
Change of use of the contaminated area – Vegetables	Selection of appropriate variety of agricultural product
	Selection of alternative agricultural product
	Cultivation of edible agricultural products that can be processed
	Selection of products that accumulate low radionuclide level
	Cultivation of non-edible products
Change of use of the contaminated area – Animals	Grow forage crops with lower tendency for contamination
	Use of the area for non-dairy animals or for animals not intended for immediate slaughter
	Alter animal species
	Deviation of products from human consumption to animal feed
	Processing milk for storable products
	Removal from contaminated areas/provide uncontaminated feeds
Treatment – Soil	Lime acid soils
	Apply sapropel (organic residues); Apply aluminosilicates
	Apply potassium fertilizers; Apply soluble phosphate fertilizers
Treatment – Animal	Supply of Prussian Blue in tablets for fast decontamination
	Supply low release Prussian Blue boli for slow decontamination
	Supply of Prussian Blue in salt-licks
	Supplement the diet with clay minerals or zeolites
	Increase of the fiber content of the diet
	Provide of high calcium diet
	Provide alginate with diet to reduce gut absorption
	Addition of stable iodine in the animal feed
Change of practice – Vegetables	Harvest crops and grass for discard or storage
	Delay the harvest of forage/crops
Change of practice – Animal	Increase of the height of the cut during when harvesting forage
	Change slaughter time
Monitoring control	Monitoring animals before slaughter

Table 5. Example database sheet

Type of area	**Residential/Urban**
Target surface	roads, walkways, other paved surfaces
Type of measure	removal/washing
Name	**Fire Hosing**
Objective	to reduce external dose in the área.
Description	Use of fire hosing equipment for removal of the contamination on horizontal paved surfaces. Water can be taken from a hydrant, if available, or from a river or lake.
Radionuclide	Cs
Scale of application	Can be carried out in densely populated areas of limited dimensions, where the equipment is more or less readily available.
Exposure pathway	External exposure
Time of application	Should be carried out as early as possible, within the first few weeks to have a significant effect, when the radiological situation is clear, but workers doses must be considered.
Technical restrictions	The waste is generally impossible to collect and must be led to the drains with the run-off water. Special care should be taken to avoid accumulating waste by the roadside.
Effectiveness	Reduction of contamination by typically 50-75% is normally achievable, if the procedure is carried out early. The effect is significantly reduced within a week after contamination due to fixation.
Technical factors affecting effectiveness	Amount of dust road at time of contamination; road surface type (particle size of dust); time of operation (fixation; also traffic removes much of the loosely held contamination thus reducing the effectiveness).
Required equipment	Hosepipe; petrol for pump, if required.
Required utilities	Water; petrol for pump, if required.
Required skills	The local fire brigade has experience that could be drawn upon, but also military/local inhabitants could perform the operation, given little instruction.
Safety requirements	Water-resistant clothing is recommended for strongly contaminated areas.
Factors affecting costs	Distance to equipment and consumables; need for a pump.
Waste amount	Typically some 100-200 g m^{-2} (contamination level ca. 5-10,000 Bq m^{-3} per Bq m^{-2}) of solid waste in some 0,25 m^3 m^{-2} of water.
Waste type	The waste is generally impossible to collect and special care should be taken to avoid accumulating waste by the roadside.
Factors affecting averted dose	Highly dependent on environment type. The method should not be considered if roads are not equipped with drains.
Additional dose	Depends on short-lived nuclides (time). The dose over a day to an operator may be 2-3 times higher than that to an individual living in the area.
Other impacts	–
Practical experience	Small scale tests conducted in Denmark and USA under varying conditions to exam the influence of, e.g., street dust loading
References	A1, B1, R3, R4, R7
Comments	–

4. CONCLUSIONS

This work is part of a larger project, devoted to emergency preparedness that has been developed in stages by IRD, since the Goiânia Accident. It is important for planning emergency responses after nuclear or radiological accidents in Brazil, especially in the surrounding areas of the Nuclear Brazilian Power Plants in Angra dos Reis (Rio de Janeiro).

The protective/remediation measures usually described in literature consider their efficiency in removing activity of a certain surface or environment. In order to determine their efficiency in the reduction of doses, the second stage is also being developed, involving the simulation of the implementation of the measures in different moments after the contamination, based on pre-defined accidents and scenarios. These simulations utilize tropical data from studies carried out in Brazil [23], which consider different characteristics from American or European data.

The effect of the measures, as a function of the type of environment (urban, rural, aquatic, forest) and of the moment of its application will be incorporate to a multi-criteria model to support the decision-making process after an environmental contamination event. This model is also being developed at IRD and later it will be able to work as a great tool for emergency response after this type of accident, avoiding not only unnecessary measures but spending of time for an appropriate response.

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