

## **PRIORITY OF AREAS FOR AGRICULTURAL COUNTERMEASURE ASSESSMENT**

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### **ABSTRACT**

Within the overall preparedness related to nuclear and/or radiological accidents that lead to the release of radionuclides to the environment with the consequent contamination of agricultural areas, the priority of research for agricultural areas should then focus on the surrounding areas of nuclear power plants that have higher probability of public exposure through the ingestion pathway. The objective of this work was to create a rank order of priority of agricultural products to be considered in assessing the effects of countermeasures, based on both economic value and doses to the public. Additionally, the study describes relevant needs of radioecological studies to improve short and long-terms dose assessments. Sixteen municipalities surrounding the Brazilian Nuclear Power Central were analyzed for a contamination with <sup>137</sup>Cs, considering seasonal aspects related to agricultural practices in the Southeastern Brazil. Rank order provided by considering economical aspects shows that there is a need for radioecological research for some high value products, such as palmetto and sugar cane, and the need to include in the current model more detailed description for some food items, such as eggs. Combined rank criteria shows that main product within the considered area is milk. As so, the study of countermeasures for the ingestion of milk should be prioritized.

### **1. INTRODUCTION**

The project on environmental modeling after a nuclear and/or radiological accident was set up since the Goiania accident in 1987 [1, 2]. Recent researches included the development of a remediation procedures database [3] and the creation of a multi-criteria decision tool to support decision-making processes after an event that lead to increased radionuclides concentration in the environment [4].

Under the project of radiovulnerability of soils, recent researches were the development and the application of a methodology to derive the vulnerability of soils to a contamination with Cs-137 [5, 6].

The methodology for classifying areas according to soil properties for the vulnerability to a Cs-137 contamination is of high importance to the preparedness related to nuclear and/or radiological accidents that leads to release of radionuclides to the environment with the consequent contamination of agricultural areas. The priority of research should then focus on

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the agricultural areas surrounding a nuclear power plant that have higher probability of public exposure through the ingestion pathway. The objective of a previous work was to create a rank order for priority of areas to be mapped based on Brazilian Research Company on Agriculture and Livestock – EMBRAPA database on soil properties. In this work, a rank order of priority is developed for those products leading to higher loss of income and higher collective doses from ingestion.

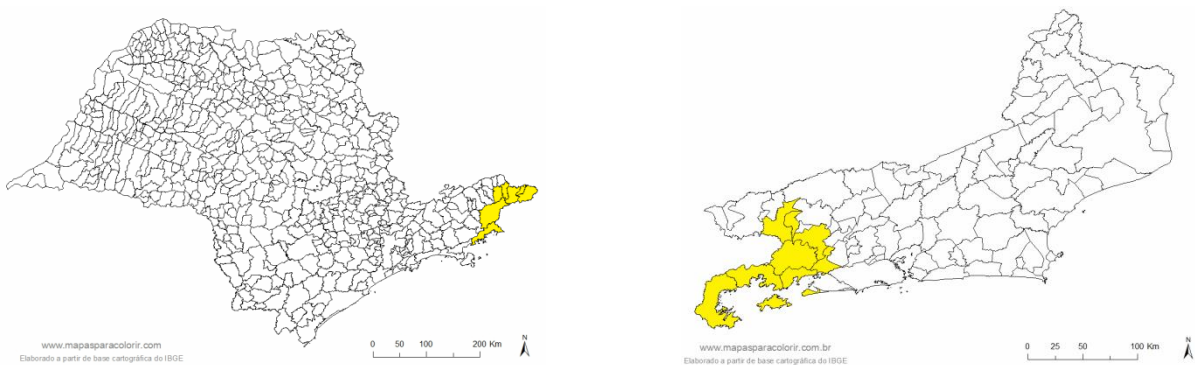
The priority defined in this study shall then guide research on both the validation of transfer factors and on the agricultural countermeasures adequate to each area according to the cause(s) of their vulnerability for the most relevant agricultural crops or animal derived products for these locations.

## 2. METHODOLOGY

The 16 municipalities previously selected to define parameters for dose assessment simulations related to the ingestion pathway for the Brazilian Nuclear Power Plants have been investigated in order to create this rank order to direct the research on radiovulnerability mapping considering their relevance to public exposure based on their agricultural productivity. The selection considered all counties within a 50 km distance from the NPPs [7].

The counties selected were (Figure 1):

- (i) State of São Paulo: Arapeí, Areias, Bananal, Cunha, São José do Barreiro, Silveiras, Ubatuba; and,
- (ii) State of Rio de Janeiro: Angra dos Reis, Barra Mansa, Itaguaí, Mangaratiba, Parati, Piraí, Resende, Rio Claro, Volta Redonda.



**Figure 1. Counties in São Paulo (on the left) and in Rio de Janeiro (on the right)**

For a same soil type, individual doses in agricultural areas, although depending on items produced in the counties, are not expected to be very different among different places [8], due to the high self-supporting condition of agricultural communities.

Collective doses however may be very different considering the productivity of the selected areas. Also, different production among different counties leads to very distinct income losses in case of discarding or banning food.

As so, two parameters were considered to create a rank order to prioritize research areas:

- (i) The cost of losing the production; and,
- (ii) The averted collective dose due to banning food one month after the accidental event.

Collective doses and financial values have been considered for the food items described in Table 1 below. The list does not reflect the whole agricultural products of each county as the costs considered did not include leafy and other vegetables that are not comprised in the agricultural survey provided by IBGE [9]. A complete database considering all the counties included in this work was not found in literature. However, although in different quantities, green vegetables are produced in almost all counties.

Collective doses are restricted to food items while economic value included all products from each county, i.e., vegetables including sugar cane used for the production of alcohol used as fuel, animal products, and silviculture products such as coal, firewood and roundwood.

Information on agricultural production and prices were taken from IBGE [10]. For the estimates on collective doses, the program SIEM [11] was used to assess food concentration one month after accident occurring. The same accident was simulated as it had happened in February, May, August and November, in order to cover seasonality aspects of the ingestion dose.

For Cs-137, the value of  $1.3 \times 10^{-8}$  Sv/Bq was used for the ingestion dose conversion coefficient for adults [12]. Collective dose was estimated multiplying the food concentration by the county production and by the dose conversion coefficient.

### **3. RESULTS AND DISCUSSION**

#### **3.1. Factor: Loss of Income due to Discard of Products**

The rank order for the products is presented on Table 1. Considering the financial loss from the discard of products for the whole study area, the five most relevant products are cow's milk, banana, wood in logs, sugar cane and coconut. From these products, only cow milk is a relevant item to population diet; individual intakes of bananas and coconut are much lower. However, for producing counties, the loss of income of any of these products would be significant.

The updated rank order for the counties is presented on Table 2. Considering the absolute values for the whole county production, it can be seen that the highest income loss will be for Cunha (SP), followed by Rio Claro (RJ) and Pirai (RJ).

**Table 1. Total value of food and forestry products produced in the study area [10]**

<b>Product</b>	<b>Total (Thousand of R\$)</b>
Cow's milk	134,100
Banana	36,769
Forestry products - Wood in logs	7,345
Sugar cane	5,287
Coconut	4,581
Cassava	4,048
Forestry products - Charcoal	3,842
Forestry products - Firewood	2,929
Corn	2,770
Palmetto	2,739
Beans	2,064
Honey	1,345
Chicken eggs	1,037
Guava	856
Tomato	342
Orange	340
Potato	217
Lemon	146
Mango	128
Persimmon	104
Coffee	96
Quail eggs	61
Passion Fruit	36
Rice	28
Tangerine	9
Sorghum	2

### **3.2. Factor: Collective Doses from Ingestion**

Ingestion doses depend on the season of the year when the contamination occurs. Considering the products grown on the whole study area, the three most relevant products for each season is presented on Table 3. Due to the high production and to habits of typical tropical climate areas, it was considered that the animals are fed by fresh pasture during the whole year, and milk was the main product contributing to collective doses at all seasons.

**Table 2. Total value of products from each county**

County	Total (Thousand of R\$)
Cunha	25,545
Resende	24,926
Barra Mansa	23,980
Itaguaí	22,081
Rio Claro	17,391
Mangaratiba	15,651
Bananal	14,778
Silveiras	13,335
Areias	12,742
São José do Barreiro	11,746
Arapeí	6,484
Piraí	6,470
Volta Redonda	5,543
Parati	5,535
Angra dos Reis	4,721
Ubatuba	293

**Table 3. First year collective dose after a deposition of 1 kBq/m<sup>2</sup> of Cs-137 (Sv)**

Deposition	Tubers	Beans	Cereal	Other veg.	Leafy veg.	Fruits	Milk	Chicken	Meat
Spring		1.65		0.02	0.45	2.53	6.37	0.00	0.97
Summer			1.18	0.01	0.45	2.24	6.37	0.00	0.97
Autumn	1.17	1.66	1.18		0.45		6.37	0.00	0.97
Winter	1.17	0.00	0.00		0.45		6.37	0.00	0.97

As a consequence, rank order for counties closely follows annual milk production. The five counties included in this study, which deal with larger absolute values on their agricultural products, are Cunha, Barra Mansa, Resende, Rio Claro and Bananal. Once again, the Cunha county leads the rank order for the municipalities. Values are not shown because the list was derived from seasonal individual lists.

### 3.3. Combined Rank

Most relevant product to perform radioecological studies aiming a better knowledge on long-term behavior on tropical climate soils is cow's milk, followed by fruits (mainly banana) and manioc.

Combining both factors described on items 3.1 and 3.2, Cunha would be the most relevant county to develop radioecological studies regarding soil characterization, soil-plant transfer factors and air-grass-cow's milk pathway. After Cunha, Barra Mansa and Resende have shown the higher rank values among the studied counties.

#### 4. CONCLUSIONS

Decisions on countermeasures related to agricultural areas is by far more complex than those ones for an urban area contamination. There is a strong influence of the season of the year on doses received due to the ingestion of crops and animals products from a specific area. Besides that, soil type has a strong influence on the transfer of deposited radionuclides to plants. There is a need to establish standard scenarios for assessing the effect of procedures aiming to reduce doses after an accidental contamination. In order to be able to create a standard scenario for a Cs-137 deposition, radioecological studies need to be performed. This work tried to prioritize such studies based on the relevance to loss of income to the county due to loss of production and locations and products leading to higher collective doses.

Considering the counties within a 50 km radius from the Brazilian Nuclear Power plants, we would suggest to develop radioecological studies with priority for milk, bananas and manioc at the counties of Cunha (SP), Barra Mansa (RJ) and Resende (RJ).

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