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PRIORITY OF AREAS FOR AGRICULTURAL RADIOVULNERABILITY MAPPING

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ABSTRACT

The methodology for classifying areas according to soil properties for the vulnerability to a ^{137}Cs contamination is of high importance to the preparedness related to nuclear and/or radiological accidents that lead to 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 plant that have higher probability of public exposure through the ingestion pathway. The objective of this work was to create a rank order for priority of areas to be mapped based on EMBRAPA database on soil properties. The 16 municipalities previously selected to define parameters for dose assessment simulations related to the Brazilian Nuclear Power Plants, located in the district of Angra dos Reis, Rio de Janeiro, 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 two aspects selected in this study account for the maximum loss of income and to the collective doses that can be averted due to the banning of agricultural

products. These quantities are inputs to optimization analysis. The priority defined shall then guide research on both the adequate values for the transfer factors and on the agricultural countermeasures suitable to each area according to the cause(s) of their vulnerability and their typical agricultural crops.

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 ^{137}Cs [5, 6].

The methodology for classifying areas according to soil properties for the vulnerability to a ^{137}Cs contamination is of high importance to the preparedness related to nuclear and/or radiological accidents that lead to release of radionuclides to the environment with the consequent contamination of agricultural areas. The priority of research should then focus on the agricultural areas surrounding a nuclear power plant (NPP) that have higher probability of public exposure through the ingestion pathway. The objective of this 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.

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 and of the typical agricultural crops 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.

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.

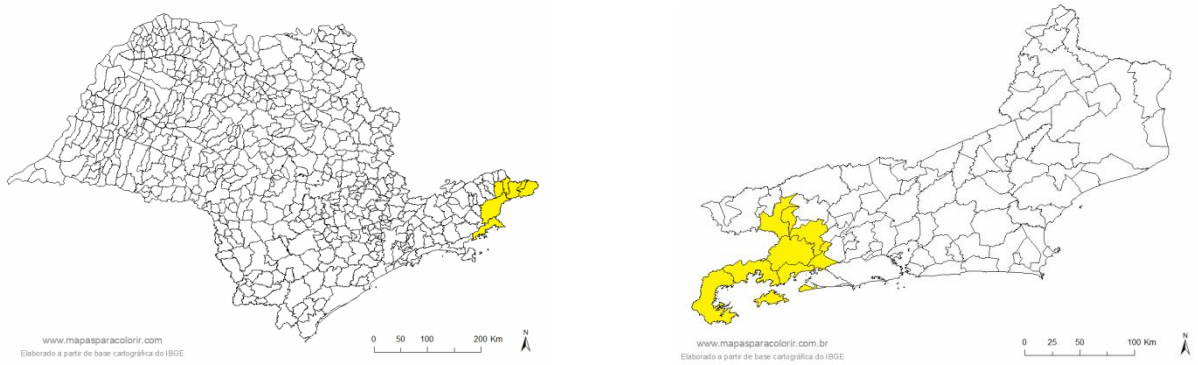

Figure 1: Counties in São Paulo (on the left) and in Rio de Janeiro (on the right).

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.

Information on agricultural production and prices were taken from IBGE [9]. For the estimates on collective doses, the program SIEM [10] was used to assess food concentration one month after the accident occurrence. 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.

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 included leafy and other vegetables that are not comprised in the agricultural survey provided by IBGE [11]. 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.

The list of items included in the cost analysis is presented on Table 1. Those items marked with a (*) were included in the dose assessment, as this was restricted to food items for which the parameters needed to perform the dose assessment are available and were included in SIEM.

Table 1: Food items considered in this study.

Permanent crops		**Temporary crops**	**Animal products**	**Other products**
Banana*	Sleeve*	Rice*	Cow's milk*	Charcoal
Coffee	Passion fruit*	Sugar cane	Chicken eggs*	Firewood
Coconut	Palmetto	Bean*	Quail eggs	Roundwood
Guava	Tangerine*	Cassava*	Honey	
Orange*		Corn*		
Lemon*		Tomato*		

For ^{137}Cs, the value of 1.3×10^{-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

Table 1 summarizes agricultural production for each county selected for this study. Table 2 presents the results for the costs associated to agricultural products of each county; these values were estimated based on the amount produced and on the price associated to each agricultural product. Table 3 shows the results for collective doses associated to each county, based on average food concentration obtained from simulations for 1 month after the accident, for accidents occurring at different seasons of the year.

Table 1: Production of food items for each county (t/y and 1000 L/y for milk).

County	Banana	Other fruits	Cereal and grains	Beans	Roots and tubers	Other vegetables	Milk
Arapeí	98	100	64	30	132	0	4300
Areias	150	0	125	30	60	0	7300
Bananal	75	75	750	30	80	0	8311
Cunha	0	0	9899	902	178	149	15414
São José do Barreiro	300	150	250	8	96	0	4370
Silveiras	110	477	300	110	400	50	5840
Ubatuba	0	0	0	0	0	0	0
Barra Mansa	108	170	72	8	130	160	24791
Resende	480	0	330	75	1200	0	20000
Volta Redonda	66	75	16	3	63	0	2120
Rio Claro	4680	0	240	180	100	90	13093
Piraí	1260	0	0	27	217	120	5124
Mangaratiba	26190	935	0	5	640	0	549
Itaguaí	21000	7320	0	0	1820	0	1345
Angra dos Reis	4800	251	0	3	728	0	228
Parati	4801	144	0	0	792	0	149

Source of data: IBGE [11].

Table 2: Values for production for each county (thousand reais).

State	*County*	*Banana*	*Other fruits*	*Cereal and grains*	*Beans*	*Roots and tubers*	*Other vegetables*	*Wood products*	*Milk*	*Eggs*	*Honey*
Rio de Janeiro	Angra dos Reis	3024	127	0	11	647	4056	0	182	79	78
	Barra Mansa	35	69	108	0	91	412	326	19833	360	72
	Itaguaí	13650	4653	0	0	1001	360	0	1076	59	136
	Mangaratiba	11785	436	0	12	384	653	0	440	16	10
	Parati	2304	93	0	0	514	2913	0	119	125	20
	Piraí	378	0	8	43	162	483	650	3331	78	274
	Resende	624	0	102	78	1200	1202	418	20000	27	224
	Rio Claro	1544	0	91	360	70	423	286	10998	153	82
	Volta Redonda	21	34	6	4	44	285	1282	1738	113	32
São Paulo	Arapeí	63	52	17	41	39	177	19	3682	27	130
	Areias	75	0	38	66	30	92	2450	6251	22	0
	Bananal	28	41	210	72	32	60	302	7117	67	43
	Cunha	0	0	4233	1109	109	287	1176	13200	36	130
	São José do Barreiro	154	70	66	34	46	90	24	3742	14	4
	Silveiras	44	190	135	234	196	74	11133	5001	53	115
	Ubatuba	0	0	0	0	0	2352	0	0	0	0

Table 4. Collective doses due to the ingestion of food produced 1 month after the accident for 1 year production (Sv).

County	**Banana**	**Other fruits**	**Cereal and grains**	**Beans**	**Roots and tubers**	**Other vegetables**	**Milk**
Arapeí	0.03	0.01	0.06	0.16	0.27	0.00	1.21
Areias	0.04	0.00	0.11	0.16	0.12	0.00	2.06
Bananal	0.02	0.01	0.69	0.16	0.17	0.00	2.35
Cunha	0.00	0.00	9.10	4.68	0.37	0.02	4.35
São José do Barreiro	0.08	0.02	0.23	0.04	0.20	0.00	1.23
Silveiras	0.03	0.06	0.28	0.57	0.83	0.01	1.65
Ubatuba	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Barra Mansa	0.03	0.02	0.07	0.04	0.27	0.02	7.00
Resende	0.13	0.00	0.30	0.39	2.50	0.00	5.65
Volta Redonda	0.02	0.01	0.01	0.02	0.13	0.00	0.60
Rio Claro	1.23	0.00	0.22	0.93	0.21	0.01	3.70
Piraí	0.33	0.00	0.00	0.14	0.45	0.02	1.45
Mangaratiba	6.88	0.12	0.00	0.03	1.33	0.00	0.16
Itaguaí	5.51	0.96	0.00	0.00	3.79	0.00	0.38
Angra dos Reis	1.26	0.03	0.00	0.02	1.51	0.00	0.06
Parati	1.26	0.02	0.00	0.00	1.65	0.00	0.04

Table 5: Rank order for cost and dose criteria and final ranking.

County	Rank for cost	Rank for dose	Sum	Final rank priority
Cunha	1	1	2	1
Itaguaí	2	2	4	2
Resende	3	3	6	3
Mangaratiba	4	4	8	4
Barra Mansa	5	5	10	5
Rio Claro	6	6	12	6
Silveiras	7	7	14	7
Parati	8	9	17	8
Bananal	10	8	18	9
Angra dos Reis	9	10	19	10
Areias	12	11	23	11
Piraí	11	12	23	11
São José do Barreiro	13	13	26	12
Arapeí	14	14	28	13
Volta Redonda	15	15	30	14
Ubatuba	16	16	32	15

It is suggested that the soil type and associated remediation procedures are performed following this rank order, and that at least the six counties with highest ranking should be investigated in more detail, according to the procedure developed to define radiovulnerability for the radionuclide ^{137}Cs and to assess the relative relevance of remediation procedures.

It is important that this assessment must be carried out in conformance with the degree of vulnerability, the cause of such vulnerability and the type of agricultural products available, and the efficiency of countermeasures in the existing agricultural systems.

4. CONCLUSIONS

It was performed a comparison of costs associated to the ban of agricultural products and of collective doses due to ingestion of food, in order to create a rank order for guiding the priority on performing specific assessment for the 16 counties previously selected to be used in emergency preparedness related to the ingestion emergency zone for the Brazilian Nuclear Power Station, located in Angra dos Reis, Rio de Janeiro.

The two aspects select account for were the maximum loss of income and the collective doses that can be averted due to the banning of agricultural products. Both quantities are inputs to optimization analysis.

With this rank order, soil vulnerability studies shall be performed aiming to develop a methodology to be used in support to this emergency preparedness for nuclear and radiological accidents that includes environmental dispersion of radionuclides with the consequent exposure of members of the public.

It must be stated, however, that individual doses are to be seen as priority under accident conditions but these are specific for site, moment and release and must be assessed as so.

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