Remediation Following the Goiania Accident

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Relevant Facts

- **Cs -137 teletherapy unit left in an abandoned clinic due to a legal dispute (1985)**
- **Regulator was not notified as established in the authorization issued in 1971**
- **Due to rumors about a valuable lead equipment, the source unit was stolen on Sept 13th, 1987**
- **Equipment was dismantled, sold to a junkyard and the source capsule opened and enjoyed its brilliant light by others (Sept 13 – 21, 1987)**
- **The Regulator, National Nuclear Energy Commission, was informed on Sept 28th - two weeks after the theft of the source**
- **50.9 TBq of 137Cs in the form of CsCl powder were released and spread throughout the urban environment**

Summary of the initial actions (emergency phase)

- **In the first screening made in the city, several sites and residences at the urban area (1km2) had elevated dose rates of ionizing radiation:**
  - **Isolation and evacuation of the area**
  - **Monitoring and treatment of the most exposed people**
  - **Decontamination/demolition of houses**
  - **Reconstruction of areas**
- **The inhabitants were removed to the Olympic Stadium of Goiania, where the first screening of the population was done.**

Hard initial works and social disruption

- **159 houses monitored, 101 houses contaminated**
- **200 persons evacuated from 41 of them**
- **42 decontaminated, 6 demolished & 53 recuperated**

Remediation of Hotspots

torrential rain → contamination was spread → deep layers of soil were contaminated

- **Removal of top soil layers and concrete cover:**
  4 sites

- **Removal of the top soil layers and soil cover:**
  1 site

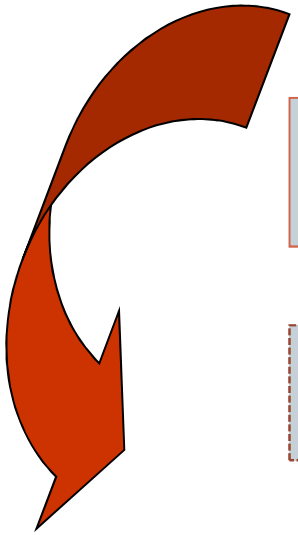
High level of anxiety amongst the public + time and resources consuming remedial actions

Restricted use

Recovery Phase: 3 months later

REMEDIATION FOR NONRESTRICTED USE OF THE LAND (PUBLIC AND PRIVATE)

MAIN CONSTRAINS

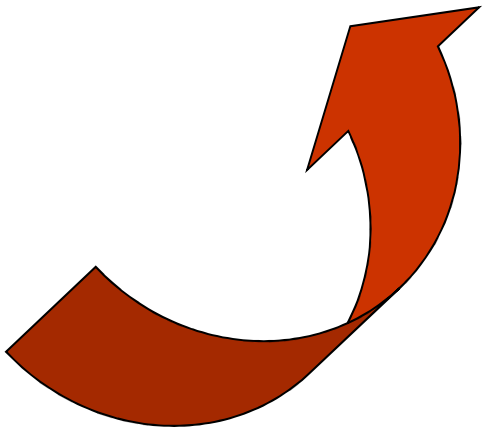


POLITICAL AND SOCIAL PRESSURE

RADIATION PROTECTION CRITERIA NOT AVAILABLE

LACK OF SITE SPECIFIC INFORMATION

DOSE CRITERIA AND ASSESSMENT VERY CONSERVATIVE



Radiation Protection Criteria

- **CNEN regulation: (CNEN-NE-3.01)**
- **1 mSv/a for members of the public (ICRP 26-practices)**
  - ADOPTED CRITERIA
  - **5 mSv in the first year**
  - **1 mSv/a lifetime average (70 years)**

Exposure Pathways

- Gamma exposure indoors
- Gamma exposure outdoors
- Internal dose
  - **Inhalation of resuspended soil**
  - **Ingestion of home grown vegetables, fruits, pork, poultry and eggs**

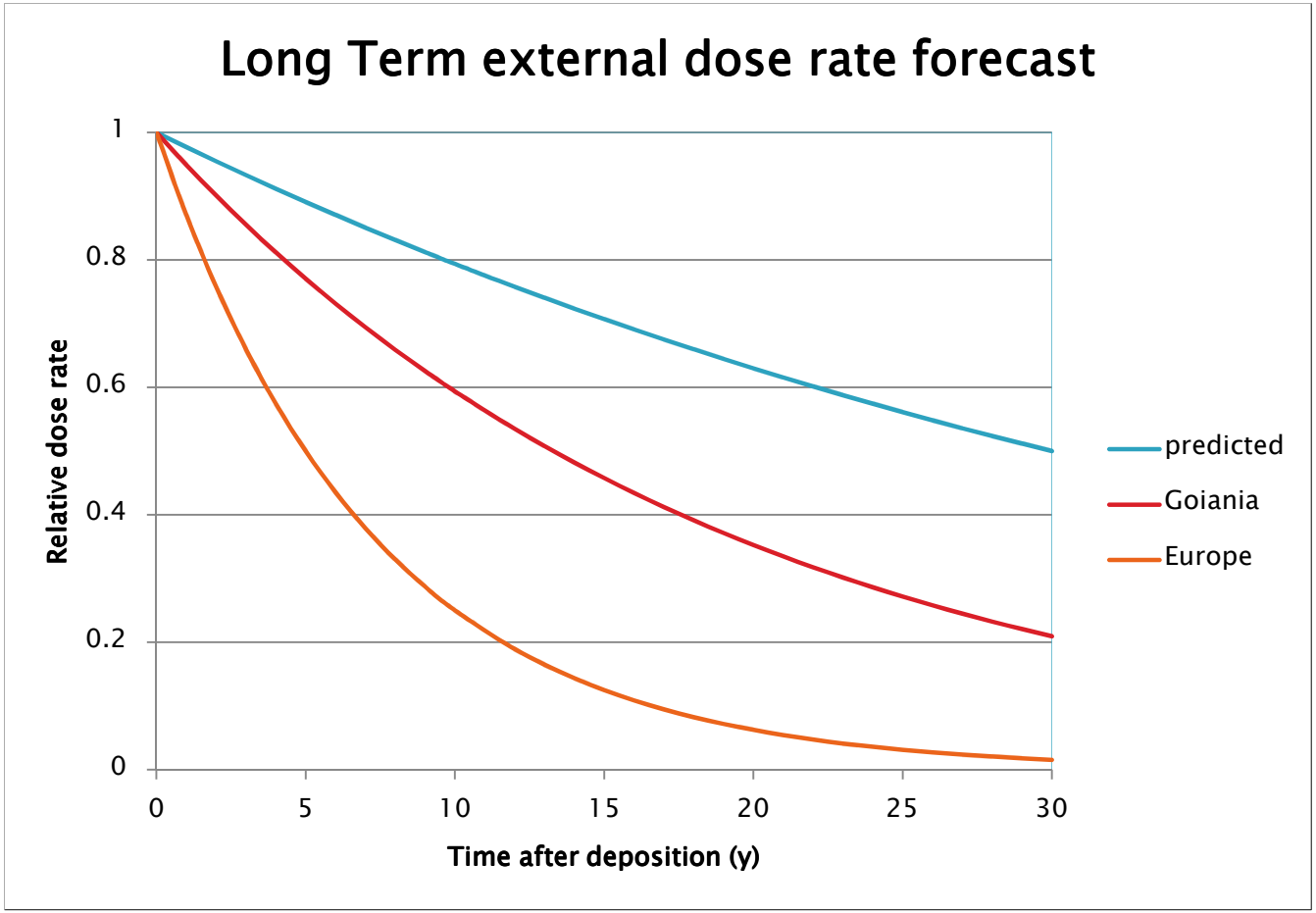
  - **Obs 1: vegetables being contaminated by root uptake and deposition of resuspended soil**
  - **Obs 2: pork being contaminated by ingestion of nonleafy vegetables (20% of diet) and chicken only by ingestion of soil**

Operational Criteria

- 1 mSv/a – gamma exposure indoors:
  - 0,5 μSv/h and 37 kBq/m^2 surfaces contamination;
- 3 mSv/a – gamma exposure outdoors
  - 1 μSv/h and 22,5 Bq/g in soil (upper 2cm layer)
- 1 mSv/a – internal dose
  - Home garden: it was reached when soil was removed to comply with gamma exposure criteria
  - fruits: 0,65 Bq/g

87Bq/g reference level for nonradioactive waste at that time – but the concept of clearance level did not exist

Removal of surface soil


Long Term external dose rate forecast
Relative dose rate
1
0.8
0.6
0.4
0.2
0
0
5
10
15
20
25
30
Time after deposition (y)
predicted
Goiania
Europe

Inventory of waste after 15 years

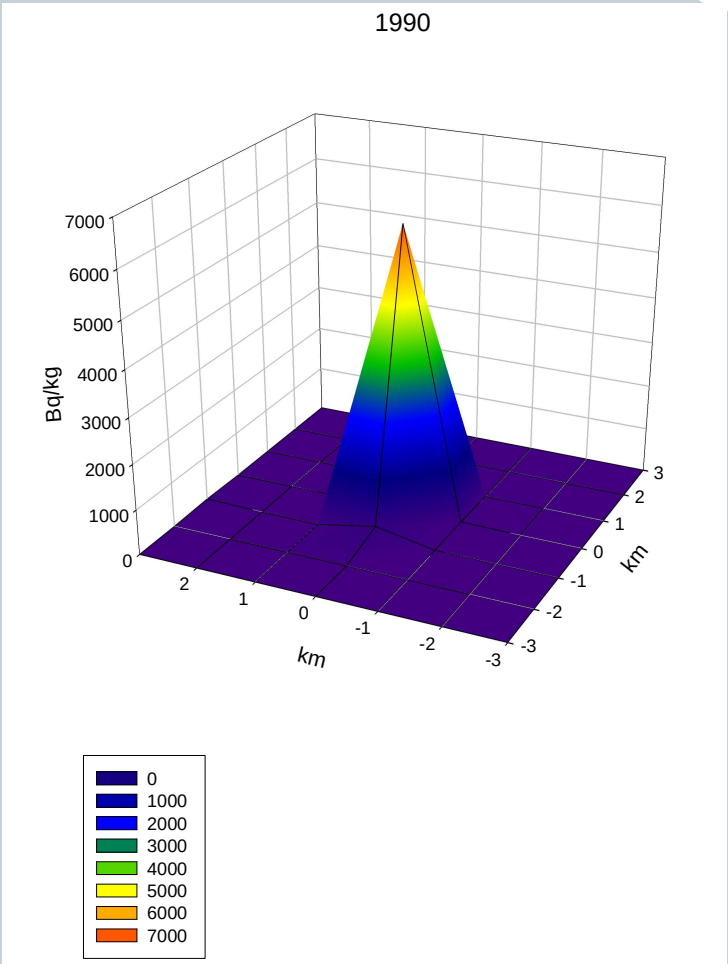
Waste Group	Time to reach 87 Bq g^{-1}	metalic boxes	drums	Volume (m^3)	Activity (TBq)
1	0	404	2710	1231	0.06
2	> 0 - 300 y	918	1511	1862	15.59
3	> 300 y	25	2	42	30.06
Total		**1347**	**4223**	**3136**	**45.71**

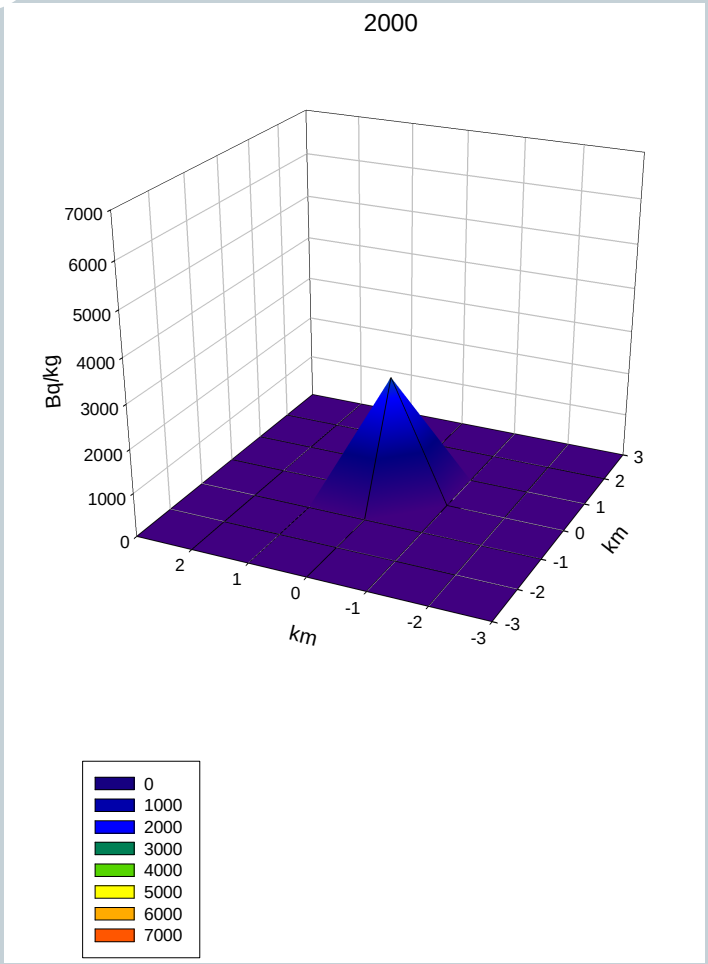
Research on Cs Spreading

- **Dose assessment probabilistic simulation have shown:**
  - **the external dose the main contribution to the dose uncertainty (external occupancy ratio)**
  - **Soil resuspension factor and the parameter related to soil concentration profile would help to improve the uncertainty**

- **Research on Cs spreading from surface soil was conducted: Goiania Project**

Behaviour of street dust





Challenges Faced during and after the Recovery Phase

- Lack of policy and strategy for remediation of contaminated areas and continuous follow up monitoring
- Lack of radiation protection criteria for remediation, for re-use and recycle of contaminated material, absence of clearance values
- Lack of information on dynamics of environmental behavior of radionuclides in urban environment
- To convince the local population that the recovery phase is necessary but they have not been in risk for so long after the emergency period
- To explain the local population that there is no need to leave the environment cesium free
- To conduct follow up studies although refused by the local population since they want to forget the event

Lessons learned during and after the recovery process

- Soil profile is a good method for determining the soil layer to be removed - 60% in average upper 1.5 cm soil layer - avoiding the jointly removal of big amounts of clean soil
- The amount of removal material was seen by the population as proportional to the risk they have been exposed to and this shall be avoided
- Further construction processes and urban services bring back to surfaces formerly buried contaminated material
- Lack of remediation criteria together with lack of site specific information lead to the use of conservative approaches and generation of unnecessary public stress, waste and costs
- Need for research to make available information of the main environmental parameters for each type of climate (the weathering half-life is much bigger in Europe than was shown in Goiania)

Conclusions

- Need of a policy and strategy for remediation of contaminated sites including the management of generated waste (it should be part of the waste management policy and strategy);
- Need of robust legal framework with clear radiation protection criteria for each type of exposure situation;
- Approval by the Regulatory Authority of possible remediation options, including the re-use and recycling of contaminated material;
- Need of radioecological research to characterize main features of country's environments such as soil type, building material properties, weathering processes;

Conclusions (cont.)

- Removal of surface soil layers should be done carefully and according to the soil profile results to avoid removal of large amounts of “clean” soil;
- Care must be taken with remediation strategies that do not physically remove the contamination from long-term accessible environments;
- Involvement of local people in tasks associated with remediation is very important to get information and gain confidence;
- Involvement of local people, governmental and non-governmental organizations are key for a good decision on strategies to be adopted.

Still left some concerns…

- **Unforeseen uses of decontaminated areas (restricted use)**
- **Urban maintenance at or close to released areas**
- **Population concerns on long term effects**

General Final Remark

- **Environmental remediation of contaminated areas is not clean up but reduction of exposure to radiation, whatever the reason and type of source. But some technical, political and social constraints and concerns can risk remediation becoming effective.**

- **How to minimize this risk and avoid improvisation?**

  - A consistent plan for remediation of contaminated areas
  - Approval in advance by regulator of possible remediation strategies (not only clean up)
  - A communication plan together with an education strategy
  - A well trained inter-agency team
  - A good follow up plan