Evaluating the sustainability of sites for nuclear facilities under the effects of climatic changes on variability of the effective dose to the representative person

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1. Background and Goal of the present work

Regarding the sustainable development, the climate change impacts should be considered, supporting policy making and planning for both adaptation and mitigation.

Despite the cooling impact of the La Niña event, which extended from 2020 to 2023, the last eight years were the warmest on record since 1850. Beyond the droughts, floods and heat waves observed all over the world, it was also detected that the Antarctic sea ice reached its lowest extension in 2022. The projections show that the melting of glaciers and the sea level rise will continue for long time.

The climatic changes impact the environmental compartments on different ways causing complexity and extreme events more frequently. Compared to the surface temperature, the precipitation is characterized by higher spatial and temporal variability.

Two actions are needed to face the climate changes: the mitigation and the adaptation. Regarding adaptation, we should consider how the climate changes will affect us, simulating possible scenarios and evaluating their results. To mitigate, efforts must focus on the reduction of the greenhouse gas emissions, through technological improvements.

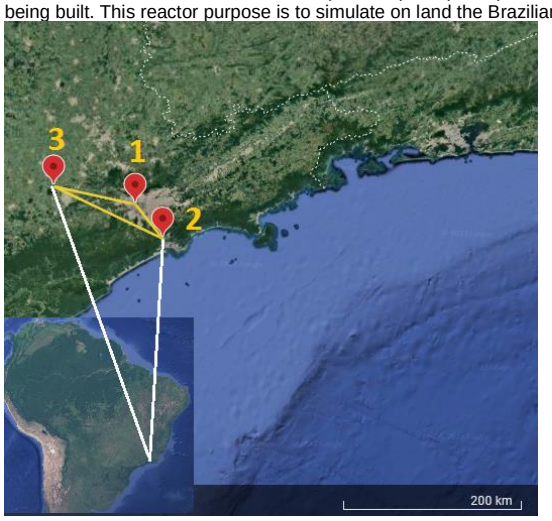
Such as in the rest of the world, Brazil has been affected by extreme weather events, which among others, impact the energy resources, since its main matrix is based on hydrological resources. Brazil is gradually increasing renewable energy sources, like solar and wind. Simultaneously, there are some initiatives to develop the nuclear activities. On this way, it is necessary to evaluate the impacts of the climate changes to the sustainability.

In this work, we proposed six different scenarios to evaluate how climate change could impact the Effective Dose (ED) to the representative person on the Aramar surroundings.

2. Methodology

2.1. Site

Aramar is a CTMSP nuclear complex at Iperó (Brazil), where a nuclear reactor is being built. This reactor purpose is to simulate on land the Brazilian Nuclear Submarine.



Iperó (pin 3) is around 90 km away from São Paulo city (pin 1) and 130 km away from Cubatão (pin 2) - Brazil

2.2. Model

- CAP88-PC Version 4.1 (US-EPA)
  - Conservative scenario (consumed foods are locally produced)
  - Population age: 15 years
  - Built time: 100 years

2.3. Data

CAP88-PC was run for the climatological means and their deviations (Table 1) and 3 years of local observational data (wind and temperature).

Table 1: Inputs and simulation list

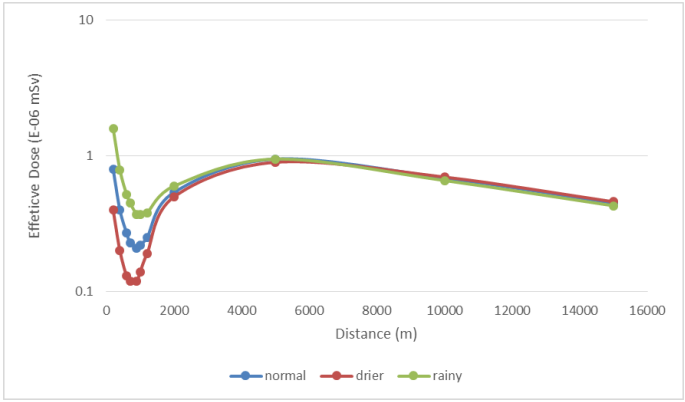
	Experiment						
	1 (Climatological Means)	2	3	4	5	6	7
PBL height (m)	1000	100	2000	1000	1000	1000	1000
Annual Temperature (°C) and Absolute Humidity (g/m³)	20.8; 13.5	20.8; 13.5	20.8; 13.5	15; 7.4	25; 17.5	20.8; 13.5	20.8; 13.5
Annual Precipitation (mm)	1330	1330	1330	1330	1330	665	2660

- Source term: estimated;
- Releases: normal operation (full time) by a 85 m chimney.

3. Results

Considerations:

- The experiments 2 and 3 represent a strong variability in comparison to the climatological value (-90% and +100%, respectively);
- The temperature was decreased (increased) by 5 °C (Experiment 4 and 5);
- The experiments 6 and 7 present more realistic scenarios compared to the previous (Experiments 2 – 5);
- The CAP88-PC only reported impacts to the Experiments 6 and 7;
- ED is reported only to the north sectors (the highest value)



ED estimates for the normal, drier and rainier scenarios (Experiment 6 and 7)

- Until 900 m away from the source: only ingestion (~27%) and ground surface (~73%) pathways contribute for ED;
- For distances greater than 900 m, the inhalation and air immersion also contribute. ED increases;
- ED increasing rate is faster for the drier scenario (distance > 900 m), since the airbone radionuclide availability is greater than for the normal and rainier scenarios;
- At 5 km away from the source, the ED is the same for the three scenarios and the ingestion is the main pathway (~74%);
- Even under normal or extreme scenarios, the ED is around 10^{-6} times lower than annual restriction value (0.3 mSv)

4. Conclusions and Acknowledgements

- The evaluation of the meteorological variables showed us that the rainfall variability produced more impacts on the effective dose.
- The impact is limited to a distance of 5 km from the source.
- On rainier scenarios, more radionuclides become available over surface, thus, the impacts over the water bodies should also be investigated.
- Only atmospheric releases were considered. The impacts due to liquid effluents remains as a suggestion for future work, since the river flow rate will also change.
- Even under conservative hypothesis, the ED remains lower than the dose restriction established by the national authority.
- The ESTE code, which is being implemented through IAEA mission, will improve the ED estimate, contributing to the sustainability of the nuclear activity and the Brazilian development.
- As rainfall presents high spatial and temporal variability, we recommend for new Brazilian facilities, that local observational data should be employed on the estimates, since the mesoescale phenomena have large impacts over the tropical and subtropical climate.
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