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Risk assessment of possible hazards of Dabaa nuclear power plant using FLEXPART model

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Abstract: New Nuclear Power Plant (NPP), which is under construction in Dabaa–Egypt, is expected to start working within few years. Such project should be associated with several scientific research works. The suitability of the NPP location as well as the assessment of the impact of its routine work and accidental failure is among the points that should be addressed. In this work the contamination risks due to uniform accidental leakage, of the radioactive aerosol ^{137}Cs, that continue for eight hours is studied. FLEXPART version 10.4 at high resolution (55 km) is applied using six hours NCEP FNL (1°x1°) gridded data to simulate the dispersion and deposition of ^{137}Cs for the subsequent five days. This process is repeated each day for the period 2008 to 2018. It is shown that high concentration and total deposition are observed particularly during the summer season. Also, considering different emission scenarios indicate that Egypt is expected to be strongly affected. Also, dispersion and concentration of the radioactive materials is notably influenced by near-surface winds (which are driven by both large-scale weather systems; e.g., the monsoons. In conclusion, FLEXPART is considered as a promising tool to explore the possible nuclear hazards under a variety of meteorological conditions. Further, a future study will consider the influence of the horizontal grid spacing and lateral boundary condition using the coupled Weather Research and Forecasting (WRF)-FLEXPART system.

Keywords Accident scenario; atmospheric dispersion; FLEXPART; risk assessment; total deposition

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1. Introducion:

In 2021, the total nuclear electricity production was about 2653 TW/h around the world [2], which amounts to 15% of global electricity production [1]. Egypt is building a nuclear power plant at Dabaa (on the Northwest Coast) as an alternative source of energy. Since the beginning of obtaining power from the nuclear energy plants, fear of nuclear contamination has been associated with them. Chernobyl () and Fukushima () are examples of serious nuclear accidents. Risk assessment of a radioactivity contamination is necessary for decision-makers in order to plan precautions and enhance safety measures. These assessments include the estimation of the concentration and total deposition of released radioactive material to the surroundings. One of most known risk assessment methodologies is the Probabilistic Risk Assessment (PRA). PRA identifies the contribution of every weather situation to the overall risk and it has been used [4] over Europe to identify possible risks from nuclear reactors under study. The purpose of the present study is to identify the possible risks from a hypothetical accident at Dabaa using the FLEXPART model. This paper is organized as follows: the Data and methodology are presented in Sect. 2, the Results in Sect. 3 and the Conclusions and Discussion of the results are in Sect. 4.

2. Materials and Methods

2.1. Study Area

Dabaa is located on the north coast of Egypt (fig.1). It lies 296 kilometres (184 mi) from Cairo on the north coast and is served by the El Alamain International Airport(which is chosen to be as a location of a new nuclear reactor). Also, Dabaa is characterized by an average Wind Speed (at height 10 m) from 5 to 8 m/s during all season with the highest record in the winter season (between 7.5 to 8 m/s).

2.2. Model Description and Experiment design

One degree 6-hourly NCEP FNL (Final; Operational Global Analysis data are on 1-degree by 1-degree grids prepared operationally every six hours)) data is used to drive the FLEXPART model. [5].

Dispersion of radionuclides has been studied with the aid of both Eulerian and Lagrangian models. Lagrangian particle models compute trajectories of a large number of so-called particles to describe their transport and diffusion in the atmosphere. The main advantage of Lagrangian models over Eulerian models is the absence of numerical diffusion. Furthermore, in Eulerian models a tracer released from a point source is instantaneously mixed within a grid box, whereas Lagrangian models are independent of a computational grid and have infinitesimally small resolution

In the current study, the Lagrangian Flexible particle dispersion model (FLEXPART version 10.4) is used to simulate transport, diffusion, dry and wet deposition of the radionuclide 137Cs. [6]. Near-ground concentration and total deposition of 137Cs radionuclides were calculated in the period 2008-2018.

In FLEXPART (forward mode), the radionuclide concentration is calculated as:

$$C_{T_c} = \frac{1}{N}\sum_{i=1}^{N} C_{T_s}$$

Where C_{T_c} is the output concentration at time Tc, while Ts is the sampling interval and N is the number of samples [8].

Our study assumes a constant total emitted mass of 1000 kg of 137Cs in 8 hours. Upon radioactive release, the model simulates its dispersion and deposition for five days in the future for each day during the period 2008- 2018.

The modular approach was adopted by flexRISK. A catastrophe model integrates assessments of the probability of a specified hazard in a particular geographic region. In order to provide an output of the probability of losses exceeding a certain level, catastrophe modelers use two different approaches: 1) deterministic and 2) probabilistic. The probabilistic modelling technique runs many hypothetical events covering a range of possible outcomes. This allows the modeler to assess the probabilities and severity of loss and to create a distribution of probabilities, which makes it possible to identify the contribution of every single reactor and every weather situation to the overall risk this study. [4].

For release shape, one dispersion calculation is done using 137Cs as an example. FLEXPART allows to specify a release as a vertical column. This is used to implement an effective release height, as FLEXPART has no mechanism for calculating an effective release height from heat flux and ambient meteorological conditions. The effective release height is not assumed as a single height but as a height interval.

3. Results

The wind is stronger in both winter and spring (Fig. 2) and the direction is generally northwest to north. Winter is characterized by the passage of the Mediterranean cyclones on their way to Eastern Mediterranean with the westerly to northwesterly winds follow the passage of the cold front. These systems also bring most of Egypt rain to the North Coast. Spring is different in that the weather is hotter and the country is affected by the thermal Saharan cyclones, which mostly originate south of the Atlas Mountain Range. These cyclones are fast and cause a considerable change in the temperature and wind along their paths. Also, we investigated the influence of time scale (seasonal average versus daily accumulation) on dispersion of Cs-137. The winter season was selected (as an example) taking into account two time periods (Figure 5a, b) for further investigation. From figure 4, it can be noted that accumulation of 5-days of Cs-137 is projected toward North-east in both time periods (Figure 4a,b). Also in Figure 3, calculating the seasonal climatology eliminates the variability of the Cs-137 concentration and shows that the Cs-137 concentration pattern is restricted to the area of the emission source. Therefore, it can be observed that time period is important in investigating the dispersion of the Cs-137 depending on the purpose of the study.

Analysis of accumulated 5 days cs-137 concentration in winter ,indicates that cs will be dispersed by local wind toward north to north east of Mediterranean.

In summer, the country is almost affected by the dominant extension of the Indian Monsoon, which raises temperature and brings considerable amount of humidity from the Mediterranean. In late autumn, weather conditions favor the decrease in the air temperature and sporadic rainfall events along the Mediterrean Coast.

The wind profile as represented by the wind rose in Fig. 2 shows the calmer winds in both summer and autumn and the stronger winds in both winter and spring.

The range of directions in Fig1. explains the relative concentration of 137Cs at emission sources is highest and then decreases when it moves away from its sources of emission.

As a result, in winter, low dispersion of 137Cs is observed and it is further concentrated in a narrow area around its origin (Dabaa Npp) with a maximum concentration of 300 - 340 pBq/m3. (Fig. 3a).

In summer, the wind pattern from north to north west wind and wind speed ranges from 5.9 to– 6.7 m/s resulted in maximum concentration of 620-680 pBq/m3. (Fig. 3b)

North West direction, showing high concentration of 137Cs at the emission source. In addition, the radioactive material 137Cs is concentrated downwind from emission source compared to other seasons (Fig. 3). Worth noting that the speed of the contaminating nuclide towards South and East of Egypt including delta region poses a high risk since most of the country population live there.

In the spring, there is a notable range of wind directions and the winds themselves are relatively strong which explains the relatively high concentration of 137Cs at emission source. In autumn, wind speed are less and the wind direction is between north to north west resulting in relatively higher concentration and deposition of 137Cs. Generally, the highest risk is found in the vicinity of nuclear reactor.

3.1. Wind rose

Wind rose in spring season shows that there is a notable range of wind direction and relatively highness of wind speed (but it is less than winter), which explains the relatively high concentration of Cs-137 at emission source compared to the one observed in winter season. Wind direction in autumn ranges from north to north west resulting in relatively higher concentration and deposition of Cs-137 Compared to winter and spring while less than that of summer

3.2. Deposition

Winter, spring and autumn are characterized by considerable range of wind direction leading decreasing of the deposited cs-137 on the ground surface. On the other hand, in the summer season, north-west is the dominant wind direction leading to higher deposition of cs-137 compared to other season (see figure 4).

3.3. Figures

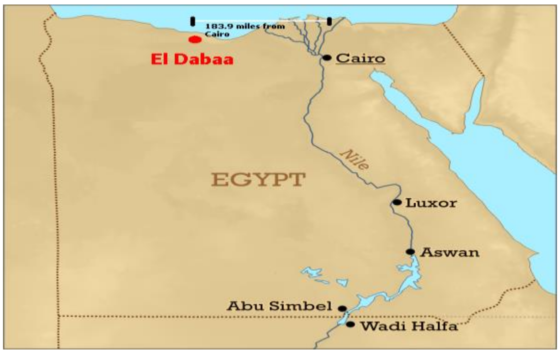
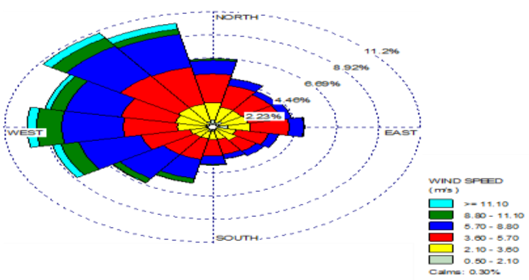
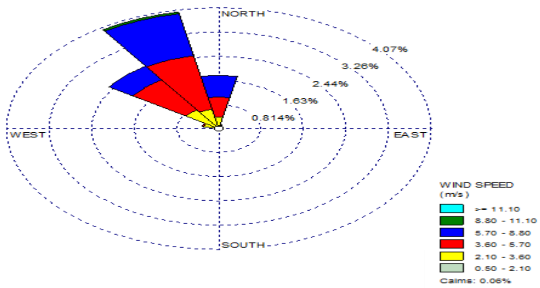


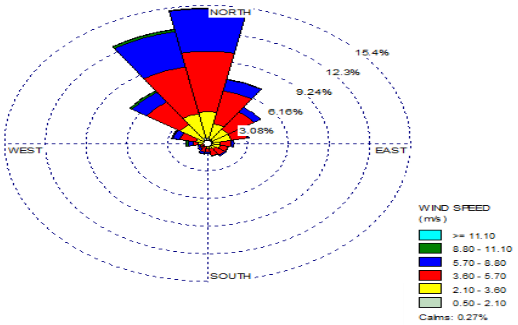
Figure 1. shows Dabaa location.



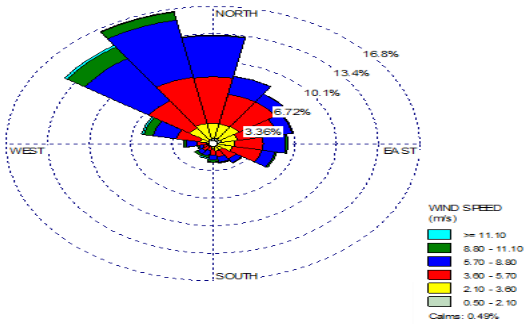
(a)



(b)

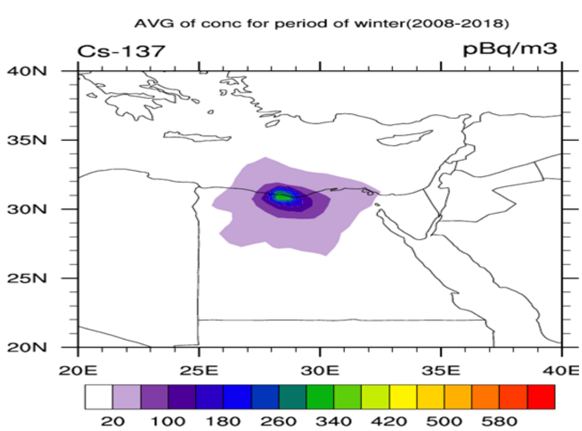


(c)

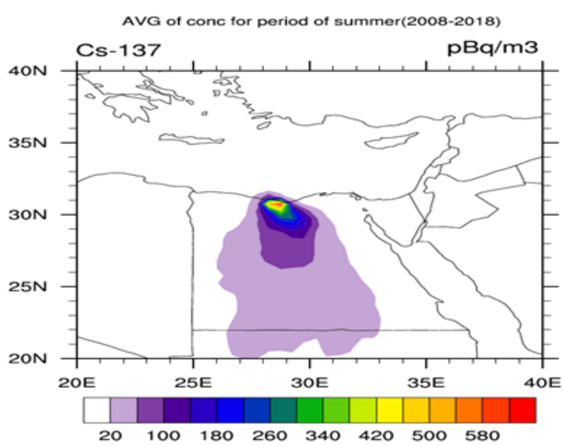


(d)

Figure 2. The average wind speed and direction at Dabaa during the period 2008-2018 for: a) winter, b) summer, c) autumn and d) spring.



(**a**)



(**b**)

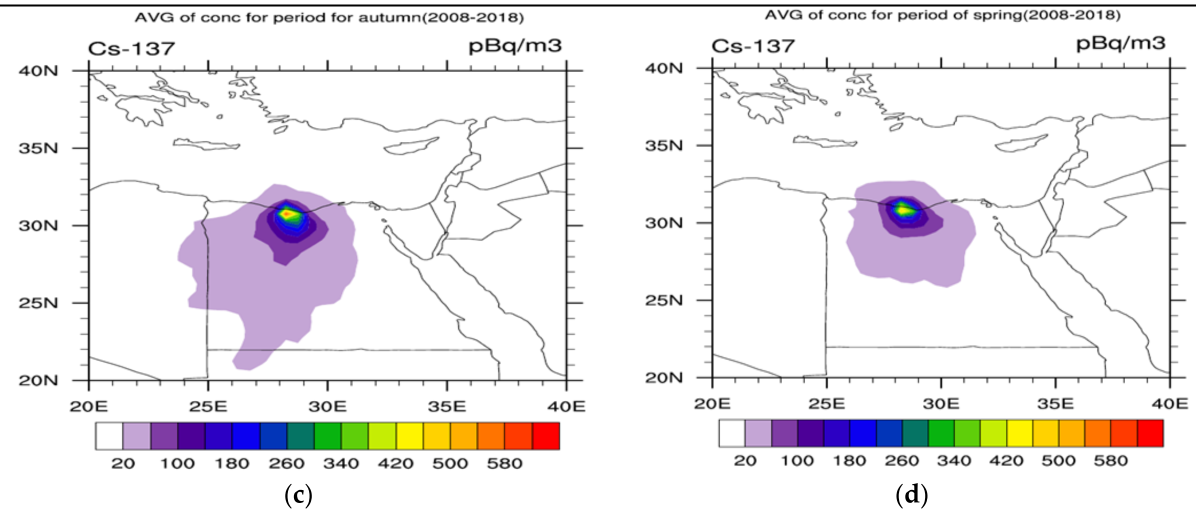


Figure 3. Average seasonal concentration of ^{137}Cs in pBq/m^3 in the period 2008-2018 for: a) winter, b) summer, c) autumn and d) spring.

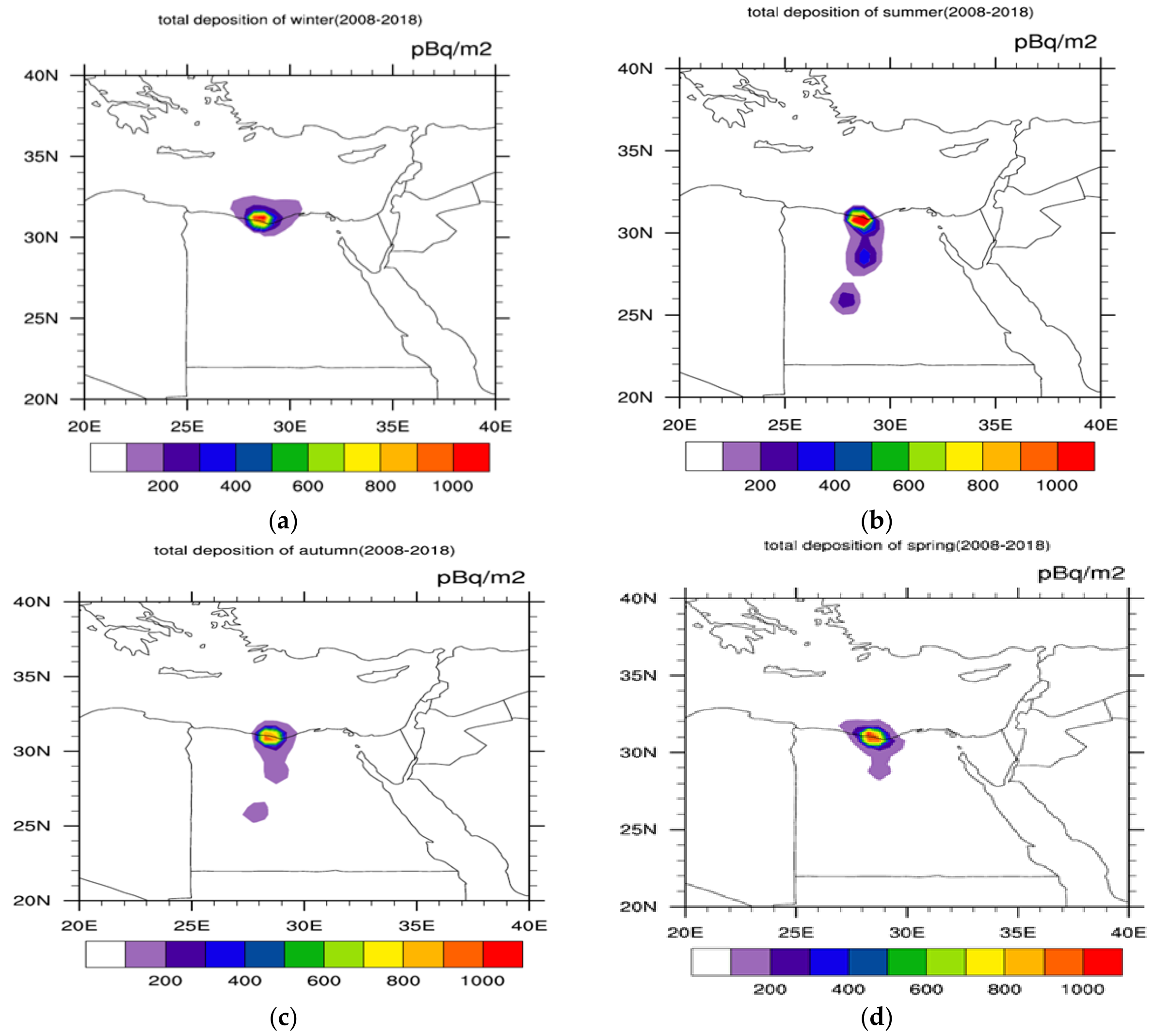
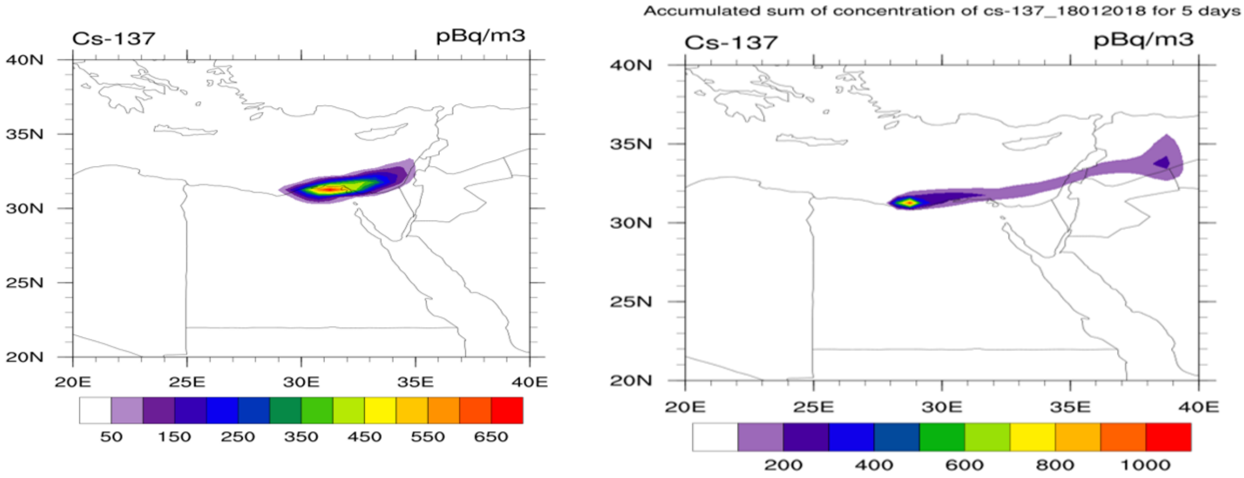


Figure 4. Average total deposition of ^{137}Cs in pBq/m^3 for period 2008-2018 for: a) winter, b) summer, c) autumn and d) spring.



(**a**) (**b**)

Figure 5. a)Accumulated 5days for winter 25-12-2018 ; (5b) accumulated 5 days for winter 1/1/2008.

4. Discussion and Conclusion

In this study we simulated a leak of a radioactive nuclide for 8 hours from Dabaa reactor every day for 5 days in the future using the FLEXPART dispersion model. The results of the simulations showed in agreement with previous studies of the Chernobyl case that the radioactive material moved corresponding to the prevailing wind in the lower troposphere even though the maximum of emission height was more than 2,000 m from the surface [7]. The risk estimates exhibit seasonal variability, with increased surface level concentration and deposition of 137Cs during summer where the pattern extended towards the south and east. Generally, as expected, the highest risk are found at the area in the vicinity of the reactor. In addition, this study shows that when the prevailing wind blows continuously in certain direction, the radioactive materials are concentrated downwind of their origins.

Supplementary Materials: Not applicable.

Author Contributions: Conceptualization, Nourhan Elshafeey; methodology, Nourhan Elshafeey.; software, Nourhan Elshafeey; validation, Nourhan Elshafeey; formal analysis, Nourhan Elshafeey; investigation, Nourhan Elshafeey; resources, Nourhan Elshafeey.; data curation, Nourhan Elshafeey; writing—original draft preparation, Nourhan Elshafeey; writing—review and editing, Nourhan Elshafeey, Zakey AS, Mohamed Mohamed Eid ; visualization, Nourhan Elshafeey; supervision, Mohamed Mohamed Eid, Amgad Saber Mahmoud and Zakey AS; project administration, Mohamed Mohamed Eid, Amgad Saber Mahmoud and Zakey AS. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest: The authors declare no conflict of interest.

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