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ORIGINAL ARTICLE

A study of the protective actions for a hypothetical accident of the Bushehr nuclear power plant at different meteorological conditions

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Abstract

In this work, protective actions have been studied assuming a hypothetical severe accident of the Bushehr nuclear power plant at different meteorological conditions. Simulations of the atmospheric dispersion of accidental airborne releases were performed using the RASCAL code. Total effective dose equivalent (TEDE) and thyroid dose received by members of the public living within a radius of 40 km around the reactor site were calculated for various atmospheric stability classes and weather conditions. According to the results of the dose assessment and by following the protective action guide of the Environmental Protection Agency (EPA), the critical zone and appropriate protective actions were determined depending on various metrological conditions. It was found that, for atmospheric stability class F and calm weather conditions, the maximum distance from the site of release for which TEDE is greater than the corresponding dose limit and for which sheltering or evacuation response actions are required, is 11 km. For the same weather conditions, the corresponding maximum distance for which iodine prophylaxis is required is 32 km. Based on the present simulations, it can be concluded that the metrological condition has a great influence on the radionuclide atmospheric dispersion and, consequently, on the critical zone where protective actions are required after the assumed accident condition.

Keywords Protective actions · Severe nuclear accident · Meteorological conditions · Atmospheric dispersion · Dose assessment

Introduction

Protective actions as part of radiological emergency response are very important during a nuclear reactor accident. Such protective actions might require urgent measures to protect the health of individuals exposed to ionizing. More specifically, during a radiological accident involving the release of radioactive materials into the environment, protection of the public might require some appropriate protective actions such as evacuation, sheltering and iodine prophylaxis (IAEA 1997, 2015). Atmospheric dispersion studies of radioactive material and radiological dose assessment during a radiological accident are indispensable for decision makers to decide whether protective actions are needed and which of the possible actions will be most effective to minimize radiation dose and protect people's safety.

The purpose of the present study is to investigate protective actions under the assumption of a severe accident of the Bushehr nuclear power plant (BNPP), for different meteorological conditions. The BNPP is a WWER-1000 type, pressurized water reactor with 3000 MWth power. This type of reactor is a four-loop reactor system with a water-cooled, water-moderated reactor (Noori-Kalkhoran et al. 2016). The BNPP site is located at the coast of the Persian Gulf, in the southern part of Iran. The Gaussian plume model has been used to simulate atmospheric dispersion and dose assessment for a BNPP severe accident on a local scale of about 40 km around the site, for different meteorological conditions. Radionuclide dispersion and deposition on the ground surface are evaluated depending on a number of important parameters such as the released radioactivity, the prevailing weather conditions, the atmospheric stability class and other

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conditions. Results of a similar study for the Tehran research reactor have recently been published (Ahangari et al. 2017; Vali et al. 2018). Protective actions are discussed depending on the radiation doses obtained for the investigated meteorological conditions, based on the recommendations given in the Protective Action Guide (PAG) and the International Atomic Energy Agency (IAEA) Standards (PAG 2013; IAEA 2015).

Public exposure due to the release of radioactive material during a normal BNPP operation has already been studied by Sohrabi et al. (Sohrabi et al. 2013a, b) using the PC-CREAM 98 computer code. Public exposure from a BNPP nuclear accident has also been studied using the PC COSYMA code (Sohrabi et al. 2013). In addition, radionuclide dispersion under normal conditions and due to an accidental release of BNPP was carried out by the CAP88-PC and HOTSPOT codes (Pirouzmand et al. 2015).

In contrast, the present study focuses on the investigation of protective actions for an assumed severe BNPP accident at the BNPP, as well as on the influence of different metrological conditions, using the RASCAL (Radiologic Assessment System for Consequence Analysis) computer code.

Materials and methods

Accident scenario and source term

The IAEA has introduced categories of nuclear accidents to analyze nuclear reactor safety (IAEA 1996, 2002). According to the probability of its occurrence and potential consequences, a nucear event may be categorized as an anticipated operational occurrence (AOO), a design basis accident (DBA) or a beyond design basis accident (BDBA). DBAs are defined as relatively frequent deviations from normal operating conditions which are caused by malfunction of a component or operator error. The first two transients should not have safety-related consequences which prevent the plant operation from being continued. An accident that occurs beyond the NPP design basis is called a beyond design basis accident (BDBA) or postulated accident, which is defined as such a rare deviation from the normal operation that it is not expected to occur but is considered in the safety assessments. In these type of accidents, damage to the plant may occur and immediate resumption of operation may not be possible. Since BDBA accidents have very low probability, DBA conditions are usually considered for safety assessment. To evaluate the potential risk of a BNPP accident, a simulation of DBAs has been performed and reported in the BNPP Final Safety Analysis Report (FSAR) (AEOI 2007). According to DBA analysis, the leakage of radionuclides from the primary to the secondary coolant circuit is the worst-case accident scenario, in terms of radionuclide release into the atmosphere. Therefore, in the present study, this hypothetical accident scenario was considered. In the case of leakage of primary-to-secondary coolant circuit, the release of the radioactive material to the atmosphere will be maximal and consequently, this scenario will represent the most critical source term, as far as the radiological dose for the public is concerned.

For a nuclear reactor, the amount of radioactive material released into the atmosphere (source term) depends on the plant design and can be estimated by computer codes. The calculated radionuclide release into the atmosphere that has been considered for BNPP as a potentially significant dose contributor in the case of a severe accident was taken from the FSAR report and is presented in Table 1 (AEOI 2007).

Meteorological condition at BNPP

Data describing the prevailing meteorological situation during a nuclear accident are important for atmospheric transport and diffusion models. The atmospheric dispersion model used in the RASCAL code requires information about wind speed, wind direction, atmospheric stability, precipitation type, precipitation rate, mixing-layer depth, and temperature at the source emitting radionuclides. The meteorological data for the site of BNPP reactor release, which is considered as the source, are taken from the BNPP 2003 environmental report (AEOI 2003). A list of relevant BNPP site-specific meteorological data for the year 2003 are presented in Table 2. In Table 2, “lid” refers, for example, to an inversion layer that prevents the rise of air beyond a certain height. The annual data of average wind speed and wind stability class frequency for 16 geographical sectors are presented in Table 3. The frequency of the wind speed and direction are reported by the BNPP meteorological center (AEOI 2003). All the data given in Tables 1, 2 and 3 were prepared as input data for the RASCAL code.

Atmospheric dispersion and deposition of radioactive material to the ground surface are very dependent on the prevailing weather condition and atmospheric stability class. The tendency of the atmosphere to resist or enhance vertical motion and thus turbulence is termed stability. Stability is related to both the change of temperature with height and wind speed. Atmospheric turbulence is categorized into six stability classes named A, B, C, D, E and F with class A describing the most unstable or most turbulent condition, and class F the most stable or least turbulent condition.

Therefore, in the present study, the simulation of radionuclide atmospheric dispersion and associated dose assessment was investigated for different atmospheric stability classes and weather conditions. The following meteorological scenarios were considered in this study, to cover a range of common weather conditions:

Table 1 Radionuclides released into the atmosphere due to an assumed primary-to-secondary leakage of the coolant circuits

Radionuclide	Released activity (Bq)	Radionuclide	Released activity (Bq)
Br-84	5.55×10^{12}	I-135	1.89×10^{13}
Kr-85m	4.44×10^{12}	Xe-135	4.07×10^{12}
Kr-85	1.22×10^{9}	Cs-137	1.04×10^{12}
Br-87	1.37×10^{13}	Xe-138	1.71×10^{13}
Kr-87	1.44×10^{13}	Cs-138	1.82×10^{13}
Kr-88	1.81×10^{13}	Ba-139	3.67×10^{11}
Rb-88	1.81×10^{13}	Ba-140	4.08×10^{9}
Kr-89	2.48×10^{13}	La-140	5.19×10^{8}
Rb-89	2.63×10^{13}	Ce-141	6.67×10^{8}
Sr-89	3.15×10^{9}	Ce-144	7.41×10^{7}
Kr-90	2.48×10^{13}	Pr-144	6.67×10^{7}
Rb-90	2.37×10^{13}	Zr-95	4.45×10^{8}
Sr-90	8.14×10^{6}	Nb-95	4.45×10^{6}
Sr-91	9.62×10^{10}	Zr-97	2.74×10^{10}
Sr-92	7.77×10^{10}	Nb-97	2.48×10^{10}
Mo-99	4.07×10^{8}	Na-24	1.00×10^{11}
Ru-103	3.44×10^{8}	K-42	4.45×10^{11}
Ru-106	4.81×10^{6}	Fe-59	7.04×10^{6}
Rh-106	4.81×10^{6}	Co-58	2.74×10^{7}
Te-131	3.45×10^{10}	Cr-51	5.19×10^{7}
I-131	1.15×10^{13}	Mn-54	7.04×10^{6}
Te-132	4.45×10^{9}	Co-60	7.41×10^{7}
I-132	3.08×10^{13}	Organic iodine	
Te-133	5.93×10^{10}	I-131	1.15×10^{11}
I-133	2.52×10^{13}	I-132	3.11×10^{11}
Xe-133	6.30×10^{12}	I-133	2.56×10^{11}
I-134	2.34×10^{13}	I-134	2.34×10^{11}
Cs-134	6.67×10^{11}	I-135	1.89×10^{11}

Table 2 Meteorological characterization at Bushehr nuclear power plant

Mixing height of lid	1000 m
Average air temperature	25 °C
Average precipitation	20 cm/year
Average humidity	8 g/m^3

All meteorological data are mean values for the year 2003 (AEOI 2003)

1. *Meteorological scenario 1* Atmospheric stability class A and calm weather (1.8 m/s wind speed, no precipitation)
2. *Meteorological scenario 2* Atmospheric stability class B and windy weather (6.75 m/s wind speed, no precipitation)
3. *Meteorological scenario 3* Atmospheric stability class C and rainy weather (3.6 m/s wind speed, 20 cm/y precipitation)
4. *Meteorological scenario 4* Atmospheric stability class D and rainy weather (3.6 m/s wind speed, 20 cm/y precipitation)
5. *Meteorological scenario 5* Atmospheric stability class E and rainy weather (3.6 m/s wind speed, 20 cm/y precipitation)
6. *Meteorological scenario 6* Atmospheric stability class F and calm weather (1.8 m/s wind speed, no precipitation)

Dispersion and deposition simulation

The RASCAL computer code uses a Gaussian model to describe the atmospheric dispersion of radioactive effluents from a nuclear reactor. The Gaussian model is the oldest model type and most commonly used in the literature. Gaussian models are most often used for predicting the dispersion of air pollution plumes originating from ground level or elevated sources (IAEA 1982). These models have frequently been used in licensing and emergency response calculations made by the Nuclear Regulatory Commission (NRC), as it provides reasonable estimates of the atmospheric radionuclide concentrations, deposition, and radiological doses (NRC 2007).

Table 3 Average wind speed and wind stability class frequency for 16 geographical sectors (AEOI 2003); definitions of stability classes are given in the main text

Wind direction	Wind speed (m/s)	Wind stability class frequency					
		A	B	C	D	E	F
N	3.1	0.2643	0.1396	0.2471	0.2102	0.0655	0.0734
NNW	2.7	0.2231	0.1880	0.1355	0.1780	0.1320	0.1435
NW	2.3	0.1929	0.2400	0.0644	0.0707	0.0755	0.3564
WNW	2.1	0.0948	0.1893	0.0755	0.2741	0.1438	0.2226
W	2.3	0.0709	0.1692	0.0458	0.0809	0.3519	0.2813
WSW	4.4	0.0800	0.1185	0.0431	0.0878	0.3283	0.3423
SW	4.0	0.0565	0.0774	0.0473	0.0802	0.4627	0.2759
SSW	4.3	0.0896	0.0772	0.0801	0.1147	0.4061	0.2324
S	4.2	0.1459	0.0641	0.0732	0.3320	0.2301	0.1546
SSE	3.8	0.1421	0.1353	0.1905	0.3645	0.0967	0.0709
SE	3.5	0.1960	0.2138	0.3584	0.1607	0.0283	0.0428
ESE	3.6	0.1831	0.2208	0.4223	0.1163	0.0251	0.0325
E	4.4	0.3069	0.3338	0.2446	0.0296	0.0222	0.0628
ENE	5.5	0.3822	0.3081	0.1761	0.0425	0.0455	0.0456
NE	5.6	0.2368	0.2546	0.2294	0.1659	0.0634	0.0499
NNE	4.4	0.1672	0.2121	0.2759	0.2036	0.0771	0.0641

Protective actions

During a radiological accident with an uncontrolled release of radioactive material, protection of the public from unnecessary exposure to radiation may require some form of intervention that will disrupt normal living. Such intervention is termed as a protective action. The main protective actions taken to avoid unnecessary exposure are (IAEA 1997; PAG 2013):

- Evacuating an area;
- sheltering-in-place within a building or a protective structure;
- administering potassium iodide (KI) as a supplemental action.

Evacuation means that members of the public are transported away from an area to avoid or reduce exposure from the radioactive plume or deposited radioactive material. In contrast, sheltering refers to having people stay inside their homes, offices, schools or other buildings, to reduce exposure to an outdoor hazard. Potassium iodide is a non-radioactive form of iodine which is used as a thyroid-blocking agent, during a radiological accident. It can be useful in conditions where radioactive iodine is released into the atmosphere. The administration of potassium iodine saturates the thyroid gland with stable iodine, so it does not absorb radioactive iodine released into the atmosphere from a radiological accident and, consequently, this reduces the risk of thyroid cancer.

Table 4 Protective actions for the early phase of a radiological accident as proposed in the Protective Action Guide (PAG 2013)

Protective action response	PAG (projected dose)
Sheltering-in-place or evacuation of the public	1–5 rem (10–50 mSv)
Supplementary administration of prophylactic drugs	5 rem (50 mSv)

In the present work, the PAGs projected dose and protective actions shown in Table 4 are used to determine appropriate protective actions in an effort to avoid, reduce or minimize potential radiation exposures during the assumed radiological accident.

Dose assessment

The objective of the present study is to determine appropriate protective actions during an assumed severe BNPP accident. To achieve this goal, available information and the RASCAL code were used to predict how much radiation dose could possibly be received by members of the public. In a second step, protective actions were identified that should be taken to avoid or minimize any potential radiation exposure. Based on the PAG report, protective actions are recommended for the following exposure situations (PAG 2013);

- Total effective dose equivalent of 1–5 rem (10–50 mSv) over 4 days
- Cumulated thyroid dose of 5 rem (50 mSv)

Table 5 Total effective dose equivalent (TEDE) and thyroid dose (mSv) received by a member of the public at various distances from the BNPP rector site, for different meteorological conditions; doses exceeding recommendations given in the Protective Action Guide (PAG) (PAG 2013) are italicized

Distance (km)	Meteorological condition 1		Meteorological condition 2		Meteorological condition 3		Meteorological condition 4		Meteorological condition 5		Meteorological condition 6	
	TEDE (mSv)	Thyroid (mSv)	TEDE (mSv)	Thyroid (mSv)	TEDE (mSv)	Thyroid (mSv)	TEDE (mSv)	Thyroid (mSv)	TEDE (mSv)	Thyroid (mSv)	TEDE (mSv)	Thyroid (mSv)
0.5	*89*	*710*	*56*	*560*	*360*	*1100*	*400*	*1100*	*410*	*960*	*160*	*1600*
1	*14*	*150*	*25*	*200*	*190*	*520*	*230*	*680*	*240*	*720*	*94*	*860*
1.5	5.90	*110*	*13*	*99*	*110*	*290*	*160*	*460*	*180*	*520*	*45*	*620*
2	4.20	*84*	8.40	*57*	*76*	*180*	*110*	*330*	*120*	*400*	*30*	*510*
2.5	3.80	*69*	5.80	37	*48*	*120*	*78*	*245*	*91*	*320*	*23*	*450*
3	3.10	*59*	2.40	26	*42*	*83*	*61*	*200*	*74*	*260*	*21*	*410*
3.5	2.70	*51*	0.99	19	*34*	*60*	*49*	*160*	*61*	*220*	*19*	*380*
4	2.30	45	0.75	15	*24*	45	*40*	*130*	*51*	*180*	*18*	*360*
4.5	2.10	42	0.61	12	*23*	35	*38*	*110*	*48*	*160*	*18*	*350*
5	1.80	38	0.49	9.50	*20*	27	*30*	*87*	*40*	*140*	*16*	*330*
5.5	1.70	34	0.39	7.80	*17*	21	*25*	*73*	*34*	*120*	*15*	*320*
6	1.50	31	0.33	6.60	*14*	17	*21*	*61*	*29*	*100*	*14*	*300*
6.5	1.40	29	0.27	5.60	*12*	14	*18*	48	*25*	*89*	*14*	*290*
7	1.30	27	0.23	4.80	*10*	11	*16*	44	*22*	*78*	*13*	*280*
7.5	1.20	25	0.20	4.20	8.40	9.20	*13*	38	*19*	*69*	*12*	*270*
8	1.10	24	0.17	3.70	7.20	7.60	*12*	33	*17*	*61*	*12*	*260*
8.5	1.05	23	0.16	3.30	6.70	6.40	9.80	29	*16*	*54*	*11*	*250*
9	0.95	22	0.14	2.90	5.70	5.40	9.20	25	*14*	48	*11*	*240*
9.5	0.90	20	0.13	2.70	4.90	4.60	8.20	22	*12*	43	*10*	*230*
10	0.84	19	0.11	2.40	4.30	3.90	7.20	19	*11*	38	*10*	*220*
11	0.81	18	0.10	2.10	1.50	3.70	3.10	18	5.50	37	9	*200*
16	0.56	12	0.07	1.40	0.22	0.84	0.52	4.40	1.10	11	7	*150*
24	0.39	8.40	0.05	0.95	0.03	0.19	0.09	0.98	0.23	3	4.60	*100*
32	0.29	6.30	0.04	0.72	0.01	0.05	0.02	0.22	0.07	0.90	3.30	76
40	0.18	4.10	0.03	0.61	0.00	0.02	0.01	0.07	0.03	0.29	2.50	47

The release of radioactive material in nuclear accidents may result in various types of exposure. In the present study, total effective dose equivalent (TEDE) and thyroid dose received by an individual are calculated as a result of accidental airborne releases into the atmosphere at various distances around the BNPP reactor, taking different metrological conditions into account. The TEDE projected dose is the sum of the effective dose from external radiation exposure (i.e., ground shine and cloud shine) and the committed effective dose from any inhaled radioactive material. The calculation of TEDE was performed by the RASCAL code considering these three dose contributions. RASCAL consists of three consequential models: *STDose, FMDose*, and *DecayCalc*.

STDose estimates the following terms:

1. Source terms for a radiological accident;
2. atmospheric transport, diffusion, and deposition of radionuclides released during the accident;
3. doses from exposure to these radionuclides.

FMDose calculates doses based on environmental measurements of radioactivity in the air and on the ground. Finally, *DecayCalc* calculates future activities of radionuclides taking into account physical decay and production of radioactive daughter nuclides.

The source term, metrological data and BNPP characterization provide the input for the atmospheric dispersion and transport models of the RASCAL code. The atmospheric dispersion and transport models used in the code estimate the radionuclide concentrations downwind, both in the air and on the ground due to deposition. The calculated activity concentrations are then used to estimate the related doses.

This TEDE is calculated assuming that no protective actions such as evacuation or sheltering are taken. Another assumption in the simulation is that people stay outdoors during the passage of the plume and will remain outdoors thus getting exposed to the ground shine from the deposited radionuclides for 4 days after radionuclide deposition.

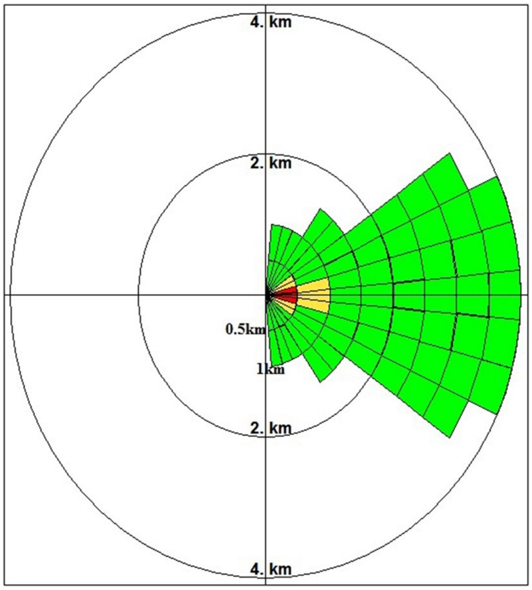

Fig. 1 Total effective dose equivalent (TEDE) zone for metrological condition 1 (stability class A and calm weather); green: 0.01–10 mSv (below EPA PAG range); yellow: 10–50 mSv (EPA early phase PAG range); red: > 50 mSv (exceeds EPA PAG range); for details see text

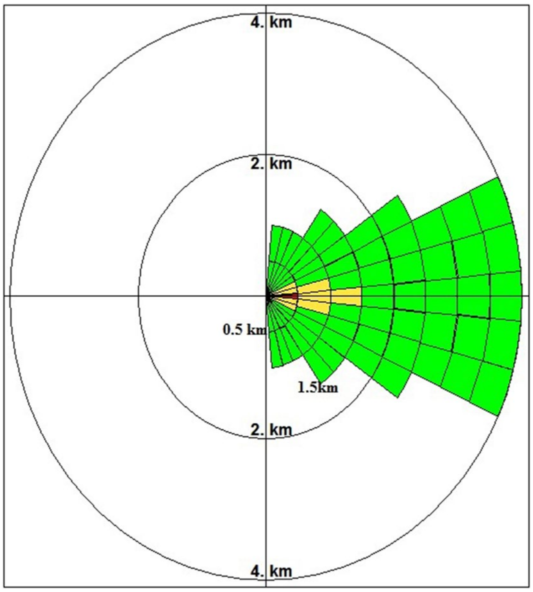

Fig. 2 Total effective dose equivalent (TEDE) zone for metrological condition 2 (stability class B and windy weather); green: 0.01–10 mSv (below EPA PAG range); yellow: 10–50 mSv (EPA early phase PAG range); red: > 50 mSv (exceeds EPA PAG range); for details see text

Results and discussion

TEDE and thyroid dose have been calculated for various atmospheric stability classes and weather conditions at the reactor site and its vicinity, for a hypothetical severe BNPP radiological accident. Calculations have been performed for TEDE and thyroid dose received by individuals living within 40 km around the BNNP reactor site for dominant wind directions. The results obtained are shown in Table 5. Based on these results, the critical zones (identified according to PAG for the public living around the BNPP reactor) can be described as shown in Figs. 1, 2, 3, 4, 5 and 6. The TEDE results at various distances and for each meteorological condition are displayed as an overlaid color-coded footprint. Each colored area represents the dose at a certain distance from the radioactive source on

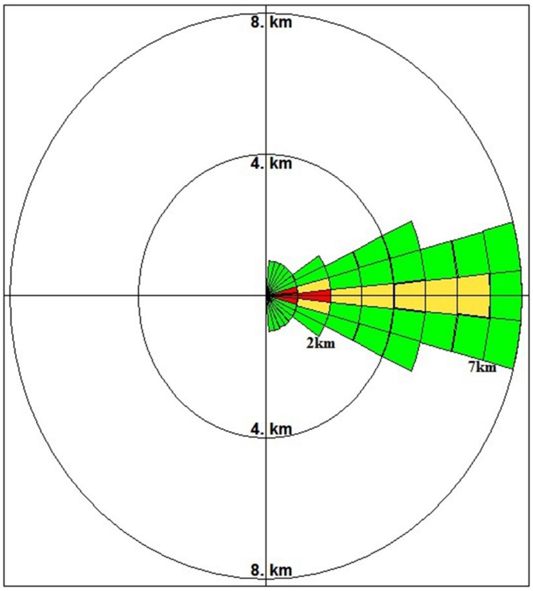

Fig. 3 Total effective dose equivalent (TEDE) zone for metrological condition 3 (stability class C and rainy weather); green: 0.01–10 mSv (below EPA PAG range); yellow: 10–50 mSv (EPA early phase PAG range); red: > 50 mSv (exceeds EPA PAG range); for details see text

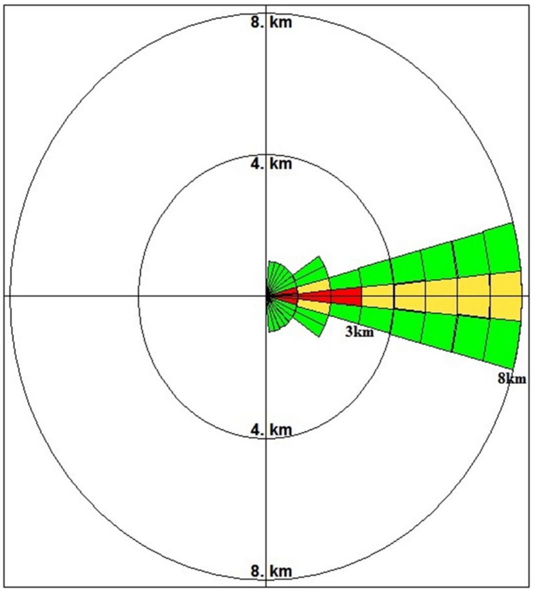

Fig. 4 Total effective dose equivalent (TEDE) zone for metrological condition 4 (stability class D and rainy weather); green: 0.01–10 mSv (below EPA PAG range); yellow: 10–50 mSv (EPA early phase PAG range); red: > 50 mSv (exceeds EPA PAG range); for details see text

the polar grid. The red color denotes exceeded PAG dose range, yellow stands for PAG range and green refers to exposures below PAG range.

According to the results (see Table 6), the following actions are required:

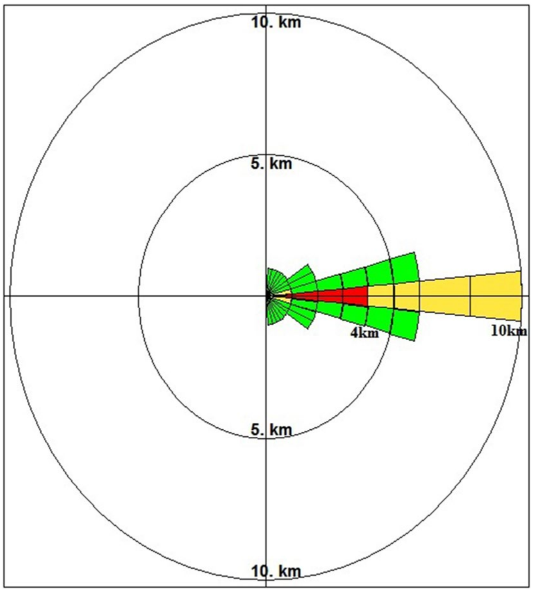

Fig. 5 Total effective dose equivalent (TEDE) zone for metrological condition 5 (stability class E and rainy weather); green: 0.01–10 mSv (below EPA PAG range); yellow: 10–50 mSv (EPA early phase PAG range); red: > 50 mSv (exceeds EPA PAG range); for details see text

- For meteorological condition 1 (stability class A and calm weather condition), as shown in Fig. 1, the TEDE value up to 0.8 km distance from the release point is greater than the PAG dose limit (10 mSv); so, sheltering or evacuation of the public should be initiated. The results given in Table 5 also indicate that thyroid dose values up to 3.2 km distance are above the PAG limit (50 mSv); so, prophylactic drugs should be administered.
- For meteorological condition 2 (stability class B and windy weather condition), according to Fig. 2 and Table 5, the TEDE and thyroid dose values up to 1.6 km distance are greater than the PAG limits; hence, the public should be sheltered or evacuated and iodine prophylaxis must be initiated.
- For meteorological condition 3 (stability class C and rainy weather condition), as shown in Fig. 3, the area around the release point up to 6.4 km distance requires sheltering or evacuation. The results in Table 5 also indicate that the thyroid dose value up to 3.2 km distance is above the PAG limit; so, the prophylactic drugs should be administrated.
- For meteorological condition 4 (stability class D and rainy weather condition), as shown in Fig. 4, the TEDE value up to 8 km distance from the release point is greater than the PAG dose limit and hence the people should be sheltered or evacuated. The given results in Table 5 also show that the thyroid dose values up to

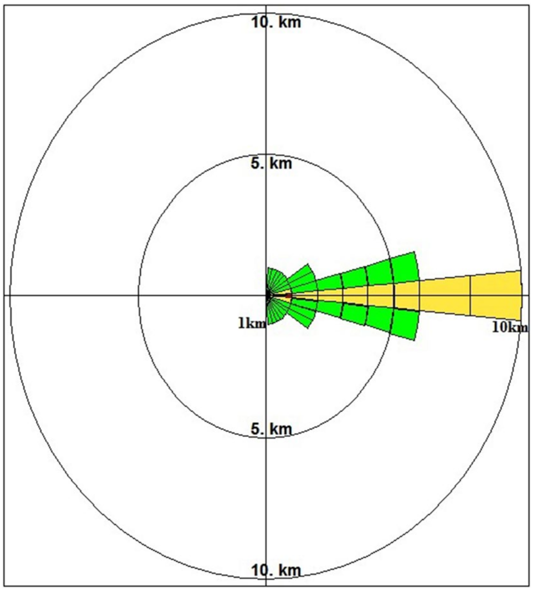

Fig. 6 Total effective dose equivalent (TEDE) zone for metrological condition 6 (stability class F and calm weather); green: 0.01–10 mSv (below EPA PAG range); yellow: 10–50 mSv (EPA early phase PAG range); red: > 50 mSv (exceeds EPA PAG range); for details see text

6.4 km distance are above the PAG limit; so, prophylactic drugs should be recommended.

- For meteorological condition 5 (stability class E and rainy weather condition), according to Fig. 5 and Table 5, the TEDE and thyroid dose values up to 8 km distance exceed the PAG limits; hence, the public should be sheltered or evacuated and iodine prophylaxis ought to be initiated.
- For meteorological condition 6 (stability class F and rainy calm condition), as shown in Fig. 6, the TEDE value up to 11 km distance from the release point is greater than the PAG dose limit; consequently, the people should be sheltered or evacuated. The results that are given in Table 5 also indicate that thyroid dose values up to 32 km distance are above the PAG limit; so iodine prophylaxis actions should be recommended.

Conclusions

Atmospheric dispersion and resulting doses to the public have been studied for the most severe DBA hypothetical accident of BNPP, for different metrological conditions. According to TEDE and thyroid dose values calculated here for the assumed radionuclides releases, appropriate protective actions to protect the public are recommended. Based on the simulations performed, it can be concluded that during this hypothetical accident, the maximum distance from the BNPP reactor site at which sheltering or evacuation protective actions are required for emergency response is 11 km for the atmospheric stability class F and calm weather conditions. Also, the maximum distance requiring administration of prophylactic drugs against radioiodine uptake of the thyroid is 32 km. The results obtained in the present study demonstrate that the prevailing metrological conditions have a great influence on the radionuclide atmospheric dispersion and on the corresponding projected doses. Consequently, the appropriate distance to take protective actions after a nuclear reactor accident is influenced by the prevailing metrological condition.

Generally, assessment of the total effective dose equivalent and thyroid dose to determine protective actions plays an important role in safety and environmental analyses for reactor licensing. This study intends to support BNPP emergency planners and health physicists, among others,

Table 6 Protective actions for BNPP hypothetical severe accident response in different metrological conditions; TEDE: total effective dose equivalent

Metrological condition	TEDE and thyroid dose (mSv)	Required protective actions
Metrological scenario 1 (stability class A and calm weather)	Up to 0.8 km, TEDE > 10	Sheltering/evacuation of the public
	Up to 3.2 km, thyroid dose > 50	Administration of prophylactic drugs
Metrological scenario 2 (stability class B and windy weather)	Up to 1.6 km, TEDE > 10	Sheltering/evacuation of the public
	Up to 1.6 km, thyroid dose > 50	Administration of prophylactic drugs
Metrological scenario 3 (stability class C and rainy weather)	Up to 6.4 km, TEDE > 10	Sheltering/evacuation of the public
	Up to 3.2 km, thyroid dose > 50	Administration of prophylactic drugs
Metrological scenario 4 (stability class D and rainy weather)	Up to 8 km, TEDE > 10	Sheltering/evacuation of the public
	Up to 6.4 km, thyroid dose > 50	Administration of prophylactic drugs
Metrological scenario 5 (stability class E and rainy weather)	Up to 8 km, TEDE > 10	Sheltering/ evacuation of the public
	Up to 8 km, thyroid dose > 50	Administration of prophylactic drugs
Metrological scenario 6 (stability class F and calm weather)	Up to 11 km, TEDE > 10	Sheltering/evacuation of the public
	Up to 32 km, thyroid dose > 50	Administration of prophylactic drugs

to determine the projected doses and identify radiological critical zones needed to implement protective actions, to protect the public against detrimental health effects during a reactor accident.

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