Analysis of the Practicability of External Emergency Planning in Germany based on Experiences from the Fukushima Accident

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Abstract

Current off-site nuclear emergency planning in Germany is based on accident scenarios with relative short release durations (typically few hours). In this work off-site radiological consequences were assessed for several case studies with long lasting releases similar to the Fukushima Dai-ichi accident. Resulting doses were compared against dose reference levels in Germany and the current off-site nuclear emergency planning was evaluated based on these results, indicating some shortcomings in case of severe and long lasting releases.

Key words

Nuclear emergency planning, radiological consequence assessment,
Fukushima Dai-ichi accident

1. Introduction

Aim of this study was to test the current off-site nuclear emergency planning in Germany with case studies based on lessons learned from the Fukushima accident. This test should demonstrate whether protection measures foreseen in the current emergency planning could adequately reduce the radiological consequences of NPP accidents with long lasting severe releases – over up to 30 days similar to the release from the Fukushima NPP. In the case studies considered two different hypothetical source terms were applied, these are described in section 2. Radiological consequences of these source terms were assessed with the decision support system RODOS (section 3), using real meteorological data for June and December 2010. Resulting doses (section 4) were compared against current dose reference levels in Germany. This comparison allowed for a first evaluation of the off-site nuclear emergency planning in Germany in the light of Fukushima-like accidents (section 5).

2. Source terms

In this study two different release scenarios (i.e. source terms) were used, which both describe a long lasting release over up to 30 days of very large amounts of radionuclides, similar to the release from the Fukushima NPP in March/April 2011.

The first source term – called “Fukushima source term” in the following – is based on data published by the Japan Atomic Energy Agency (Chino et al 2011). This data was estimated for the Fukushima Daiichi nuclear power plant accident – according to the authors – by a “reverse estimation of the source term by coupling environmental monitoring data with atmospheric dispersion simulations”. The data set only contains release rates for I-131 and Cs-137 discharged into the atmosphere from March 12 to April 5, 2011. Based on environmental monitoring data - which is being published regularly on the web site of the Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT 2011) – and supported by the work of Chino et al (2011) additionally releases of Te-132/I-132 and Cs-134 were assumed for the Fukushima source term with radioactivity ratios of I-131:(Te-

132/I-132):Cs-137:Cs-134 being 1:1:0.1:0.1 (for the begin of the major release on March 12). It is further assumed that the ratio of gaseous to aerosol bound iodine is 3:1 - according to monitoring data from the Japanese Chemical Analysis Centre in Chiba (JCAC 2011) – and gaseous iodine is assumed to be equally distributed to elemental and organic iodine (since no information was available about this ratio).

As second release scenario a very simple source term was used in this study, which contains a constant emission rate for all radionuclides over 30 days. The main idea behind introducing this somehow artificial source term was to allow for an easier investigation of the effects of changing meteorological conditions without disturbing effects from varying emission rates. The constant emission rates were deduced by simply distributing the total released activity per radionuclide from the largest source term resulting from a recent German research project, in which potential source terms for German nuclear power plants were assessed based on PSA level 2 studies (GRS 2010). For short-lived radionuclides this approach certainly leads to an overestimation of the release for later time intervals, but should not significantly influence the calculated dose results. Table 1 contains the total release for each of the source terms used in this study.

Table 1: Total releases for the source terms used in this study

Source term	Release (Bq)		
	Noble gases	Iodine	Aerosols
Fukushima	0	1,5E+17	1,1E+17
constant emission	1,2E+18	2,6E+17	1,7E+17

3. Radiological consequence assessment

Radiological consequences of the source terms described in the previous section were assessed with the decision support system RODOS (Ehrhardt 2000). RODOS has been developed within several European research projects and is currently being used in more than 20 countries world wide (Raskob 2010). RODOS includes inter alia models for simulating atmospheric and aquatic dispersion, dose assessment and simulation of countermeasures.

Atmospheric dispersion calculations within RODOS were based on on-site meteorological monitoring data from 2010. This data was measured with the on-site surveillance system (KFÜ) at the NPP Unterweser in Northern Germany (approx. 40 km north-west of the city of Bremen) and included information on wind speed, wind direction (both in several heights), diffusion category, precipitation and temperature in 10-minute time intervals. The data was aggregated into 1-hour time intervals. While in June winds from north are prevailing (about 46%), in December winds from west occur most frequently (about 35%), but wind directions are more evenly distributed than in June.

Case studies were calculated with RODOS using both source terms from section 2 and the meteorological data from the NPP Unterweser for June and December 2010. All calculations started at the first day of June resp. December and covered 30 days. Various dose estimates were also obtained with RODOS based on the dispersion calculations, with doses being integrated over 30 days. All RODOS results were calculated for a square area of 300 km x 300 km, centred around the NPP Unterweser. Thus radiological consequences could be assessed at least up to a distance of 150 km from the NPP. The results displayed in section 4 only show the inner part (up to 50 km) of the calculation area for better visibility.

4. Results for accident scenarios for one NPP in Northern Germany

Figure 1 shows estimates of the effective dose from external exposure and inhalation (over 30 days) for potential releases from the NPP Unterweser – the two source terms as described in section 2 - during June and December 2010. The black circles and sectors around the NPP in the centre of the maps indicate the emergency planning zones (RE 2008): the central zone up to a distance of 2 km, the inner zone up to 10 km and the outer zone up to 25 km. The far zone is following the outer zone up to 100 km (not shown in the figures). Inner zone, outer zone and far zone are divided into sectors of 30° each, numbered clockwise and starting with one for the sector symmetric to the north direction. Orange and red colours indicate areas with dose values above the reference level for sheltering (10 mSv), while within purple areas the reference level for evacuation (100 mSv) is exceeded.

The results for June in figure 1(a) show a clear dominance of areas with serious radiological consequences with a preferred direction to south-east, while for the December scenario in figure 1(b) of areas with serious radiological consequences are more equally distributed around the power plant (with up to 6 preferred directions). This characteristic can be explained by the prevailing winds from north-west especially in the first days of June 2010, while wind directions are more evenly distributed in December 2010.

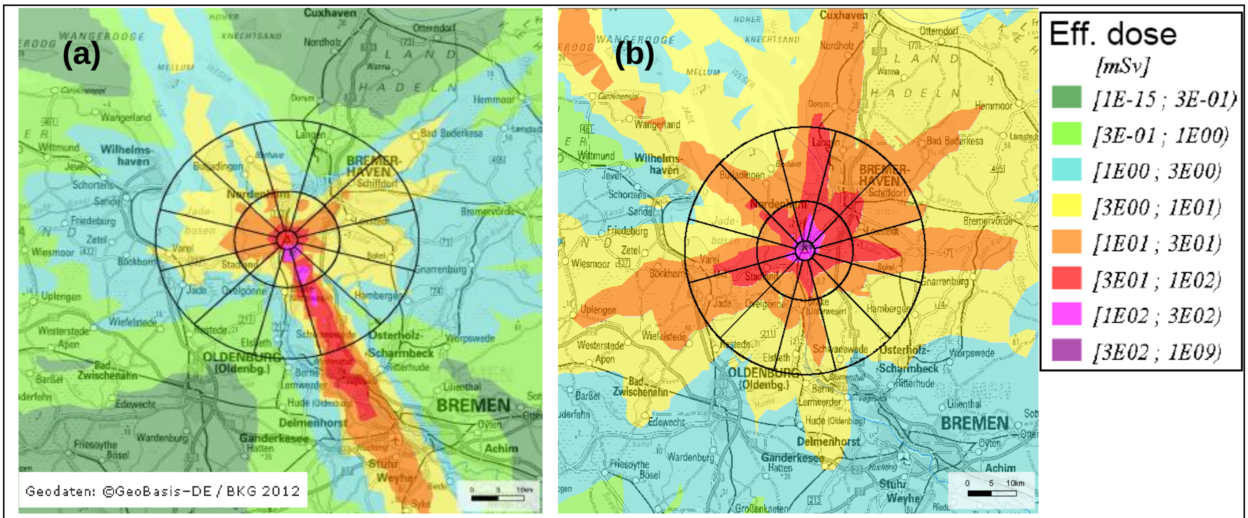

Figure 1: Effective dose for adults from external exposure and inhalation integrated over 30 days:
(a) Fukushima source term, meteorological data for June 2010;
(b) Source term with constant emission, meteorological data for December 2010

5. Discussion

In the following the calculated doses are compared against the German dose reference levels and potential consequences for the implementation of protective actions are discussed. In contrast to the dose integration period of 7 days as defined for the dose reference levels in Germany, in this study an integration period of 30 days was used due to the long duration of the considered releases. The influence of the length of the integration period on the resulting doses is discussed in section 5.3.

5.1. Size and extent of seriously affected areas and comparison with emergency planning

Table 2 shows a summary of the radiological consequences of the various accident scenarios as described in sections 2 and 3. Accident scenarios are identified by source term and month (of the weather data used) in the first column, the last three columns contain the characteristics of the areas where the respective reference level of the indicated protective action (second column) is exceeded.

One can easily see that for many scenarios the number of affected sectors is quite high (in all cases 11 or 12 sectors meaning that all directions are affected). Planning for protective actions in Germany is often based on the assumption, that typically one (or two) sectors is affected by the accident and protective actions are then implemented for this sector plus the two neighbouring sector (so called “key-hole principle”). Application of such emergency plans may become difficult when many more sectors are equally affected.

According to German guidelines for emergency management for nuclear power plants („Rahmenempfehlungen für den Katastrophenschutz in der Umgebung kerntechnischer Anlagen“ (RE 2008)) the protective actions sheltering and evacuation have to be pre-planned for the central and the inner zone (i.e. up to 10 km), while in the outer zone (up to 25 km) distribution of iodine to all persons not older than 45 years and in the far zone (up to 100 km) distribution of iodine to children (< 18 years) and pregnant women has to be considered. It can be seen from table 2 that for several accident scenarios protective actions have to be implemented at distances beyond these maximum planning distances, see cells in the table highlighted in red. For example, sheltering is required up to about 75 km in the scenario “Fukushima source term / June 2010”, while this is being pre-planned only up to 10 km. Distribution of iodine to children and pregnant woman is required up to a distance of more than 180 km in the same scenario, while planning is limited to a distance of 100 km.

Tab. 2: Summary of radiological consequences with respective to the protective action “sheltering”

Scenario	Figure	Areas where reference levels exceeded		
		Maximum distance (km)	Size (km2)	# of affected sectors
Fukushima, June 2010	1(a)	≈ 75	≈ 560	11
const. emission, June 2010	-	≈ 45	≈ 740	12
Fukushima, Dec 2010	-	≈ 60	≈ 1200	12
const. emission, Dec 2010	1(b)	≈ 95	≈ 2400	12

	not foreseen in emergency planning

5.2. Influence of location

The influence of the location of the NPP on the results was investigated by repeating the scenario calculations for a NPP in southern Germany, the NPP Philippsburg (located at the river Rhine between Karlsruhe and Heidelberg). Even if the detailed results can not be included in this study, the results indicate that the main findings of this study regarding size and extent of seriously affected areas can be fairly well reproduced for a location in southern Germany.

5.3 Influence of length of dose integration period

Dose reference levels for sheltering, evacuation and iodine prophylaxis are defined in Germany based on a dose integration period of 7 days (RG 2008). For long lasting releases - like those investigated in this study – large differences can occur in dose estimates depending on the chosen 7-day-interval, mainly depending on when and how long the contaminated plume was hitting the respective location. Especially problematic the situation would be if the reference level of 100 mSv for evacuation was never exceeded in any of the 7-day-intervals, but the total dose integrated over 30 days exceeded the reference level. In this case evacuation would not be implemented according to the current principles, but the affected population would still be exposed to a significant risk.

5.4. Implications for iodine prophylaxis

In the accident scenario „constant emission, Dec. 2010“ the dose reference level for iodine prophylaxis for children and pregnant women is exceeded in the cities of Cuxhaven, Bremerhaven, Wilhelmshaven, Oldenburg (partially) and Bremen (partially). This means that in these five cities alone approx. 175,000 children are affected by this action. The time window in which stable iodine tablets have to be taken can vary significantly depending on the accident scenario and the location concerned.

Figure 2 shows the daily thyroid doses for infants from inhalation of radioiodine approx. 8 km north-east of the NPP, which exceed the reference level for iodine prophylaxis on four days within an interval of 15 days and are close to the reference level at another 3 days. In such a situation a single intake of stable iodine would not be sufficient for protecting the infants against large thyroid doses, since it gives adequate protection only for one day (WHO 1999). In this scenario an optimal protection of the infants would be only given if stable iodine tablets are taken each day over a period of at least 15 days. Such a repeated intake of stable iodine is currently not sufficiently considered in nuclear emergency planning.

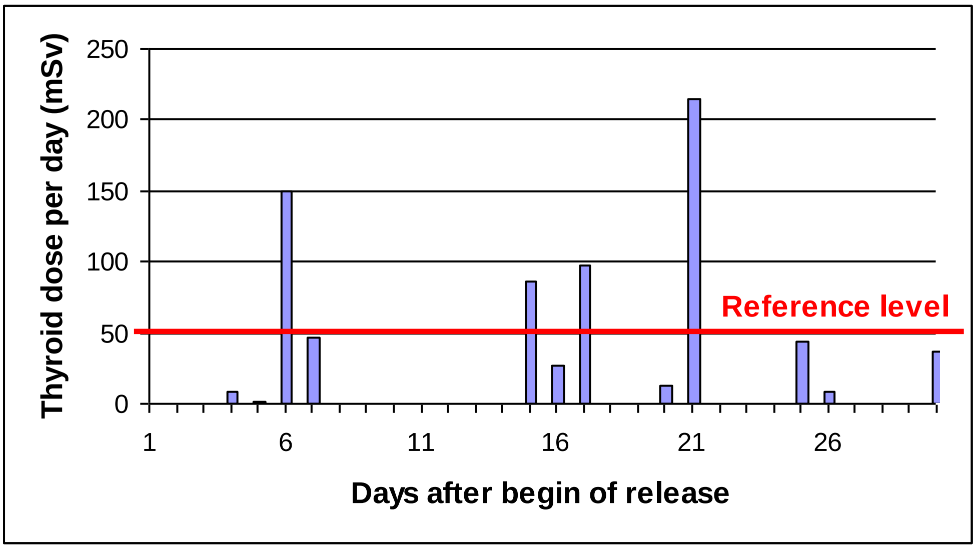

Fig. 2: Thyroid dose per day for infants from inhalation of radioiodine approx. 8 km north-east of NPP (scenario “const. emission, Dec 2010 “).

6. Conclusions

The results of this study indicate that the current nuclear emergency planning does not sufficiently consider all implications of long lasting severe releases like the Fukushima Daiichi accident, some shortcomings are:

- ► The size of these areas, where reference levels for protective actions „sheltering“, „evacuation“ and „iodine prophylaxis“ are exceeded, by far exceeds the emergency planning for many of the accident scenarios considered in this study.
- ► Current plans for implementing protective actions in this sector (from the EPZ), which is directly hit by the contaminated plume, and in the neighbouring sectors does not fully account for long lasting releases where often all sectors around the NPP are affected to similar extent.

- In case of long lasting severe releases the critical situation can occur, that reference levels for protective actions are not exceeded in any 7-day-interval (for which some of the reference levels are currently defined in Germany), but the total dose over the release period by far exceeds the reference level.
- In case of long lasting severe releases an one-time intake of stable iodine often is not sufficient for protecting the population against large thyroid doses. Multiple intake of stable iodine tablets is currently not sufficiently considered in emergency planning. Furthermore, optimal protection may only be guaranteed if the intake of stable iodine is ordered at different times for different areas.
- In case of long lasting severe releases the protective action “sheltering” imposes additional problems (e.g. the danger of being forced to order late evacuation even during passage of the plume), which may endanger the applicability of the action in general.

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