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COASTEX Scenario Report:
nine maritime accident scenarios
Report no. 1 from the NKS-B COASTEX activty

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Abstract

There is a notable maritime traffic of nuclear-powered civilian vessels (icebreakers and cargo ships), nuclear-powered military vessels and maritime transports of spent nuclear fuel and other radioactive materials along the Nordic coastlines and in the Arctic. This traffic represents a risk for potential accidents and events resulting in radioactive contamination and spread of radioactive materials into the Nordic and Arctic marine and terrestrial environments. These kinds of events request a good preparedness, possibility for a direct cooperation between neighbouring countries as well as interaction, assistance and coordinated activities to manage the situation, including mitigation.

In 2015, the NKS-B NORCOP-COAST project identified several needs for further improvement of maritime emergency preparedness and cooperation, including the need for definition of relevant scenarios with follow-up exercises in the Nordic countries. To address this issue, the NKS-B COASTEX project (*Scenarios and table top exercise concept on events related to traffic of nuclear-powered vessels and transportation of spent nuclear fuel along the Nordic coastline*) was initiated.

This report is the first of the three reports of the NKS-B COASTEX project. It provides methodology and framework for scenario development as well as a scenario bank with the description of nine maritime scenarios for nuclear accidents related to the traffic of nuclear-powered vessels and transports of spent nuclear fuel, and other radioactive materials. The aim of the scenarios is to describe a variety of possible maritime accidents in order to raise focus on the most important challenges related to these accidents, and to provide a foundation for conducting exercises within this field.

As appendices, separate factsheets are included with detailed source specifications for each scenario.

For effective planning, it is suggested to read also the Report no. 2 – *"COASTEX Exercise Guide"*. The NKS-B COASTEX project implementation is summarised in the Report no. 3 – *"Final report from the NKS-B project COASTEX"*.

Key words

Nordic coastline, the Arctic, maritime accident scenarios, nuclear emergencies, scenario elements, radioactive cargo, radioactive sources, nuclear icebreaker, nuclear-powered vessels, floating nuclear power plant, cross-border preparedness.

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1. Background and introduction

There is a notable maritime traffic of nuclear-powered civilian vessels (icebreakers and cargo ships), nuclear-powered military vessels and maritime transports of spent nuclear fuel and other radioactive materials along the Nordic coastlines and in the Arctic. This traffic represents a risk for potential accidents and events resulting in radioactive contamination and spread of radioactive materials into the Nordic and Arctic marine and terrestrial environments. These kinds of events request a good preparedness, possibility for a direct cooperation between neighbouring countries as well as interaction, assistance and coordinated activities to manage the situation, including mitigation. The uncertainty and complexity in the situation, and the large possible consequences for health, environment, local communities, industries and other societal matters, put additional pressure on monitoring and responding authorities, coastguards and rescue services.

In 2015, the NKS-B NORCOP-COAST project identified several needs for further improvement of maritime emergency preparedness and cooperation, including the need for definition of relevant scenarios with follow-up exercises in the Nordic countries. This would contribute to better emergency preparedness and response capabilities along the Nordic coastline and in the Nordic countries (Nalbandyan *et al.*, 2016). The NKS-B COASTEX project *"Scenarios and table top exercise concept on events related to traffic of nuclear-powered vessels and transportation of spent nuclear fuel along the Nordic coastlines"* was initiated by the Norwegian Radiation Protection Authority in collaboration with the Swedish Radiation Safety Authority, the Icelandic Radiation Safety Authority and the Danish Emergency Management Agency as a follow-up of the identified needs in previous work. The project resulted in three reports: The *"COASTEX Scenario Report: nine maritime accident scenarios"*, the *"COASTEX Exercise guide"*, and the *"Final Report from the NKS-B Project COASTEX"*. The reports are available on the NKS website http://www.nks.org/.

The report *"COASTEX Scenario Report: nine maritime accident scenarios"* is the first of the three reports of the NKS-B COASTEX project. The report provides methodology and framework for scenario development, including building blocks in scenarios, phases, trigger events and possible effects. Additionally, the report provides a developed scenario bank with the description of nine maritime scenarios for nuclear accidents related to the traffic of nuclear-powered vessels and transports of spent nuclear fuel and other radioactive materials. The nine scenarios are based on input from the participant countries in the project. They reflect different needs and experiences identified by the participants.

The aim of the scenarios is to describe a variety of possible maritime accidents, to raise focus on the most important challenges related to these accidents, and to provide a foundation for conducting exercises within this field. Each scenario provides a source description, a time-based development in different phases, a table with defined scenario elements, possible exercise elements in the scenario, and proposed or possible learning objectives during an exercise. As appendices, we have included more detailed fact sheets with further source specifications for each scenario.

The target groups for these scenarios and follow-up exercises are the potentially affected monitoring and responding authorities, radiation safety authorities, coastguard and rescue services.

2. Methodology for scenario development

2.1 Building blocks in the scenarios

Based on international recommendations and the division of events into distinct phases, project participants have developed a set of building blocks, or elements, that build up a scenario. The elements are very specific in time and place, and considered as a framework where each element can be changed, depending on local (or national) needs. Since the scenario elements are very specific, they will enhance the work with planning exercises, and guide the planners to formulate more specific goals or objectives for the exercise.

According to OECD/NEA, "Effective emergency response requires development and implementation of emergency plans and procedures; established arrangements at the local, national and international levels; acquisition and maintenance of resources (funding, equipment and personnel); training of personnel; conduct of exercises; and a feedback programme whereby improvements to the emergency management system are made based on lessons identified from exercises and actual events" (OECD-NEA, 2007). Although this is well known and implemented, we realise that lessons identified from exercises and actual events are still difficult to feed back into the emergency plans and procedures in a successful way.

One step moving towards a more structured way of exercising, is to develop more structured scenarios. We believe some of the long-term key benefits will be:

- Improved consistency and standardisation of approach to drills and exercises;
- Easier to build drills and exercises quickly from a structured scenario bank, allowing collaboration with peers and distribution of duties;
- Copying scenario elements into a new exercise rather than rebuilding everything;
- Easier to record evaluations of exercise objectives to track performance improvement.

The accompanying *"COASTEX Exercise Guide"* report will elaborate more on *how* to identify exercise objectives and goals based on scenario elements.

2.2 Trigger events and possible cascading effects

The introduction of trigger events enables us to both identify pre-events that might be used as notification exercises, and as incidents involving increased readiness or attention, because they indicate that something is about to happen.

Possible cascading effects can be introduced in the exercise either to make the situation more severe, and thereby increasing the pressure on the participants. It can also be used to involve more decision makers or other sectors, which are likely to be affected by the event. Cascading effects can also be introduced in cases where the scenario is based on a real event, but the situation gets worse.

2.3 Phases

According to the IAEA (IAEA, 2005), all emergencies can be divided into three phases:

- Phase 1: the initial phase
- Phase 2: the accident control phase
- Phase 3: the post-emergency phase

When introducing phases in the scenarios, we have implemented this structure. In any actual accident or exercise, many of the response actions in the accident control phase may be commenced in the initial phase of the accident or exercise as well. However, much emphasis has been put on the fact that the post-emergency phase is seldom exercised. By dividing the scenario into different phases, we provide more informed decisions on what phase and what objectives will be exercised.

2.4 Roles and responsibility

The target group for these scenarios are the affected monitoring and responding authorities, radiation safety authorities, coastguard and rescue services. The aim of the scenarios is to address issues related to regional and international interaction, crisis management, assessments and prognoses, communication with the public, and possible international assistance.

An overview of the emergency roles and responsibility in the different Nordic countries are given in Chapter 4. Although there are several similarities, each country is organised a little different, and when it comes to accidents at sea, the roles and responsbilities gets multifaceted. The scenarios in this report were first and foremost developed to aid the radiation protection authorities in the Nordic countries to further develop their emergency preparedness and exercises. A further step of improvement would be to include local and regional preparedness organisations, and conduct joint common exercises, either locally or as regional exercises with more than one country involved.

2.5 Scenario descriptions and background information

The participating authorities in the project have contributed with different scenarios and background information. The scenarios reflect different needs and experiences identified by the participants. Several of the scenarios are based on previous exercises.

Scenario 1 and 2 were provided by Geislavarnir Rikisins, scenario 3 and 4 were provided by the Norwegian Radiation Protection Authority, scenarios 5-8 were provided by the Swedish

Radiation Safety Authority, and scenario 9 was provided by the Danish Emergency Management Agency.

The Norwegian Radiation Protection Authority was the project coordinator, with assistance from Atomkameratene.

3. The scenarios

In the following, nine maritime accident scenarios are described. Additionally, factsheets with background information, source specifications and risk/hazard assessments for each scenario are included in the appendices.

3.1 Scenario 1: Release of radioactive materials into the ocean or a rumour about such a release

Source specification

In this scenario the source is unknown.

Phase 1 (Crisis development – before release or exposure)

After attempting to seek lee during a severe storm, a ship has run aground on a skerry [north] of Country X. The vessel, belonging to Country Y, is seriously damaged, but the crew refuses all assistance. The vessel is said to have been involved in the recovery of radioactive waste previously dumped in the ocean. Country Y has kept information about these activities to a minimum, apparently for political reasons. The waste materials included both liquids and solids housed in various containers in uncertain condition.

An overflight reveals some oil and diverse debris around the wreck. It becomes evident that the ship will not get off the stranding site by its own power. A decision has to be made what action to take.

Source: www.static.pexels.com

Phase 2 (Crisis management – ongoing release or exposure)

Operations center activates communication channels with and coordinates involvement of:

- policy making organs (Ministries, Coast Guard, Civil Protection, Police);

- first responders (Civil Protection, Ministries, Coast Guard, Police, other SAR parties);
- parties responsible for technical aspects of emergency (Directorate of Fisheries, the Marine Research Institute, Meteorological Office, the NCA for radiological issues, academia);
- stakeholders, the media and the public (municipalities, fisheries, embassies).

Ministry X suggests immediate action, such as that the Directorate of Fisheries / Marine Institute announce an emergency or temporary fishing closure in the area and determine the size of the area. This decision has to be carefully backed up by measurements and evidence to minimise the financial, and possibly health and environmental, consequences while maintaining safety and credibility.

The NCA for radiological aspects of emergencies together with Marine Research/Oceanographic Institute, University and the Met. Office explore the availability of marine dispersion models suitable for the affected area that can be used with real weather conditions.

The Coast Guard gets patrol ships and helicopters ready, and prepares for a rescue operation but are uncertain of how to go about the release of radioactive materials. Ministry of X requests an immediate report on the Coast Guard's capabilities to handle the situation.

The incident gets public via mass media instantly. The market responds quickly and formal enquiries from buyers about the safety of seafood products start to be received.

A monitoring strategy has to be established quickly, including the investigation of existing background data if any. The NCA, having limited laboratory resources, must seek assistance in the measurements and analyses of samples requiring chemical preparation, e.g. for α and β emitters.

- Information to the public.
- Information to neighbouring countries.
- Reporting to IAEA.
- RANET: What assistance to request and how, how to receive assistance.

Phase 3 (Consequence management – after release or exposure)

Daily reports of monitoring results are issued during the first weeks after the incident, later on a weekly basis.

Information to neighboring countries.

Formal reporting to IAEA.

Risk re-evaluation and re-evaluation of vulnerability assessment plan.

RANET: how to request and how to receive assistance.

Table 3.1: Relevant scenario elements.

Scenario element		Phase 1	Phase 2	Phase 3
	Scenario overview			
	Time (time of year, time of day etc.)	Late fall	Late fall, winter	Following months and years
	Duration	4 hours	4 months	4 years
	Location			
	Wind (strength and direction)	NE 23 m/s, gusts up to 45 m/s	NE 20 m/s	Not applicable
	Sea current	Prevailing from West to North, variable at surface	Prevailing from West to North	Not applicable
	Weather conditions	Storm	Winter conditions with occasional ice drift	Not applicable
	Temperature (air and water)	Air -2 Water +3	Air: changeable Water +3	Not applicable
	Sequence of events	Ship runs aground. Rumour about release of radioactive materials to the ocean	Assistance, rescue operations. Survey and monitoring strategy. Provide information to stakeholders and public/media	Monitoring and dissemination of information, reporting.
	Scope (population affected, areas etc.)	Sensitive sub-arctic ecosystem		
	Source term and amount of release/ release rates	Unknown	Unknown	None
	Observed levels of radioactivity			
	Comparable events			

	Ripple effects			
	Contributing factors	Bad weather	Weather. Lack of background data	Lack of background data
	Coinciding events	Economically important fishing season		
Intentional act? No				

Possible exercise elements in this scenario:

Typical exercise elements in this scenario will be:

- National and international notification (according to agreements);
- Requisition of rescue resources (nationally/internationally);
- Mapping and monitoring operations;
- Assessment of releases and contamination;
- Estimate of possible doses to law-enforcement officers/first responders;
- Assessment of measures (such as evacuation, use of iodine tablets, restrictions on travels etc.);
- Decision-making processes and involvement of stakeholders;
- Crisis communication in a complex situation;
- Local authorities and management vs. governmental authorities and management;
- Cooperation and/or hand over between civilian authorities and military/law enforcement authorities.

Proposed or possible learning objectives during an exercise:

The various exercise elements will be considered and identified in advance of the exercise. Learning objectives and practice goal will depend upon which exercise elements are selected.

- This exercise focuses on the radiological aspect of the scenario with emphasis on response activities, coordination of actions of different institutions, involvement of academia, existence/completeness of emergency response plan.
- Crisis communication in a complex situation.
- Planning of long-term, regular situation updates (monitoring measurements etc.) to the media and the public (and to the IAEA community).

3.2 Scenario 2: Unidentified ship with a large Cs-137 source

Source specification

Category 1 Cs-137 source, partly shielded.

Phase 1 (Crisis development – before release or exposure)

Police receives information from a repair technician that a ship is carrying material with a radiation signal. The ship is a container carrier situated offshore.

Source: www.static.pexels.com

The captain is non-compliant, refuses any cooperation and claims that arbitrary suspicions about unauthorized transfer of radioactive materials in no way justify any delay to his schedule. He has set the ship to cruise at 24 knots. The ship could exit the territorial waters of the country within an hour.

It is the result of an initial assessment that the information alert is credible and that the relevant competent authorities should implement procedures and protocols with the view to interdict and interrupt a potential criminal act, or unauthorized act, with radiological security implications.

Phase 2 (Crisis management – ongoing release or exposure)

Police contacts National Competent Authority (NCA) and Coast Guard (CG). Communication channels between NCA and CG are activated. NCA contacts licence holders and initiates investigation to identify possible missing source or MORC (Material Outside of Regulatory Control). The Directorate of Customs (DC) is contacted to ensure access to shipping documents and collect any information available about transit cargo.

The repair technician is interrogated and confirms that she saw a radiation sign, probably indicating a Category 1 source. She also confirms having informed the media about this. Reports have started to appear in the media and there is a rumour about an intended malicious act.

The [responsible party] decides that the situation justifies the implementation of any available detection measures to verify the presence of radioactive material onboard the ship, including aerial radiological survey and that the relevant competent authorities should commence with response activities.

Special unit fastropes onboard ship. Gain control and search ship for radiological materials. Secure radiological material for analysis and as evidence.

Information to the public.

Information to neighbouring countries.

Reporting to the IAEA.

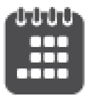
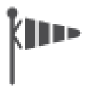
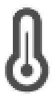
Phase 3 (Consequence management – after release or exposure)

Information to the public.

Information to neighbouring countries.

Formal reporting to IAEA – event (USIE), illicit trafficking (ITDB).

Table 3.2: Relevant scenario elements.

Scenario element		Phase 1	Phase 2	Phase 3
	Scenario overview	Information received, operations control activated, decision making.	Survey, takeover, material secured.	Lawsuit, reporting, information to IAEA, media and public.
	Time (time of year, time of day etc.)	X	X+1h	X+1h+4m
	Duration	1h	4h	4m
	Location	10 NM offshore	40 NM offshore	Not applicable
	Wind (strength and direction)			Not applicable
	Sea current			Not applicable
	Weather conditions			Not applicable
	Temperature (air and water)			Not applicable
	Sequence of events	Threat assessment, decision making, activate operations control.	Confirm threat, board and secure ship, secure radiological material.	

	Scope (population affected, areas etc.)	Potentially large if used as RDD	Potentially large if used as RDD	Not applicable
	Source term and amount of release/ release rates			
	Observed levels of radioactivity	Not applicable	5 μSv/h at 1 m	Not applicable
	Comparable events			
	Ripple effects	Public unrest, scepticism	Massive media interest	Public criticism. Review of transit cargo monitoring capabilities
	Contributing factors		Weather	
	Coinciding events	None	Possibly: two rescue helos are needed for offshore operations, so helo operations might be aborted due to other emergency.	None
Intentional act? Possibly				
	Intention	Transport for later malicious use		
	Background			Falsified documents, intended malicious use
	Capacity & Capability	Strong sources can be obtained relatively easily and transported via transit areas		

Possible exercise elements in this scenario:

Possible exercise elements in this scenario are:

- The command- and air elements in a large-scale operation;
- National and international notification;
- Requisition of rescue resources (nationally/internationally);
- Mapping and monitoring operations;
- Assessment of releases and contamination;
- Decision-making processes and involvement of stakeholders;
- Crisis communication;
- Local authorities and management vs. governmental authorities and management;
- Cooperation and/or hand over between civilian authorities and military authorities.

Proposed or possible learning objectives during an exercise:

The various exercise elements will be considered and identified in advance of the exercise. Learning objectives and practice goal will depend upon which exercise elements are selected.

3.3 Scenario 3: Accident involving a nuclear submarine off the Norwegian Coast

Source specification

An allied nuclear-powered submarine with a PWR reactor.

Phase 1 (Crisis development – before release or exposure)

An allied submarine is heading towards one of the outer islands in one of the fjords in Northern Norway for medical evacuation of one of the crew members.

Source: www.static.pexels.com

The location in question is commonly used for such brief visits by allied nuclear-powered vessels in Northern Norway. Close to the location, the submarine collides with an unknown object, resulting in damages to the hull. It is unclear whether the submarine has struck submerged rocks or another vessel.

The submarine requests assistance from Norwegian authorities. Due to the extent of the damages, the submarine is towed to a harbour in the area. Contacts between the Norwegian Armed Forces, the Ministry of Defence in the allied foreign country and NATO headquarters in Brussels are established.

Phase 2 (Crisis management – ongoing release or exposure)

Due to the condition of the vessel, it is not advisable to send the vessel out to sea (despite good weather and calm seas). The population of the municipality in question and the neighbouring municipalities are notified, and it is recommended to stay indoors Monday night.

The national radiation protection authority sends personnel to the area, and sets up its mobile monitoring systems. The measurements identify I-131 and noble gases (Ar-41 and Kr-85) in the air. They also find traces of Cs-134, Cs-137 and Sr-90.

The allied foreign MoD contacts Norwegian authorities and asks for reinforced protection while the submarine is moored at the harbour.

The Mayor of the largest nearly municipality wishes to distribute iodine tablets to children and adolescents.

Reinforced protection of the submarine leads to media speculation whether the submarine has nuclear weapons on board. It is speculated that the submarine can be a highly attractive target for groups who wish to acquire fissile material, in the form of easily transportable missiles.

Phase 3 (Consequence management – after release or exposure)

After four days at the harbour, the emissions have stopped. The reactor is under control, and the leaks have stopped. Efforts to map contamination of adjacent areas, on land and in the sea are ongoing. No special measures are implemented, except restricted access to the harbour with reinforced protection in place. It is uncertain how long the submarine must remain moored in place.

Table 3.3: Relevant scenario elements.

Scenario element		Phase 1	Phase 2	Phase 3
	Scenario overview	Submarine collision	Submarine is towed into harbour, release of radionuclides	Submarine in harbour, release has stopped
	Time (time of year, time of day etc.)	Summer: Sunday, June 26th at 05:20	Monday June 27th- Thursday June 30th	July
	Duration	12 h	4 days	1 month
	Location	Norwegian coastal waters	Local naval base, Northern Norway	Local naval base, Northern Norway
	Wind (strength and direction)	East, NorthEast 3 m/s	2-5 m/s NE to N	Not relevant
	Sea current	Not relevant	From N to S, tidal current changing to S to N	Not relevant
	Weather conditions	Calm conditions, summer weather	Calm conditions	Variable, some rain and fog, mostly nice
	Temperature (air and water)	Air: 14° C Water: 9° C	Air: 16° C Water: 11° C	Air: 8-20° C Water: 10-15° C
	Sequence of events	Collision leads to disruption of cooling circuit	Heating of reactor Releases of radioactivity in air and water	Contamination of local land areas. Minute releases to the sea

	Scope (population affected, areas etc.)	Initial: 1300 people in nearby areas	25 000 in the largest nearby municipality, 2 180 in another nearby municipality	Contaminated area < 500 km^2
	Source term and amount of release/ release rates	No release	Releases of noble gases and fission products	
	Observed levels of radioactivity	None	Dose rates on board: 105 µSv/h On shore: 45 µSv/h I-131 in air: 5000 Bq/m^3 also Cs-137, Ar-41, Kr-85, H-3 and Pu-239 has been detected	Deposition on land: 1-500 Bq/m^2 Cs-137 and Sr-90. 5000 Bq/m^2 H-3 500 Bq/m^2 I-131
	Comparable events	HMS Tireless sought refuge in Gibraltar – leakage in cooling circuit, 2000. HMS Triumph hit the sea bed, 2000. HMS Trafalgar runs aground, 2002. HMS Vanguard collided in the Atlantic Sea 2009. HMS Turbulent and HMS Tireless went to sea with safety valves sealed off, 2010.		
	Ripple effects		Nordic countries seeking information	
	Contributing factors	Summer holidays – less rescue people available?	Many tourists in the area due to a music festival.	
	Coinciding events	None	None	none
Intentional act?				
	Intention	Possible collision with Russian submarine – intentional?		
	Background	Long history of «hide and seek» in Polar waters.		
	Capacity & Capability	Only national states have larger submarines.		

Possible exercise elements in this scenario:

Possible exercise elements in this scenario are:

- National and international notification (according to agreements);
- Requisition of rescue resources (nationally/internationally);
- Mapping and monitoring operations;
- Assessment of releases and contamination;
- Assessment of measures (such as evacuation, use of iodine tablets, restrictions on travels etc.);
- Decision-making processes and involvement of stakeholders;
- Crisis communication;
- Local authorities and management vs. governmental authorities and management;
- Cooperation and/or hand over between civilian authorities and military authorities.

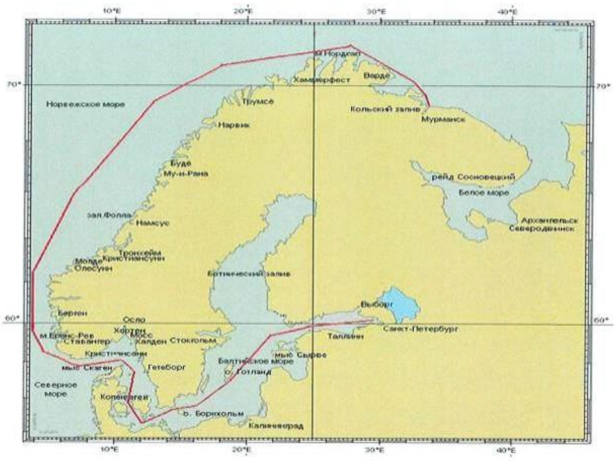
Proposed or possible learning objectives during an exercise:

The various exercise elements will be considered and identified in advance of the exercise. Learning objectives and practice goal will depend upon which exercise elements are selected.

3.4 Scenario 4: Towing of Russian Floating Nuclear Power Plant in Nordic waters

Source specification

A Russian floating nuclear power plant towed from St. Petersburg to Murmansk experiences difficult weather conditions en route.



Source: www.static.pexels.com

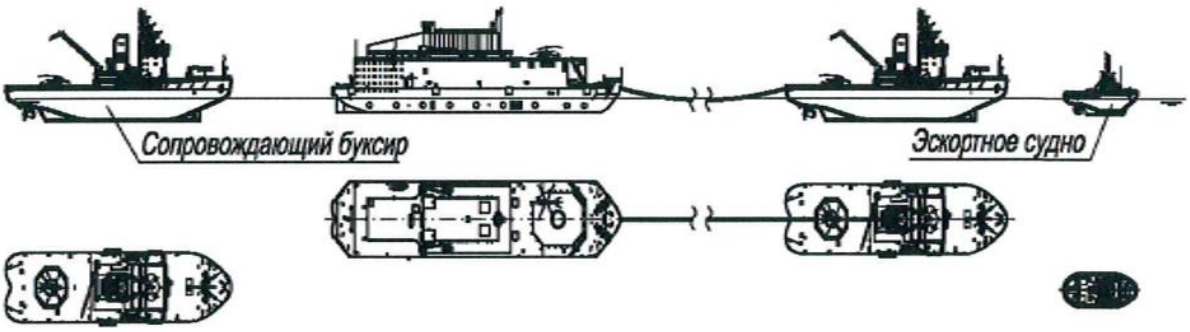


Figure 1: Set up for towing in open waters (no ice) from St. Petersburg to Murmansk (Rosenergoatom, Russia).

Phase 1 (Crisis development – before release or exposure)

The towing is expected to last for 19-22 days from St. Petersburg to Murmansk. There are seven areas along the Norwegian coast with dangerous waves and possible difficult conditions. We have chosen Stadlandet as the place where problems arise. The location could however also be in the Baltic Sea.

Nuclear fuel has been loaded and the power plant has been running tests for the last three months. The vessel is 140 meters long, 30 meters wide and with a total displacement of 21 000 metric tons. Towing starts from St. Petersburg on May 9th, expected arrival in Murmansk May 30th. The conditions for safe towing via open water is a speed of 5-6 knots, wind speed not more than 15 m/s, and restrictions on wave disturbance.

Outside the Norwegian coast, a low pressure system is moving in, with expected winds from 17-25 m/s. Late on the 18th of May, and the following day the winds are increasing and reaching 20 m/s at open sea. The convoy is now in the very exposed Stadhavet Sea.

The convoy experience trouble, and the floating nuclear power plant breaks free from the lead tug boat. During the initial phase, the tug boats are able to support the vessel, but are drifting slowly in a northeasterly direction.

Phase 2 (Crisis management – ongoing release or exposure)

The traffic control centre of the Norwegian Coastal Administration are noticing that the convoy has changed their direction, and are heading towards land. They contact the convoy, and receive information about the status and that assistance might be needed. The total crew consists of 75 men.

The Coastal Administration assesses the situation as critical – and issues an alert, and start looking for possible resources. The Norwegian Radiation Protection Authority is contacted and the Crisis committee is summoned.

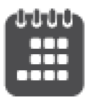
Due to severe weather, the convoy requests to seek safe harbor in Ulsteinvik. Before giving permission, the Norwegian authorities asks for more information, technical specifications and an emergency plan, in case anything goes wrong. Assisting tug boats are on their way from Murmansk, but it will take 4 days before they reach the area.

Norwegian authorities are considering giving permission to seek shelter outside Ulsteinvik.

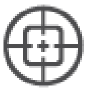
Phase 3 (Consequence management – after release or exposure)

The convoy is maneuvered into calmer waters outside Ulsteinvik. It is uncertain how long the convoy must remain in place, before they can move on. There is a need for improved towing capacity, and a new towline is needed.

Table 3.4: Relevant scenario elements.

Scenario element		Phase 1	Phase 2	Phase 3
	Scenario overview			
	Time (time of year, time of day etc.)	19th of May at 23:30	20-21 of May	The following week
	Duration	12 h	24 h – situation unclear	7 days, depending on weather conditions and additional tug boats

	Location	Off the west coast of Norway – Stadt. Known for difficult wave conditions	Ulsteinvik, Ulstein kommune	Ulsteinvik
	Wind (strength and direction)	17 m/s from SW incrasing to 20 m/s	12 m/s SW	4-8 m/s SW
	Sea current	Norwegian current – from S to N	Local currents and tidal waters	Local currents and tidal waters
	Weather conditions	Low pressure system coming in from England. Rain and wind		
	Temperature (air and water)	Early summer: Air 15^{o} C Sea 8^{o} C		
	Sequence of events			
	Scope (population affected, areas etc.)		Population of 8500 in Ulstein municipality, majority between 20-40 years old	
	Source term and amount of release/ release rates	Reactor with 70 MW capacity. Fuel operated for 3 months		
	Observed levels of radioactivity	None	None	None
	Comparable events	Several towing operations (ships and submarines) in this area has failed – vessel lost or sunken.		
	Ripple effects	none	none	none
	Contributing factors	Difficult weather conditions	Takes time to assemble sufficient tug boat capacity	
	Coinciding events	None	None	None

Intentional act?				
	Intention	Hostile takeover of NPP – **unlikely**		

Possible exercise elements in this scenario:

Possible exercise elements in this scenario are:

- National and international notification (according to agreements);
- Requisition of rescue resources (nationally/internationally);
- Mapping and monitoring operations;
- Decision-making processes and involvement of stakeholders;
- Crisis communication;
- Local authorities and management vs. governmental authorities and management;
- Requesting assistance from military resources.

Proposed or possible learning objectives during an exercise:

The various exercise elements will be considered and identified in advance of the exercise. Learning objectives and practice goal will depend upon which exercise elements are selected.

3.5 Scenario 5: A dirty bomb using a Sr-90 source from an unmanned light-house of Soviet construction

Source specification

A ten cm long steel cylinder, weight approx. 5 kg, containing initially 40 000 Ci (1.48 PBq) Sr-90. Temperature of cylinder uncooled about 300° C. Estimated source term is 0.75 PBq.

Source: www.iaea.org

Phase 1 (Crisis development – before release or exposure)

A resourceful criminal organization have obtained the dismantled radioactive source from an unmanned lighthouse that was carried away from its fundament by arctic ice during a winter. The lighthouse was found submerged many years later by local fishermen, who sold the information to the criminals. The latter managed to move the radioactive source and transport it away hidden in the filled water tank of a fishing vessel. The source was then sold to a terrorist organization.

The terrorist organization have placed a dirty bomb, made of conventional high explosives and the radioactive source, on the top of a fishing vessel and moved it to a position just outside a Nordic capital. The terrorists demand that the Nordic country immediately stops it engagement in the war in Y-country and release named terrorists from its prisons or they will set of the radiological dispersion device (RDD).

Phase 2 (Crisis management – ongoing release or exposure)

The military option to sink the vessel by force is out-ruled due to legal aspects.

Police SWAT team intervenes.

The dirty bomb is intentionally set of by the terrorist at the beginning of the police operation.

The population of the Nordic capital and the neighboring municipalities has been warned through media and typhoon alarms are sounded after the explosion. It is highly recommended to stay indoors, close doors and windows and shut off ventilation until the authorities provide more information.

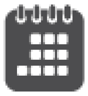
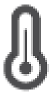
The national radiation protection authority sends personnel to the area and set up its mobile monitoring systems and mobile radiological lab units. Strong beta radiation from Sr-90 is indicated in the plume from the explosion. Prognosis team at the radiation protection authority evaluates the situation and recommends action to be taken.

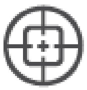
The police is considering evacuation.

Phase 3 (Consequence management – after release or exposure)

After four hours, the radioactive plume has passed the city and some deposition had taken place. Most of the activity deposited less than one kilometer from the explosion site, in the vicinity of the harbor. Decontamination teams in full protective gears are ready to assess and map the contamination and to start remediation work.

Table 3.5: Relevant scenario elements.

Scenario element		Phase 1	Phase 2	Phase 3
	Scenario overview			
	Time (time of year, time of day etc.)	Summer		
	Duration	4 hours		
	Location	Nordic seaside capital		
	Wind (strength and direction)	Sea breeze 3 m/s		
	Sea current	Calm		
	Weather conditions	Sunny, warm calm summer weather?		
	Temperature (air and water)	Air 25˚C. Sea 18˚C.		
	Sequence of events	Threat and demands.	Bomb set off.	Estimating damage. Cleaning up.
	Scope (population affected, areas etc.)	600 000 persons Including visitors	Initial release and contamination of harbour and part of city.	After effect.
	Source term and amount of release/ release rates		0.75 PBq.	Contamination.

	Observed levels of radioactivity		Strong beta activity in the harbour region	Remediation actions
	Comparable events	Cs-137 on top of reactor 4 in Chernobyl		
	Ripple effects			Other (empty?) threats.
	Contributing factors		Wind direction	Summer activities of the population.
	Coinciding events		none	
Intentional act?				
	Intention		yes	
	Background		International terrorism	
 	Capacity & Capability	Quite capable to perform radiological terrorism		

Possible exercise elements in this scenario:

Possible exercise elements in this scenario are:

- National and international notification (according to agreements);
- Requisition of rescue resources (nationally/internationally);
- Mapping and monitoring operations;
- Assessment of releases and contamination;
- Assessment of measures (such as evacuation, use of iodine tablets, restrictions on travels etc.);
- Decision-making processes and involvement of stakeholders;
- Crisis communication;
- Local authorities and management vs. governmental authorities and management;
- Cooperation and/or hand over between civilian authorities and military authorities.

Proposed or possible learning objectives during an exercise:

The various exercise elements will be considered and identified in advance of the exercise. Learning objectives and practice goal will depend upon which exercise elements are selected.

Scenario 6: Accident involving highly-enriched uranium (HEU)

Source specification

About 100 kg of highly-enriched uranium (HEU), equivalent to about five nuclear devices (according to safeguard definitions).

Phase 1 (Crisis development – before release or exposure)

A secret sea transport from the Baltic Sea to the arctic region with highly-enriched spent research reactor fuel (HEU-MTR). The material was loaded on an inconspicuous minor freighter belonging to a nuclear weapons state, with hidden heavily armed guards on board. The vessel is on route across the Baltic Sea during a pitch black night, not using the maritime positioning system or position lights, for security reasons.

Source: www.gettyimages.com

A high speed ferry between A and B, travelling at 30 knots, does not in time observe the freighter and a collision occurs. A fire breaks out on the freighter and the hull is taking in water. The ferry's propulsion system is severely damaged, but the hull is intact. The ferry drifts away from the freighter.

Phase 2 (Crisis management – ongoing release or exposure)

The Coast Guard is alerted by the ferry. Sea rescue operations start by the coastal states.

The freighter declines assistance. The Master of the freighter declares he awaits a tugboat from his country. He declares that the fire has been extinguished by the crew, but the freighter is not maneuverable.

A shore based gamma monitoring station in the wind direction sets off an alarm to the duty officer of the nearby coastal state's radiation protection authority. More gamma stations sound an alarm. Trajectories calculated by the radiation protection authority come in the direction from the freighter. Their emergency preparedness organization is mobilized, and fixed wing sea surveillance aircrafts detect radioactive fission products around the freighter.

The Government of the freighters flag state admits now that there is an emergency onboard the freighter, which is INF-3 classed. The foreign Government claims that there is a minimal risk for a criticality accident.

Release scenarios are considered and calculated by the surrounding Nordic radiation protection authorities. Distribution of iodine tablets in case of a release through criticality reactions is considered by some of the authorities.

The national radiation protection authority sends personnel to the adjacent areas, and sets up its mobile monitoring systems.

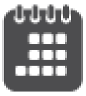
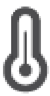
- Notification to authorities and the public?
- Recommendation to stay indoors?
- Evacuation of ships and closing of ship lanes?
- Distribute iodine tablets?
- Freighter towed away?

Phase 3 (Consequence management – after release or exposure)

Nuclear cargo stabilized and subcritical.

Freighter towed away under naval escort by flag state.

Table 3.6: Relevant scenario elements.

Scenario element		Phase 1	Phase 2	Phase 3
	Scenario overview			
	Time (time of year, time of day etc.)	Winter		
	Duration	6 hours		
	Location	Baltic Sea		
	Wind (strength and direction)	North 8 m/s		
	Sea current	moderate		
	Weather conditions	Icy conditions, snowfall.		
	Temperature (air and water)	Air -10˚C. Sea 1˚C.		
	Sequence of events	Collision.	Release. Freighter on fire.	Estimating damage. Cleaning up.

	Scope (population affected, areas etc.)	50000 persons living along the coast	Crew most affected.	
	Source term and amount of release/ release rates	No information	No information; worst case scenario is a criticality excursion with release.	
	Observed levels of radioactivity		Low; Kr-85 and Cs-137 mainly.	
	Comparable events	Fire on nuclear sub with release.		
	Ripple effects			Other threats.
	Contributing factors		Wind and unwillingness to cooperate with sea rescue teams.	
	Coinciding events		None.	
Intentional act? No – security is high				

Possible exercise elements in this scenario:

Possible exercise elements in this scenario are:

- National and international notification (according to agreements);
- Requisition of rescue resources (nationally/internationally);
- Mapping and monitoring operations;
- Assessment of releases and contamination;
- Assessment of measures (such as evacuation, use of iodine tablets, etc.);
- Decision-making processes and involvement of stakeholders;
- Crisis communication;
- Local authorities and management vs. governmental authorities and management;
- Cooperation and/or hand over between civilian authorities and military authorities;
- Political implications.

Proposed or possible learning objectives during an exercise:

The various exercise elements will be considered and identified in advance of the exercise. Learning objectives and practice goal will depend upon which exercise elements are selected.

3.7 Scenario 7: Containership on fire

Source specification

20 PWR fuel elements, containing about 15 metric tons of low-enriched uranium (LEU) in several B(U) containers loaded in one 20 foot CSC-container and ten 30B-cylinders with 30 metric tons of uranium hexafluoride (UF_6) loaded on three 20 foot flat racks.

Source: www.static.pexels.com

Phase 1 (Crisis development – before release or exposure)

A containership coming from North America with a cargo of 2000 sea containers bound for Gothenburg. Among the cargo is dangerous goods in the form of 20 PWR fresh fuel elements, containing about 15 metric tons of low-enriched uranium (LEU) and 30 metric tons of uranium hexafluoride (UF_6) in 30B-cylinders. In addition, other dangerous goods such as flammable liquids and ammunition are transported together with 25 veteran cars in sea containers. When the ship is halfway between Hirtshals and Gothenburg a minor explosion occurs and fire starts among the veteran cars. Thick black smoke obscures the view and the fire seems to spread from amidships to the bow, where the radioactive material is.

Phase 2 (Crisis management – ongoing release or exposure)

Can firefighting with water from tugboats give rise to a criticality accident with release?

At very high temperatures the UF_6 cylinders might burst and uranium may be dispersed and huge amounts of extremely poisonous hydrogen fluoride may be released.

Is it advisable to redirect or sink the vessel. Or try to tow the vessel out to sea?

Notification to authorities and the public (in the wind direction), recommending them to stay indoors.

The national radiation protection authorities send personnel to the area, and sets up their mobile monitoring systems?

Evacuation of population?

Distribute iodine tablets to children and adolescents?

Unloading radioactive material and other dangerous goods?

Protective measures on container ship.

Other ships in the vicinity?

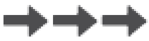
Phase 3 (Consequence management – after release or exposure)

Efforts to map contamination of adjacent areas, on land and in the sea are ongoing.

No special measures are implemented, except restricted access contaminated areas with reinforced protection in place.

Table 3.7: Relevant scenario elements.

Scenario element		Phase 1	Phase 2	Phase 3
	Scenario overview			
	Time (time of year, time of day etc.)	Summer		
	Duration	Approx. 4 hours		
	Location	At sea		
	Wind (strength and direction)	West		
	Sea current	Calm		
	Weather conditions	Sunny, warm calm summer weather		
	Temperature (air and water)	Air 25˚C Sea 18˚C		
	Sequence of events	Fire onboard	UF-6 cylinders burst from high temperature	Estimating damage and contamination. Cleaning up
	Scope (population affected, areas etc.)		Initial release and contamination of area	
	Source term and amount of release/ release rates			

	Observed levels of radioactivity			
	Comparable events	Fire on “Atlantic Cartier” in Hamburg, Germany, 1 May 2013 (2 containers with fuel elements). Fire on “Parida” in Moray Firth, Scotland, 7 Oct 2014 (radioactive waste).		
	Ripple effects			Denial of shipment
	Contributing factors			
	Coinciding events			
Intentional act? No				

Possible exercise elements in this scenario:

Possible exercise elements in this scenario are:

- National and international notification (according to agreements);
- Requisition of rescue resources (nationally/internationally);
- Decisions on possible use of foam and CO_2 internally;
- Decisions on cooling the hull externally;
- Maintaining the ship’s stability;
- Mapping and monitoring operations;
- Assessment of releases and contamination;
- Decision-making processes and involvement of stakeholders;
- Crisis communication;
- Local authorities and management vs. governmental authorities and management;
- Cooperation and/or hand over between civilian authorities and military authorities.

Proposed or possible learning objectives during an exercise:

The various exercise elements will be considered and identified in advance of the exercise. Learning objectives and practice goal will depend upon which exercise elements are selected.

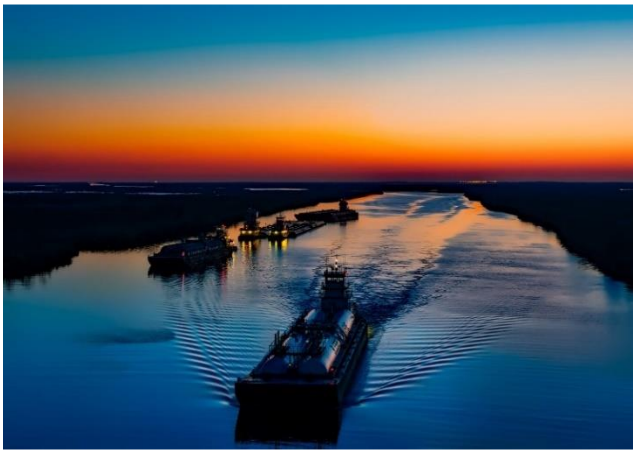
3.8 Scenario 8: M/S Sigrid transporting spent nuclear fuel is maliciously attacked

Source specification

Four B(U)F packages (casks) with spent nuclear fuel, containing 68 spent fuel elements.

Phase 1 (Crisis development – before release or exposure)

M/S Sigrid is transporting four flasks of spent nuclear fuel (BWR) from Ringhals NPP to the intermediate storage (CLAB) at Oskarshamn.



Source: www.static.pexels.com

Phase 2 (Crisis management – ongoing release or exposure)

When the ship is passing through Öresund she is attacked by adversaries with armor piercing devices damaging several casks, producing a release.

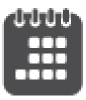
Phase 3 (Consequence management – after release or exposure)

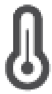
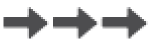
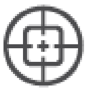
Ship drifts during the attack onto a sand bank and is stuck there. Police SWAT teams clear the ship from the terrorists. The explosions have damaged two casks and there is a release into the cargo hold.

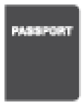
Kr-85 and Cs-137 is detected outside the ship and at gamma stations ashore in the wind direction.

I-131 is not present as the fuel has cooled more than 2 years prior the transport.

Table 3.8: Relevant scenario elements.

Scenario element		Phase 1	Phase 2	Phase 3
	Scenario overview			
	Time (time of year, time of day etc.)	Autumn		
	Duration	6 hours		

	Location	Öresund		
	Wind (strength and direction)	NW 5 m/s		
	Sea current	calm		
	Weather conditions	Overcloud, no rain		
	Temperature (air and water)	8˚C/10˚C		
	Sequence of events		Malicious attack. 2 casks punctured. Release	
	Scope (population affected, areas etc.)			
	Source term and amount of release/ release rates			
	Observed levels of radioactivity		2 mSv/h 50 m from the vessel in wind direction; varies with time	
	Comparable events			
	Ripple effects			Denial of shipment
	Contributing factors		2 damaged casks	
	Coinciding events		None	
Intentional act?				
	Intention		Yes	

	Background	International terrorism	International terrorism	
 	Capacity & Capability	Very capable	Very capable	

Possible exercise elements in this scenario:

Possible exercise elements in this scenario are:

- National and international notification (according to agreements);
- Requisition of rescue resources (nationally/internationally);
- Law enforcement actions;
- Mapping and monitoring operations;
- Assessment of releases and contamination;
- Assessment of measures (such as evacuation, use of iodine tablets, restrictions on travels etc.);
- Decision-making processes and involvement of stakeholders;
- Crisis communication;
- Local authorities and management vs. governmental authorities and management;
- Cooperation and/or hand over between civilian authorities and military authorities.

Proposed or possible learning objectives during an exercise:

The various exercise elements will be considered and identified in advance of the exercise. Learning objectives and practice goal will depend upon which exercise elements are selected.

3.9 Scenario 9: Accident involving nuclear icebreaking freighter in Danish waters

Source specification

Collision between the Russian nuclear icebreaking freighter "Sevmorput" and a Danish heavy bulk carrier ship.

Severe damage to the hull and subsequent grounding of "Sevmorput", during high tide, 70 km east of the Danish city Aarhus.

Low tide combined with possible damage to the reactor installation, leads to Loss-of-coolant accident (LOCA) and airborne release of radioactive substances from "Sevmorput".

Photo: Knud Olsen (maritimedanmark.dk).

Figure 2: Route-T (IMO recommendation) for all vessels with a draught of 11 meters or more, and Vessels carrying highly radioactive material. Points shows default positions where a time-of-arrival and plume-prognosis calculation is prepared by NUC DEMA.

The scenario takes place over 2 days in three phases with increasing difficulty and intensity in the events – this is an approach to exercise planning that makes it possible to get the most out of the exercise days.

Phase 1 (Crisis development – before release or exposure)

Development stages:

- On November 11. 2015 - 0402A DEMA/Birkerød receives a note that the Russian ship "Sevmorput" will enter route T.
- At 0431A the Danish Meteorological Institute put out warning of strong wind from NE 30 m/s, gusting to hurricane strength and warning of elevated water levels.
- At 0551A South of Anholt – the Bulk Carrier "Torm Island" is on its way north – also through Route Tango.
- At 0556A South of Anholt – "Sevmorput" is on its way south through Route Tango, less than 2 nautic miles from "Torm Island".
- At 0600A Rute Tango, 40 nautical miles S of Anholt collision occurs.
- At 0730A "Sevmorput" reports about trouble with propulsion in Kattegat, 20 NM NE of Ebeltoft.
- At 0800A the captain of "Sevmorput" deliberately grounds "Sevmorput" on Hjelm Banke, 10 NM E of Ebeltoft. This to avoid uncontrolled floating around.
- "Sevmorput" repeatedly refuses to receive outside help.
- At 11 NOV 2015, 1430A ROSATOM FLOT reports that there has been a small explosion onboard "Sevmorput" but with no damage to the reactor, later the same day.
- At 2100A ROSATOM reports that "Sevmorput" will try to raise the effect of the reactor.

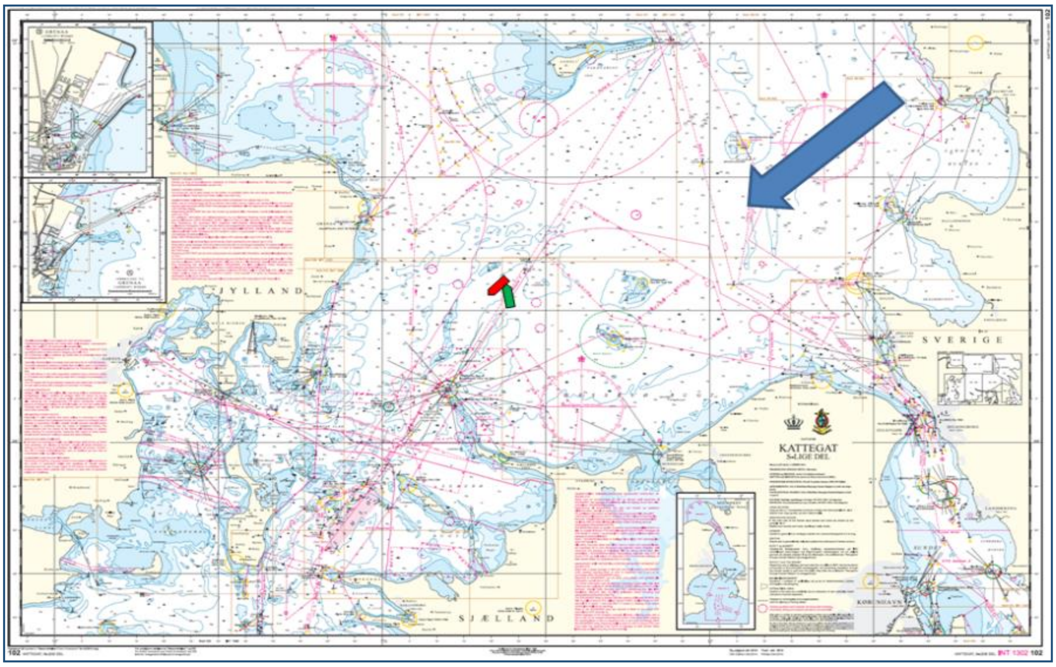


Figure 3: A map showing the sea route and the accident location. The blue arrow is the wind direction.

Prognosis shows that at 1800A the storm will die out and the wind will shifts to SE during the night.

Phase 2 (Crisis management – ongoing release or exposure)

Development stages:

- 12. NOV 2015, 0800A Weather report wind from South-East.
- 12. NOV 2015, 0817A "Sevmorput" suddenly reports that the reactor cooling system is severely damaged and measurements shows that contaminated coolant water are released to the sea.
- The public has been informed about the situation since the morning and there is massive news covering and social media are flooding with stories. Worries, fears, anger, frustration and curiosity causes autonomous self-evacuation, catastrophe-tourism, public demanding of iodine etc.
- Traffic chaos, mobile net-overload, stop of ferries and sail restriction in Kattegat.

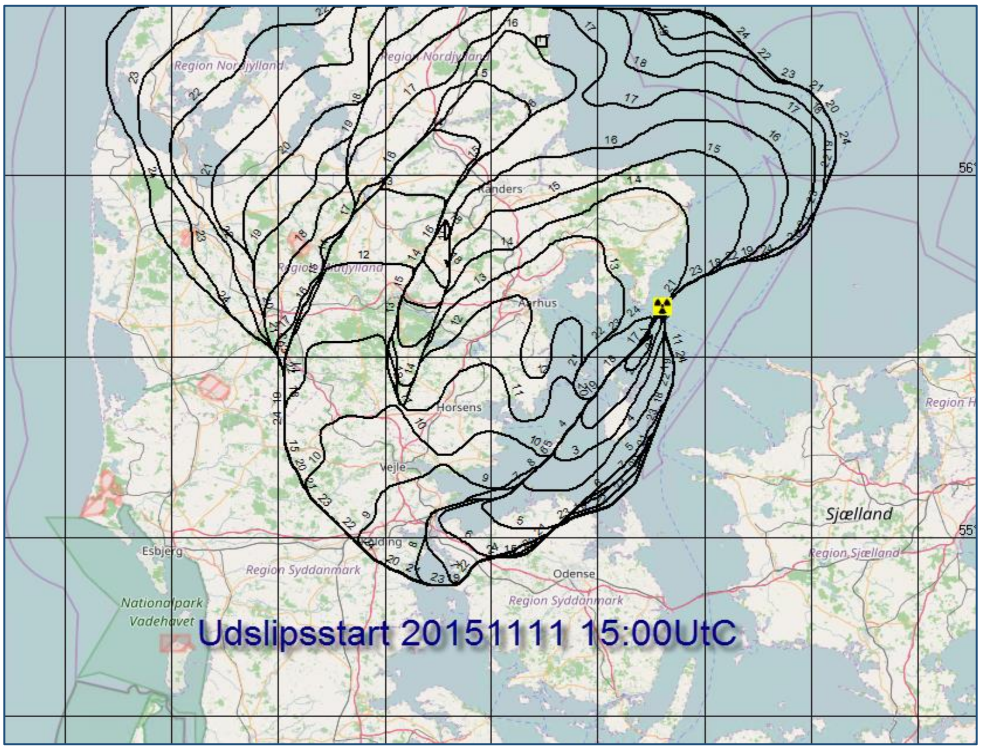
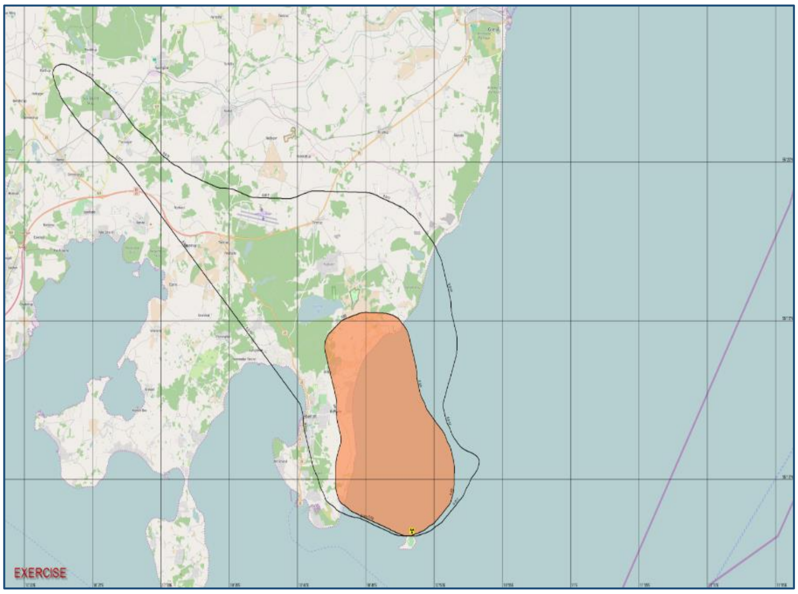


Figure 4: Modelling of the release distribution.

Phase 3 (Consequence management – after release or exposure)

At 12. NOV 2015 10:47 a big explosion onboard "Sevmorput" and heavy smoke is observed. Shortly after is the crew evacuating the ship.

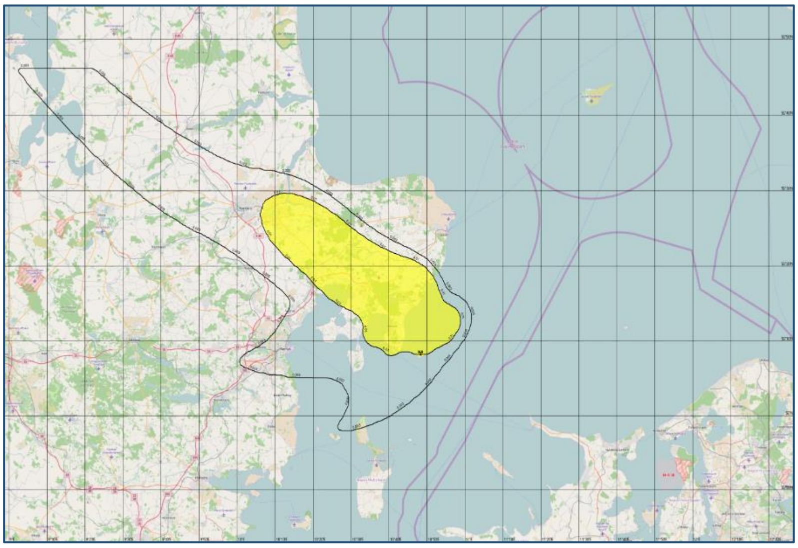
Prognosis show that a release will reach Ebeltoft within an hour and within few hours the plume will spread towards and over the cities of Århus and Randers.



PROGNOSE FOR THYREOIDEA DOSER (GY) FOR VOKSNE ved UDENDØRSOPHOLD
TYPE: MEDIUM UDSLIP FRA SEVMORPUT (80% ædelgasser, 8 % I og 4% Cs)
VÆRKTYPE: VLT40
TERMISK EFFEKT: 135 Mw
UDSLIPSSTART: 12. november 2015 KL. 10:50 DANSK TID (09:50 UTC)
UDSLIPSVARIGHED: 3 timer
UDSLIPSPROFILNAVN: Kris Medium
POSITION: Breddegrad: 56,139354 Længdegrad: 10,806407
FARVEFORKLARING:
50 mGy - Jod tabletter bør overvejes til voksne
17 mSv - 30 % af grænse for jod tabletter
ANBEFALINGER OG GRÆNSER FRA NOTAT: Beskyttelsesforanstaltninger for befolkningen ved nukleare nødsituationer – Den akutte fase (Sundhedsstyrelsen og Beredskabsstyrelsen, 2015)

Metrologisk datasæt: DMI- HIRLAM SKA

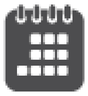
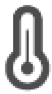
Figure 5: A forecast for thyroid doses (Gy) for adults staying outdoor from a medium release from "Sevmorput".



PROGNOSE FOR TOTAL EFFEKTIV DOSIS (SV) FOR 10 ÅRIGE BØRN ved 7 DAGES UDENDØRSOPHOLD
TYPE: MEDIUM UDSLIP FRA SEVMORPUT (30% ædelgasser, 0,3% I og 0,1% Cs)
VÆRKTYPE: VLT40
TERMISK EFFEKT: 135 Mw
UDSLIPSSTART: 12. november 2015 KL. 10:50 DANSK TID (09:50 UTC)
UDSLIPSVARIGHED: 3 time
UDSLIPSPROFILNAVN: Kris Medium
POSITION: Breddegrad: 56,139354 Længdegrad: 10,806407
FARVEFORKLARING:
10 mSv - Indendørsbeskyttelse skal overvejes
3 mSv - 30 % af grænse for indendørsbeskyttelse
ANBEFALINGER OG GRÆNSER FRA NOTAT: Beskyttelsesforanstaltninger for befolkningen ved nukleare nødsituationer – Den akutte fase (Sundhedsstyrelsen og Beredskabsstyrelsen, 2015)

Figure 6: A forecast of total effective dose (Sv) for a 10-year old child staying outdoor for 7 days.

Table 3.9: Relevant scenario elements.

Scenario element		Phase 1	Phase 2	Phase 3
	Scenario overview			
	Time (time of year, time of day etc.)	November	November	November
	Duration	1 day	½ day	½ day All timeframes can be changed
	Location	Denmark Route T and near the coast	Denmark Route T and near the coast	Route T and near the coast
	Wind (strength and direction)	Very strong	Middle	Middle
	Sea current	Strong	-	-
	Weather conditions	Storm with gust of hurican strength	Fresh	Fresh
	Temperature (air and water)			
	Sequence of events	Collision -> Leads to worry	Collision+Explosion+Unknown factors -> LOCA	LOCA -> Release
	Scope (population affected, areas etc.)	Jutland and isles	Djursland, middle of jutland. Farming lands and larger cities.	Djursland, middle of jutland. Farming lands and larger cities.
	Source term and amount of release/ release rates			
	Observed levels of radioactivity			

	Comparable events			
	Ripple effects		Self-evacuation Panic Concequences for farming industry and export Economical concequences	
	Contributing factors			
	Coinciding events			
Intentional act?	No			

Possible exercise elements in this scenario:

Possible exercise elements in this scenario are:

- National and international notification (according to agreements);
- Foreign affairs and policy;
- Requisition of rescue resources (nationally/internationally);
- Mapping and monitoring operations;
- Assessment of releases and contamination;
- Assessment of measures (such as evacuation, use of iodine tablets, restrictions on travels etc.);
- Decision-making processes and involvement of stakeholders;
- Crisis communication;
- Local authorities and management vs. governmental authorities and management;
- Cooperation and/or hand over between civilian authorities and military authorities.

Proposed or possible learning objectives during an exercise:

The various exercise elements will be considered and identified in advance of the exercise. Learning objectives and practice goal will depend upon which exercise elements are selected.

4. Target groups and further use

The scenarios in this report were first and foremost developed to aid the radiation protection authorities in the Nordic countries to further develop their emergency preparedness and exercises. A further step of improvement would be to include local and regional preparedness organisations, and conduct joint common exercises, either locally or as regional exercises with more than one country involved.

The previous NKS-B project NORCOP COAST (Nalbandyan *et al.*, 2016) gave an overview of the most important authorities in the Nordic countries, as well as an overview of how an accident at sea would be dealt with. A brief summary of this is:

Denmark

The Danish Emergency Management Agency (DEMA) is a Danish governmental agency under the Ministry of Defence. The agency was formed under the Danish Emergency Management Act, which came into force on January 1, 1993. DEMA's mission is to cushion the effects of accidents and disasters on society and to prevent harm to people, property and the environment. Consequently, DEMA has a series of operational, supervisory and regulatory functions concerning emergency management and preparedness.

In Danish preparedness planning five general principles are used:

- Sector responsibility i.e. that the department or agency which has the daily responsibility for a given sector retains responsibility for that sector during crisis;
- Similarity stating the importance of maintaining the largest similarity possible between the daily setup and the crisis management setup in order to minimize the extent of organisational re-arrangements when activating the crisis management organisation;
- Subsidiarity, which means that emergency management and crisis management activities should be handled at the lowest organizational level possible;
- Cooperation: Authorities are responsible for cooperating and coordinating with each other in terms of both preparedness planning and crisis management;
- Precaution in a situation with unclear or incomplete information, it is always preferable to establish a higher, rather than a lower, level of preparedness.

The Danish Emergency Management Agency's (DEMA) Nuclear Division (NUC) is responsible for maintaining the general nuclear emergency preparedness plan for Denmark and is National Competent Authority (NCA) in accordance with IAEA conventions. The nuclear Division maintains expert knowledge regarding measurements and consequence assessment and is responsible for the physical protection of transport of nuclear materials in Denmark. In addition to this the Danish Nuclear Division has an inspectorate function for the remaining parts of the old RISØ research reactors.

The Nuclear Division at DEMA has created Standard Operation Procedures in case of passage of nuclear propelled vessels. When DEMA NUC becomes aware of a passage, other authorities and countries are informed and steps are taken to follow the ship and estimate its course and time-of-passages and make dispersions calculations.

Finland

In the case of a nuclear or radiological accident, several Finnish authorities will be involved in decision-making and protective actions. Each authority decides upon measures concerning their own administration responsibilities. The Nuclear and Radiation Safety Authority STUK issues information concerning the accident, radiation situation and the impact of the situation on public health and safety.

In the case of maritime accidents, the most important Finnish authorities include Finnish Transport Agency (under the Ministry of Transport and Communications), Border Guard, and Defence Forces. The Finnish Transport Agency as a VTS authority (Vessel Traffic Service) can close the sea area, the sea route fully or partially in Finnish territorial waters. It is also able to warn about radiological incidents ships outside Finnish territorial waters. The Border Guard is leading maritime rescue authority, and responsible for the Search and Rescue operation. Maritime Forces has some ships suitable for assisting in radiation accidents.

The major challenge in the management of maritime radiological accident is communication between different authorities. Thus, it is important to exercise regularly also these kind of situations in addition to nuclear power plant exercises.

Iceland

In the *Icelandic system*, the situation differs from Finland and Sweden in that there is no nuclear industry and a less complex organisational structure with short and effective communication channels between few responsible actors. Given the large size of the Icelandic SAR area, financing and human resources are limited. Experiences from natural disasters such as earthquakes and volcanic eruptions have established well-tested and efficient cooperation between IRSA and relevant response parties. In a crisis situation, the National Rescue Centre will be activated to coordinate and handle the crisis.

The Icelandic Coast Guard plays a key role in the coordination and execution of SAR at sea, while the Civil Protection Department of the National Commissioner of the Police is responsible for general coordination in emergency situations, e.g. when the National Rescue Centre is activated. Natural disasters are not uncommon in Iceland and general and specific emergency plans are relatively mature and frequently implemented in exercises and actual situations. The Icelandic Search and Rescue Region is fairly large (1,8 million km^2) and challenging due to rough seas, dark winters, cold weather conditions and long distances. This limits the rescue capabilities in the region. The sensitive ecosystem of the area and the importance of the fishing industry for the economy of the country are among main concerns regarding increased maritime traffic.

The Icelandic Radiation Safety Authority (IRSA), as a National Competent Authority, builds upon streamlining with existing emergency preparedness infrastructure, with special emphasis on establishing and maintaining communication with first responders, law enforcement, academia, research institutions and related parties domestically and abroad through training, exercises, communication tests and scientific cooperation. Real-time monitoring of aerosols and total gamma dose rates, together with monitoring of radionuclides in yearly samples of seawater and biota from Icelandic waters provide a background for measurements that could be made in emergency situations.

Norway

The Norwegian Coastal Administration is a Norwegian authority under the Ministry for Transport and Communications. The main responsibilities includes coastal management and infrastructure planning, maritime traffic safety and monitoring, and preparedness and response against acute pollution. The geographical area of responsibilities includes Norwegian territorial waters to 12 nm, and Norwegian EEZ (to 200 nm or to neighbouring states EEZ), as well as intervention at high seas based on international intervention conventions. The most important acts for the Norwegian Coastal Administration pollution preparedness and response is the Pollution Control Act and the Svalbard Environmental Protection Act. An important regulation is the Regulations concerning notification of acute pollution or danger of acute pollution.

Outside national waters, in the 200 nautical Economic Zone, the Pollution Control act applies to all off shore oil and gas exploration installations and to all Norwegian ships. For international traffic in the Norwegian Economic Zone and in international waters, the possibilities for intervention are based on international law and regulations. The most important once being the IMO Convention relating to Intervention on the High Sea in cases of Oil Pollution and radioactive substances.

The Norwegian Search and Rescue (SAR) service is coordinated by two Joint Rescue Coordination Centres (JRCC). The SAR service is defined by "The organised activity in connection with immediate effort, to save human lives from death or injuries caused by sudden accidents or danger." The Norwegian SAR is a fully integrated set of services directed by a single coordinating organisation responsible for all types of rescue operations (sea, land, air). These services are performed through a cooperative effort involving governmental agencies, voluntary organisations and private enterprises.

The Norwegian Radiation Protection Authority (NRPA) is the Norwegian Competent Authority and National Warning Point on all matters related to nuclear and radiological issues, including emergency management, nuclear safety and security and radioactive contamination. The NRPA is administratively organised under the Ministry of Health and Care Services. Additionally, the NRPA serves as a directorate for the Ministry of Foreign Affairs and the Ministry of the Environment and Climate Change, but also advices all other ministries as well.

The Norwegian radiological and nuclear emergency preparedness is organised around the Crisis Committee for Nuclear Preparedness. The Crisis Committee consists of representatives from key government offices, who have a special responsibility for a sector in the management of a nuclear or radiological event. The emergency preparedness organisation comprises the Crisis Committee for Nuclear Preparedness, the Crisis Committee's advisors, the Crisis Committee's secretariat, and the county governors as the Crisis Committee's regional representives.

The Crisis Committee has the authority to, and is responsible for, implementing protective measures (NRPA, 2013). The Crisis Committee for Nuclear Preparedness is chaired by the Director General of the Norwegian Radiation Protection Authority. The county governors have regional forums for coordination in which affected government agencies participate on a regional level and establish plans for their nuclear preparedness. The county governors are the link between the national authorities and the local authorities and municipalities.

Sweden

The Swedish emergency preparedness system is organised in levels and is based on interaction between all the organisations operating in each level. Each organisation is responsible to carry out its tasks within their level, and to cooperate with other organisations at all levels. In the first instance, a crisis is managed by the municipality or the municipalities where the crisis occurred, together with the licensee responsible for the activity. If necessary, the Regional County Administrative Boards support the counties in aligning and coordinating the resources in their region at the regional level. Both the counties and the Regional County Administrative Boards can accept support from the central authorities to be able to handle the crisis in the best way. At the national level, the government can support both the county and regional level by appointing one of the authorities to coordinate the available resources.

Because the system is based on collaboration, it is important to achieve an effective way of working that leads to coordination of resources and agreement on direction of handling. That requires a good ability to communicate between the organisations to be able to interact on relevant issues at the right time and to provide consistent information to media and to the public.

When it comes to maritime accidents there are two organisations that have operational responsibility. The Swedish Coast Guard takes the operational crises management at sea. If there is any radioactive release spreading in over land, the counties take the lead of the crises management within their own county. In case the release is spread out over a whole region the County Administrative Board support the counties with coordination of resources within their region. In case of terror attacks the Police take the lead of the crises management at sea with assistance from the Swedish Coast Guard.

There are several authorities involved in a radiological emergency, therefore the Swedish Contingencies Agency, MSB, has an important role in encouraging the authorities to see the big picture, and based on this, coordinate resources and prioritize actions for the good of the public. The Swedish Radiation Safety Authority (SSM) is responsible for providing advices and recommendations concerning protective measures regarding radiation protection, radiation measurements, clean-up and decontamination following a release of radioactive substances.

The emergency organisation of SSM manages the crisis from a control center. When an alarm goes off, the crisis management start with cooperation between the radiation protection officer on duty, the reactor safety officer on duty and the press officer on duty. All, with availability 24 hours a day. If an accident is considered to be of the nature Crisis the Emergency response group is called in to handle the crisis as the first shift. The organisation as a whole includes experts in nuclear safety and security, radiation safety and communicators.

International Aspects

In order to intervene outside national waters, contact has to be established with owners, flag state, etc. before action is taken. There are also other Marpol- regulations concerning the prevention of pollution from ships. Another system of notification is the Safe Sea net. Early notification to the traffic Control makes it possible to follow HAZMAT transports closely and take precautionary action. This system of notification applies only to ships coming to or from an EU-harbour.

The IAEA Incident and Emergency Centre is a world's centre for coordination of international emergency preparedness and response assistance. The IAEA centre can assist in notification, assessment of potential emergency, provision of public information, provision of assistance upon request and coordinate inter-agency response. The Early Notification Convention includes notification of maritime accidents. The IAEA also administers the RANET – Response and Assistance Network (http://www-ns.iaea.org/tech-areas/emergency/ranet.asp).

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Appendix I

Factsheet for Scenario 1: Release of radioactive materials into the ocean or a rumour about such a release

Background information

The focus in this exercise should be on inter-agency response coordination mechanisms, an assessment of the country's ability to measure samples and analyse data (possibly in large numbers), the provision of information and confidence building measures following a release of radionuclides to the marine environment or a rumour about such a release.

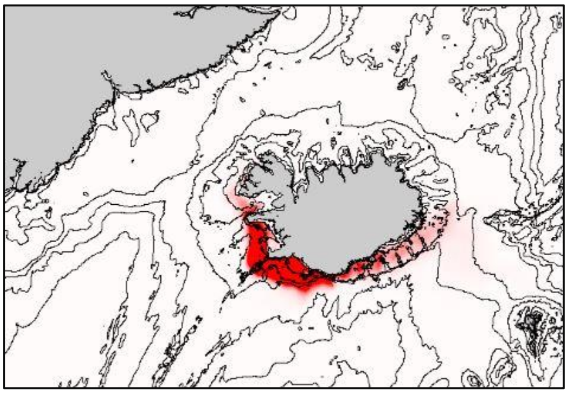

Photo: Marsýn, University of Iceland
http://www.marsyn.is/

To a large extent an exercise based on this scenario would require the same actions to be taken whether or not the vessel in question actually carried dangerous amounts of radioactive materials.

Transport by sea is a common practice for radioactive material within the nuclear fuel cycle, such as uranium hexafluoride, enriched uranium, spent nuclear fuel and solidified high level waste. It is not uncommon that vessels seek lee near land. Occasionally they turn out to be carrying sparsely defined cargos of radioactive materials and sometimes this has been a matter of concern. While the usual kind of commercial transportation happens regularly and is generally without much actual risk, the scenario assumes the unlikely event of a vessel that is said to have been involved in the recovery of radioactive waste previously dumped in the ocean, forcing the exercising country to take action of some sort.

Resources required for responding to the situation would include marine dispersion models to predict the spread of contaminants and thus to help in the planning of remediation actions, risk assessment and general decision-making.

Further challenges would include the assessment of potential emergency, and prompt coordination of inter-agency response.

The use of RANET – IAEA's Response and Assistance Network should be considered and exercised.

It has become clear that one of the most important factors to bear in mind in case of an incident or a mere rumour about one is the specific attention that needs to be paid to communication at the national and international level.

Notification and information exchange in an emergency need to be timely as well as objective, clear and transparent, and arrangements and tools for notification and information exchange need to be in place. Provision of clear, objective and understandable information to the public in an emergency reduces public concern and contributes to the prevention and mitigation of consequences of an emergency.

Public communication arrangements need to be made at the preparedness stage.

The source specification

Since the idea behind this scenario is to exercise things of a less technical nature, but rather to put emphasis on inter-agency response coordination mechanisms, existence and availability of background monitoring data, communication etc., no specific source term has been selected. The user would be encouraged to select an appropriate source: suitable yet challenging. Given the rumour about radioactive materials from a dump site, one or more radionuclides such as ^{3}H, ^{90}Sr, ^{134}Cs, ^{137}Cs, ^{55}Fe, ^{58}Co, ^{60}Co, ^{125}I, ^{238}Pu, $^{239+240}$Pu, ^{241}Am and ^{14}C in liquid or solid form could be selected.

Hazard/Risk assessment

The IAEA has no records of accidents or losses during the regular, commercial transport of cargoes by sea resulting in releases to the marine environment. In reality, contamination to the marine environment would be measureable, but probably not directly harmful. Derivative effects, such as economical impact, could potentially be considerable.

References

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Appendix II

Factsheet for Scenario 2: Unidentified ship with a large Cs-137 source

Background information

The exercise provides a training opportunity in a joint (meaning both air and sea) environment, and training in preparation for complex operational assignments.

Radioactive sources are extensively and commonly used in a wide range of medical, industrial, agricultural and research applications. The odds of a radiological dispersion device falling into malevolent hands have triggered particular public anxiety. The exercise assumes that the recovery of a radioactive source illegally carried on a container ship has been ordered.

Northern Viking 2011 Exercise.
Photo: Icelandic Radiation Safety Authority.

Exercise activities focus on crisis response operations, and can also offer training opportunities in maritime search and rescue and maritime law enforcement operations. The activity will test the abilities of the participating experts in the field of radiological measurement and assessment to operate quickly and effectively, distantly from their usual support structures and in a complex and challenging environment.

The source specification

Radioactive sources vary widely in physical size and properties, their amount of radioactivity, and ease of access. For this scenario a sealed Cs-137 source has been selected. Sources of this kind are in relatively widespread use and could be used with malevolent intent. They have often been manufactured using the compound caesium chlorine (CsCl), a salt whose physical form is a highly dispersible powder similar to talc in its spreading properties. The Cs-137 source proposed for a model exercise is a sealed 6 GBq source, placed on the deck during the overflight, but moved to a container during an on-board search and being partly shielded as a result.

In a model exercise several more sources could be used, including 2,5 kg of depleted uranium and a Co-60 source. These sources could be introduced in order to test the ability of first responders with limited training to locate them as well as to test the ability of specialists to identify them on-site.

Hazard/Risk assessment

The environmental impact either during the recovery operations or in the case of the actual use of the radioactive source as a radiological dispersion device (RDD) is of relatively little concern in the scope of this scenario. The spread of radioactive material on board the ship would be limited to a small area. If an attack using a RDD actually occurred, the device would probably scatter radioactive material over a small area, restricting contamination to possibly the ship and aircraft, and to a very small area of the ocean. This would pose a minor risk, but could lead to a small scale, but easily measurable contamination. However, even if an RDD would not injure many people nor cause considerable environmental contamination, it could certainly cause much terror- and psychological-related distress.

References

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Appendix III

Factsheet for Scenario 3: Accident involving a nuclear submarine off the Norwegian Coast

Background information

Nuclear powered submarines as of 2016

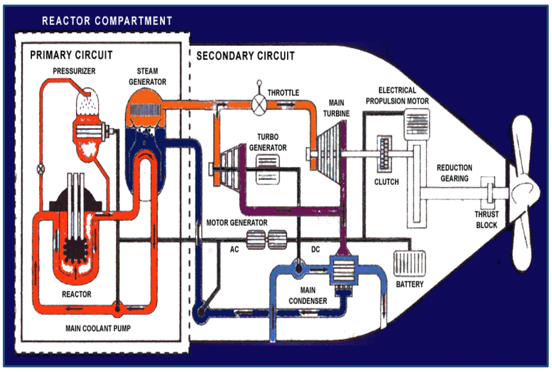
In 2016 there were a total of 152 nuclear powered submarines in commission, from USA, Russia, Great Britain, France, China and India. Many of these patrol the North Atlantic and Barents Seas. Many of these submarines also carry nuclear weapons. Scenario no. 3 does not consider an accident involving nuclear weapons.

Norway receives regularly visits with nuclear-powered allied submarines from Great Britain, France and the United States. For instance, the Great Britain operates a total of 10 nuclear powered submarines, 4 of the SSN Trafalgar class, 2 of the SSN Astute class and 4 of the SSBN Vanguard class. The attack submarines (SSN) do not carry nuclear missiles. It is only the strategic class (SSBN) that carries these.

A British SSN Astute class submarine ready for launch. The class has a 7,400 t submerged displacement. Source: Defence. Industry Daily.

Reactor design

The submarine reactors are small, with a volume of approx.. 1 m^3 for the core. All submarine reactors are today pressurised water reactors (PWR), and it is assumed that British submarine reactors operate on ^{235}U enriched fuel, with an enrichment of minimum 93% (HEU), (FFI, 2016). Most likely the fuel is a mixture of metallic alloys, in total around 100 kg of uranium. Expected output is in the range from 50 to 300 MW(t). The run period is expected to be equal to the lifespan of the submarine. The new reactor design, Core H, won't require refuelling during the submarine's operating life.



The reactor compartment layout for British nuclear powered submarines. Source: World Nuclear Association.

The source specification

A typical inventory of radioactivity in the core of the reactor consists of radioactive noble gasses (isotopes of I, Kr, etc.), fission products (such as isotopes of Cs, Sr, etc.), transuranics (isotopes of Pu, Np, etc.) and other species such as activation products in cladding and reactor materials.

The primary groups of concern from a pollution point of view are the fission products and transuranics as the noble gas isotopes and activation products tend to have short half-lives. The amount of fission products produced in a reactor depends largely on the amount of ^{235}U

that has undergone reaction. More detailed information on the amounts of ^{235}U in the reactor and operational parameters is needed to assess the inventory of the reactor.

Hazard/Risk assessment

In any accident involving nuclear powered vessels, there will be a need to assess any potential releases of radioactivity from the nuclear reactor. Releases of radionuclides to air, as well as to sea water will typically include noble gasses and fission products, such as ^{137}Cs, ^{90}Sr, ^{131}I and other short lived radionuclides. There might also be potential long term impacts of sunken debris from the submarine.

The HMS Astute being rescued after she ran aground in October 2010. Source: The Guardian.

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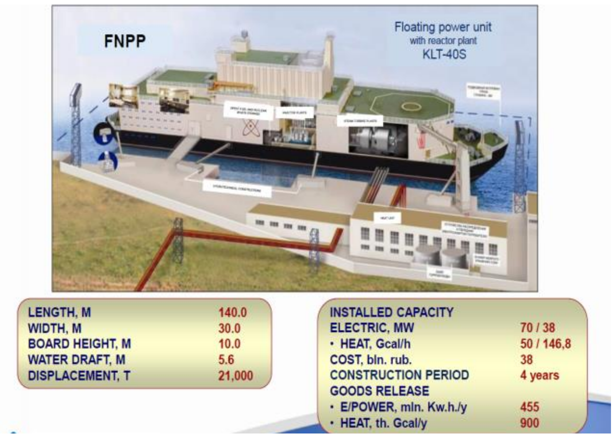
Appendix IV

Factsheet for Scenario 4: Towing of Russian floating nuclear power plant in Nordic waters

Background information

KLT-40S reactors

Russia is developing floating nuclear power units utilising modified KLT-40S reactors – two reactors per vessel. These reactors are water cooled and moderated, output expected to be 2*38 MW(t) or 2*85 MW(e). The run period is expected to be 3-4.5 years with a total operational life of 40 years. The floating nuclear power plant (FNPP) will have onboard facilities for storage of spent nuclear fuel (SNF) and solid and liquid radioactive wastes. Annual generation of waste volumes are expected to be of the order of 16-20 m^3 of LRW and 5 m^3 of SRW.



Schematic diagram of a Floating Nuclear Power Plant.
Source: Rosenergoatom

Construction of *Academician Lomonosov*

Construction of FNPP *Academician Lomonosov* began 15th of April, 2007 at Sevmash shipyard in Severodvisk, and later moved to the Baltic shipyard in St.Petersburg. Two modified KLT-40 reactors are placed on a floating, barge-like, non-propelled platform.

The KLT-40S reactor type is a well established design that has been employed in Russian nuclear powered vessels for approx. 20 years, such as the *Sevmorput*, *Taimyr* and *Vaygach*.

The KLT-40S core is some 1.3 m tall and 1.2 m in diameter and utilises 121 fuel assemblies, each fuel element being 6.2 mm in diameter.

The fuel itself is reported to be UO_2 silumin matrix of <20% enriched ^{235}U in a zirconium cladding.

The KLT-40S is a two circuit PWR (forced circulation in the primary circuit) reactor, the main reactor plant itself comprised of the reactor, the steam generating plant and pumps connected by the main pipe conduits and forming a steam generating “block”.

The containment system is constructed such that any radioactivity released will be held within the containment. The containment vessel is designed to withstand internal pressure of 0.5 MPa.

Ship under construction in St. Petersburg.
Photo: Rosenergoatom

The fuel itself is reported to be UO_2 silumin matrix of <20% enriched ^{235}U in a zirconium cladding.

The KLT-40S is a two circuit PWR (forced circulation in the primary circuit) reactor, the

main reactor plant itself comprised of the reactor, the steam generating plant and pumps connected by the main pipe conduits and forming a steam generating "block". The containment system is constructed in a way that any radioactivity released will be held within the containment. The containment vessel is designed to withstand internal pressure of 0.5 MPa.

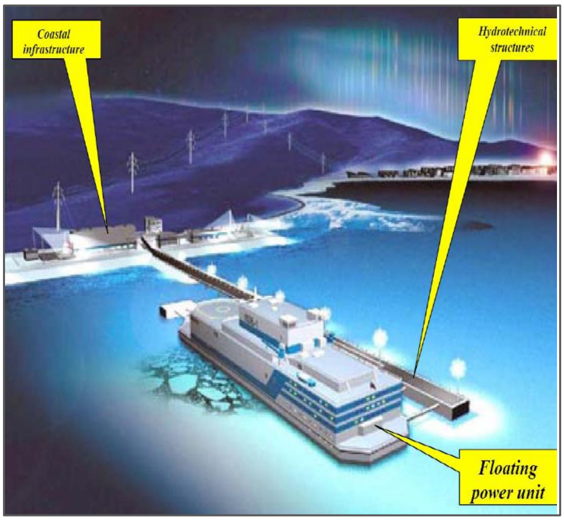
The source specification

The inventory of radioactivity in the core of a reactor consists of radioactive noble gasses (isotopes of I, Kr, etc.), fission products (such as isotopes of Cs, Sr, etc.), transuranics (isotopes of Pu, Np, etc.) and other species such as activation products in cladding and reactor materials.

The primary groups of concern from a pollution point of view are the fission products and transuranics as the noble gas isotopes and activation products tend to have short half-lives. The amount of fission products produced in a reactor depends largely on the amount of ^{235}U that has undergone reaction. Without detailed knowledge of the amounts of ^{235}U in the reactor and operational parameters, an apriori evaluation of the inventory of the reactor is impossible to derive.

Hazard/Risk assessment

In relation to the potential long term impacts of a sunken FNPP, a broad assessment of radionuclide releases from a range of dumped reactors in the Kara Sea is reported in IEAE-TECDOC-938. The presence of stored SNF and LRW and SRW on board is a factor that is less easily assessed.



Depiction of the coastal and hydrotechnical infrastructures to support a floating power unit. Source: OKBM/IAEA.

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Appendix V

Factsheet for Scenario 5: A dirty bomb using a Sr-90 source from an unmanned light-house of Soviet construction

Background information

A *radioisotope thermoelectric generator* ***(RTG)*** *is* a device used to produce electricity by converting heat generated by a radioactive substance to it with help of thermocouples. A well-installed unit is in principle maintenance free.

A radioisotope thermoelectric generator. Source: Bellona homepage: http://bellona.org , published 1 April 2005.

The Soviet Union used RTGs as power sources loaded with Strontium-90 (Sr-90) in light-houses along remote coastal locations in the Arctic and also in the Baltic region. After the decline of the Soviet Union some light-houses were looted for metals, other were carried away by the ice and disappeared. It has to be assumed that not all units have yet been recovered.

The source specification

A ten cm long steel cylinder, weight approx. 5 kg, containing initially 40 000 Ci (1,48 PBq) Sr-90. Temperature of cylinder uncooled about 300 ˚C. Estimated source term is today (year 2017) 0,75 PBq. The chemical composition, that is essential regarding area contamination, is unknown. Possible content may be SrF_2 (soluble) or insoluble $SrTiO_2$ or SrO.

Hazard/Risk assessment

Sr-90 has a half-life of 28.8 years and is mainly a beta-emitter. The nuclide is extremely radiotoxic as it has similar biological properties as calcium. The biological half-life in human is disputed, but is said to be up to 30 years.

Internal contamination of the human body may result in accumulation in bone similar to calcium and irradiation of the bone marrow. Children are especially vulnerable. External contamination will give severe skin burns. Decontamination of affected areas could be difficult.

References

1. A.Grigoriev, A.Katashev. IAEA. Russian RTG Disposal Program. IAEA CEG Workshop 2013.

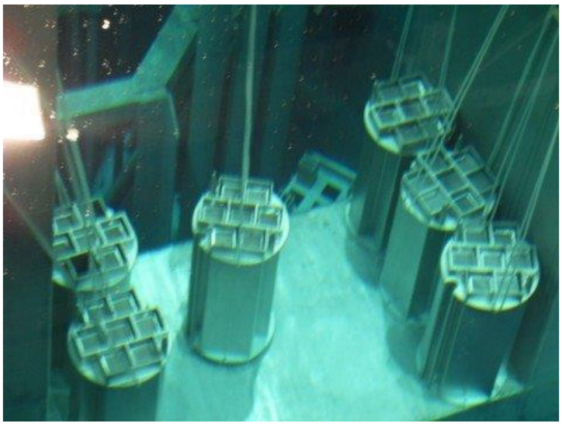
2. "IAEA Bulletin Volume 48, No.1, September 2006 – Remote Control: Decommissioning RTGs" (PDF). Malgorzata K. Sneve.

Appendix VI

Factsheet for Scenario 6: Accident involving highly-enriched uranium (HEU)

Background information

Highly-enriched uranium (HEU) is by the International Atomic Energy Agency (IAEA) defined as uranium where the enrichment of U-235 is higher than 20% by mass. Uranium with an enrichment of about 90 % U-235 is regarded as weapon grade uranium (WGU). The latter could be directly used in nuclear weapons. About 20 kg is said to be enough for a nuclear charge.



Spent highly-enriched research reactor fuel. Photo: National Nuclear Security Administration (NNSA), USA. https://nnsa.energy.gov/

Research reactors around the world have until recently mainly used HEU of different enrichments in their nuclear fuel. It has a lot of advantages from a reactor physics standpoint, but disadvantages from a nuclear safeguards and security one. The latter was a reason to try internationally to replace HEU fuel with low enriched fuel (LEU), and to ship the HEU fuel back to the supplying states (ex. nuclear weapons states such as USA and Russia). Of obvious reasons, such transports are done secretly and under heavy escort.

The source specification

The source consists of about 100 kg HEU calculated as heavy metal (HM) in spent fuel assemblies and placed in a number of fissile B(U) type packages separated in secluded ship compartments. The fuel has been collected from a number of reactors in neighboring countries. The initial enrichment for the exercise is assumed to be 93% U-235.

Scenario details: transport by sea

The fissile packages were through a secret operation brought to a harbour in the south Baltic Sea and loaded on a ship with INF classification (Code for the Safe Carriage of Irradiated Nuclear Fuel, Plutonium and High-Level Wastes on Board Ships). The ship leaves the harbour at nightfall, heavily escorted and with the ships transponders in off position. The destination is an ice-free Artic harbour. The route is planned through Öresund.

Hazard/Risk assessment

There are two radiological scenarios suggested:

A. The collision between the vessels and the following fire eventually ruptures some of the packages. There is a limited release of fission products such as Cs-137 and I-125 and some transuranium elements (plutonium, curium). Contamination of the vessel and the Sea. The fuel has cooled in wet reactor intermediate storages for several years prior to the transport.

B. The collision and fire ruptures a number of packages and the contents spreads in the hold. There is a build-up and accumulation of fissile materials. The geometry is from criticality standpoint favorable and moderating water flushes in. A criticality excursion happens, and with a blue flash, everything comes apart. The physical damage to the ship is low, but the excursion gives nearby standing crew instant up to 4 Sv whole body dose. The short- lived fission products such as I-131 occur and spread locally. The is a contamination of the vessel and the Sea.

References

3. LA-10860-MS. Critical Dimensions of Systems Containing U-235, Pu-239, and U-233.1986 Revision. Los Alamos national laboratory.

4. IAEA INFCIRC/274/Rev.1. Convention on the Physical Protection of Nuclear Material.

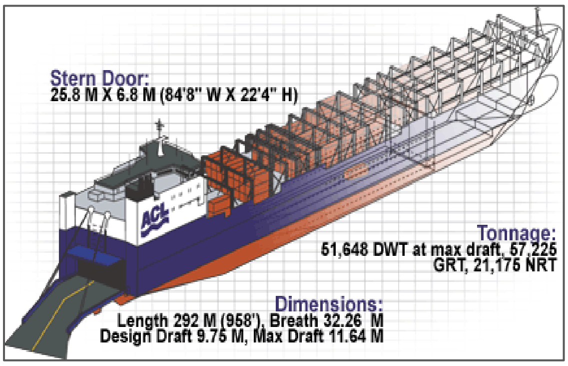
5. Strålsäkerhetsmyndigheten. Rapport 2015:15 användning av låg- och höganrikat uran – en studie från ett icke-spridningsperspektiv.

Appendix VII

Factsheet for Scenario 7: Container ship on fire

Background information

There are several combinations of container/ro-ro ships (ConRo) in use in the North Atlantic Ocean. A typical route make stops at Baltimore (USA), Halifax (Canada), across the Atlantic to Liverpool (UK), Antwerp (Belgium), Hamburg (Germany) and Gothenburg (Sweden) and reverse. A ConRo generation 3 ship in use in the Atlantic Ocean can carry 1850 containers (TEU), including dangerous goods, as well as 1000 cars or other items, such as buses, trams, planes, materials, etc. Generation 4 ships are now being taken into service and can carry 3800 containers as well as 1300 cars or other items in the hold (28900 m^2).



Generation 3 Container/Ro-Ro Ship. Source: Atlantic Container Line.

Scenario details

In the evening of May 1, 2013, a fire broke out on a generation 3 ship in the harbor of Hamburg. The fire spread over 12 of about 70 new cars and about 200 firefighters were engaged in the firefighting. Tugboats were also cooling the ship's hull by spraying water. Onboard were also several containers with dangerous goods, including two containers with radioactive material (fuel rods). Because the ship was in port during loading, they managed to unload some of the containers with dangerous goods during the fire. There was also a risk of flooding over the ship and capsizing it, but it was recognized at an early stage.

Generation 4 Container/Ro-Ro Ship. Source: Atlantic Container Line.

The source specification

The two containers with radioactive material were loaded with 736 nuclear fuel rods to be shipped to the USA. The fuel rods were loaded in Type A packages that are designed to withstand normal conditions, not accident conditions. The radioactive contents of these containers could withstand very high temperatures without dispersing; however, the danger may consist of a terror, as a result of not knowing this information. The real danger could be expected from the other containers with dangerous goods contents, such as gases, flammable liquids, oxidizing materials or explosives.

Hazard/Risk assessment

Where to place the cargo on the ship is partly due to the logistics of the transport activities: containers that should be unloaded at the next port must be accessible and, if possible, new containers to be loaded to the ship should not be placed on top of these or block containers due for unloading at the next port. The safety aspects of positioning of the containers must also be met: explosives should be stacked above the sea level as far away from the crew quarters as possible and radioactive materials should preferably be positioned below the sea level, but also as far away as possible from the crew. The combination of these dangerous goods positioned relatively close to each other is not optimal in case of a fire; an explosion could cause dispersion of the radioactive material.

Elimination of a fire at sea can be a difficult task, especially when the cargo consists of many containers with dangerous goods, thus putting personnel and rescue ships at risk. Firefighting with water can cause reactions with certain kinds of dangerous goods, if the packages are damaged, especially substances that emit flammable gases in contact with water. If UF-6 is carried onboard and the cylinder bursts in the fire, it may cause the uranium to react with water, releasing huge amounts of poisonous hydrogen fluoride. For this reason, a risk assessment of the carried cargo / dangerous goods and the consequences of the actions should be made, before taking an action.

There is also a risk of flooding the ship and capsizing it, if the water is used to eliminate the fire. The risk of the fuel rods becoming critical is considered unlikely, but has to be taken into account.

References

1. International Maritime Dangerous Goods Code (IMDG-code), IMO, 2016.

2. Atlantic Container Line, Grimaldi Group, 2017.

Appendix VIII

Factsheet for Scenario 8: M/S Sigrid is maliciously attacked while transporting spent nuclear fuel

Background information

The INF-3 Class ship M/S Sigrid is on route with 8 spent nuclear fuel casks of type TN17/2 from Ringhals NPP. The destination is the central interim storage for spent fuel near Oskarshamn, CLAB. Each package (cask) could carry 7 fuel elements within its shielding by inter alia 30 cm of steel. Adversaries on small vessels in the Öresund narrows attack her. Two anti-tank rockets hit M/S Sigrid in the cargo area. The explosive beams penetrate both the double hull- and two adjacent-spent fuel packages.

Swedish nuclear cargo vessel M/S Sigrid.

Photo: Swedish Nuclear Fuel and Waste Management Co. http:// www.skb.se

The source specification

The spent nuclear fuel in the two packages hit by the terrorists contains in total 14 PWR elements. They are medium burn up and had cooled for one year in the pools of the NPP. Their inventory of activity is in total 400 PBq (= 400 000 TBq). Of main concern is the volatile Cs-137. The release of noble gas Kr-85 is an additional hazard, together with I-125.

Hazard/Risk assessment

Cs-137 and I-125 are volatile nuclides with a half-life of 30.2 years and 60 d. They may build up to a plume due to heat from the explosions and threaten coastal areas. A realistic source term has to be established based on assumption on damage to the containment of the activity.

The real danger would be the psychological effect of such a release that may create chaos and severe traffic accidents when people panic and try to get out of the nearby area.

References

1. Radionuclide content for a range of irradiated fuels. NIREX, UK. 2002.

2. SSM exercise Pilot-2015. http://www.ssm.se

Appendix IX

Factsheet for Scenario 9: Accident involving nuclear icebreaking freighter in Danish waters

Background information

Collision between the Russian nuclear icebreaking freighter “Sevmorput” and a Danish heavy bulk carrier ship.

Severe damage to the hull and subsequent grounding of “Sevmorput”, during high tide, 70km east of the Danish city Aarhus.

Low tide combined with possible damage to the reactor installation leads to Loss-of-coolant accident (LOCA) and airborne release of radioactive substances from “Sevmorput”.

The scenario takes place over 2 days in three phases with increasing difficulty and intensity in the events. This is an approach to exercise planning that makes it possible to get the most out of the exercise days.

KLT-40 reactor in the icebreaking freighter Sevmorput

“Sevmorput” was commissioned in 1988. The ship is 260 m long, 32 m width, draught 10.6 m (for icebreaking) and summer draught deadweight 33,980 t. The vessel is designed to break 1m flat ice and the hull is divided into 12 compartment by transvers waterproof partition walls.

The Icebreaker “Sevmorput”. Photo: Rosenergoatom.

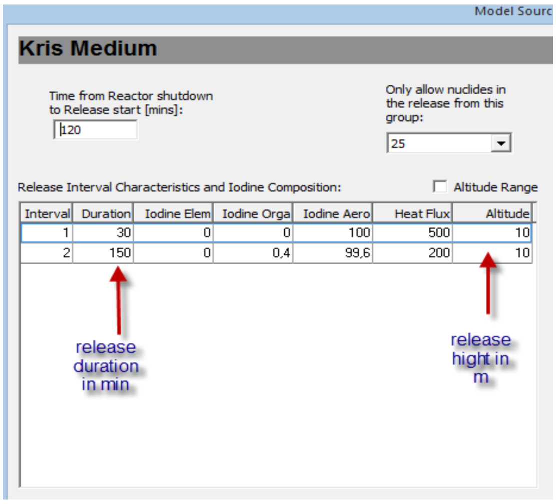
The Power Plant in “Sevmorput” is a third generation nuclear propulsion system KLT-40 reactor with a thermal capacity of 135 MWt (40,000 shp). Version KLT-40 M is rated at 171 MWt and being used in the newest icebreakers.

KLT-40 reactor. The KLT-40 reactor is rated 135 MWt and is a 4-loop PWR reactor (4 steam generators), the original core of KLT-40 reactor was enriched to 90 % with a uranium-zirconum alloy, the icebreaker was refuelled in 2001, some sources claim that the new core could have an enrichment around between 40 % and 20 % (Bellona, 2001). The burn-ups of the fuel is 62,000 to 68,000 MWd. The power of the reactor is controlled with the feedwater pumps and the reactivity with shim and scram rods.

The reactor has an improved containment system of the OK-900 reactor that is designed the way that accidental releases from the reactor ideally will be released to the containment. If the ship sinks, valves in the containment will stay open as long as the pressure outside the vessel is higher than inside the vessel; the seawater will then flood (and cool) the containment (we did not have access to more advanced evaluation of a beyond design accident).

The source specification

The source term (time dependent release profile of radioactive nuclides) is based on a modified PWR-4 source term from the “Rasmussen” report, with a total release of 80 % of noble gases (Xe-133, Xe-135 etc.), 8 % iodine, 4 % of the alkalines (Cs-137, Cs-134 etc.) and 3 % tellurium as the major nuclides.



Interval	Duration	Iodine Elem	Iodine Orga	Iodine Aero	Heat Flux	Altitude
1	30	0	0	100	500	10
2	150	0	0,4	99,6	200	10

Source Term definition from ARGOS (DEMA, Krisøv 2015 exercise).

The original PWR-4 source term is modified with a 30 min burst simulating the barrier break and then a 150 min continuous release.

The alkalines (Cs-137, Cs-134 etc.) are reduced with 50 % from the original release (for exercise reasons it is suggested to avoid major long-term effect for the food production). With realistic condition and using updated models, the release time would probably be by an order of magnitude higher.

Nuclide Distribution: Nuclides in pct of total reactor inventory

Nuclide	Intv. 1	Intv. 2
Ba-140	0,1	0,4
Cs-134	2	2
Cs-137	2	2
I -131	6	2
I -132	6	2
I -133	6	2
I -135	6	2
Kr- 85	60	20
Kr- 85m	60	20
Kr- 88	60	20
La-140	0,01	0,03
Pu-239	0,01	0,03
Rb- 88	2	2
Ru-106	0,1	0,2
Sr- 89	0,1	0,4
Sr- 90	0,1	0,4
Te-132	1,5	1,5
Xe-133	60	20
Xe-135	60	20

Source Term definition from ARGOS (DEMA, Krisøv 2015 exercise).

The radioactive inventory of the KLT-40 was calculated from the Russian VVER-440 PWR reactor by scaling the thermal effect of the reactor to the KLT-40 reactor. It should be emphasized that the source term was designed to give the exercise the desired input and *not as a reactor safety study*. By grounding the “Sevmorput” in the scenario it become impossible to flood the containment.

Hazard/Risk assessment

See the KLT-40S reactor description in the factsheet for Scenario 4 (the floating nuclear power plant) in this report.

References

1. Rasmussen report. WASH-1400 NUREG 75/014 NRC - The Reactor Safety Study.

2. Bellona. The Arctic Nuclear Challenge. The Bellona Report Vol. 3, 2001.

Bibliographic Data Sheet	**NKS-390**
Title	COASTEX Scenario Report: nine maritime accident scenarios. Report no. 1 from the NKS-B COASTEX activity
Author(s)	Inger Margrethe H. Eikelmann[1], Anna Nalbandyan[1], Øyvind Gjølme Selnæs[2], Øyvind Aas-Hansen[1], Helmuth Zika[3], Michael Wallin[3], Kjartan Guðnason[4], Jeppe Vöge Jensen[5], Tone D. Bergan[6]
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No. of pages	63
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No. of illustrations	6
No. of references	38
Abstract max. 2000 characters	There is a notable maritime traffic of nuclear-powered civilian vessels (icebreakers and cargo ships), nuclear-powered military vessels and maritime transports of spent nuclear fuel and other radioactive materials along the Nordic coastlines and in the Arctic. This traffic represents a risk for potential accidents and events resulting in radioactive contamination and spread of radioactive materials into the Nordic and Arctic marine and terrestrial environments. These kinds of events request a good preparedness, possibility for a direct cooperation between neighbouring countries as well as interaction, assistance and coordinated activities to manage the situation, including mitigation. In 2015, the NKS-B NORCOP-COAST project identified

several needs for further improvement of maritime emergency preparedness and cooperation, including the need for definition of relevant scenarios with follow-up exercises in the Nordic countries. To address this issue, the NKS-B COASTEX project (*Scenarios and table top exercise concept on events related to traffic of nuclear-powered vessels and transportation of spent nuclear fuel along the Nordic coastline*) was initiated.
This report is the first of the three reports of the NKS-B COASTEX project. It provides methodology and framework for scenario development as well as a scenario bank with the description of nine maritime scenarios for nuclear accidents related to the traffic of nuclear-powered vessels and transports of spent nuclear fuel, and other radioactive materials. The aim of the scenarios is to describe a variety of possible maritime accidents in order to raise focus on the most important challenges related to these accidents, and to provide a foundation for conducting exercises within this field.
As appendices, separate factsheets are included with detailed source specifications for each scenario.
For effective planning, it is suggested to read also the Report no. 2 – *"COASTEX Exercise Guide"*. The NKS-B COASTEX project implementation is summarised in the Report no. 3 – *"Final report from the NKS-B project COASTEX"*.

Key words Nordic coastline, the Arctic, maritime accident scenarios, nuclear emergencies, scenario elements, radioactive cargo, radioactive sources, nuclear icebreaker, nuclear-powered vessels, floating nuclear power plant, cross-border preparedness.

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