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RNSARBOOK (2022), Nordic Handbook for Search and Rescue in a Maritime Radiological / Nuclear Environment

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Abstract

Maritime operations in waters surrounding the Nordic countries include traffic of nuclear propelled vessels and vessels transporting radioactive materials. These operations present a risk of encountering emergency situations at sea where radiological or nuclear (RN) concerns will be an inherent part of conducting successful Search and Rescue (SAR) operations in order to save lives and provide assistance to persons in distress.

The aim of the Nordic handbook for search and rescue in a maritime radiological/nuclear emergency (RNSARBOOK) is to provide harmonized guidelines and recommendations for the handling of maritime SAR operations involving radiological/nuclear material by Nordic SAR and RN authorities. The handbook is not intended to be used during an ongoing SAR-operation when situational stress is high, but rather to be used for harmonized contingency planning and educational purposes by both SAR and RN organizations.

The primary target audiences are SAR and RN authorities and planners at the operational level. The handbook will provide guidance to SAR authorities with a responsibility to coordinate maritime SAR, and RN authorities that have a mandate in providing liaison and expert advice to the SAR authorities, as well as the possible involvement of specialized radiation measurement teams. The guidelines and procedures explain RN emergencies and safety issues in general and clarifies roles, responsibilities, chain of command and coordination, so both RN and SAR authorities can work efficiently and have an understanding of how the operations are conducted and what is needed in order to respond to these kinds of incidents.

Key words

maritime search and rescue, radiological and nuclear
emergency, emergency response, Nordic, handbook, guidelines, standard operational procedure

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RNSARBOOK

Nordic Handbook for Search and Rescue in a Maritime Radiological / Nuclear Emergency (RNSARBOOK)

DSA

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Cover photo, top: Raymond Engmark, Arctic REIHN exercise. Cover photo, bottom: DSB, Arctic REIHN exercise.

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Guidelines for future revisions

RNSARBOOK project encourages future revisions. We propose revisions to the Nordic version of the handbook should be approved by all the contributing partners. Partners can modify the handbook to fit national needs. For inquiries contact: dsa@dsa.no, refer to RNSARBOOK v/ Oscar Mork

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List of acronyms

ATS	Air Traffic Service
Bq	Becquerel (1 Bq = 1 decay per second)
CSC	Convention for Safe Containers
DV	Distress Vessel
EEBD	Emergency Escape Breathing Device
EmS Guide	Emergency Response Procedures for Ships Carrying Dangerous Goods
FNPP	Floating Nuclear Power Plant
GMDSS	Global Maritime Distress and Safety System
Gy	Gray
IAEA	International Atomic Energy Agency
IAMSAR	International Aeronautical and Maritime Search and Rescue
IMDG	International Maritime Dangerous Goods code
IMO	International Maritime Organization
INF code	International code for the Safe Carriage of Packaged Irradiated Nuclear Fuel, Plutonium and High-Level Radioactive Waste on Board Ships
INES	International Nuclear and Radiological Event Scale
IP	Industrial Package
JRCC	Joint Rescue Coordination Centre
LSA	Low Specific Activity
MARPOL	International Convention for the Prevention of Pollution from Ships
MEDEVAC	Medical Evacuation
MIRG	Maritime Incident Response Group
MMA	Multi-response Maritime Accident
MCC	Mission Control Centre
MOB	Man Overboard
MRCC	Maritime Rescue Coordination Centre
MRO	Mass Rescue Operation
MSDS	Material Safety Data sheet
MWt	Megawatts thermal
NKS	Nordic Nuclear Safety Research
NM	Nautical Mile
NPV	Nuclear Propelled Vessel / Nuclear Powered Vessel
OIL	Operational Intervention Levels
OPRC-HNS	Protocol on Preparedness, Response and Cooperation to pollution by Hazardous and Noxious Substances
OSC	On-Scene Coordinator
PAZ	Precautionary Action Zone
POC	Point of Contact
POB	Person on Board
PPE	Personal Protective Equipment
RAD	Radiation
RCC	Rescue Coordination Centre
RN	Radiological and Nuclear
RNSAR	Search and Rescue in Radiological and Nuclear environments
RPAS	Remotely Piloted Aircraft System
SAR	Search and Rescue
SCBA	Self-contained Breathing Apparatus
SCO	Surface Contaminated Object
SITREP	Situational Report
SMC	Search and Rescue Mission Coordinator

SMR	Small Modular Nuclear Reactor
SOLAS	Safety of Life at Sea
SOP	Standard Operational Procedure
SRU	Search and Rescue Unit
Sv	Sievert
TMAS	Maritime Tele-medical Assistance Service
TTX	Table-top Exercise
UF6	Uranium Hexafluoride
UN	United Nations
UPZ	Urgent Protective Action Planning Zone
VTS	Vessel Traffic Service

Introduction

Maritime SAR operations in a RN environment

Maritime operations in waters surrounding the Nordic countries include traffic of nuclear-propelled vessels and vessels transporting radioactive materials. These operations present a risk of encountering emergency situations at sea where radiological or nuclear (RN) concerns will be an inherent part of conducting successful Search and Rescue (SAR) operations in order to save lives and provide assistance to persons in distress.

RN incidents are characterized by their potentially high consequences. However, they are low-probability events, which means that SAR authorities and responding personnel might not have first-hand experience in dealing with them (1).

During RNSAR operations, a specialized understanding of the released material, its properties, and operational procedures to work safely in its vicinity are needed to adequately assess and manage the risks that responding search and rescue units (SRUs) will face. This includes knowledge about the radioactive material, protective gear, monitoring of radiation, handling procedures and other safety issues.

This highlights the paramount need for good cooperation between national radiation and SAR authorities for planning and training purposes, as well as for specific guidance during ongoing RNSAR operations. In addition, the complexity and challenges posed by maritime RN incidents may require international assistance (1).

Intentions of this handbook:

The aim of the *Nordic handbook for search and rescue in a maritime radiological/nuclear emergency (RNSARBOOK)* is to provide harmonized guidelines and recommendations for the handling of maritime SAR operations involving radiological/nuclear material by Nordic SAR- and RN authorities.

The handbook is not intended to be used during an ongoing SAR-operation when situational stress is high, but rather to be used for harmonized contingency planning and educational purposes by both SAR and RN organizations.

Target audience (end-users):

The primary target audiences are SAR and RN authorities and planners at the operational level. The handbook will provide guidance to SAR authorities with a responsibility to coordinate maritime SAR, and RN authorities that have a mandate in providing liaison and expert advice to the SAR authorities, as well as the possible involvement of specialized radiation measurement teams. The guidelines and procedures explain RN emergencies and safety issues in general and clarifies roles, responsibilities, chain of command and coordination, so both RN and SAR authorities can work efficiently and have an understanding of how the operations are conducted and what is needed in order to respond to these kinds of incidents.

Other target groups are first responders, special rescue teams, volunteers, environmental response authorities, shipping companies, vessel crews, and other stakeholders in the whole chain that might play a role or be affected by RNSAR operations. Such other stakeholders may use the handbook to improve their understanding of the topic and to further develop and adapt their own contingency plans and procedures to such events.

Structure and contents:

This handbook addresses SAR operations in RN environments (RNSAR). RNSAR is here understood as a SAR operation within an RN context, or more specifically a situation where:

> [...]rescue and emergency workers are, or may be, subject to radiation exposures higher than normal as a consequence of an imminent threat or actual exceptional event [including] situations where a) hazardous radioactive material is at risk of being spread, or have been spread to the environment, or b) the shielding of a radioactive source is in danger of deteriorating or has already deteriorated, or c) a radioactive sealed source is, or is at risk of being, out of control (2)

The handbook is divided into two main parts. The first part gives an introduction to radiation and SAR operations. The purpose is to offer a basic understanding of RN and its terminology to SAR authorities and a basic knowledge of SAR operations to RN authorities. Furthermore, the first part gives an introduction to exercises with an emphasis on interorganizational and intersectoral collaboration.

The second part presents standard operational procedures (SOPs) for an RNSAR operation. The actors involved in this type of an operation often have their own organizational or unit-specific guidelines and procedures for SAR operations. The SOPs of this handbook are not intended to contradict existing standards nor increase the workload of the SAR mission coordinators and supporting RN advisors/personnel. The objective of this section is to provide additional guidance and knowledge to the normal daily SAR procedures.

It is our intention that the RNSARBOOK should be an online resource which is revised based on experiences from its use. The current edition includes revisions based on experiences collected during the large EU-funded Arctic Radiation Exercise in the High North (ARCTIC REIHN), which was held in Bodø in May of 2023. The RNSARBOOK was used in the planning phase of the exercise to provide injects and exercise goals based on the operational procedures. After the exercise and practical testing of action cards that were developed based on this handbook, the RNSARBOOK was revised to include further definitions and clarification on operational actions such as determining restriction areas, and exposure limits for rescue personnel.”

Contributors and funding

This handbook builds on previous work done under the Nordic Nuclear Safety Research (NKS) funding scheme and follows up identified gaps in past projects such as the ones under the Arctic Council EPPR Working Group (*e.g.* ARCSAFE, RADEX, RADSAR). The format of the RNSARBOOK was inspired by the ChemSAR Handbook ("*Handbook for maritime SAR in hazardous and noxious substances (HNS) incidents*"), led by the Finnish Border Guard. We have strived to ensure that the guidelines and procedures of the RNSARBOOK are based on international standards and guidelines from the International Atomic Energy Agency (IAEA), the Nordic guidelines and the International Aeronautical and Maritime Search and Rescue (IAMSAR) manual, and are not intended to contradict existing standards and framework nor increase the workload of the SAR mission coordinators/responders or crew of a distress vessel, but rather provide additional guidance, knowledge and harmonization.

RNSARBOOK was financed by NKS and in-kind contributions by all participant organizations over an approximately 1-year period in 2021 - 2022. The project was coordinated by the Norwegian Radiation and Nuclear Safety Authority and the Joint Rescue Coordination Centre North Norway, with partner contributions from the Icelandic Radiation Safety Authority, the Icelandic Coast Guard, the Joint Rescue Coordination Centre Denmark, the Danish Emergency Management Agency, the Finnish Border Guard, and Nord University which also had one master student in emergency management and preparedness (MASIK-program) doing his thesis-work within this project.

Disclaimer

This handbook does not address nuclear propelled submarines as this type of vessel is not covered under the IAMSAR. Nevertheless, an incident involving a nuclear propelled submarine would present similar consequences and the radiation principles presented in this handbook would still apply.

The content in this handbook is based on the work conducted by the RNSARBOOK project partners and has been prepared with due care. Nevertheless, the information provided is not comprehensive. The RNSARBOOK project and its partners cannot be held legally responsible for the information provided in this handbook or on decisions taken based on the information provided in the handbook. This information does not replace or interfere with any international, national, regional, or local decision procedures unless particularly decided so. Also, national and organizational occupational safety regulations have to be followed in search and rescue operations.

Part 1
RN IN SAR OPERATIONS

The first part of this handbook offers an introduction to radiation, Radiological and Nuclear emergencies at sea, SAR operations in RN environments, and exercises.

The purpose of this section is to offer a basic understanding of RN and its terminology to SAR authorities, offer a basic understanding of how these types of operations could play out and be handled, as well as an introduction to suggested exercises that could increase competence in handling of RNSAR operations.

Photo credit: Anders Røeggen/Kystverket

1. Radiation and dose

In this chapter, the handbook offers an introduction to the levels, effects, and risks of radiation exposure:

1. Radiation and radioactivity
2. Dose and intensity
3. The effects of radiation
4. Practical radiation protection
5. How radiation is measured
6. Contamination and exposure

1.1 What is radiation

Radiation is energy that travels through space either as a wave or a particle. Radiation in this document refers to ionizing radiation. Ionizing radiation is radiation that has enough energy to potentially harm cells and organisms. Radiation can be generated artificially or occur naturally. Humans are surrounded by and constantly exposed to radiation from radioactive sources in the environment and cosmic radiation from outer space. Artificial sources are primarily used in medicine, in industry and for the generation of nuclear power (3).

1.2 Radioactivity

Radioactive materials are composed of atoms with an unstable nucleus. They are also known as radionuclides. To become stable, they emit energy in the form of ionizing radiation. This nuclear transformation is defined as radioactive decay. Radioactive substances will continue to decay and emit ionizing radiation until the "last" radionuclide has decayed. The decay rate depends on the element and is known as half-life, the time it takes for half of the nuclides to decay. The half-lives of radioactive atoms can range from nearly instantaneous to longer than the age of the universe. The half-lives of some radionuclides relevant to RNSAR are given in table 1.

Table 1: Radionuclides and half lives

Radionuclide	Half life
Iodine-131	8 days
Caesium-134	2 years
Caesium-137	30 years
Strontium-90	29 years

Radioactivity or simply activity, relates to the amount of ionizing radiation released by a material regardless of the type of radiation. It indicates how many atoms in the material decay per second. The unit of measurement for radioactivity is the becquerel (Bq). The higher the activity, the more radiation is emitted. For most practical applications 1 Bq is a small unit. The human body contains 3700 Bq of naturally occurring potassium-40 (3).

1.3 Types of ionizing radiation

The most important types of ionizing radiation are alpha, beta, gamma, x-rays and neutron radiation.

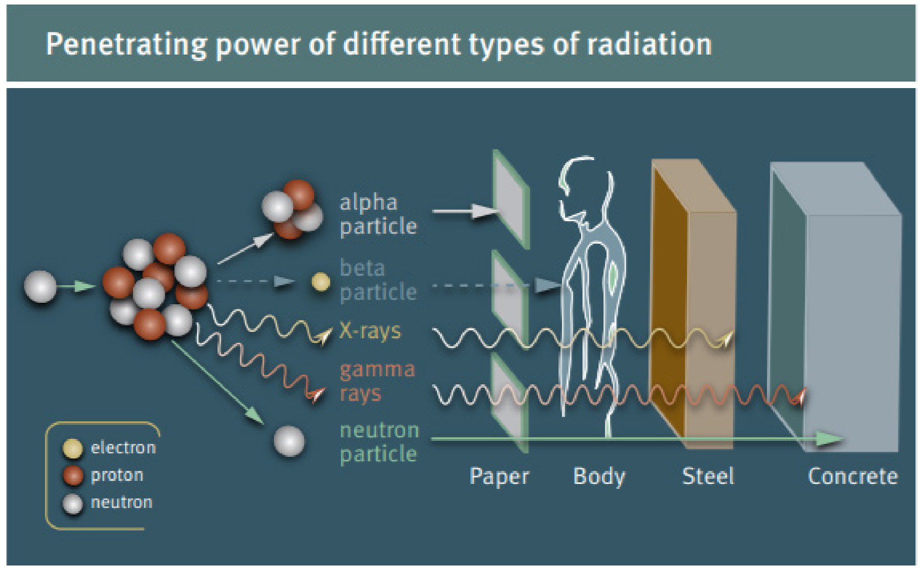

Figure 1: Penetration capacity (3)

Alpha particles consist of two protons and two neutrons and are the same as a helium nucleus. They are very energetic but lose energy fast, have a very short range in human tissue, and can be shielded by a sheet of paper. In the case of external exposure, alpha radiation can only penetrate the outer layers of the skin and do not pose a danger but if alpha-emitters are inhaled or ingested, they can lead to a considerable radiation exposure. As alpha particles deposit their energy within a very small area, they can cause severe damage to tissue. Alpha particles are emitted in the decay of the heaviest radioactive elements, such as uranium, radium, and polonium. The penetrating power of different types of radiation is shown in Figure 1.

Beta particles are electrons or positrons. They have a longer range than alpha and can travel distances from a few centimeters in air, to a few millimeters or even centimeters in soft tissue. They can be stopped by a layer of clothing or by a few millimeters of aluminum. Beta particles deposit energy over a larger area compared to alpha particles and are less damaging to living tissue. They can still lead to considerable damage if emitted inside the body. They are mainly emitted by naturally occurring materials such as strontium-90.

Gamma radiation is electromagnetic radiation and consists of weightless packets of energy called photons. This type of radiation is highly penetrating and is only stopped by heavy materials like lead, concrete, or large bodies of water. Hence, it is harmful to humans both in the case of external and internal exposure. They are often emitted along with alpha or beta particles during radioactive decay.

Neutrons are uncharged particles mainly released during nuclear fission, which is the mechanism behind the atomic bomb and nuclear power. Neutrons are highly penetrating and have a strong interaction with biological tissue. They are considered more hazardous than beta and gamma radiation but less so than alpha particles. Neutrons are also the only radiation that can make other objects radioactive through a process called neutron activation.

X-rays are photons just like gamma radiation but have a different origin and generally contain less energy than the other types of ionizing radiation. They are mainly used in medicine and industry and are not so relevant in the RNSAR context (4).

1.4 **Measuring radiation**

Ionizing radiation is not detectable by human senses. However, it can be measured with the appropriate equipment. A variety of measuring instruments have been invented for different purposes and applications.

Alpha and Beta radiation have a very short range, so normally gamma rays are measured to obtain doses from external exposure. Gamma rays in air can be measured with a dose rate meter, and the measurements are usually reported in microsievert (µSv/h) in most European countries.

Something to bear in mind, is that neutron radiation cannot be measured with standard equipment.

1.5 **Radiation dose**

A person can be irradiated both externally, from a source outside the body, or internally from a source inside the body. In both cases, the body may be exposed to equal amounts of radiation. Internal exposure is caused by ingestion, inhalation, absorption from the skin or wound contamination of radioactive material. Once inside the body, radionuclides tend to accumulate in specific organs where they continue to emit radiation. Radioactive compounds are gradually excreted from the body through metabolism.

Several different terms are used to describe radiation dose. When radiation passes through a material (could be tissue or concrete), either all or parts of its energy is absorbed.

Absorbed dose refers to the amount of energy absorbed by a material (like human tissue) exposed to radiation. It is a measurable, physical quantity, and is usually expressed in grays (Gy).

The effect that this passing radiation has on the human body varies depending on the type of radiation and the dose distribution in the body, even if the absorbed doses are the same. 1 Gy of alpha radiation is more damaging than 1 Gy gamma radiation, and 1 Gy to the intestines is more damaging than 1 Gy to the hands.

Effective dose is a calculated value that takes three factors into account. The first factor is the total absorbed dose to all organs of the body. The second is the type of radiation, and its damage-capabilities (alpha-particles cause more harm internally than gamma-radiation). Lastly, each organ-specific sensitivity to radiation is taken into account. It is a summed whole-body dose that reflects the potential damage caused by the radiation exposure, like the risk of cancer. The larger the dose, the more adverse effects of the radiation. Effective dose is usually expressed in sieverts (Sv) and is a calculated value, which is not measured directly. However, most dose meters use sievert in their readings. They do not directly measure this, but show approximate values based on measured physical quantities, like absorbed dose in air. Typical effective doses are shown in Figure 2.

In radiation protection, effective doses are often in the order of millisievert (mSv) or even microsievert (µSv). mSv is a thousand of a sievert and µSv is a millionth of a sievert, as shown in Table 2.

RN in SAR Operations

Table 2: Unit conversions

Sievert (Sv)	Millisievert (mSv)	Microsievert (µSv)
1 Sv	= 1000 mSv	= 1’000’000 µSv

Dose rate is the radiation dose delivered per unit time, usually expressed in mSv/h or µSv/h. If the dose rate is 10 µSv/h in an area, you will receive a dose of 10 µSv if you stay in the area for one hour. If six minutes are spent in the same environment, you will receive a dose of 1 µSv (5).

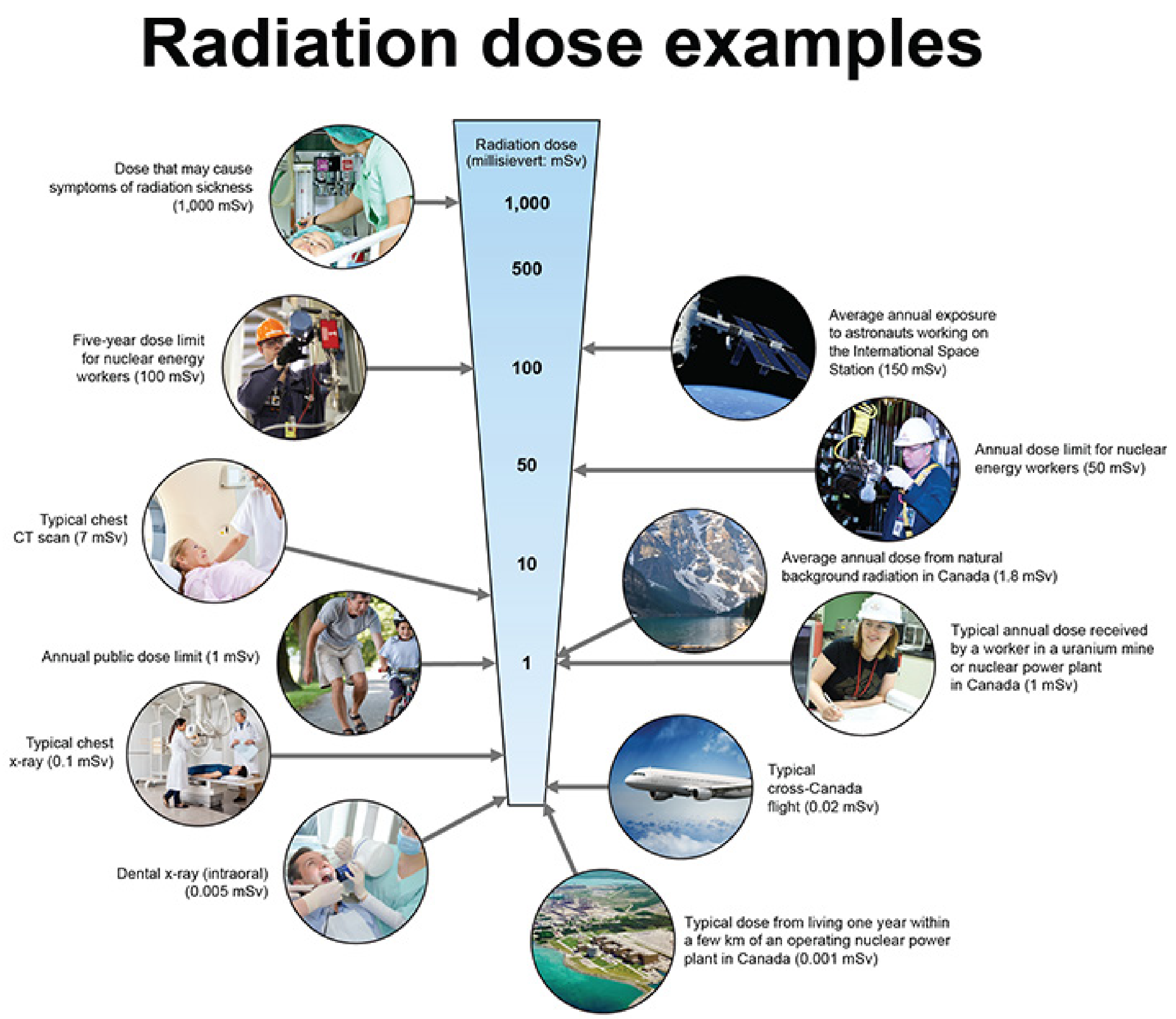

Figure 2: Radiation dose and dose limit example in Canada (6)*s.*

1.6 **How does radiation affect the body?**

Exposure to radiation can cause two kinds of health effects.

Early health effects are caused by extensive cell death/damage caused by radiation. They are observable health effects that typically occur hours to a few days after exposure and above a certain threshold dose. Example health effects are vomiting, sterility, hair loss, skin burns, acute radiation syndrome and worst case, death. The severity of the effect increases with increasing dose.

At low dose levels, radiation causes no immediate perceptible damage to people. However, **delayed health effects** may still occur a long time after exposure. They are based on damage in the genetic material and have no known threshold dose. Examples health effects include cancers, leukemia, and possibly hereditary effects. Hereditary effects are effects that are seen in offspring from individuals exposed to radiation, such as chromosomal damage or congenital disorders. The probability, but not the severity, of radiation-induced effects increase with increasing dose (3). However, attributing actual elevated levels of long-term effects such as cancer to low-dose radiation exposure, is considered difficult as the general incidence of cancer in a population is relatively high.

Table 3 gives an overview of the health effects of radiation.

Table 3: Overview of the health effect of radiation

LOW RADIATION DOSES	4-5 mSv	Annual average dose for the general population (including SRUs) originating from "natural radiation" as ionizing radiation of natural, terrestrial, or cosmic origin	Low radiation doses (under 100 mSv) do not pose an acute danger to living organisms and developing further sickness has a low probability
	1 mSv	Annual dose limit for the general population (including SRUs) **in addition to** natural radiation levels.	
	20 mSv	Annual dose limit for occupationally exposed workers.	
	≥ 50 mSv	Only for informed, voluntary personnel in life saving work and disaster mitigation (applicable in some Nordic countries).	
	≥ 100 mSv	Increased statistical chance for developing cancer as well as heart and lung problems at a later stage. Damage to a fetus can occur. Only for informed, voluntary personnel in life saving work and disaster mitigation (applicable in the EU and some Nordic countries)	
MODERATE RADIATION DOSES	150 mSv	Temporary sterility in men	Moderate doses of radiation (100 mSv – 1 Sv), can have effects at the cellular level. These effects do not cause further sickness necessarily; however, cancer and foster damage can occur.
	500 mSv	Small changes in blood. In exceptional cases a dose ≥ 500 mSv can be allowed. With doses higher than 500 mSv acute radiation symptoms could occur.	
	> 1 Sv	Serious health repercussions	High doses of radiation (> 1–2 Sv) can cause acute life-threatening sickness (starting with acute radiation syndrome). Possible symptoms include nausea, diarrhoea, headache, fever, dizziness, weakness, and hair loss. With very high exposure during a short period, symptoms can develop in a matter of minutes.
HIGH RADIATION DOSES	2 Sv	Lowest acute deadly dose. Nausea, erythema, low blood pressure	
	4 Sv	50% chance of survival	
	10 Sv	Not possible to survive	

(7,8)

1.7 Practical radiation protection

In a nuclear or radiological emergency, protective measures should be used to avoid or minimize radiation exposure of emergency workers and the public. The golden principle of radiation protection is that radiation dose to humans should be As Low As Reasonably Achievable, also known as the ALARA-principle.

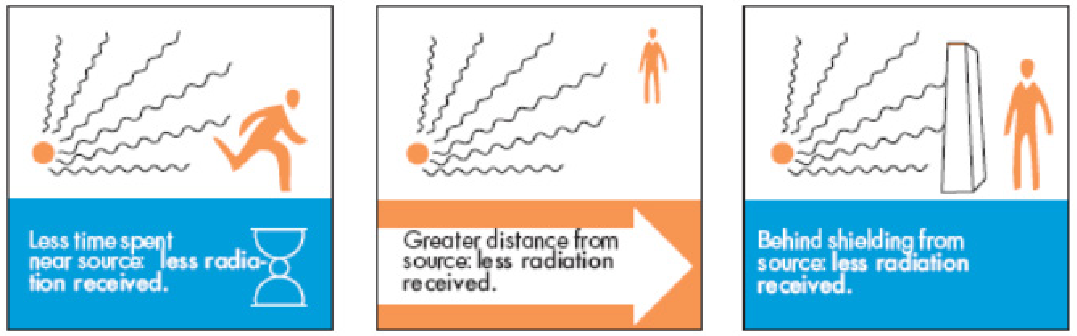

Figure 3: The three basic radiation protection principles for external exposure

The three basic radiation protection principles shown in Figure 3 include:

1. Reduced time

Doses are proportional to the time of exposure.

It is crucial to minimize the time spent in a contaminated area or in the presence of a radioactive source. Halving the exposure time will halve the dose.

2. Increased distance

Given there is only one point of origin for the radiation, doubling the distance to the source will reduce the exposure to 1/4.

3. Shielding

The use of personal protective equipment can be used by SRUs but will only give protection against radioactive material emitting Alpha and Beta particles. This is described further in chapter 3.

Gamma radiation can to some extent be shielded by high-density materials such as lead and concrete. Dose reduction during an emergency can be obtained by sheltering behind walls or buildings or to cover the source with a high-density material.

1.8 Radioactive release and contamination

In the case of a nuclear or radiological accident, radioactive material can be released and dispersed into the air. A radioactive release to air will probably contain nuclides like plutonium, uranium, iodine, cesium and strontium. These will be dispersed by the wind, but eventually fall to the ground because of gravity and rainfall. Water, surfaces, soil, and people can become contaminated when these isotopes settle on the surface.

In the case of an accident with a radioactive release to air, the particles will be spread by weather conditions and eventually fall covering everything in the vicinity. Additional disturbances e.g. downwash, movement of people, or wind can cause the particles becoming airborne again and spreading further on. Note, that a dispersion of radioactive material in air may be in the form of different-sized particles, aerosols or gases, and may be part of fire smoke. The release can involve all types of ionizing radiation (depending on what RN material it constitutes). Rainy conditions or spraying the area with water may contribute to the radioactive particles deposition and reduce further spread.

A person becomes contaminated when radioactive material is ingested, inhaled, or deposited on the body surface.

Externally contaminated persons have radioactive material, in the form of dust, powder or liquid on the skin, hair or clothing. People who are externally contaminated can contaminate other people or surfaces that they touch.

People can become internally contaminated if radioactive material gets into their body. Internal contamination occurs when people ingest or inhale radioactive materials or when radioactive materials enter the body through an open wound or are absorbed through the skin. People who are internally contaminated can expose people near them to radiation, and the person's body fluids like blood, sweat and urine can be radioactive (9).

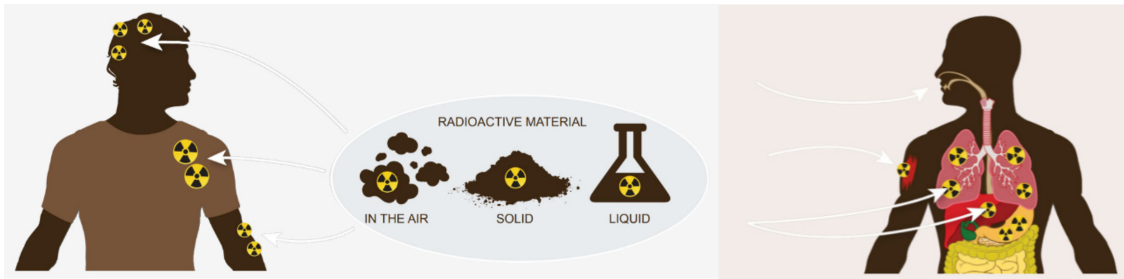

Figure 4: External vs internal contamination (9)

1.9 Iodine thyroid blocking

A radioactive release to air from any nuclear reactor, such as from a nuclear propelled vessel (NPV), will most likely contain radioactive iodine. When radioactive iodine is inhaled or ingested it is absorbed by the thyroid gland. Large concentrations of iodine can cause both acute damage to the thyroid and increase the risk of thyroid cancer in young people. If the thyroid gland is saturated with stable (non-radioactive) iodine before being exposed to radioactive iodine, the uptake of the latter will be blocked. Rescue workers are at risk of exposure to high doses of radioactive iodine and are likely to benefit from iodine tablets irrespective of their age (10).

NB! A release from a reactor contains a lot of different radionuclides. Iodine tablets only protects from radioactive iodine.

2 Safety of responders

Guaranteeing the safety of search and rescue units (SRUs) is paramount in conducting a successful RNSAR operation as well as to secure the viability/continuity of the national emergency preparedness system in the short, medium and long term. SAR personnel responding to an emergency in an RN context might be exposed to radiation that could potentially cause long term consequences and be fatal in the worst case.

NB! Pregnant women should not participate in RNSAR operations where there is a risk of exposure or contamination.

This chapter offers an introduction to:

1. Radiation monitoring equipment
2. Personal protective equipment
3. Reference dose levels
4. Operational intervention levels
5. Decontamination

2.1 Radiation monitoring equipment

When conducting a rescue operation in a radiological environment, the responders or crew of the SRU must have a personal dosimeter. This is to guarantee that the responders do not receive a higher dose than recommended.

A personal dosimeter is a dose rate meter that is worn by the responders or crew and that warns when the dose rate (in µSv/h) surpasses a set intensity and when the effective dose (in mSv) reaches a set limit (7).

Table 4: Examples of alarm thresholds

NB! The volume of an alarm on a personal dosimeter is typically 90 dB. In some cases, the responders might not be able to hear the alarms due to loud ambient noise. Consequently, the SRUs should have routines to visually check the personal dosimeter or use other equipment, such as a dose rate meter, to monitor radioactivity (intensity and total received dose).

	Denmark	Finland	Iceland	Norway	Sweden
Dose rate alarm level	100 µSv/h	100 µSv/h	100 µSv/h	100 µSv/h	100 µSv/h
Dose alarm level	10 mSv	10 mSv	N/A	10 mSv	5 and 20 mSv

When a responder or SRU approaches a radioactive source and the dose rate alarm signals, the responders will know that:

- The radiation being received is not related to background radiation
- The border between warm and hot zone is reached
- By staying in the same place, it will take about 100 hours to reach the dose level alarm of the personal dosimeter, i.e. 10 mSv for Denmark and Norway.

If the SRU is to advance into the hot zone, new measurements should be taken with a dose rate meter (7).

2.2 Personal Protective Equipment

Personal protective equipment (PPE) should be worn by all personnel involved in a search and rescue event where contact with radioactive material and release of radioactive particles to air is likely. The main purpose of PPE in a radiation and nuclear scenario is to provide a barrier between particles and contamination in the air and the body. PPE will not protect against external gamma radiation and must not give the user a false sense of security. However, wearing PPE will make decontamination easier, and prevent radioactive particles from entering the body, thus limiting the exposure from internal radiation.

If there is knowledge or a suspicion about radioactive contamination within the hot zone, only the SRUs with the appropriate PPE should enter the area (7,8).

If it is presumed that the radioactive release contains radioactive iodine (I-131), operatives should take iodine tablets before entering the contaminated area, and preferably 1-2 hours before. It is beneficial for exposed rescuer to take iodine tablets from 24 hours prior to exposure and up to two hours after. Taking iodine long after exposure (may) do more harm than benefit.

Below, there are a couple of examples of useful equipment that could/should be utilized in a radiation/nuclear scenario based on recommendations made by the Norwegian health authority on CBRNE equipment:

HOT-ZONE (class A equipment):

<u>Coveralls:</u> To avoid contamination of clothes and provide an outer layer of protection, coveralls or hazmat-suits should be worn by rescue personnel. This is a layer of clothing that should be easy to remove if contaminated and prevent contact between radioactive material and the skin. The coveralls should be in one piece with a hood to cover the head. Also, protective bags could be worn over the shoes. The coveralls should ideally be made of a material with some chemical resistance.

<u>Respiratory protection:</u> Personnel who enter a hot-zone with release of particles must use a “Self-contained breathing apparatus (fresh-air system)” that supply compressed air independently from ambient air. These masks are pressurized and prevent contaminated air from entering. Proper fitting of the mask is of utmost importance, as a poorly fitted mask will not filter out all the particles, and thus lead to inhalation and ingestion of radioactive particles.

Figure 5: Field personnel from a radiation monitoring exercise, equipped with recommended PPE for warm zone: Full-type gasmask, disposable coveralls and shoe-covers, double set of robust disposable gloves and a small electronic dosimeter attached to a belt. The left image shows in-action contamination check of personnel after returning from a contaminated exercise field. Photo: DSA

Gloves: A double layer of disposable gloves is an effective way of protecting the hands. The double layer will provide extra protection, and the outer layer can be removed if seriously contaminated surfaces have been touched. The gap between the gloves and sleeves of the coveralls should be taped to prevent radioactive materials from entering underneath the suit. Other gloves could also be used, but these should be impenetrable to contaminated water and dust and must be discarded if contaminated.

Personal dosimeter: An electronic personal dosimeter with a pre-set dose threshold alarm must be worn by the emergency personnel. This instrument registers the total received dose and is important to make sure no dose-thresholds are exceeded. This information is also important in the follow-up of involved personnel due to health risks of radiation. The simplest dosimeters only provide the received dose, but there are also more sophisticated versions that provide "live" dose-rate readings as well. This is useful for estimating the amount of time the rescue personnel may stay in an area.

Warm zone (class B equipment):

Respiratory protection: Ideally, a full-type gasmask with replaceable CBRN (Chemical, Biological, Radiological and Nuclear) filters (e.g HEPA filters, or active coal filters) should be worn. It is important that the mask covers the entire face to prevent inhalation of radioactive particles, and to prevent skin and/or eye contact. Alternatively, a half-type mask and goggles can be used, but these do not offer the same level of protection as a full-type. These types of respiratory protection must be fitted in advance, as non-fitted equipment may lead to inhalation of radioactive dust or particles.

Except from the respiratory protection, personnel operating in the warm zone should wear the same PPE as the personnel operating in the hot-zone, as there may be radioactive particles in the air, and they may handle contaminated patients or people exiting the hot-zone.

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Cold zone:

Personnel staying in the cold zone do not require PPE. However, the personnel conducting decontamination should be equipped with a protective suit, gloves, and an all covering face mask with carbon and particle filter (FFP3 facemask and protective glasses as a minimum) (8).

When the radioactive material is not scattered, or contamination is not possible, the necessity of specialized PPE can be reconsidered.

2.3 Reference dose levels

The annual dose limit for the public is 1 mSv (including all SRUs) and 20 mSv for radiation workers (who will be working in a vessel with a nuclear reactor for example). In a rescue operation, the exposure should remain whenever possible below those limits. If the emergency situation is such that it is not feasible to adhere to those limits, a higher reference level can apply. The Nordic countries have different reference levels as shown in Table 5.

Table 5: Radiation exposure limits for the public, radiation workers, SRUs in emergency response operations, and SRUs in exceptional situations as defined under the radiation act of the respective countries

	Denmark	Finland	Iceland	Norway	Sweden	EU
Annual dose limits for the public including all SRUs	1 mSv	1 mSv	1 mSv	1 mSv	1 mSv	1 mSv
Annual dose limits for radiation workers (e.g. some of the crew in an NPV)	20 mSv	20 mSv	20 mSv	20 mSv	20 mSv	20 mSv
Emergency personnel exposure limits	100 mSv	100 mSv	100 mSv	50 mSv	100 mSv	100 mSv
Lifesaving condition, prevent severe radiation-induced health effects, or prevent the development of catastrophic conditions	500 mSv	500 mSv	100 mSv[1]	500 mSv	500 mSv	500 mSv

[1] Exposure to emergency worker should not exceed these reference levels if possible

If exceeding the emergency occupational exposure levels (as shown in table 5) is considered possible, SRUs must be clearly and comprehensively informed in advance of the associated health risks and the available protection measures and undertake these actions voluntarily.

With a given anticipated (or measured) external dose rate, it can be calculated how long SRUs or other volunteers can operate within reference dose levels.

If for example, the external dose rate on the bridge of a vessel in distress is 1000µSv/h (or 1mSv/h), the crew or an SRU will receive a dose of 20mSv after staying 20 hours on the bridge.

1000µSv/h * 20 h = 20.000µSv = 20 mSv

Let assume that the vessel must be steered to a safe location and the external dose rate on the bridge is 25000µSv/h (or 25mSv/h). Sailing the vessel to that location is estimated to take 6 hours. Then the personnel on the bridge would receive the dose:

25000µSv/h * 6 h = 150.000µSv = 150 mSv

That would exceed the reference dose levels for SRUs, unless this action is necessary to prevent catastrophic conditions where the emergency occupational exposure limits can be exceeded.

2.4 Operational intervention levels for protection of SRU

As part of the protection strategy in an RN emergency, the IAEA has established operational intervention levels (OILs). These propose the appropriate protective actions based on an environmental measurement (typically dose rate). OILs should be developed and optimized at the preparedness stage to achieve efficient response in an emergency. OILs and protective measures for emergency workers are listed in Table 6.

Table 6: Operational intervention levels and protective measures for emergency workers

Operational intervention levels for protection of emergency workers	
Anticipated external dose rate	**Protective measure**
• The external dose rate is, or is anticipated to be 10-100 µSv/h	• Protective clothing and respiratory protection when in contaminated areas • Iodine tablet during emergencies in predefined risk facilities where significant amounts of iodine might be involved (the tablet should be taken 1-2 hour before exposure) • Iodine tablet, if a general recommendation of iodine tablets has been recommended to the public • Work time and location recorded as accurately as possible • If an external dosimeter is in use, dose rates recorded at regular intervals • If there are personal dosimeters or a joint dosimeter for a work group, they shall be used according to the instructions
• The external dose rate is, or is anticipated to be 100-1000 µSv/h	In addition to the previous measures: • If the situation continues over a longer period (i.e with a 100 mSv emergency occupational exposure dose limit this implies 100-1000 hours on site), the total working time of a worker needs to be planned and restricted in order to make sure that the total dose does not exceed limits as shown in chapter 2.3

• The external dose rate is, or is anticipated to be 1000-10000 µSv/h (=1-10 mSv/h)	In addition to the previous measures: • Staying in contaminated area restricted when possible and when it does not impede necessary urgent work. For instance, to ensure the safety of the mobile measurement teams, decisions need to be made regarding continued radiation monitoring and other measurement actions. • The total working time of workers need to be restricted (i.e with a 100 mSv emergency occupational exposure dose limit this would imply 10-100 hours on site) in order to make sure that the total dose does not exceed limits shown in chapter 2.3 unless special circumstances apply and a higher dose is allowed • Working time and location are recorded as accurately as possible
• The external dose rate exceeds, or is anticipated to exceed 10000 µSv/h (>10 mSv/h)	In addition to the previous measures: • Only work, which is absolutely necessary to ensure the safety of the public is conducted. • Working times are restricted to less than 10 hours; if possible, the dose to a worker is restricted to 100 mSv • Working time and locations are recorded as accurately as possible

Source: (2)

2.5 Decontamination

NB! Decontamination should never be a hinder for conducting life-saving operations

SRUs that have been contaminated or are suspected of being contaminated must be checked with a dose rate meter (corrected for background radiation). Remove the outer layers of clothing or protective equipment and measure with a contamination monitor.

The probe of the dose rate meter should be held about 1 cm from the person and moved around 5 cm/s following the below algorithm:

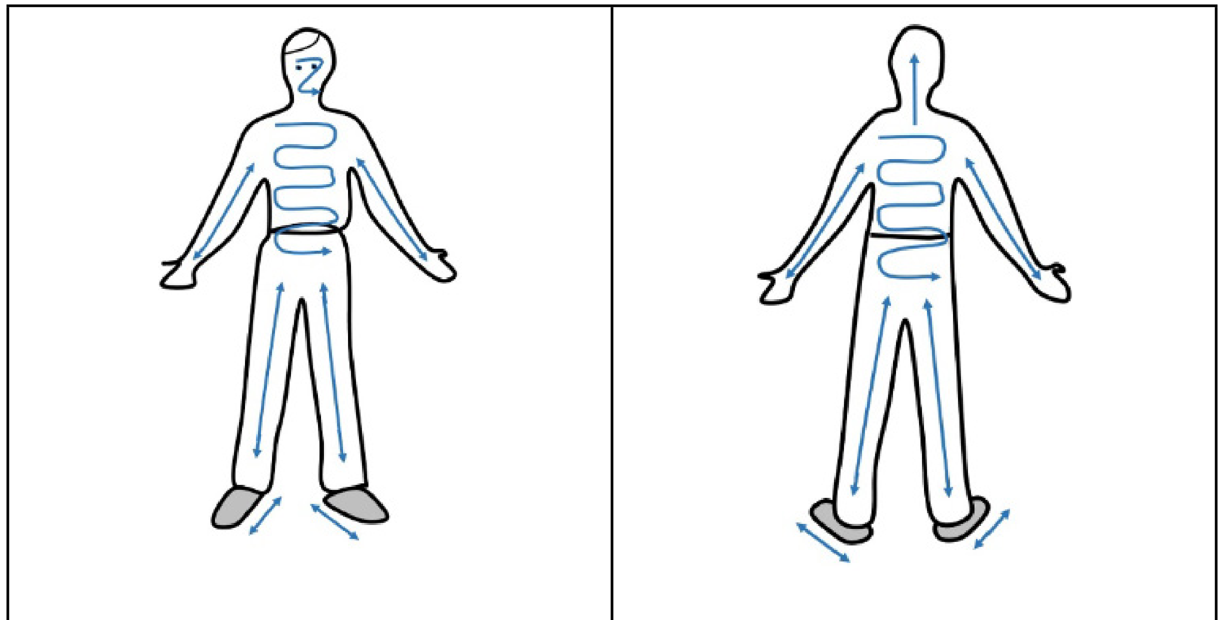


Figure 6: Contamination detection procedure (7)

If the measurements still show rates that are higher than the background radiation, the SRU is contaminated and must be decontaminated.

Table 7: Decontamination procedure

1. Removal of clothing
2. Removing hair and beard if necessary
3. Shower with soap (if necessary)
4. Conduct a new detection algorithm

Figure 7. Contamination detection in action during Arctic REIHN exercise. Picture by: Raymond Engmark

Decontamination of both SRUs and people in distress should ideally be conducted on site or on board a designated vessel to avoid contaminating the cabin of a helicopter (or any other transport means). However, fear of contamination should never be a hinder for conducting life-saving operations.

If internal contamination is suspected, further specialized treatment should be considered (7). This can only be provided in a hospital.

The equipment used during the operation (including vehicles) should also be measured and decontaminated if necessary.

Considerations regarding the collection of waste (including water) used in the decontamination process should also be made.

Figure 8. Decontamination during the Arctic REIHN exercise

3 Radiological and nuclear emergencies at sea

This chapter offers a brief introduction to:

1. Regulations and guidelines
2. Emergency preparedness categories
3. Maritime traffic involving nuclear reactors
4. Maritime traffic involving transport of RN materials.

Maritime operations in waters surrounding the Nordic countries include traffic of nuclear-propelled vessels (NPVs) like icebreakers, military submarines and surface vessels; floating nuclear power plants (FNPPs); vessels transporting medium and high-level radioactive waste, spent nuclear fuel and fissile materials, as well as the foreseeable transport of Small Modular Nuclear Reactors (SMRs) in the future (11–13). In addition, radiation generators and other radioactive sources are in use and subject to transport at sea e.g. as part of the oil and gas industry activities. Also, a substantial amount of low radioactive waste is generated as a result of the naturally occurring radioactive material encountered in the oil and gas industry reservoir rock (13).

These types of maritime industry operations present a risk of a radiological or nuclear (RN) incident at sea (1,14) and the necessity of conducting Search and Rescue (SAR) operations in RN environments in order to save lives, provide assistance to persons in distress, in the long term minimize damage to maritime and terrestrial habitat, and reduce the socio-economic and psychosocial impact to the wider society (15).

Two aspects are critical to the potential severity of any RN scenario:

A) Whether or not there is a risk of airborne releases of radioactive material
This may be due to a RN material containment failure (e.g. due to loss of coolant, nuclear reactor accident, or due to fire or explosion), or the change of state of the RN material into an atmospheric form due to severe fire or explosion. Such RN material in air may be in the form of different sized particles, aerosols or gases, which require special procedures, protective gear and protective equipment as described in Chapter 2 of this handbook.

B) The amount, type of radiation (alpha, beta, gamma, neutrons) and energy range (keV, MeV for radionuclides or MW thermal power for reactors) of the RN material
The radiation hazards (internal and external) may be different depending on the properties of the RN material in question.

The severity of emergencies involving vessels with a nuclear reactor can be very high if the nuclear reactor is compromised. Atmospheric release from a reactor is the worst-case scenario and emergencies involving severe core damage have the potential to cause severe health effects both on-site and off-site. In comparison, emergencies involving transport of radiological or nuclear material would be less severe and have more local effects.

3.1 Regulations and guidelines

Important international safety regulations for maritime traffic involving nuclear reactors and sea transports of radioactive material are maintained by the United Nations (UN) including its specialized agencies the International Atomic Energy Agency (IAEA) and the International Maritime Organization (IMO). In addition, there are several other regulatory frameworks and guidelines of relevance to both SAR- and RN authorities. Table 8 gives an overview of some of the most central documents.

Table 8: Overview and short description of some of the most central international regulatory frameworks and guidelines to ensure the safety of maritime traffic involving nuclear reactors and the transport of radioactive material by sea.

SOLAS	The International Convention for the Safety of Life at Sea (SOLAS). Ch. VII – Carriage of Dangerous Goods, Ch. VIII – Nuclear Ships, Part A – Carriage of dangerous goods in packaged form, Part B – Special requirements for the carriage of packaged irradiated nuclear fuel, plutonium and high-level wastes on board ship. Regulations I/12, I/13, I/19 and XI/4 are also relevant.
MARPOL	The International Convention for the Prevention of Pollution from Ships (MARPOL). Annex III – Regulations for the prevention of pollution by harmful substances carried by sea in packaged form.
IMDG Code	The International Maritime Dangerous Goods (IMDG) Code lays down basic principles on the transport of dangerous goods by sea. It contains detailed recommendations for individual substances, materials and articles and a number of recommendations for good operational practice, including advice on terminology, packing, labelling, stowage, segregation and handling and emergency response action. The IMDG Code is mandatory under SOLAS and MARPOL and is harmonized with the UN Recommendations on the Transport of Dangerous Goods (The Orange Book). Ch. 1.5 General provisions concerning class 7, Ch. 2.7 Class 7 – Radioactive material, Ch. 6.4 Provisions for the construction, testing and approval of packages and material of class 7, Ch. 7.3 Special provisions in the event of an incident and fire precautions involving dangerous goods.
EmS Guide	The Emergency Response Procedures for Ships Carrying Dangerous Goods (EmS) Guide. Guidance on emergency response procedures for ships carrying dangerous goods including the emergency schedules to be followed in case of incidents involving dangerous goods regulated under the IMDG Code. Guidance mainly in two parts: Part 'F' dealing with fire schedules and Part 'S' dealing spillage schedules.
INF Code	The International Code for the Safe Carriage of Packaged Irradiated Nuclear Fuel, Plutonium and High-Level Radioactive Wastes on board Ships (INF Code). The INF Code is mandatory under SOLAS and addresses the safe transport of packaged irradiated nuclear fuel, plutonium and high-level radioactive wastes carried as cargo. Must also comply with class 7 requirements of the IMDG Code, including shipboard emergency plan, and notification in the event of an incident involving INF cargo.
OPRC-HNS Protocol	Protocol on Preparedness, Response and Co-operation to pollution Incidents by Hazardous and Noxious Substances (OPRC-HNS Protocol). Provides a framework developing national and regional capacity to prepare for and respond to HNS pollution incidents, and a platform to facilitate international co-operation and mutual assistance. It also sets out the organizational role in the event of an HNS pollution incident.
IAEA	The IAEA Safety Standards Series No. SSG-65 "Preparedness and Response for a Nuclear or Radiological Emergency Involving the Transport of Radioactive Material" provides guidance and recommendations on arrangements to be made at the preparedness stage for emergencies involving the transport of radioactive material. The SSG-65 is aimed at any State and its government, regulatory bodies and other response organizations, including consignors, carriers and consignees. It supports the implementation of the requirements established in IAEA Safety Standards Series No. GSR Part 7 for such emergencies, irrespective of their cause, and the IAEA Transport Regulations, IAEA Safety Standards Series No. SSR-6 (Rev. 1).

Orange Book	The UN Recommendations on the Transport of Dangerous Goods ("Orange book") refer to the IAEA Regulations, and fully integrate them. As a result, the Regulations apply to the transport of radioactive material almost anywhere in the world. These Recommendations are addressed to governments and international organizations concerned with the regulation of the transport of dangerous goods and are developed in light of the requirement to ensure the safety of people, property and the environment. They do not apply to the bulk transport of dangerous goods in sea-going or inland navigation bulk carriers or tank-vessels.
Nordic Flag-book	Nordic Guidelines and Recommendations for Protective Measures in Early and Intermediate Phases of a Nuclear or Radiological Emergency.
NB! Different countries might have additional national regula-tions.	

3.2 IAEA emergency preparedness categories

SAR emergencies involving radiological / nuclear materials may be categorized based on their potential severity and need for SRUs with a requirement for more specialized knowledge and protective equipment.

Response to an emergency requires rapid and coordinated action that require a common operational framework. This can be accomplished by using internationally agreed classification system.

IAEA provides guidance on approaches for developing the capability to respond to a nuclear or radiological emergency, which differ depending on the characteristics of the emergency. Emergency preparedness and response has to be in line with hazards and potential consequences of an emergency associated with facility, activity or source.

Table 9: Emergency preparedness categories I-V (16) *(relevant for SAR operations with bold)*

Threat category	Description	Radiological threat
I	Facilities, such as nuclear power plants, where an accident/ incident could result in deterministic effects offsite, and which could require precautionary urgent protective actions, urgent early protective actions, or early protective actions to achieve the goals of emergency response. (e.g. **reactors > 100MWt** megawatts thermal)	Severe deterministic health effects off-site
II	Facilities, such as some research reactors **and nuclear reactors used onboard seagoing vessels (e.g. ships and submarines),** for which an accident/incident could give rise to doses to people off-site that would warrant urgent protective actions or early protective actions to achieve the goals of emergency response. (e.g. reactors 2-100MWt)	Warranting urgent protective actions off-site, deterministic health effects on-site
III	Facilities, such as industrial irradiation facilities or some hospitals, for which an accident/incident could warrant protective actions on-site to achieve the goals of emergency response. (e.g. radiotherapy facility)	No urgent protective actions off-site are warranted, severe deterministic effects on-site
IV	Activities and sources leading to a RN accident/incident that could warrant protective actions to achieve the goals of emergency response in an unforeseen location **(e.g. transport of fissile material [fresh & spent fuel],** strong radioactive sources).	Minimum level of threat –all countries
V	Areas within emergency planning zones and emergency planning distances in a State **for a facility in category I or II located in another State.**	Food contamination due to transboundary contamination necessitating food restrictions

Threat categories I, II and III represent decreasing levels of threat at major facilities and therefore correspond to decreasing stringency of requirements for emergency preparedness and response.

Facilities in threat categories I and II warrant extensive on-site and off-site arrangements for emergency preparedness. For facilities in threat category III, the radiation related threat is limited to the site or to areas on the site (e.g. treatment rooms or laboratories), but arrangements to inform and reassure the public in the event of an emergency are still warranted.

Threat category IV includes radiological emergencies that could occur anywhere unexpectedly and applies always in all jurisdictions, possibly together with other threat categories.

Threat category V includes activities that might yield products with a significant likelihood of becoming contaminated, as a result of events at facilities in threat category I or II, to levels necessitating prompt restrictions on products in accordance with international standards.

3.3 International Nuclear and Radiological Event Scale (INES)

IAEA and the Nuclear Energy Agency of the Organization for Economic Cooperation and Development have developed the International Nuclear and Radiological Event Scale (INES) as a tool for communicating the safety significance of nuclear and radiological events to the public (Figure 8) (17).

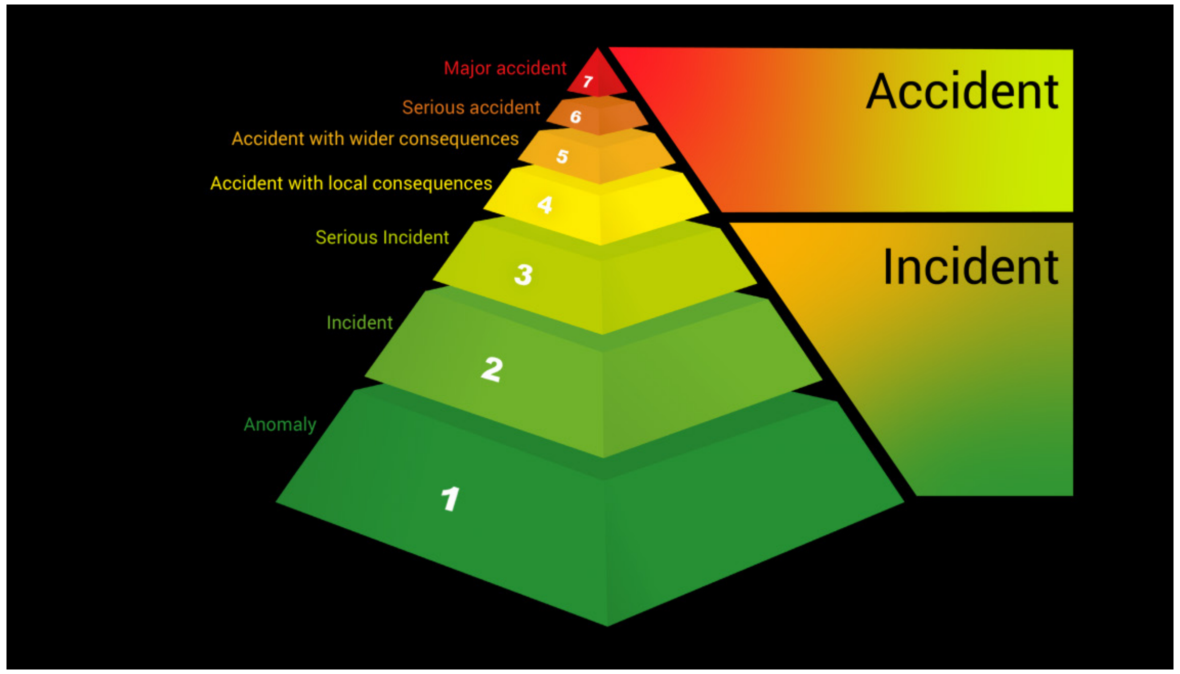


Figure 9: Member States use INES to provide a numerical rating that indicates the significance of nuclear or radiological events (17)

Member States use INES on a voluntary basis to rate and communicate events that occur within their territory. INES covers events at facilities and activities involving radiation sources. It is used for the rating of events that result in a release of radioactive material into the environment and in the radiation exposure of workers and the public. It is also used for events that have no actual consequences but where the measures put in place to prevent them, did not function as intended. Importantly, INES is not a notification or reporting system to be used in emergency response and should not be used for military application.

3.4 **Maritime traffic involving nuclear reactors**

Compared to other parts of the world, the Nordic waters have frequent traffic of civilian and military NPVs. All the civilian NPVs have their homeport in Murmansk close to the Norwegian border, with some of these typically making trips along the Norwegian, Danish, Swedish and Finnish coasts every year. In addition, the Murmansk area is home port for many of the Russian military NPVs whereas NATO-NPVs frequently visit the Norwegian ports of Bergen and Tromsø and with military NPVs having a high presence in the waters of all the Nordic countries. The NPVs typically travel in international waters, i.e., outside of 12 nautical miles most places, but may be much closer to shore when passing Denmark, Sweden and Finland. Also, the civilian NPVs and FNPP are constructed in St. Petersburg, Russia, and may return there for maintenance and repair, or if there is need for increased ice-breaking capacity during winter.

3.4.1 **Examples of civilian NPVs and FNPPs in Nordic waters**

Examples of civilian NPVs and FNPPs in Nordic waters are listed in Table 10. These are operated by Rosatomflot of the Russian Federation. Military NPVs are not included in this list but these are far more prevalent than civilian and have thermal power in the range of approximately 200-1600 MWt (18) *e.g.* the U.S. aircraft carrier Harry S. Truman (which has visited Nordic waters) has two A4W PWR reactors with 550MWt each.

RN in SAR Operations

Table 10: Overview of civilian NPVs and FNPPs in Nordic waters (all operated by Rosatomflot)

Vessel name (commissioned year,IMO number)	Reactor specifications	Crew (approximate)
Lieder-class icebreakers (project 10510): *Rossiya (2027, IMO 9911238), under construction.* *TBN (2030, IMO 9945930), cancelled or delayed until after 2035.* *TBN (2032, IMO 9945942), cancelled or delayed until after 2035.*	2 x 315 MWt RITM-400 light-water reactors	unknown
LK-60Ya class icebreakers (project 22220): Arktika (2020, IMO 9694725) Sibir (2022, IMO 9774422) Ural (2022, IMO 9658642) Yakutia (2024, IMO 9911202(?)) *Chukotka (2026?, IMO 9924106(?)) under production. TBN6 (2028), and TBN7 (2029) are planned.*	2 x 175 MWt RITM-200 light-water reactors	50-75
Arktika-class icebreakers (project 10520): Yamal (1992, IMO 9077549) 50 Let Pobedy (2007, IMO 9152959) Sovetskiy Soyuz (1989, IMO 8838582). Decommissioned, presumed still moored at Atomflot for future removal of nuclear material (dismantling). Rossiya (1985, IMO 8424240). Decommissioned, presumed still moored at Atomflot for future dismantling. *Sibir (1977, IMO 7604491), decommissioned and dismantled, presumed moored at Atomflot for future scrapping.* *Arktika (1975, IMO 7429061), decommissioned, presumed docked at Nerpa shipyard for dismantling and future scrapping.*	2 x 171 MWt OK-900A type reactors	100-110
Container- and cargoship / icebreaker (project 10081): Sevmorput (1988, IMO 8729810)	1 x 135 MWt of KLT-40M type reactors	60
Taymyr-class icebreakers (project 10580): Taymyr (1989, IMO 8417481) Vaygach (1990, IMO 8417493)	1 x 171 MWt of KLT-40M type reactors	90-100

Sources: (19–23)

Figure 10: Nuclear-powered icebreakers of the Arktika-class at Rosatomflot, Murmansk, September 2021 (photo Ø. Aas-Hansen, DSA).

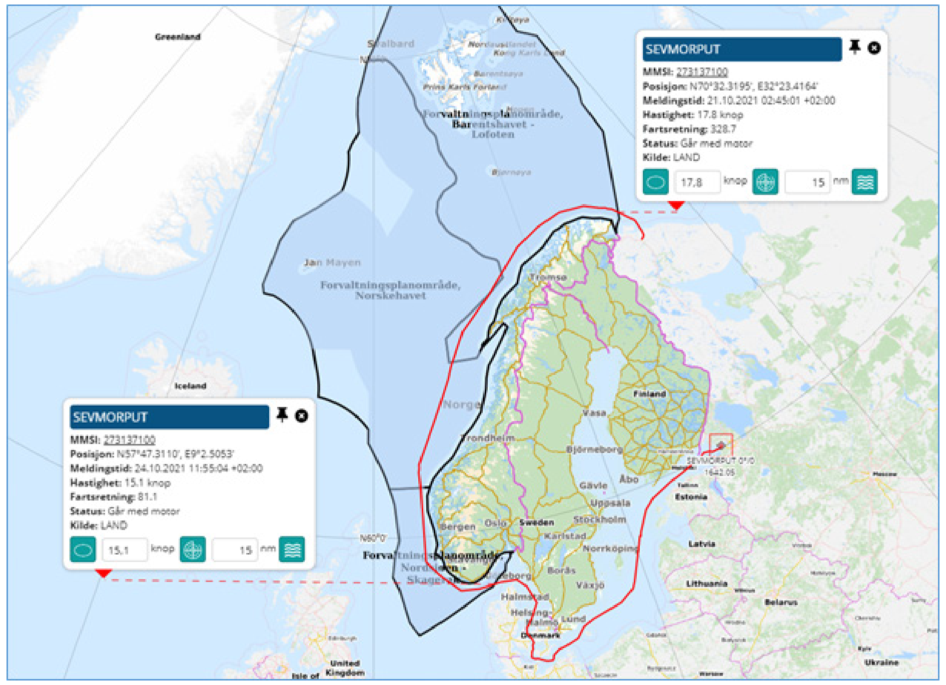


Figure 11: AIS-tracking showing a journey by the nuclear-powered containership Sevmorput from Murmansk to St. Petersburg in October 2021 (image courtesy of Norwegian Vessel Traffic Service).

3.4.2 **Prognosis calculation of atmospheric release and dispersion**

In case of a release from a nuclear accident, RN authorities will perform prognosis calculations of atmospheric release and dispersion. Figure 12 presents simulated total effective dose from an example release from Akademik Lomonosov FNPP in Norwegian waters performed with the decision support system ARGOS. On this basis, RN authorities will predict emergency zones.

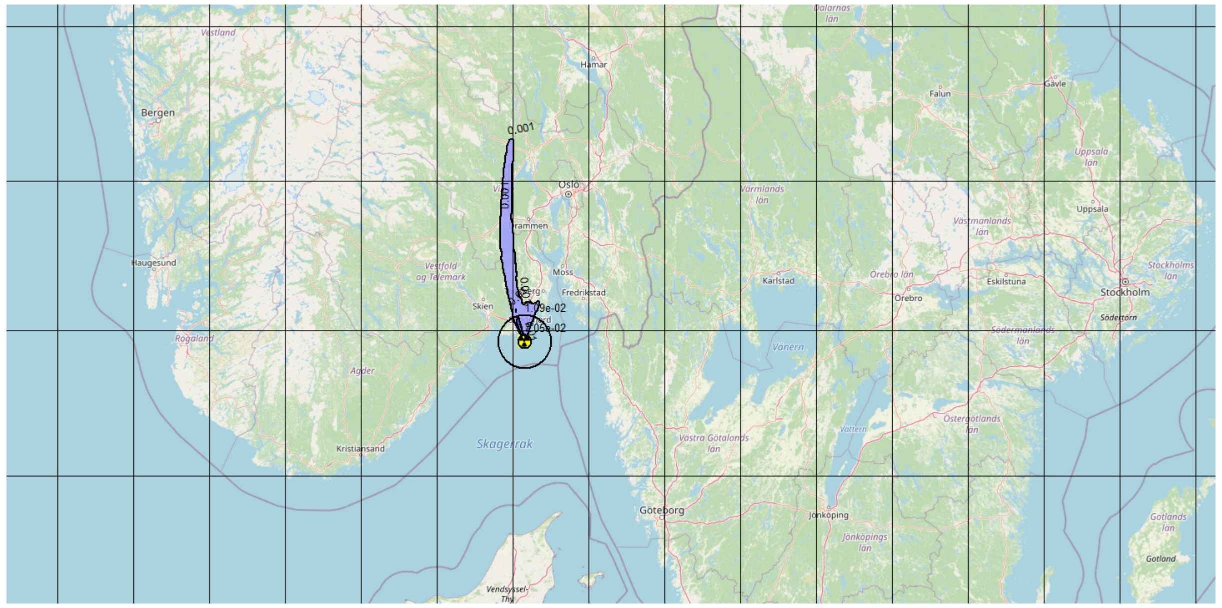


Figure 12: ARGOS prognosis visualizing total effective dose in Sv for adults, within the first 7 days after 4 hours release from Akademik Lomonosov FNPP. Circles correspond to distances of 5 km and 20 km in radius. Isocurves correspond to 10 mSv (0,01 Sv) and 1 mSv (0,001 Sv) (Courtesy of DEMA)

3.5 **Maritime traffic involving transport of RN material**

The primary safety barrier for transport of RN cargo is the packaging. However, for INF materials there are also ship requirements.

3.5.1 **Classification of RN cargo**

The basic concept of the recommended regulatory standards of the IAEA Regulations for the Safe Transport of Radioactive Material is that safety is vested principally in the package. The regulations provide a graded approach to packaging, whereby the package integrity is related to the potential hazard. Packages are grouped into five categories as per their performance under various conditions and the properties of the radioactive materials they may contain.

The packages provide shielding to protect workers, the public and the environment against the effects of radiation, to prevent an unwanted chain reaction, to prevent damage caused by heat and also to provide protection against dispersion of the contents under normal conditions and also accident conditions of transport for the more highly radioactive materials. In addition, radiation doses to workers and the public should be reduced as far as reasonably achievable by adopting best practice at the operating level. The IAEA also sets performance standards (design requirements and test procedures) for each package type. Table 11 lists package types and a short description of possible content.

Table 11: Package types and descriptions. See for example (24)

Package type	Description	Possible contents	Risk of exposure and contamination
Excepted packages	Excepted packages are packages in which the allowed radioactive content is restricted to such low levels that the potential hazards are insignificant and therefore no testing is required with regard to containment or shielding integrity.	Small calibration sources	Exposure: Very Low Contamination: Insignificant
Industrial packages (IP)	IPs are used to transport Low Specific Activity (LSA) and Surface Contaminated Object (SCO) material. Both types of material are inherently safe, either because the contained activity is very low, or because the material is not in a form easily dispersible. IPs are sub-divided into three categories designated as IP-1, IP-2 and IP-3, which differ regarding the degree to which they are required to withstand routine and normal conditions of transport. All of the combinations of industrial packaging and respective admissible LSA materials and SCO contents are intended to give the equivalent level of safety.	LSA: Radioactive material which by its nature has a limited specific activity or radioactive material for which limits of estimated average specific activity apply. Example: low-level and intermediate-level radioactive waste or ores containing naturally occurring radionuclides (e.g. uranium or thorium) and concentrates of such ores.	Exposure: Very Low Contamination: Possible
		SCO: Non-radioactive objects having low levels of surface contamination. Example: parts of nuclear reactors, whose surfaces have been contaminated by coolant or process water.	Exposure: Very Low Contamination: Possible
Type A	Type A packages are used for the transport of relatively small, but significant, quantities of radioactive material. Since it is assumed that this type of package theoretically could be damaged in a severe accident and that a portion of their contents may be released, the amount of activity they can contain is limited by the IAEA Regulations. In the event of a release, these limits ensure that the risks from external radiation or contamination are very low. Type A packages are required to maintain their integrity during normal transport conditions and therefore are subjected to tests simulating these conditions.	Well-logging sources and fixed and portable gauges are likely to require Type A packages.	Exposure: Low - medium Contamination: Possible
Type B	Type B packages are required for the transport of material with high activity. These packages must withstand the same normal transport conditions as Type A packages, but because their contents exceed the Type A limits, it is necessary to specify additional resistance to release of radiation or radioactive material due to accidental damage. This type of package must be capable of withstanding expected accident conditions, without breach of its containment or an increase in radiation to a level which would endanger the general public and those involved in rescue or clean-up operations. The adequacy of the package to this requirement is demonstrated by stringent accident conditions testing.	Type B packages are used to transport material as different as unencapsulated radioisotopes for medical and research uses, spent nuclear fuel, and vitrified high-level waste. Industrial radiography, radiotherapy and irradiator sources are likely to require Type B packages.	Exposure: Medium - high Contamination: Possible
Type C	Type C package requirements were introduced by the IAEA for the transport of high activity material by air. Type C is designed to be able to withstand a plane crash.	Same as Package type B	Exposure: Medium - high Contamination: Possible
Special arrangement	Special arrangement is used when a consignment do not satisfy all applicable requirements of the regulations; alternative measures are taken, approved by the competent authority.	Large variety	Exposure: could be high Contamination: Possible
UF6 package	Uranium Hexafluoride has the property to move from solid state to a liquid or gaseous state by small temperature variations. It is used most of the time in its gaseous state in industrial processes to enrich Uranium in the Uranium-235 isotope. Hex forms solid grey crystals at standard temperature and pressure, is highly toxic, reacts with water, and is corrosive to most metals	Uranium Hexafluoride (UF6 or Hex)	Exposure: High Contamination: Possible NB! The main hazard of UF6 to persons is when exposed to water, HF will form, which is very corrosive and poisonous.

NB! Transport of UF6

Packages containing non-fissile or fissile excepted quantities of UF6 that are involved in an accident may release UF6 with its associated chemical hazard. There may be potential for deaths following a UF6 release due to chemical toxicity of HF (product of a UF6 release). The potential risk is a function of the UF6 inventory. Greatest risk appears to be ruptures of heated tanks containing many tonnes. There is no risk of any radiological consequences requiring special protective actions. Ground contamination resulting from the emergency may require decontamination.

3.5.2 Package markings and associated hazards

IAEA has developed a portable digital assistant for first responders to a radiological emergency where they categorize UN numbers and associated hazards as presented in Table 12. A UN number is a four-digit code used to identify hazardous materials and articles (eg, explosives, flammable items, or toxic substances).

Table 12: Package markings and associated hazards (25)

UN number marking	Possible other marking	Hazard
2908, 2909, 2910, 2911	None	Non hazardous
2912, 2913, 3321, 3322, 3324, 3325, 3326	Type IP-1, Type IP-2, LSA, SCO	Possibly hazardous if inhaled or ingested
2915, 3327, 3332, 3333	Type A	Possibly hazardous
2916, 2917, 3328, 3329	Type B	
3323, 3330	Type C	

3.5.3 INF Code ship requirements

Every aspect of ship construction, equipment, manning and operation must comply with domestic and international regulations. Domestic legislation is established from the many conventions and regulations agreed within the IMO, including the International Convention for the Safety of Life at Sea (SOLAS), the International Convention for the Prevention of Pollution from Ships (MARPOL) and the International Maritime Dangerous Goods Code (IMDG Code). These regulations apply to all types of vessels and collectively they cover just about every aspect of ship design and operation. In addition, the INF Code imposes more stringent regulations for vessels carrying irradiated nuclear fuel, plutonium, and high-level radioactive waste. Consequently, an INF vessel must comply with INF, IMDG, MARPOL and SOLAS requirements. Table 13 lists descriptions of INF classes and requirements.

Table 13: INF class ships and requirements (24)

Ship class	Description
INF Class 1 Ship	Ship certified to carry INF cargoes with an aggregate activity less than 4,000 TBq[2]
INF Class 2 Ship	Ship certified to carry irradiated nuclear fuel or high level waste with an aggregate activity of less than 2 x 10^6 TBq and ships which are certified to carry plutonium with an aggregate activity less than 2 X 10^5 TBq.
INF Class 3 Ship	Ship certified to carry irradiated nuclear fuel or high level wastes and ships which are certified to carry plutonium with no restriction of maximum aggregate activity of the material.
The INF code requirements include criteria for: • Damage stability • Fire protection • Temperature control of cargo spaces • Structural considerations • Cargo securing arrangements • Electrical supplies • Radiological protection • Management, training, and shipboard emergency plan • Notification in the event of an incident involving INF cargo	

A ship that is certified for the carriage of INF cargoes is subject to regular inspections and surveys, as required in SOLAS 74, chapter 1. These surveys are carried out by the vessel's flag state. On completion of build or after conversion and prior to transporting INF cargoes, the ship must be internally surveyed, including a complete examination of its structure, equipment, fittings, arrangements, and material. On passing an initial survey, an International Certificate of Fitness for the Carriage of INF Cargo is issued. This Certificate ceases to be valid if surveys have not been carried out or if the ship no longer complies with this Code when the Certificate has expired (24)

2 *TBq = Tera-becquerels in the SI unit of disintegration of a radioactive nuclei per second e.g. 9 x 10^{12} Bq can be expressed as 9 TBq.*

4 Operational Plan for RNSAR emergencies

This chapter offers an introduction to SAR operations in RN environments. The chapter is structured following the rescue operations stages according to the IAMSAR Manual (26). This operational plan is supplemented by the RNSAR SOPs.

When an RN incident at sea involves a danger to human life or health, a maritime search and rescue operation will be carried out. SAR operations are guided by both international and national laws and regulations. **The Rescue Coordination Centre (RCC)** for the search and rescue region where the incident is taking place, has the responsibility for coordination of the maritime SAR operation. (28)

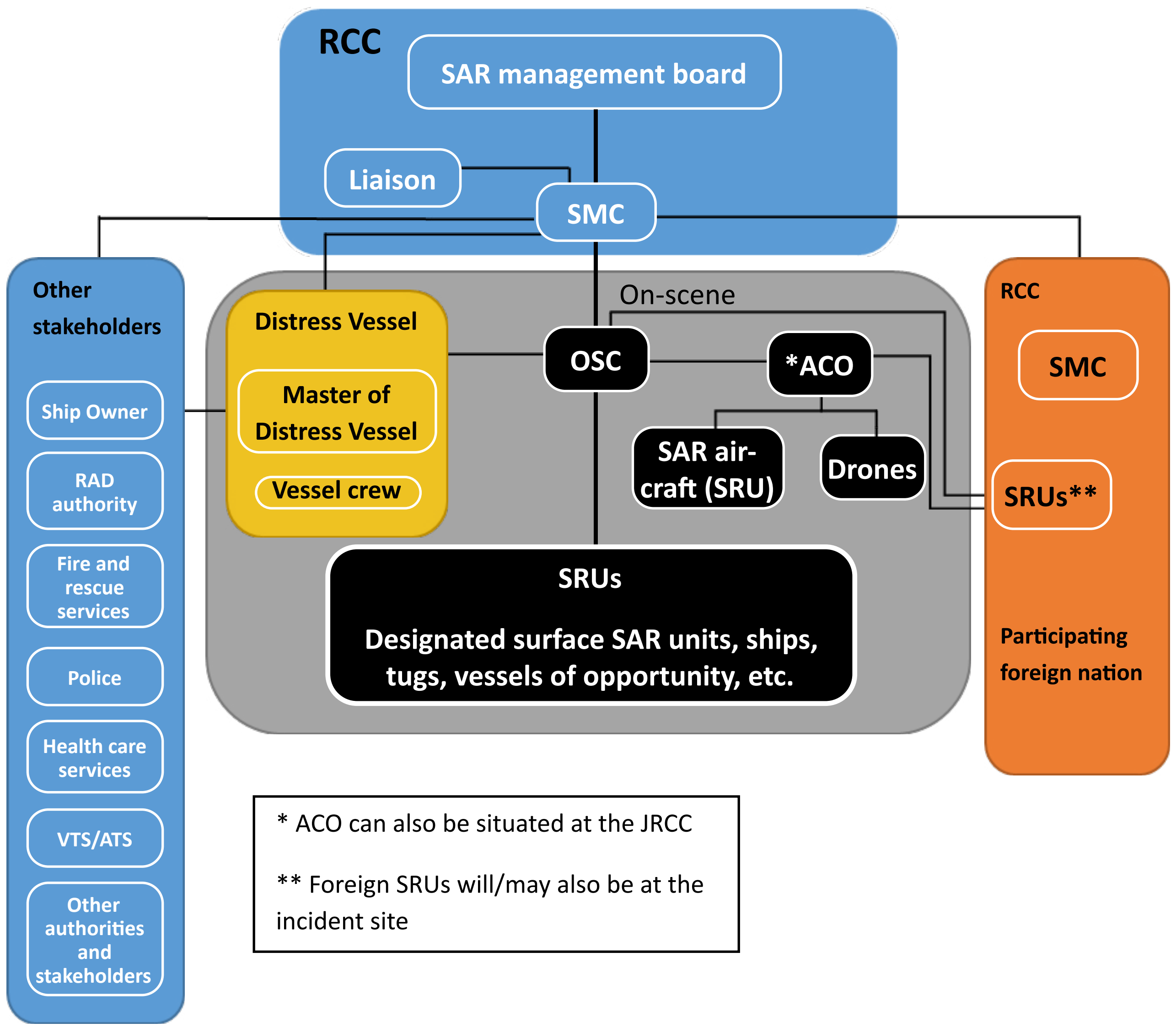
SAR operations are normally carried out under the direction and supervision of a **SAR mission coordinator (SMC)**, who is usually the supervisor of the RCC or Rescue Sub-Centre (RSC) watch team. The SMC is responsible for gathering information about the emergency, making accurate and workable plans based on the emergency incident information and dispatching and coordinating the facilities, which will carry out the SAR missions. (26)

In maritime SAR operations, where two or more **search and rescue units (SRU)** are working together on the same mission, the SMC may assign an **On-Scene Coordinator (OSC)** to co-ordinate the activities of all participating units. OSC may be a person in charge of an SRU, ship or aircraft participating in a search and rescue operation such as the coast guard, armed forces, sea rescue society, or someone at another nearby facility who is able to handle OSC duties. (26) The OSC is, first and foremost, responsible for carrying out a search and rescue action plan and coordinating, monitoring and providing information to all SAR facilities on-scene. (46) The master of the **distress vessel (DV)** also has a major role on-scene, since he has the authority for the vessel and responsibility for the persons on board. The OSC works closely together with the master of the DV. (46)

An aircraft coordinator (ACO) can be appointed by the SMC to coordinate aerial units arriving to the incident site. The purpose of the aircraft coordinator (ACO) function is to maintain flight safety and cooperate in order to make the SAR operation more efficient. Generally, the ACO is responsible to the SMC; however, the ACO must coordinate closely with the OSC. The ACO can be located at a fixed-wing aircraft, helicopter, ship, a fixed structure, or on shore e.g. at ATS (Air Traffic Service) or RCC.

A search and rescue unit, SRU, is a unit of trained personnel provided with equipment to carry out SAR operations. These are the responders conducting the mission on-scene.

Figure 13. Example of a command structure in a large-scale SAR operation



SAR incidents usually follow defined stages, which may help to organize response activities:

4.1 **Awareness Stage**

The awareness stage is a period during which the SAR authorities become aware of an actual or potential incident. This is done by interpreting early warning signals. It involves developing an awareness of the elements comprising the environment, gathering information, understanding and interpreting the meaning of this information as well as the prediction of the possible outcomes. This is crucial for decision-making. (27)

4.1.1 **Needed information**

The initial notification of the RN incident might be reported to the RCC from the distress vessel (DV), a Vessel Traffic Service (VTS) center or a third party. In some cases, the notification might be a report of a situation that can or has been handled by the crew of the DV. In all cases, the notification should be evaluated (28).

Uncertainty on the early phase of an incident poses challenges for conducting a correct assessment of the situation, and thus planning the rescue operation. Achieving situational awareness is paramount to setting adequate operating procedures, selecting the most relevant assets to conduct the necessary tasks, and guaranteeing SAR personnel's protection and safety (28).

As in any SAR incident, obtaining information about the incident's typology, weather, vessel details, and the situation of the crew and DV, as well as the availability and capabilities of SRUs and Vessels of Opportunity within the area is important. In addition, in RNSAR, knowing the characteristics of the material involved becomes vital.

In this early phase, there might be uncertainties regarding how the RN incident evolves. Therefore, acquiring the necessary information about the nature, state and location of the material, the external factors that could have an impact on its behavior, and the capacity and capabilities of the SRUs to work in an RN environment as quickly as possible should be a priority.

This information will also help in defining potential hazards and to update the risk analysis that will be carried out (28). The risk analysis should be carried out continuously.

4.1.2 **Information gathering**

In RNSAR operations, communication between the RCC and the DV should be conducted regularly to share information about updates on planned or executed actions, as well as the situation on the DV and possible changes to it. At this early stage, the aim of the communication will be to create a common operational framework and situational awareness (28).

Upon first contact, the RCC and the DV should clarify the following details:

☐ Nature of the emergency
☐ Type of assistance needed
☐ Urgency
☐ Intentions of the master
☐ Vessel type and description
☐ Capacity of the crew to handle the incident
☐ Name and registration
☐ Position
☐ Persons on board (POB)
☐ Number of deceased/injured/missing
☐ Available alternative means of communication
☐ Estimated Time of Arrival (ETA) for assisting assets
☐ Weather and weather prediction

(26,28)

Furthermore, in RN incidents the RCC should acquire information about:

Whether the ship is transporting RN material/substance:
☐ What kind of RN material
☐ Location of the RN material
☐ Status on the RN material and/or containment
☐ Significance of the threat to other people, infrastructure, and environment
☐ If available, vessel RN sensor readouts

If the ship is nuclear powered/propelled:
☐ Status of the reactor (both as propulsion and possible damage)
☐ Predicted outcome

(28)

In addition to the communication with the DV and the master, the RCC will be to gather information about the nature of the incident from:

☐ Competent RN authorities, national and neighboring
☐ The shipping company, e.g ship safety plan and cargo separation/cargo plan
☐ The ship`s agent
☐ The departure and destination harbors
☐ The cargo's owner (sender and/or receiver)
☐ Customs
☐ Databases e.g. Safe Sea Net
☐ VTS centers
☐ Other vessels in the vicinity

(28)

Based on the obtained information, the RCC can then plan the operation and task resources in an efficient manner (28).

The gathered information should be verified to the extent that is possible and evaluated. Some of the gathered information might be irrelevant, misleading, or false. In accordance, the SMC must assess the data and classify it according to its relevance and reliability (26).

4.1.3 **Characterizing the incident**

Knowing the nature of the incident is of prime importance since it will dictate different rescue measures and procedures. The characteristics of the RN material, its behaviour, and the type of radiation will also require different protective measures and lines of action.

Learning about the conditions of the DV's crew and their capability to handle the situation, organizing evacuation and their possibilities to avoid an uncontrolled abandoning of the DV is critical (28).

NB! When the RN material involved is unknown, the assessment should consider the situation as dangerous

4.1.4 **Predicting possible outcomes**

Based on the gathered data, the SMC will conduct a risk analysis of the situation considering possible pathways in which the incident could evolve and the emergence of uncontrollable factors that could lead to secondary damage or a worst-case scenario, in order to prepare to manage the consequences (28). This assessment will influence the choice of resources to be used and any possible safety measures to be taken. A radioactive release to air may also cause other consequences for the SAR operation besides contamination and radiation exposure.

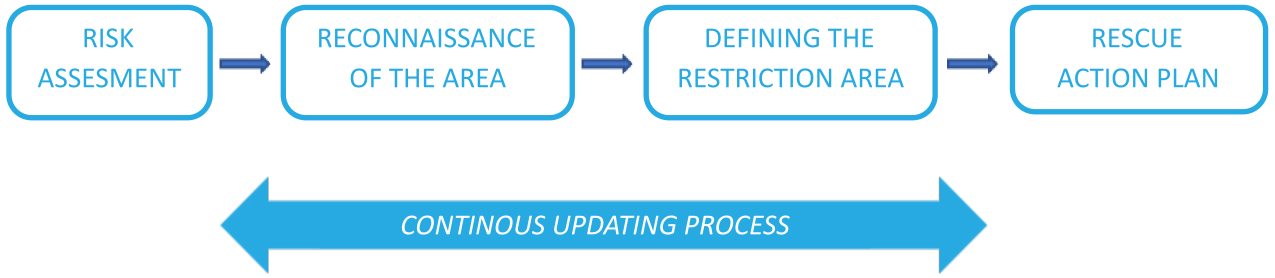
4.2 **Initial Action Stage**

Normally, after evaluating the initial available information and considering the degree of the emergency, the SMC should declare the proper emergency phase and immediately inform all centres, personnel, and facilities. Most RCCs have lists describing what steps are to be taken according to the declared emergency phase. According to the IAMSAR manual, the emergency phases determining which initial SAR actions to take, are:

- **Uncertainty phase**: *"exists when there is knowledge of a situation that may need to be monitored, or to have more information gathered, but that does not require dispatching of resources. When there is doubt about the safety of an aircraft, ship, or other craft or persons on board, or it is overdue, the situation should be investigated, and information gathered."*
- **Alert phase:** *"exists when an aircraft, ship, or other craft or persons on board are having some difficulty and may need assistance but are not in immediate danger. […] SRUs may be dispatched, or other SAR facilities diverted to provide assistance if it is believed that conditions might worsen or that SAR facilities might not be available or able to provide assistance if conditions did worsen at a later time."*
- **Distress phase:** *"exists when there is reasonable certainty that an aircraft, ship, or other craft or persons on board is in danger and requires immediate assistance."* (26)

4.3 **Planning Stage**

The planning process is important for the success of a SAR operation. All variables must be considered, from the capability of the individual SAR asset to the weather forecast. The main goal of any SAR operation is to rescue people in distress. Preventing further damage to the environment and property is the secondary goal.



When assessing the situation, it is paramount to determine appropriate resources and operating procedures to conduct the primary and, when possible, the secondary goals in an efficient and safe manner.

4.3.1 **Risk assessment**

Saving people in distress from the risk of death or serious injury has a high priority in SAR operations. This mandate has to be considered even if radiation dose limits are exceeded. Therefore, a quickly executed SAR operation could serve a purpose of rescuing people and reducing risk for the SRUs, i.e. reducing exposure time of radiation and avoiding reaching critical values.

In situations where the crew and passengers of the DV have abandoned the distress vessel and no longer face an immediate hazard from the RN substance, the risk potential (radiation exposure or contamination) for SRUs participating in the operation is considerably lower. Nevertheless, detection and monitoring should be established at an early stage to get an early warning if the situation were to get worse. Thus, a risk assessment will always be required.

One aid when making situational assessments is the Vessel Triage system (29). With this system, the situation is assessed using the same criteria by both the RCC and the DV. Thus, creating a shared situational awareness.

GREEN	YELLOW	RED	BLACK
Vessel is safe and can be assumed to remain so	**Vessels is currently safe, but there is a risk that the situation will get worse**	**Level of safety has significantly worsened or will worsen, and external actions are required to ensure the safety of the people aboard**	**Vessels is no longer safe and has been lost**
GENERAL SITUATION	**GENERAL SITUATION**	**GENERAL SITUATION**	**GENERAL SITUATION**
- The situation aboard is stable. Although the vessels may have been damaged by the accident, this damage does not threaten its seaworthiness or the people aboard. - The damage to the vessel has been assessed. It is highly unlikely that the damage will spread or get worse. - The vessel still protects the people aboard against the prevailing conditions.	- Damage to the vessel might affect its seaworthiness or the full extent of the damage has not yet been determined. - Internal damage control measures and rescue operations have not been completed. Damage control is possible with reasonable resources available to carry out the proper measures. - Damage to the vessel may pose a direct or indirect threat to the people aboard.	- The vessel is significantly damaged, affecting its seaworthiness, and there is a threat to the people on board. - A fire, leak, or other damages to the vessel are not under control and escalation is highly likely. - The vessel no longer protects the people aboard against the prevailing conditions. - Major external resources are required.	- The vessel is capsized, sunk, burnt, or otherwise damaged so badly that it no longer provides protection to the people aboard against the prevailing conditions (that is, the vessel has totally lost its seaworthiness). - Even if the vessel is still completely or partly afloat, it is no longer safe to work aboard, even to save human lives.

GREEN	YELLOW	RED	BLACK
Vessel is safe and can be assumed to remain so	**Vessels is currently safe, but there is a risk that the situation will get worse**	**Level of safety has significantly worsened or will worsen, and external actions are required to ensure the safety of the people aboard**	**Vessels is no longer safe and has been lost**
OPERATIONAL FOCUS	**OPERATIONAL FOCUS**	**OPERATIONAL FOCUS**	**OPERATIONAL FOCUS**
- Damage control or firefighting operations are not or are no longer required. - If there are injured people aboard, the operational focus is on emergency care. - Only patients in need of urgent care are evacuated from the vessel. - Active monitoring of the situations aboard is important.	- The operational focus is on limiting damage/damage control and preparations for possible evacuation from the vessel. - In addition to carrying out damage control measures and rescue operations, it is important to determine the actual condition of the vessel. - At the discretion of the master of the vessel, non-essential persons can be evacuated from the vessel. - Proactive measures are taken to stabilise the situation aboard so that its condition becomes “green” or alternatively to allocate more time for evacuation and other rescue operations. - Continuous monitoring of the situation aboard is important (risk of the situation turning “red”)	- The operational focus is on evacuation of the vessel. - All non-essential persons will be evacuated from the vessel. - Patient classification may not be able to be carried out aboard the vessel. - If enough resources are available, damage control/ firefighting will be carried out to provide extra time for actual evacuation. - Emergency towing to shallows could be an alternative to evacuation, or a means of gaining time for actual evacuation. - Continuous monitoring of the situation aboard becomes more important (damage usually spreads progressively= significant risk of the situation turning “black”	The operational focus is on rescuing people on the hull as well as searching for and rescuing those in the water. - Patient classification cannot be carried out aboard the vessel. - Operations involving diving or rescue by means of hull penetration are special operations that are planned and decided separately. - As a rule, additional personnel are not dispatched from land into the vessel.

Threats	GREEN	YELLOW	RED	BLACK
Flooding	Flooding affects a limited or contained space and has no effect on the vessel's stability and seaworthiness.	Flooding can be kept under control with pumps and watertight compartments, but the seaworthiness of the vessel is restricted.	Extensive flooding or progressive flooding to undamaged watertight compartments. Flooding cannot be kept under control and poses a direct danger on the entire vessel.	Flooding is so severe that evacuation operations are no longer possible. **OR** Vessel has capsized or sunk.
Listing, decrease of stability	Listing or decrease of stability does not affect the seaworthiness of the vessel.	Seaworthiness of the vessel is restricted due to a decrease of stability or a notable list.	Large heel angles. The seaworthiness of the vessel is significantly impaired, its stability is threatened and there is an imminent need to evacuate.	Stability is decreased to such an extent that evacuation operations are no longer possible. **OR** Vessel has capsized or sunk.
Decrease of manoeuvrability	Vessel's manoeuvrability is hampered, but the vessel can still proceed on its course.	Vessel has lost its manoeuvrability but is still capable of emergency anchoring or drifting safely.	Vessel has lost its manoeuvrability and is not capable of emergency anchoring or drifting safely.	(Not applicable)
Black-out	Functions important for ship operations are kept running by backup systems while the fault is repaired.	Operational capability of the vessel is limited: Backup systems do not work as planned **OR** functions important for ship operations are kept running by backup systems, but the fault cannot be repaired at sea.	A full black-out of long duration that cannot be repaired at sea poses a direct danger on the entire vessel.	(Not applicable)
Fire, explosion	Fire has been extinguished and there is no danger of re-ignition **AND/OR** the consequences of an explosion do not affect the vessel's safety.	Fire or explosion affects only a limited area and can be brought under control with the vessel's own or external damage control/ firefighting resources.	Fire cannot be kept under control OR the consequences of an explosion pose a direct danger on the entire vessel.	Conditions on board the vessel are not survivable. The consequences of the fire or explosion pose a direct danger to persons aboard. **OR** Vessel has been destroyed.
Danger posed by hazardous substances	Release of hazardous substances on board does not pose any danger on the vessel.	Release of hazardous substances on board poses a danger in certain sections of the vessel, but the release can be contained to these sections.	Release of hazardous substances on board poses a direct danger on the entire vessel.	(Not applicable)

Threat factor	Example questions to obtain insight in the severity level of the threat factor
Flooding	• What is the immediate cause of flooding? • What is the extent of flooding? How many compartments are affected? • What is the location of flooding? • Can the flooding be kept under control? Are control measures still available? • What measures have been taken to control the situation? Are these successful? • To what extent do the prevailing environmental circumstances influence the severity of the situation? • What assistance is required by the vessel? How urgent is it?
Listing/decrease of stability	• What is the immediate cause of listing? • How large is the list? Is the list angle increasing? • To what extent does the list affect other activities on the vessel? • What measures have been taken to control the situation? Are these successful? • To what extent do the prevailing environmental circumstances influence the severity of the situation? • What assistance is required by the vessel? How urgent is it?
Decreased maneuverability	• Has the malfunction been caused by an internal or external cause? • Are the propulsion system, rudder and steering propellers of the vessel functioning normally? • Has a suitable steering method been correctly selected and is it usable? • Is the vessel using its backup steering system? If so, how does this limit operations? • Can the malfunction be repaired using the vessel's own resources? • What measures have been taken to control the situation? Are these successful? • To what extent do the prevailing environmental circumstances influence the severity of the situation? • What assistance is required by the vessel? How urgent is it?
Black-out	• What is the reason for the malfunction? • What is the extent of the black-out? Does it affect only certain sections/systems or the entire vessel? Are the critical systems operational? • Has the emergency generator been switched on in the network? • If the vessel is running on backup power, how long can it continue to operate? • Can the malfunction be repaired using the vessel's own resources? • What measures have been taken to control the situation? Are these successful? • To what extent do the prevailing environmental circumstances influence the severity of the situation? • What assistance is required by the vessel? How urgent is it?
Fire/explosion	• What is on fire? What has exploded? • Where is the fire? Where has the explosion occurred? • How extensive is the fire? How extensive are the damages? • Is the smoke toxic? Are hazardous substances involved? What amount? What is their nature? • How does the fire behave? Has it spread beyond the section where it initialized? • To what extent does the fire affect other activities on the vessel? • What measures have been taken to control the situation? Are these successful? • To what extent do the prevailing environmental circumstances influence the severity of the situation? • What assistance is required by the vessel? How urgent is it?
Danger posed by hazardous substances	• In which section of the vessel are the hazardous substances released? • Have the released substances been identified? What are they? In what form? What are their hazardous characteristics? Is there a possibility of a chain reaction? • How much of these substances are on board? Can these be removed from the vessel? • To what extent does the released substances affect other activities on the vessel? • What measures have been taken to control the situation? Are these successful? • To what extent do the prevailing environmental circumstances influence the severity of the situation? • What assistance is required by the vessel? How urgent is it?

Figure 14: Vessel triage system (29)

The following considerations are key in any maritime SAR operation:

✓	Specifying the nature of the danger and determining the action plan, including task prioritisation.
✓	Finding out the sufficiency of the personnel, equipment, and special equipment for the situation in question and for the planned tasks.
✓	In order to determine appropriate measures for the situation, one needs to clarify (or assess) e.g., the need for immediate rescue measures on board the distress vessel, the possibility of monitoring and isolating the area, and the need for additional information about the substance or substances in question and their behaviour in the current circumstances.
(28)	

At an early stage of the incident, it is important to develop backup plans alongside the main rescue plan. For example, one factor that could limit operational capabilities would be the calculated radioactive downfall dispersal based on prevailing wind direction. In such a situation, one should consider whether vessels are able to operate in the area at all.

Another factor to bear in mind, is the type of radiation and the intensity (mSv/h) as well as the possibility of radiation contamination, as it will dictate whether an SRU can partake in the operation and the time a rescue team will be able to be in the affected area before reaching the maximum radiation exposure.

Table 14: Reference dose levels for SRUs

Maximum dose for SRUs	1 mSv (millisievert)
For life saving reasons	100 mSv [3]
Never over	500 mSv [4]

These thresholds will limit action possibilities depending on the protective gear the SAR asset and the individual rescue crew members have.

The SAR authorities should carefully consider consequences and need for decontamination when tasking an SRU in an RN scenario. For example, a SAR helicopter could be out of service for a prolonged time due to contamination. As an example, in the Fukushima Daiichi nuclear power plant disaster, it took around 536 personnel-hours to decontaminate each aircraft (45).

The on-scene rescue operation should ideally begin after the situational assessment and risk assessment have been completed, and when SRUs have the necessary protective equipment according to the estimated risk at hand. The deployed SRUs should have updated information about the situation to establish effective precautionary measures, decontamination measures and appropriate first aid facilities.

Furthermore, information should be obtained from RN authorities regarding the type of RN substance, the quantity the prevailing conditions, and, when relevant, an estimate of the velocity and direction of spreading of radioactive particles and/or gas clouds as well as dispersion model predictions (if available).

The impact of the prevailing weather conditions as well as its predicted developments should also be considered when conducting the assessment.

[3] 50 mSv in Norway
[4] 100 mSv in Iceland

RN in SAR Operations

4.3.2 **Reconnaissance of the area**

Measurements taken during reconnaissance must be used to assess the risk for radiation and define safety limits.

The DV will have its own radiation monitoring system, which can provide measurement results to the RCC and RN authorities.

In addition to stationary monitoring stations, coastal states might have RN monitoring and measuring equipment installed on their rescue vessels and/or aircraft. Some may also be mounted on Remotely Piloted Aircraft System (RPAS). Such resources should be sent to the distress area to carry out radiation measurements.

SRUs conducting monitoring and measurement tasks must have the appropriate PPE and have adequate training in measuring radioactivity. Based on the first detections, the limits of the danger zone will be set (e.g. hot zone = 100 µSv/h).

The more detailed information, the more the danger zone can be reduced or increased in size. In practice, however, the limit of the area is set at the measuring points where the most distant readings have been observed. The areas should be made large enough to consider the fact that radioactive clouds/gases and vapors do not spread or move evenly.

4.3.3 **Defining the restriction area**

Determining the restriction area for all vessels and aircraft should also be considered as part of the action plan. The restriction area includes both the zone of immediate danger (hot zone), the danger zone (warm zone), and the safe working area for rescue operations (cold zone) (28). Formally, a restriction area can be set within the territorial sea, 12 nautical miles (nm), however if there is a need to limit traffic from a dangerous area outside the territorial sea, this area can be referred to as **temporary precaution area** for vessels and **temporary danger area** for aircraft.[5]

The dangerous area (hot and warm zones) is normally defined around the entire distress vessel following the next values.

Table 15: Example hot, warm, and cold zone thresholds[6]

	Cold zone	Warm zone	Hot zone
Dose rate	0,2 – 0,8 Microsievert per hour *(µSv/h)*	0,8 – 100 Microsievert per hour *(µSv/h)*	>100 Microsievert per hour *(µSv/h)*
Maximum hours of exposure allowed	Unlimited, background radiation	1250 hours *(0,8 µSv/h)* - 10 hours *(100 µSv/h)*	Less than 10 hours

[5] Ref. UNCLOS and example from UK legislation on TEZs (Merchant Shipping Act 1995)

[6] Based on official Norwegian values

Following the acquisition of new knowledge on the RN source, its nature or other information, the areas may be reduced to parts of the DV or expanded. In the early stages of the incident, when no detailed information about the incident is available, the restriction area should be made sufficiently large.

RN authorities might be helpful in this by presenting prognosis models. Nevertheless, SAR authorities should be made aware of the reliability of predictions. The results derived from these models cannot be completely trusted. Inaccurate results might be caused by insufficient initial values, or the parameters may be inadequate. The reliability of these results also depends on the model's internal structure and how valid the system is.

These prognosis models can never be a substitute for measurements. To define a correct hazard assessment, one must utilize real-time measurements. Detecting and analyzing radioactivity in the incident's early stages is essential to clarify its properties and potential hazards as well as to define the restriction area and its form (28).

If the RN source is unknown and it is not possible to take any measurements, the possibility of larger risks should be taken into consideration when determining the restriction area. The following examples from the IAEA illustrate the possible range of restriction areas in the planning phase, if the vessel is anchored in a harbour, depending on thermal power of reactor. Precautionary action zone (PAZ) and Urgent protective action planning zone (UPZ) predefine the boundaries of the zones for which protective actions, including evacuation, sheltering and stabile iodine prophylaxis are implemented. For PAZ all 3 provisional protective actions should be implemented <u>before</u> start of the release. For UPZ initiation of urgent protective actions such as sheltering and stabile iodine prophylaxis should be implemented before or short after the start of the release.

Table 16: IAEA's suggested emergency zones and area sizes (30)

Facilities with thermal power	Precautionary action zone (PAZ) radius	Urgent protective action planning zone (UPZ) radius
Reactors >1000MWt	3-5 km	5-30 km
Reactors 100-1000 MWt	0.5-3 km	5-30 km
Reactors 10-100 MWt	None	0.5-5 km
Reactors 2-10 MWt	None	0.5 km

Figure 15: FNPP "Akademik Lomonosov" (2 x 150 MWt reactors) during towing from St. Petersburg to Murmansk in May 2018 (Photo: Øyvind Aas-Hansen).

The purpose of determining larger restriction areas respond also to the need to set a safe area for other maritime traffic as well as to ensure an isolated area for the rescue operation on-scene (28).

When radiation is not emitted by a single point source, weather conditions and any expected changes should be considered (see figures 16 and 17). In these cases, rescue units must maintain upwind at a distance assessed to be adequate. Maritime and air traffic other than vessels involved in the rescue operation, are to be directed to stay clear at a sufficient distance (28).

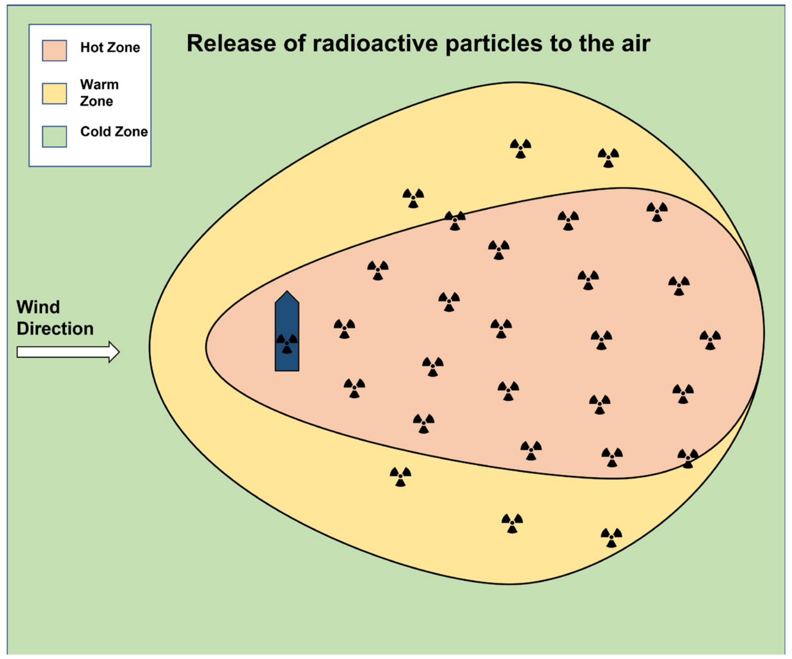


Figure 16. In cases where there is a release of radioactive particles to air

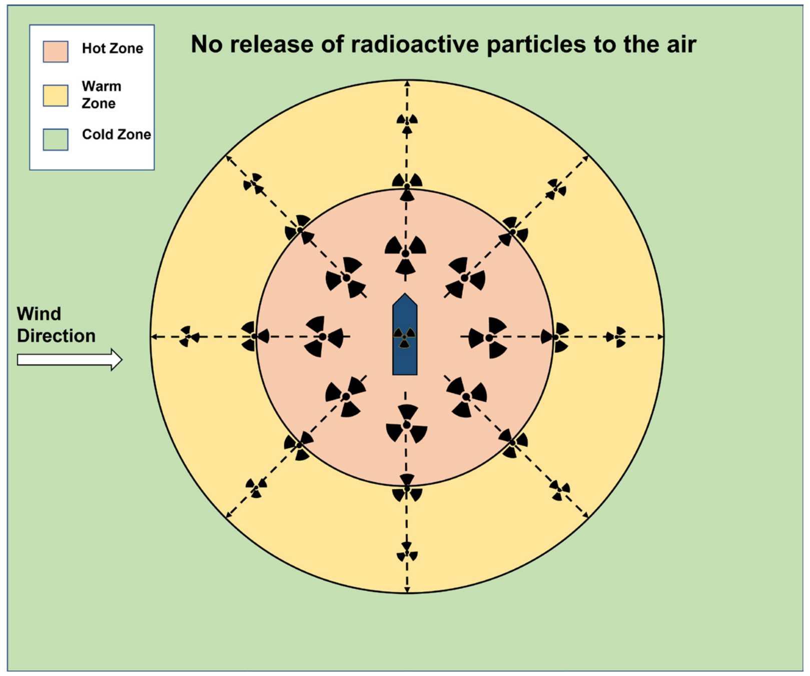


Figure 17. Radiation emitted by a single point source and there is no release of radioactive particles to air

In addition, measures to warn the population about possible radiation hazards and/or the threat of spreading radioactive clouds and outfall should be taken when necessary.

4.3.4 **Rescue action plan**

Rescue and possible response actions on board the DV should ideally rely on the crew's actions and secondarily on external assistance (28). External assistance should be provided when it can help getting the situation under control e.g. by changing the heading of the vessel by using emergency towing or by sending a rescue team to the DV.

Alerting and consulting RN authorities as early as possible will enable executing the operation in a timely fashion and the activation of correct rescue and response measures. It is possible that certain actions may make the situation worse, and therefore consulting the RN authorities early is crucial. In addition, alerting and consulting other relevant national resources as well as the need for international assistance should be considered.

When conducting a SAR operation in an environment with an unknown RN component, the maximum level of protection procedures and equipment for SRUs should be provided. **The use of radiation detection devices is a minimum requirement for SRUs participating in a RN SAR operation.**

4.3.5 **Preparation and updating process**

In the planning stage, it is also important to consider the continuity of the SAR operation itself by making sure that additional personnel and necessary equipment are made available. One should also consider the resilience of the whole SAR system by making sure adequate decontamination procedures for personnel and equipment are in place in case they are contaminated during the SAR operation, and therefore unavailable for other operations.

SITREPS must be provided regularly to other relevant authorities and any other relevant parties.

In all stages of the incident, the action plans should be reassessed, adapted, and updated as necessary based on the latest information available and the development of the situation. (28).

4.4 **Operations stage**

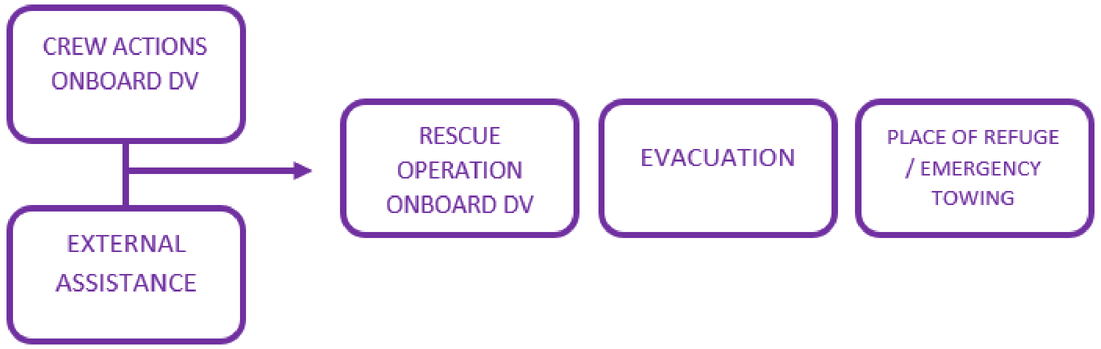


Figure 18: Operations stage (28)

4.4.1 **Crew actions taken on the distress vessel**

In the starting phase of an incident, the crew of the DV will be best positioned to handle and de-escalate the situation and minimize threats. These initial actions are essential (28). The master of the DV has the responsibility to launch, organize and direct these actions.

When an incident takes place, regardless of the crew's capacity to handle the situation, it must be reported to the responsible authorities as soon as possible in order to speed up the task of getting external assistance if later required (28).

Having accurate, complete, and up-to-date information on the nature of the incident, and initiated actions will help authorities in preparing and providing the necessary assistance.

The RCC will also be able to provide expert help on the RN situation in question through their connections to RN authorities, including information about its behavior and spreading prognosis.

4.4.2 **External assistance**

SAR assistance on-scene might be limited or delayed due to different circumstances such as prevailing weather conditions or the remoteness of the location.

To develop an efficient SAR plan, the SMC must consider several critical aspects to establish situational awareness. These include assessing how the RN situation will develop over time and what the SAR asset transit-to-scene time will be.

Defining consequences for the SAR personnel is also important. Worst case scenarios should be developed and communicated to the SAR assets so they can prepare their choice of equipment and procedures, including decontamination possibilities and procedures. In addition, foreseeing possible consequences for the environment and the population in surrounding areas might become necessary (28).

When establishing a rescue plan, the SMC could - together with RN advisors - consider if SAR assets can make an effort to mitigate the RN situation, i.e. reducing or containing the release or neutralising the RN substance (28). Such actions may prevent the situation from getting worse and might secure the initial SAR work on site.

Depending on the situation on site, a rescue unit could be tasked to observe and register the RN situation, the purpose being to collect data for establishing the risk level for the SAR operation.

Vessels and aircraft with installed RN detection equipment and other on-site radiation monitoring systems will play an important role in measuring and detecting radiation levels to designate safe working zones, determine the required personal protection equipment and to continuously monitor the hot zone (28).

Tasks to be conducted in hot and warm zones, should only be given to SRUs that have the capacity, protective measures, and systems to operate in a safe manner.

A very important protective measure is to decide on the maximum exposure time (see chapter 2) for rescue personnel that operate in hot zones. When the situation includes a release, prognoses calculations are to be done by RN authorities taking weather conditions into account. This will help SAR planners to organize the operation in a safe manner and minimize exposure and contamination of SRUs.

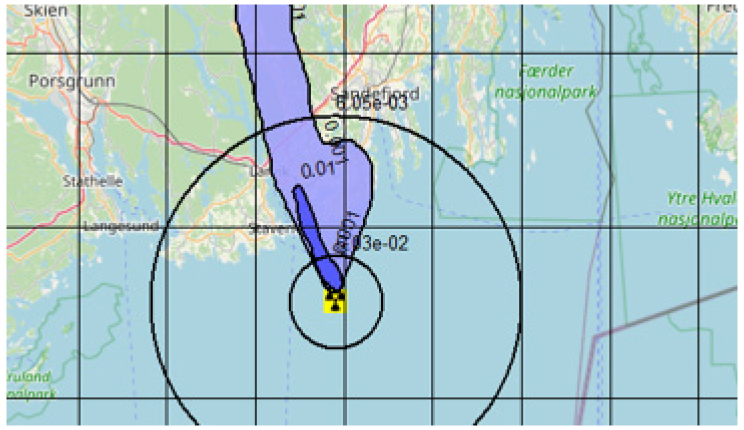


Figure 19: Total effective dose in Sv for adults, within the first 24 hours after 4 hours release from FNPP "Akademik Lomonosov", simulated with decision support system ARGOS. Circles correspond to distances of 5 km and 20 km in radius. Isocurves correspond to 10 mSv (0,01 Sv) and 1 mSv (0,001 Sv). (Courtesy of DEMA).

4.4.3 **Action options**

Emergency towing and place of refuge

In some situations, the vessel must be shifted by emergency towing to a more sheltered location, e.g. to enable evacuation or to shift the DV to position further away from an inhabited or otherwise risk-sensitive area to reduce the radiological impact on these areas.

When the vessel in distress can cause a risk for environmental disaster, the coastal state can appoint a place of refuge for the vessel. The request for the place of refuge might also come from the vessel in distress to the Coastal Administrations through RCCs. In that situation, the coastal state should assist the vessel and bring it to a safe area or to the designated place of refuge. The request can also come from the authorities of a neighbouring coastal state.

Bringing a ship to a place of refuge near a coast may endanger the coastal state, both economically and environmentally. Countries have different legislation and responsible authorities, and the process varies among them. Although many countries have plans for a place of refuge included in their maritime emergency plans, the decisions are made case-by-case to minimise the risks and to prevent damage and pollution.

Evacuation

Depending on the situation, a full or partial evacuation of the DV might be a relevant solution. Evacuation options should be discussed with the master of the DV in the initial phase. For the SRU, approaching the DV on-site might be too hazardous due to the RN situation/risk. An option in this case, might be for the persons on board the DV to abandon ship with lifesaving appliances and move away from the DV, to be picked up by SRU outside the hazardous area. This will mitigate the RN risk for the SRU.

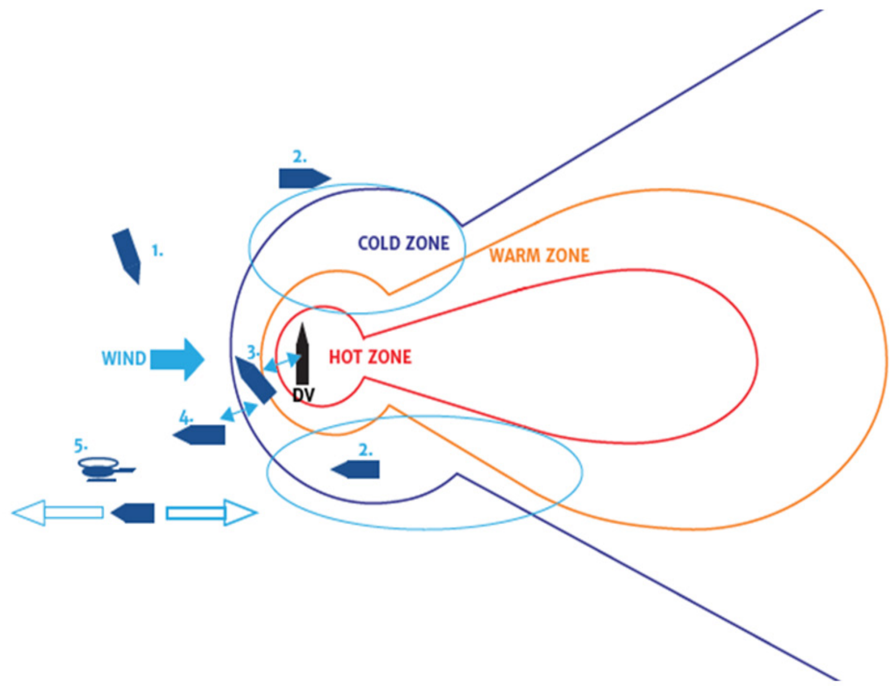
In situations where there are radiation and radioactive outfall spread widely, an evacuation can be carried out at a later stage through this hazardous atmosphere only if the evacuees have the possibility of wearing protective equipment that enables a safe exit (e.g. a filter mask, Emergency Escape Breathing Device (EEBD) or equivalent, and protective clothing). If the DV is short on such equipment, one might consider arranging for transport of such clothing and equipment to the rescue vessels in the area and onwards to the distress vessel (e.g. by helicopter to a support vessel).

In some RN scenarios, the safest place for the crew and passengers is within the distress vessel's accommodation or in some other compartment of the vessel where the effect of the radiation is reduced or not present.

4.4.4 **Rescue operations for saving human lives on board distress vessel**

While creating a rescue plan, one considers the resources required for executing the rescue operation. Additional needs arise if the situation is prolonged (e.g. more first responders, options for decontaminating a larger number of persons and equipment, and emergency medical care for victims and transport for further treatment).

Personnel that are moved from hot zone to cold zone must go through a decontamination point. If the decontamination station cannot be established, a shower/flush point (jet fog and provision of extra air) is a minimum requirement for the first stage emergency decontamination, combined with removal of exterior clothing/footwear. The purpose of such a decontamination is to remove at least a significant remainder of the radioactive contaminants from casualties, rescue personnel, clothing and equipment in a fast, efficient, and safe manner. The decontamination station or decontamination point should be set up (depending on circumstances) outside the hot zone, in the warm zone and/or the cold zone. In situations where the rescue operation work zones can be located on board the distress vessel, the cold zone is the pressurised interior of the vessel. An alternative is to establish the decontamination station on a support vessel that can work in the hazardous atmosphere. In both cases, first aid and treatment areas should be in the cold zone.



Possible tasks for SAR assets while deconaminating
1. On Scene Coordinator
2. Measurement and monitoring
3. Evacuation of personnel and decontamination first/inner vessel
4. Evacuation of personnel and decontamination second vessel
5. Transportation of evacuees to shore (by vessel or helicopter)

Figure 20: Illustration of organization of decontamination stations in a situation with a risk of release of radioactive material to air (contamination risk). Modified from ChemSAR handbook (28)

The decontamination point or station should be as close as possible to the scene of operations to prevent the spread of RN to a wider area. In some situations, however, it is not possible to set up the decontamination point on board the distress vessel (size, circumstances, and weather conditions). In any case, efforts should be made to at least set up 'a flush point' that meets the minimum emergency decontamination requirements on board the distress vessel. Attention must be paid to the distance set between the hot zone and the decontamination point, considering the dispersal of nuclear clouding and outfall, to prevent the RN from spreading with secondary contamination.

SRUs entering the hazardous zone are primarily there to save lives and will reduce their exposure time to a minimum. The focus is to organize and conduct evacuation of personnel from the hazard zone, sometimes giving critical medical treatment on-site before evacuation. Depending on the situation, other tasks may also be relevant such as supporting the communication between the DV and RCC, assessing the risk on board, and supporting the master of the DV for decision-making (28).

SRUs should take RN measurements and register on radiation values as a protective action. The SAR workers should refer to the recommendations of their units.

If the SAR asset is incapable of performing own decontamination, SAR workers leaving the hazard zone or hot zone must pass through a decontamination point. This must also be arranged for SAR assets, i.e., helicopters and smaller SRUs.

SRUs must be informed about safety issues before the start of the operation based on the updated risk assessment. All the involved personnel should be acquainted with and understand the task, risks, initial action plan and emergency plan.

4.5 Concluding Stage

The SAR operation will reach its concluding stage when all lifesaving activities are completed, e.g. all evacuees have been safely transported to the reception area and/or healthcare.

At this point, there will be a transition from a SAR operation to an RN management operation. This will most likely involve a change in the organization and structure of the response. SAR and RN authorities will strive for a smooth transition.

The details of the operation, tasks assigned to the SRUs, actions conducted in the RN affected zone and information regarding exposure or contamination by SRUs should be documented for evaluation and learning purposes.

Upon completion of the SAR operation, efforts must be directed towards decontamination of personnel, clothing and equipment if required. In these cases, the affected units must undergo a safe and effective decontamination process executed by professionals (28).

5 General Preparation and Exercises

In this chapter the handbook offers:

1. An introduction to why collaboration exercises are the most important type of training for RNSAR operations
2. An example of an exercise design for RNSAR event at operational level

5.1 Why do we need joint training for RNSAR operations

A maritime SAR operation in a RN environment differs from a standard SAR operation by adding a high complexity of organization, different roles and responsibilities, other types of resources, new tasks, difficult decisions and assessment of measures for personnel protection. This type of operation demands a shared perspective on collaboration in incident response. For maritime SAR operations, collaboration is proven to be particularly important. Many incident investigation reports point out the inter-organizational coordination challenges. Collaboration is a central process in situations when different organizations are coordinating preparedness resources and seek to achieve situational awareness and control.

This brings forward the necessity of joint training for collaboration for SAR responders in RN context. A report by the Norwegian Directorate for Civil Protection analyzed potential of national and regional training and competence development centers. It concludes that complex organizational structures create extra demands for collaboration skills, and that there is a need for analyzing and systematizing practices of joint operations and joint exercises (31). There have not been many practices of joint exercises that include both SAR and RN authorities, neither there is any data analysis basis for developing collaboration of these sectors. The first large scale exercise including SAR and RN authorities was held in May 2023 in Bodø, Norway. Arctic REIHN (Arctic Radiation Exercise in High North) is an EU project funded under the umbrella of Union Civil Protection Mechanism (32). The overall aim of the Arctic REIHN was to test, verify, and further develop emergency preparedness and response in the case of a nuclear or radiological accident in the Arctic. The Arctic REIHN project involved several sub-exercises prior to a full-scale exercise. This included a notification exercise – (ALARMEX), a command post exercise, and two tabletop (TTX) exercises with different topics related to a maritime RN incident. The Arctic REIHN exercise provided an opportunity to test and develop the current procedures and guidelines on RNSAR, including this handbook.

Many professional emergency preparedness organizations have good experience in exercises within own institution, however, they often repeat the same scenarios without focus on learning, reflection, and evaluation (31).

In such complex incidents as RNSAR, there is a need to have shared understanding of the exercise concept for collaboration across sectors and professional institutions. Situational awareness, decision-making, communication, utilizing expertise and resources are all dependent on certain collaborative competences and skills. Exercises may be seen as active learning activities facilitating deeper understanding and application of these skills.

It is not an easy task to enhance collaboration during complex response operation. It is useful for operational planners to apply pedagogical approaches in developing exercises and scenarios to develop collaborative attitude and skills among the parties (33).

The overall emergency preparedness picture is characterized by a diversity of organizations that are responsible for different preparedness efforts. When organizations collaborate in a response operation, they must co-ordinate actions across own established operational patterns and organizational boundaries. In case of a RN SAR incident, there will be at least two preparedness systems involved – organization of search and rescue with the capacities for maritime SAR and nuclear safety preparedness organization with capacities to support decision-making and leadership of the operation. Both organizations have their own expertise and capacities, and the complexity relates to coordination of the response towards other involved organizations who are not familiar to this type of crisis.

Collaboration is about utilizing each other's competence and capacity (34). It requires clarified roles and communication lines between SAR responders and RN advisors, overview of capacities from both sides, as well as established coordination mechanisms to ensure shared risk perception. Lack of collaboration in a complex incident may cause a slowdown in progress and different interpretations of significance of consequences.

Emergency responders are highly skilled within their own professional fields, but when larger and complex incidents occur, they will have a limited capacity and expertise to solve the incident themselves. This happens because their organizational/professional knowledge has been developed at three levels (1) educational, (2) organizational and (3) operational (35) (Table 17). Knowledge, culture, and routines have been formed with limited interaction among various organizations. Training collaboration and other non-technical skills at these levels will enhance the participants' ability to work with each other in real situations (36).

Table 17: Collaboration knowledge levels

Knowledge levels	Collaboration training recommendations
Educational knowledge level	include participants previously educated in different professional sectors
Organizational knowledge level	include representatives from organizations that will be somehow involved in case of a complex incident with their expertise
Operational knowledge level	include levels above and under the incident command crisis team

5.2 An example of an exercise design for RNSAR event at operational level

A collaboration exercise is a time-limited learning activity where the purpose is to improve crisis management capability in collaboration with other participants. Designing exercises means systematic planning of all the activities connected to an exercise, as well as choosing strategies aimed at maximization of the learning and developing competencies necessary for effective performance.

We would like to demonstrate an example of a RNSAR exercise design which consists of basic steps needed for planning, execution and evaluation (Figure 18).

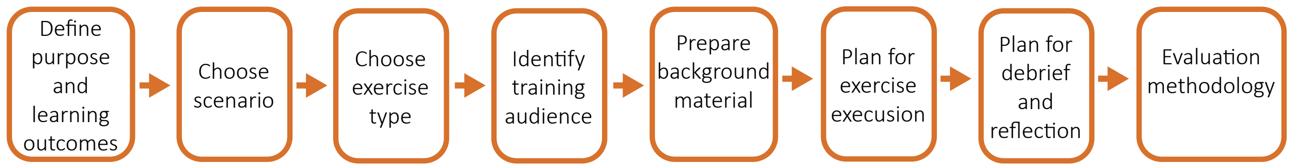


Figure 21 Exercise design

5.2.1 Define purpose and learning outcomes for an exercise

When starting to plan an RNSAR exercise for two preparedness organizations, it is important to meet the needs of each sides. The purpose of the exercise can be to improve interaction and collaboration between the organizations during RNSAR. For better utilizing of resources and expertise, the SAR organizations need to understand how the RN authorities would organize their advisory bodies and perceive the needed action. The RN authorities would in turn need to understand the roles and organization of the SAR and which information is needed for incident response. Both authorities need to think their communication lines and information needed in short-term and long-term coordination cycles (37). Mutual understanding of roles and responsibilities, communication and information sharing lines are central for all RAD and SAR authorities involved in the incident response (Table 18). Because of the handbook's focus on operational level, we may suggest to include planning learning outcomes for all organizations at the operational level who are involved in the incident response in RN emergencies – RCCs, Navy, Coast Guards, helicopter support, Police, Fire and Health authorities, etc.

Table 18: Examples of learning outcomes

1.	Understanding SAR and RN authorities' roles and areas of responsibility
2.	Understanding the challenges and limitations of each other's capabilities
3.	Understanding connection to the strategic level in their own organization and across organizations
4.	Understanding of the communication lines across the sector and within own organizations
5.	Understanding what kind of information is important to pass on from RAD to SAR and from SAR to RAD.
6.	Understanding of standard operating procedures and the operational pattern

5.2.2 Choose scenario

Scenario and exercise type are chosen together with a purpose and learning outcomes. For RNSAR exercises, it is important that a scenario contains details that are realistic and credible both for SAR responders and for RAD experts. Participants should recognize and connect it to their experience, knowledge, or their usual function. Not realistic scenarios will give the participants an incorrect perception of their ability to deal with crisis and accident events.

Two COASTEX reports (12,38) were developed under Nordic Nuclear Safety Research (NKS-B) to guide in maritime accident scenarios and exercise planning. The COASTEX reports show that one step moving towards a more structured way of exercising, is to develop more structured scenarios. Scenario elements are very specific in time and place and can be joined together to develop an exercise depending on local (national) needs.

These elements could be: sources, events, releases of radioactivity, location and consequences.

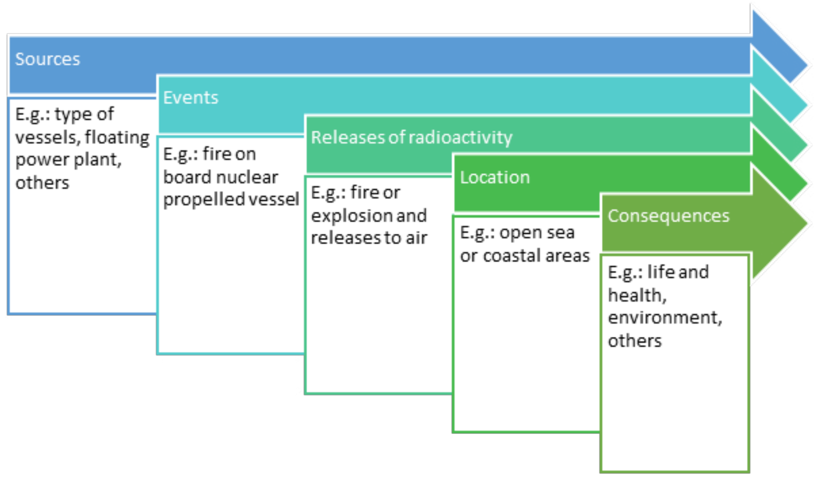


Figure 22 Examples of scenario elements (Coastex report nr.2)

The choice of scenarios for RNSAR can be made depending on learning objectives of an exercise. For example, to test the capacities that the SAR responders can use in RN context or to test how SAR experts can rely on decisions made by RAD experts.

In complex scenarios, it is important to encourage and facilitate collaboration behavior and have a clearly stated collaborative purpose. That means to have an open window for discussing possible decisions and worst-case scenarios. Solutions or the right ways of handling the situations will not appear immediately, but better understanding and mastering will be achieved after training, through reflection and discussion.

The table 19 and following examples provide a series of nuclear reactor accident scenarios and a series of RN transport accident scenarios. For further reference, the COASTEX report 1 offers a comprehensive framework for scenario development as well as a scenario bank with the description of nine maritime scenarios for nuclear accidents. (12)

Table 19 Examples of scenarios

Emergencies involving nuclear reactors	Emergencies involving transport of RN material
Example 1: Nuclear propelled freighter IAEA Threat category II	Example 3: Transport of a radioactive source Below IAEA Threat categories
Example 2: Floating Nuclear Power Plant IAEA Threat category II	Example 4: Transport of an excepted package Below IAEA Threat categories

Example scenarios for emergencies involving nuclear reactors

Example 1: Nuclear propelled freighter

A nuclear propelled freighter informs relevant authorities that they will be entering the national waters of a neighboring country. During the night, the vessel notifies that they have collided with a cargo ship. The master of the vessel informs that they will conduct a damage assessment, and that they might be in need of assistance.

After a while, the master reports that they are experiencing a loss of cooling of the reactor. The emergency leads to immediate mobilization of the emergency preparedness organizations and nuclearauthorities.

Example 2: Floating Nuclear Power Plant

A FNPP has produced power for residents and industry in a remote part of country A for a 10 years period. It is now being transported along the coastline of country B and C back to its origin for refueling and maintenance in the south of country A. The transport is carried out by towing. Relevant authorities from neighboring countries have been notified in advance of the tow and will consequently monitor the transport through each of their countries' economic zones. The tow will follow the typical shipping route.

During the transport, there is a fire on board which leads to large radioactive release from reactor units onboard the FNPP. The emergency leads to immediate mobilization of the emergency preparedness organizations in affected countries.

Example scenarios for emergencies involving transport of RN material

Example 3: Transport of a radioactive source

This type of emergency involves accidents with vessels transporting relatively small but significant quantities of radioactive material e.g. well-logging sources.

An offshore supply ship is en route to a drilling platform, with a crew that will conduct well-logging. The ship carries a neutron source (^{241}Am–Be) in a Type B shipping shield. The supply ship arrives at the site and transfers the crew and logging equipment.

While the engineer and operator retrieve the neutron source out of the shipping shield and start the installation, an explosion occurs in the drilling deck and a subsequent fire erupts and starts spreading. The platform transmits by radio that they have one casualty and another person being treated by the medic on site, and that the firefighting crew is already working to put out the fire. A trawler responds to the call and offers to come to the site to assist in evacuation if necessary.

The platform informs that fire is out of control and personal dosimeters of the firefighting crew show that the radiation doses have been surpassed. They assume that the shield of the neutron source is breached. The evacuation process has started, and they require immediate assistance.

Example 4: Transport of an excepted package

This type of emergency involves normal vessels e.g. offshore supply vessels. These shipments contain only minor amounts of radioactive material and there is no risk of any radiological consequences requiring special protective actions. The severity is consequently very low, and no threat category is considered for these transports.

Following a SAR operation, the personnel were made aware that the vessel contained an excepted package of RN cargo. RN severity is low but may be perceived much higher by the involved SRU.

5.2.3 **Choose exercise type**

There are different types of exercises which can be used for collaboration competence development. Table-top exercises are a well-used tool for enhancing understanding of collaboration. This form of exercise is extensively used by emergency preparedness organizations, SAR authorities, and industries, especially in maritime sector and oil industry (39).

Table 20: Examples of exercise types

Exercise type	Format	Examples of collaboration competence to achieve
Tabletop Exercise (TTX)	Tabletop is a discussion-based exercise type where all participants are gathered in one common room, and all communication takes place in this room. In digital formats it is possible to gather participants in one common meeting session and divide into smaller breakout rooms. The input is given orally or on paper/screen/ learning management system. No action should be taken physically, and no contact should be made outside the exercise room. The participants therefore do not play or simulate an action, like a meeting of a crisis management team, but discuss and reflect upon general and specific issues related scenario presented by a discussion leader. Table-top exercises are a well-used tool for enhancing understanding of collaboration. This form of exercise is extensively used by emergency preparedness organizations, SAR authorities, and industries, especially in maritime sector and oil industry (39).	- Plans, roles and responsibility, - Shared language and terminology, - Collaborative coordination, - Knowledge of past events and exercises, - Collaborative culture
Games and role-play exercises	A game or role-play can be illustrated as an exercise that consists of players and counterplayers. The participants will most often be in their usual function under their known premises and resources at their disposal. They simulate acting in their roles within a realistic operation. During counterplay the participants may be set in challenging circumstances through a number of injects planned in a scenario play book. An inject would be a message/contact from someone who is not a training audience.	- Decision-making, - Information sharing, - Collaborative communication, - Shared situational awareness, - Individual role improvisation - Shared knowledge of proper SRU's equipment for disposal in RNSAR
Functional Exercise	Functional exercise has a purpose to practice a function of the system or the use of actual procedures and facilities. Functional exercises can also be referred to as procedural exercises. Examples are alarming and communication exercises.	- SOPs, action cards, - Interoperability, - Collaborative communication
Simulator-based Exercise	By using simulator, we can simulate various activities that make the exercise credible and realistic. Simulator-based exercises provide experiential means by which to train people in an environment that is realistic as possible for a yet unknown crisis (40). Simulated crisis scenarios are in many ways effective tools for both organizational and individual learning. Advantages of simulation games lay in the provision of a safe training environment, where users are able to play and test without serious consequences.	- Team effectiveness training, - Shared situational awareness, - Decision-making, - Collaborative communication
Full-scale Exercise	A full-scale exercise involves a field response operation, an actual mobilization of personnel and organizational resources in real time. This form requires rigid timeframe, long planning, complex administration, and a large budget. Often full-scale exercises are performed at several locations and combined with other forms of competence development.	- Test of organizational capabilities, - Test of inter-organizational coordination, - Collective improvisation - Information sharing - Decision-making

The exercise can be seen as a part of competence development, a step in a learning staircase for individuals and organizations. The staircase goes from individual and collective learning from theory and background lectures, seminars and workshops aimed at competence development of relevant participants before starting the actual exercise (Figure 20).

The next step after TTX could be a simulator-based or full-scale exercise of SAR and RN authorities in collaboration where communication, decision making, and situational awareness are included in learning objectives. Finally, it can be an advantage to complete exercise series with an analyzing event to share the learning points.

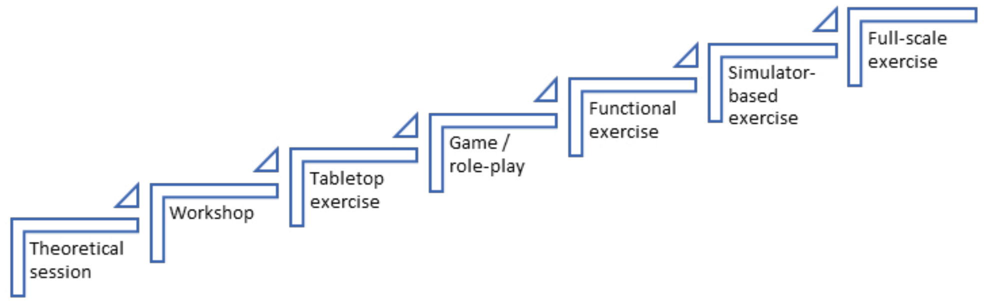


Figure 23: Learning staircase for collaboration exercises

5.2.4 **Identify training audience**

Exercise design may set up certain learning strategies for participants with various backgrounds, individual learning styles and professional roles. Each participant brings different competencies and skills (41). The existing knowledge of training audience, their positions in organizations and professional interests may lead to different interpretations of the situation and possible response action.

Looking at the examples in section 5.2.2, several organizations will be involved at the operational level. In addition, international conventions and bilateral agreements will connect authorities from the neighboring countries if international assistance request is exercised.

There will be at least two different organizations - organization of SAR and nuclear safety preparedness. The RCC will coordinate the SAR operations in close cooperation with the RAD authority counterparts who are involved immediately. There is a need to understand how organizations are involved at the operational level as well as the capabilities and limitations of support from the Coast Guard, the Navy, Air Traffic Service (ATS), Vessel Traffic Service (VTS) and civil defense among others (see Figure 21).

Since collaboration competences are needed to facilitate utilizing capacities of the involved organizations, an interaction of as many participants as possible is preferable. Working together during an exercise should bring common understanding.

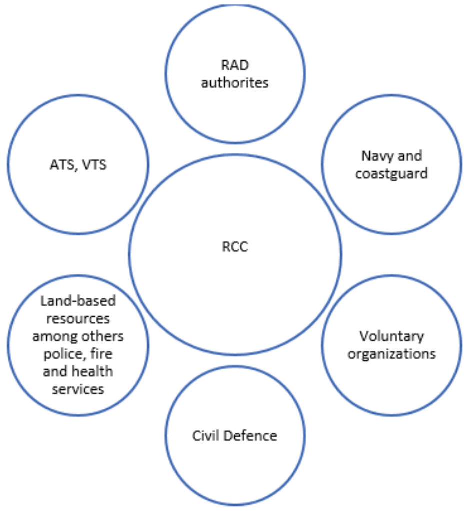


Figure 24: Organizations at the operational level

5.2.5 **Prepare background material**

Background materials for RNSAR exercises may include:

- Regulations
- Booklets published by Radiation and Nuclear Safety Authorities
- Prognosis maps
- Location and weather situation
- Bilateral and international cooperation agreements
- SOPs for SAR in an RN context
- Job descriptions and responsibilities

There is no fasit for possible content. The background material should comply with what the authorities use on the day to day basis. It is essential to prepare background material in advance to figure out the starting point for an exercise and align mutual expectations and learning prerequisites.

5.2.6 **Plan for exercise execution**

To design an RNSAR scenario together with several authorities working on a playbook is often useful. It will be a tool for an exercise facilitator to control the progress. The playbook ensures exercise dynamics through possible scenario injects, involving responders with their own responsibilities. Mentors from both SAR and RAD organizations can facilitate discussion on collaboration from both types of authorities. It is recommended to keep the timeline of the exercise, have enough time for discussion and never compromise with debrief, reflection and evaluation.

5.2.7 **Plan for debrief and reflection**

Debriefing is important for identifying learning episodes and turning such experiences into common knowledge. The design should plan for reflection from each participant and the group as a whole (40). Through debrief and reflection, exercises may uncover potential for improvement of RNSAR SOPs and develop responders' capacity to manage new situations. Mentors and facilitators are important to provide feedback and support the group learning processes.

For example, participants may start with reflecting whether the learning outcomes were achieved. Then, some interesting points uncovered in the exercise may be touched upon. Participants may elaborate on detected radiation source, for instance neutron radiation cannot be measured with standard equipment. This influences the risk perception among the participants and triggers appropriate response procedures. Other reflections may be connected to the organization of the management levels across two main preparedness sectors – SAR and nuclear safety, and how to collaborate with other organizations supporting this operation and their hierarchical levels.

Finally, written feedback from each participant with reflections on the learning points connected to their personal experiences can contribute to a deeper learning process and ultimately to improvement of collaboration. This is also a practical way for analysis and reporting which will support organizational learning.

When each participant connect own prior experiences to the exercise, individual cognitive processes lead to learning (37). Learning outcomes may be too abstract after the exercise and become meaningful only when they are understood in practice.

Experiences from learning increase the participants' curiosity and desire to learn more in the future, for instance through other exercises.

5.2.8 **Evaluation methodology**

The evaluation methodology should have a plan for accessing feedback from SAR and RAD mentors and participants. The key to good learning is continuous evaluation and follow-up, well established system for that and that the responsible leaders (senior management) are aware of their responsibilities. In general, we should find out what worked well and should be continued as it is (*confirmation*), and what should be changed or improved (*change and deeper understanding*) (43). Besides the improvements of the exercise itself, it is important to reflect on challenges and limitation in operational patterns that were discovered, and whether any improvements in procedures or plans are needed (*improvement points*).

Different methods are used to collect information during exercise. Often questions on what went well and what could go better are discussed during oral debrief and may be included in the written evaluation questionnaire. Observations from mentors and facilitators are useful for improving the exercise planning. It is important to make a plan for next exercises and how to follow up the feedback (table 20).

Table 21: Example of evaluation criteria. Based on (44)

The evaluation criteria may be as follows: ➢ whether the exercise has achieved its objectives; ➢ whether there is a need for any improvements in plans, procedures, or guidelines; ➢ whether there is a need for any improvements in functions and roles; ➢ whether there is a need for any professional behavioral change; ➢ equipment needs; ➢ need for further exercising in learning staircase (see 5.2.3).

Part 2
Standard Operational Procedures (SOPs) for RNSAR

The Standard Operational Procedures (SOP) are intended to act as supplements to existing SAR procedures, not intended to replace them. The target group for the SOPs are SAR personnel involved in a RN SAR mission, both as planners, executers and Search and Rescue Units (SRUs).

The SOPs represent the common ground on how an RN situation may affect a SAR incident, seen from the RCC's level. The procedures can assist the RCC planners in developing their plans and action cards. In addition, the SOPs can guide SRUs in harmonizing their own plans and action cards, ensuring that the plans and procedures developed are based on the same principles as the RCC's.

In an actual event, the SOPs do not have to be used chronologically, but can be used as required based on the situation.

Photo credit: Anders Martinsen, ARCSAR LIVEX22

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SOP 1: Assessment of the incident

SAR operation involving an RN risk might have a great impact on assessing the rescue plan possibilities. During the rescue planning phase, the nature of the RN material must be taken into account when analysing the incident and the area, assessing possible rescue procedures, resources, and rescue plan options.

1. The first two things to be established:
2. is there a risk for increased radiation. And,

is there a risk of release of radioactive material to air *i.e.* a possibility for contamination of people and equipment (see figure 5), as this is going to limit the resources that the RCC will be able to deploy.

1.1 Risk assessment

Information gathered from the distress vessel (DV) and from RAD experts concerning the incident and the RN situation involved, gives the RCC a possibility to do a risk assessment of the incident and plan the best available option for rescuing people on board / from the distress vessel.

- General information addressing:
  - Type of RN vessel
- NPV, FNPP, transport
  - Information on the RN material
  - Identification (UN number, package…)
  - State (contained, released, time of release…)
  - Reactor (stability, thermal power
- Spreading prognosis
  - DV crew
  - Training
  - Measurement capabilities
  - PPE
- Prognosis on integrity RN material and the incident
  - Situation
  - Incident (dynamic, static)
  - Weather (precipitations, waves, wind…)

NB! Deploying appropriate resources with measuring equipment early on-scene could provide valuable data for the risk assessment.

1.2 Resources

The situation on board might require assistance. One needs to define the applicable SRUs that have the capacity to perform and support rescue operations in RN environments. SAR plans and agreements should be timely identified and activated.

In a situation where national resources are not sufficient for rescue measures, international partners (RCCs, experts, liaison officers, etc.) should be informed and consulted in an early phase to identify available international resources.

To ensure and secure continuous and effective SAR operations, the supportive procedures such as replacement of personnel, materials, and equipment should be organized in the early planning phase. This will also include plans and procedures for decontaminating rescue personnel and rescue equipment (28).

1.3 Action options

Depending on the situation on board the DV, action options can be one or several of the following:

- No external assistance needed
- Consultation (Maritime Telemedical Assistance Service (TMAS), RN experts, etc.)
- External assistance needed outside the DV
- Ship abandonment, Mass Rescue Operation (MRO)
- Handling the RN source (shielding, removal…) (28)

Early ship abandonment should be considered if the situation on board the DV is predicted to worsen (e.g. uncontrollable RN release) or the SRU's arrival on-scene is expected to be delayed. Use of the Vessel Triage categorisation system could give an impression of the status of the situation and its development. The need for the Place of Refuge / Safe Haven for the DV should also be considered and a preparation procedure launched if deemed necessary (28).

SOP 2: Determination of the restriction area

2.1 First phase area isolation actions

The dangerous area must be isolated from maritime (and air) traffic. The restriction area should be established by the RCC in cooperation with the RN authorities. However, the RCC should have developed initial action plans/action cards for this (see chapter 4). In general, only SRUs with an adequate self-protection capability should be permitted to enter the restricted zone, and only with RCC approval (28).

2.2 Continuous risk assessment

Information to update a risk assessment and maintain the situational awareness is essential when defining any restrictions for responding to the actual RN hazards on-scene. The continuous process of updating the restriction and working areas should be based on the latest risk assessment, RN measurements, and weather conditions (28).

2.3 Assessment of the RN impact

The initial risk assessment process for the operation (including RN assessment when possible) starts by the RCC considering the information gathered as described in SOP 1. Thereafter, the assessment should be complemented with support from RAD experts.

This assessment should include:

- The risk on-scene (e.g. radiation dose for SRUs and crew of the DV)
- The risk off-scene (e.g. if high doses to people far from the scene can be expected)
- The development of the situation both on- and off scene (probable development and worst-case development, timelines)

The RCC will include the assessment from the RAD experts to update the initial assessment and should continuously update the situational awareness picture. The risk for SRUs should be weighed against the need for immediate action to save lives.

2.4 Defining the restriction area

Restriction areas for maritime and air traffic should be determined based on either pre-planned procedures or latest measured information regarding the calculated or measured RN risk.

If there is no risk of release of RN material to air, the determination is done by formulating a circular (or hemisphere if there is a NO-FLY zone) area around the distress vessel. The radius of the immediate restriction area should initially be at least 0.1NM (Nautical Miles).

In the cases of risk of release to air, the restriction areas should be expanded considerably taking the meteorological conditions into account (see figure 18 as an example).

The initial established area restrictions from the RCC should be updated to increase or reduce radius and shape of the restricted area by consulting RAD experts. Consulting other experts might be relevant as well e.g. for the drift estimations and calculations (28).

Note: Formally, a restriction area can be set within the territorial sea, 12NM, however if there is a need to limit traffic from a dangerous area outside the territorial sea, this area can be referred to as temporary precaution area for vessels and temporary danger area for aircraft.

2.5 Information

Maritime traffic should be regularly informed considering the restriction area with Global Maritime Distress and Safety System (GMDSS) PAN-PAN or MAYDAY RELAY messages. Contact VTS and ATS concerning the restriction of the areas. Relevant authorities should be contacted to inform of warnings and access restrictions area (28). If media is to be contacted, the RCC will inform about the SAR operation and the relevant RN authorities will inform about the RN situation at hand.

The restriction area should be under the surveillance and maritime traffic approaching the area should be informed and rerouted if necessary (28).

2.6 Determining the areas for SAR operations.

The three-level working zone system of area designation:

Table 22: Hot, warm, and cold zone thresholds (dose rate values)

Cold zone	Warm zone	Hot zone
0,2 – 0,8 µSv/h	0,8 – 100 µSv/h	100 µSv/h
(7) NB! These values are the official values in Norway and are used to show a reference point in this handbook. Recommended values in other countries might vary.		

Depending on the RN situation, it might be essential to monitor the radiation levels before launching rescue operations. In these cases, the RCC can plan and coordinate the task for the detection and monitoring patrols, in cooperation with the RN authorities.

The purpose of these measurements is to define the outer limits of the dangerous area to determine the area restrictions.

Based on a RCC and RN authority decision, the following information should be distributed prior to executing the task:

- Measuring plan (i.e. starting point, route, safe direction, and distance to approach)
- Use of appropriate detection and measurement equipment
- Use of applicable rescue craft or tender and equipment
- First team to enter dangerous area in situation where the RN situation is not yet identified, should be equipped with the highest possible PPE level.

For information: NATO has developed a set of guidelines for managing CBRNE events, Publication ATP-45, Edition F, Version 2 “WARNING AND REPORTING AND HAZARD PREDICTION OF CHEMICAL, BIOLOGICAL, RADIOLOGICAL AND NUCLEAR INCIDENTS (OPERATORS MANUAL)”.

In these guidelines, they define 3 different hazard areas, namely Long-term Hazard Area (R1), Acute Hazard Area (R2), and Severe Hazard Area (R3). These are not to be confused with, nor are they equivalent to, the terminology Cold-, Warm- and Hot-zones used to define safety areas in this handbook.

Different RN scenarios have different definitions of R1/R2/R3 in the NATO guidelines, and the scenarios relevant for the RNSARBOOK are release type F, case 3 “Exposed/unshielded source”, and release type H case 3 “Minor release from Nuclear power plant or any release from other nuclear facility”, found in table 5-2 of the NATO document. We mention these NATO guidelines as an SMC may encounter the terminology when interacting with a NATO-assets during an emergency.

The Long-term Hazard Area for incidents involving release from a nuclear propelled vessel (release type H, case 3), referred to in the NATO guidelines, is in line with the recommended Urgent protective action planning zone (UPZ) radius suggested by IAEA, referred to in table 16 of the RNSARBOOK (reactor with thermal power 100-1000 MW).

2.7 Entry and exit points

Entry and exit points in SAR operations ensure that operations security is in place, deconflicting movements based on procedures. When in a contaminated area, entry- and exit points should also consider the RN threat. Entering and exiting the zones should be only for vessels with the capacity to perform rescue operations in the restricted area. The current and predicted weather should be considered when establishing the entry and exit points of the restricted area, to ensure that the SAR assets are kept on the safe side as far as possible.

General procedures for coordination are found in the IAMSAR-manual.

SOP 3: Arrival to the scene of incident

The RCC should consider the arrival of SAR assets at the scene of an incident. The assets should be capable of RN self-monitoring and possess basic RN knowledge.

3.1 Resources

To ensure correct tasks assignments, previously registered information regarding the capabilities of the SRUs should be analysed. Information on the following facts will assist the decision-making process when planning:

- Designated vessels (air and maritime) that are equipped and trained for RN measuring operations.
- Rescue vessels capable of entering and working in the hazardous atmosphere (hot and warm zones – rescue operations)
- Rescue vessels with none or limited capability of entering hazardous atmosphere (cold zone – isolation and support)
- Rescue craft on board rescue vessels that can be used for transport, boarding and evacuation (hot and warm zones)
- Vessels of Opportunity in the area (cold zone or outside the restriction area – support and transport)
- Available aircraft for transport/ reconnaissance
- Available special groups (e.g. Maritime Incident Response Group (MIRG)) (28)

SRU-specific capabilities:
Capacity for RN detection and monitoring
Capacity for decontamination and first aid / emergency medical care
Capacity of the available personnel
Ability to monitor and maintain own safety is a crucial point
Available Personal Protective Equipment (PPE)
Response equipment (28)

3.2 RN risk assessment

RN risk information should be requested from RN experts. This, in order to evaluate and define risks on-scene, information on the suggested area restrictions, safe direction to approach the dangerous area, suggested working zone definitions, possible dangers, and drifting/spreading calculations.

3.3 Communication

The Rescue Coordination Centre (RCC) will coordinate the distress communication in the area and will determine the channels and frequencies that will be used in different phases of the rescue operation (28).

3.4 Rescue operation

In the rescue plan, all the following procedures should be planned and performed:

- Protection procedures (both vessel and personnel)
- Reception plan for receiving contaminated persons on board the SAR unit
- Supportive procedures (transport, safe environment, first aid, equipment and material)
- Supportive procedures to replace personnel (28)

3.5 Executing the plan

Once planning is completed and the action plan established, the SMC will consult with the master of the DV and inform all SRUs on-scene. This information should include the following:

- RN risk information (radiation levels, exposure range, exposure time, downfall etc.),
- Current status of the DV,
- Area restrictions,
- Approach direction,
- Exit point,
- Withdrawal plan, and
- Estimations / drifting calculations (28).

3.6 Safety measures

Before entering the incident area, the SRUs should prepare and test the vessel-specific protection systems and safety procedures (28):

- Pressurization of the vessel if there is radiation contamination
- Radiation detection, monitoring and analysing systems
- Water curtain or water spray system
- Emergency evacuation and rescue plan (28).

3.7 Detection and measurement

Crew monitoring should be continuous, and the results of crew measurements should be reported to the Rescue Coordination Centre (RCC).

Fixed or portable sensors should be used for detection and measurements of radiation intensity when the SRU intends to enter the dangerous area on a mission (28).

Portable devices such as dosimeters are compulsory for the teams for monitoring radiation in the area.

3.8 Situation report (SITREP)

The RCC should be informed by the SRUs at regular intervals, radiation measurements are of special importance. Updates on drifting/spreading estimation and weather forecast should also be collected (28).

SOP 4: Boarding

4.1 Risk assessment and occupational safety

Safe procedures to evacuate rescue teams boarding the DV should be confirmed in case of an unexpected emergency situation. Consultation with the master of the DV should be performed concerning possible escape ways and safe locations. The distress vessel`s safety plan, if available, should be used. Standby boats should be arranged as ‘ready to launch’ for the evacuation of the rescue teams, DV’s crew in case of an emergency evacuation (28).

The SMC and/or OSC should consult with RAD experts to determine the needed RN protection procedures. At minimum, the rescue teams need to have clear information about:

- PPE,
- detection and measurement equipment,
- exposure times and -doses, and
- decontamination procedures (28).

Prior to boarding the DV, the participating units/teams should be informed about:

- the action plan,
- their task,
- situation on board the distress vessel,
- risk assessment,
- communication channel, and
- the situation on-site (28).

Basic procedure to approach the DV for boarding in the RN environment should contain at least:

- the safest direction to approach when relevant,
- the use of detection and measurement devices, and
- the appropriate PPE level and safety equipment (28)

After the briefing and before the practical execution, it is recommendable to register all rescue personnel. Recording the entry and exit time is crucial.

4.2 Limitations

When assessing different possibilities, the following factors might influence the decision or can be exclusionary:

- The result of the RN risk assessment,
- Limitations on the use of the helicopter (distance to reach the DV, and/or using a helicopter is too dangerous or impossible due to the RN hazard close to the DV),
- Weather may impact landing, winching and boarding,
- Capabilities of the SRUs in the area
- The DV’s manoeuvre capability and possibility to anchor (28)

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4.3 Pre-boarding measures

Measures to facilitate safe boarding the DV should be considered and executed. The SMC should consult the master of the DV and the RN experts if the DV crew are able to do actions that may help the RN situation to not escalate, if the risk assessment allows for it. Before approaching the distress vessel, spraying the vessel with water cannons should be considered to reduce the RN outfall impact (28).

This action can be taken by the DV’s crew and SRUs after consultation with the RCC. The decision on boarding the DV should be done after discussions with the master of the DV (28). The following preparation operations on board the distress vessel should be confirmed:

- Landing or winching procedures for the helicopter
- Boarding procedures for the rescue craft or tender
- Reception and guidance of the rescue personnel boarding the DV
- Assistance of the rescue personnel to establish an emergency decontamination station and first aid facilities on board, if possible, and
- Provision of supplementary Self-contained Breathing Apparatus (SCBA), Emergency Escape Breathing Devices (EEBDs) or the equivalent for evacuating the casualties when relevant (28).

SOP 5: Rescue Operation on board the distress vessel

5.1 Risk assessment

The situation must be assessed continuously.

The rescue action plan should be continuously updated. SRUs should be informed about the changes. The common situation awareness between participating units should be confirmed, by the SMC (28).

5.2 Rescue procedures

5.2.1 Preparation

The commander of the SRU should decide on the initial entry preparations of his/her unit. The following procedures should be completed before launching the operation:

- Decontamination station must be set up, tested and operational
- First aid/Emergency medical care facilities must be ready
- All the units involved must have the knowledge, understanding about their role(s) and planned activities,
- Communication channels and outside supervision of the teams has to be organised., and
- Sufficient and suitable PPE should be available (28).

5.2.2 Entry procedure

Before entering the hot zone, confirm procedures that rescue teams (entry and backup teams) are at the entry point prior to authorizing the entry (28). Based on the situation, this will be regulated by the OSC or in some cases, the RCC.

5.2.3 Rescue activities on board

Rescue activities are based on the rescue plan and the tasks given to the boarding rescue teams by the RCC. The first rescue teams boarding the distress vessel will provide information that will facilitate updating the risk assessment and the rescue plan (28).

Possible tasks for the rescue teams on board can be for example:

- facilitating communication between DV and RCC
- Risk assessment on board, supporting the master of the vessel for decision-making
- Minimising radiation exposure
- MEDEVAC (medical evacuation)
- Emergency decontamination procedures
- Preparations of MRO (28)

5.2.4 Disembarking

Safe disembarking procedures for the rescue teams and evacuees should be ensured. First stage decontamination (or emergency decontamination) should be done on board the distress vessel if possible. Rescue teams and specialists that operated in the hot zone should be decontaminated (28).

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SOP 6: Evacuation and emergency towing

6.1 PAX tracking

The number evacuees and the number of injured and affected people should be clarified with the master of the DV. It is also important to clarify the situation on board and the location of people in danger to plan the evacuation in an effective manner (28).

6.2 Resources

The SMC should define the capabilities and capacities of the DV's crew as well as of the SRUs in the area with the Master of the DV and the OSC in order to evacuate the distress vessel.

This will help in determining if additional assistance is required (28).

6.3 Risk assessment

Safe measures to evacuate the DV, should be ensured. The situation in the area, results from the measurements, and the RN impact on rescue personnel and evacuees must be considered while finding measures of evacuating persons from the DV. In some situations, abandoning the distress vessel might not be the safest solution (28).

6.4 Action plan

When preparing the action plan for evacuation, the possibility of a partial evacuation can be considered (28).

Some points to consider, might be:

- What protective equipment is needed for evacuees,
- What is the need/possibility for using the boarding team or rescue personnel on board the DV to assist in the evacuation (compared to the DV crew capabilities),
- What are the transport possibilities from the DV to the SRU, and
- How to transport evacuees to the evacuation centre or further medical care (28).

The Master of the DV must accept the proposed measures.

The possibility of life rafts launched from the DV drifting to an RN contaminated area should be considered and if possible, prevented. Use the national and/or organisational Mass Rescue Operation (MRO) plans and procedures if applicable.

6.5 Measures

The possibility to evacuate people from the DV should be considered either by using rescue crafts or tenders or with a SRU vessel with the RN protection capacity to enter the hazardous area alongside the DV to evacuate many people disembarking from the vessel. The use of helicopters might be reduced due to the spread of contaminated particles (28).

6.6 Operation

When evacuating persons in the RN affected area, several actions should be organized:

- Arrange provision of the protective breathing devices for evacuees, e.g. filtration masks, Emergency Escape Breathing Devices (EEBD) (or similar easy-to-use breathing devices) or Self-Contained Breathing Apparatuses (SCBA).
- Define the need for extra protective clothing or equipment when evacuating persons.
- Stabilize the condition of the casualties, if possible, and arrange for emergency decontamination procedures and establish decontamination lines for mass decontamination when necessary.
- Define and plan for RN-specific procedures for first aid when arranging emergency medical care facilities.
- Persons confirmed as deceased should be left in the hot zone or on board the DV until all other persons have been evacuated (28).

6.7 Documentation

All evacuates must be registered to ensure later control and further medical treatment if deemed necessary. A casualty tracking system should be established. This might include:

- Identification and personal information
- Possible contamination
- Possible received medical treatment (28)

6.8 Emergency towing

The situation might call for a safe haven or a place of refuge or anchorage in situations where the DV has to be towed to a harbour and the DV or parts of it are contaminated (28). The RN impact on the surroundings must be discussed with the RN authorities and the Coastal Administration, and also local authorities on shore, *i.e.* the municipality.

In cases where there is radioactive contamination, the SRU-specific pressurization and warning systems should be activated. While emergency towing procedures are being prepared SRUs should be equipped with the appropriate PPE (28).

SOP 7: Decontamination

7.1 Preparation

Basic requirements for the decontamination station should be ensured. The decontamination station should be located upwind from the actual incident and have the means for effective operation (e.g. access to the hot zone, a usable water supply, the possibility to collect contaminated liquids and waste) and access to first aid facilities to ensure the prompt commencement or continuance of emergency medical care (28).

The specifics of the RN incident are essential to ensure an effective and sufficient decontamination process. The number of contaminated persons, the type of contamination and the number of casualties on board the distress vessel (DV) should be clarified to have resources for carrying out planned tasks.

7.2 Establishing phase

When establishing the decontamination station, a designated number of assisting personnel with the required level of personal protective equipment (PPE) should be made available. All areas where the decontamination process takes place should be clearly marked. Access to the cold zone from the decontamination station should be organised to ensure a reliable decontamination process and prevent secondary contamination (28).

Establishing a full-scale decontamination while at sea might be a task that cannot be fully completed due to external factors such as SRU capacities, weather, and sea state. Hence, a plan for emergency decontamination needs to be developed based on the resources on board SRUs beforehand.

7.3 Decontamination process

7.3.1 Emergency decontamination

Emergency decontamination is defined as the process where one must decontaminate the evacuees as quickly as possible even though one does not have a fully established site for decontamination. Emergency decontamination should be carried out as soon as possible to minimize the effects of radiation by removing contaminated particles. Emergency decontamination should be conducted at the decontamination point. Lifesaving medical measures have priority over (coarse) decontamination. Self-protection of the assisting and medical personnel must be assured (28).

There might occur situations where the medical condition of the patient goes first, and decontamination will have to be executed later. In such situations, the SAR personnel should ensure that the contamination on the injured person(s) is isolated as much as possible to avoid further contamination of the SRU e.g. by blankets.

Confirm that receiving hospitals are informed and have the capacity to respond to the situation.

7.3.2 Search and Rescue unit (SRU), crew and equipment decontamination

When assessing the possibilities to arrange decontamination for the SRUs, it is important to consult RN authorities and relevant experts to find out the process needed for the decontamination. In some situations, decontamination of vehicles or equipment can be very complicated and pose problems for the emergency management system as a whole (28). The SRUs, including crew, vehicles and equipment, must be decontaminated as quickly as possible and should be taken to a decontamination station.

Some categories of SRUs (e.g. Coast Guard, other specialized vessels) might have competence, equipment and internal procedures for self-decontamination. They might also contribute to the decontamination of other SRUs that lack this capacity.

7.3.2 Decontaminated waste

Facilities to handle contaminated waste should be arranged offshore and onshore before SRUs arriving to land (28).

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Nordic Handbook for Search and Rescue in a Maritime Radiological / Nuclear Emergency (RNSARBOOK)

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Abstract max. 2000 characters	Maritime operations in waters surrounding the Nordic countries include traffic of nuclear propelled vessels and vessels transporting radioactive materials. These operations present a risk of encountering emergency situations at sea where radiological or nuclear (RN) concerns will be an inherent part of conducting successful Search and Rescue (SAR) operations in order to save lives and provide assistance to persons in distress. The aim of the Nordic handbook for search and rescue in a maritime radiological/nuclear emergency (RNSARBOOK) is to provide harmonized guidelines and recommendations for the handling of maritime SAR operations involving radiological/nuclear material by Nordic SAR and RN authorities. The handbook is not intended to be used during an ongoing SAR-operation when situational stress is high, but rather to be used for harmonized contingency planning and educational purposes by both SAR and RN organizations. The primary target audiences are SAR and RN authorities and planners at the operational level. The handbook will provide guidance to SAR authorities with a responsibility to coordinate maritime SAR, and RN authorities that have a mandate in providing liaison and expert advice to the SAR authorities, as well as the possible involvement of specialized radiation measurement teams. The guidelines and procedures explain RN emergencies and safety issues in general and clarifies roles, responsibilities, chain of command and coordination, so both RN and SAR authorities can work efficiently and have an understanding of how the operations are conducted and what is needed in order to respond to these kinds of incidents.
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