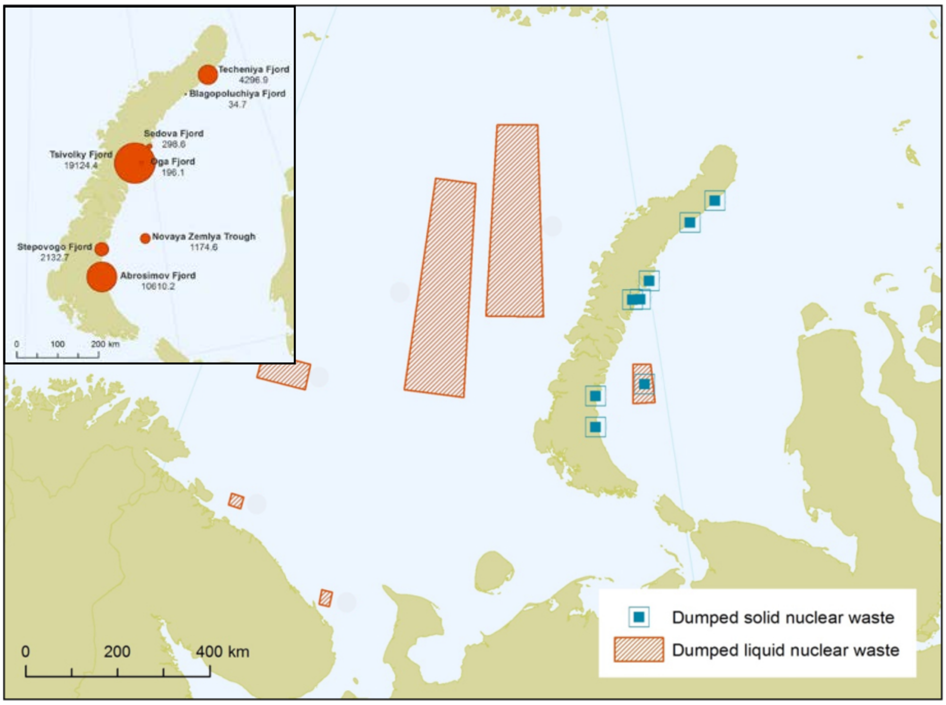
The dumped Russian nuclear submarine K-27

Marine dumping of liquid and solid radioactive waste in the Arctic was practiced by the former USSR and later by Russia from the early 1960s until the early 1990s. Reactors and reactor compartments with a total activity of about 36.6 PBq were dumped in the Kara Sea; 21.8 PBq of this amount being due to spent nuclear fuel (SNF).



Main dumping areas in the Barents and Kara Seas as reported in the White Book 2000. The insert shows revised estimates of the maximum total activity (TBq) of the dumped solid waste at the time of dumping as reported in the White Book 2000. Adapted from JNREG, 2014: http://www.nrpa.no/dav/063b47fa42.pdf.

Of all the radioactive waste dumped in the Arctic Seas, objects containing SNF constitute the greatest potential radioecological hazard. The reactors of the submarine K-27, dumped in Stepovogo Fjord on Novaya Zemlya, had an associated activity, at the time of dumping in 1981, slightly in excess of 2 PBq.

In recent years, concerns have been expressed by various parties regarding the radiological consequences of potential releases of radionuclides from dumped nuclear wastes in the Barents and Kara Seas. In 2011, the Norwegian Radiation Protection Authority (NRPA) and the IAEA Contact Expert Group (CEG) organised a workshop to specifically address the issue of dumped objects containing spent nuclear fuel in the Arctic Seas. The workshop paid particular attention to challenges related to the salvaging of the submarine K-27. The potential recovery of K-27 has received growing attention both from the Russian side and from the international community.

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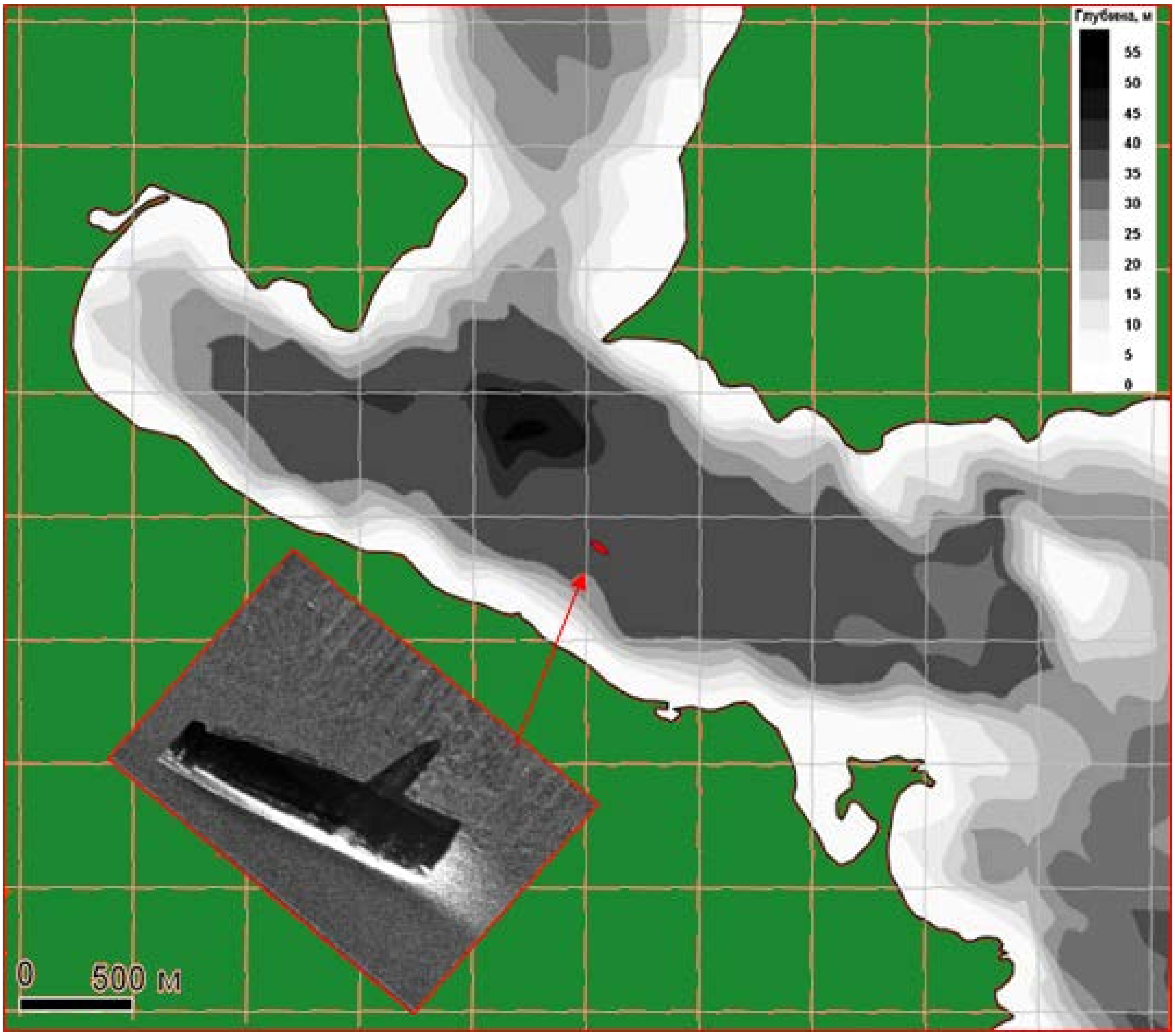


Bathymetry of Stepovogo Fjord and the location of the K-27 submarine. Taken from Kiknadze O.E. (2013): General information regarding objects with SNF dumped in the Arctic. Presented at the Russian Research Center "Kurchatov Institute", Moscow.

As a response to increased concerns regarding environmental safety, the issue of the recovery of the K-27 submarine has become a frequent discussion point in many fora debating the theme of dumped nuclear waste in the Arctic. In this context, the NRPA initiated a study with the objective of providing a new and updated human health and environmental impact assessment for the submarine.

The study is based on the elaboration of different hypothetical accident scenarios and evaluation of possible radiological impacts of potential releases with particular focus on possible salvage operations. Focus has been placed on the assessment of near field (local) impacts and intermediate field (regional) impacts over various time-scales. The results of this study will be presented in 2 reports. The first report's main focus is to provide an overview of the extant and available facts and information regarding the submarine, characterising the source term and considering the various conditions under which a spontaneous chain reaction might occur.

Two major steps in the process of acquisition of data for conducting environmental and health impact assessments are the estimation of inventory of the submarine and the characterization of the concomitant source term. While the former aims at making an evaluation of the present activity in the K-27 reactors, the latter characterises the quantity and types of potential for release of radionuclides (and also their physical and chemical properties) and associated release patterns.

A summary of the most up-to-date assessment of the inventories of the submarine's reactors is presented in Table 1. The results indicate that the total inventory of the submarine is of the order of 3.70E+14 Bq (as of 2015), of which about 82% is fission products. The report also discusses various release scenarios based on consideration of different hypothetical accidents including those involving a criticality.

Regarding criticality, the reactor protection barriers of K-27 might be breached suddenly due to natural disasters (e.g., earthquakes), malicious or terrorist acts, through natural degradation or under raising operations. In a case involving the destruction of the protection barrier, water, which acts as a neutron moderator, could penetrate into the reactor core and increase the reactivity of the reactor. The starboard and the portside reactors would attain critical states when the amount of water that has penetrated reaches 5 6 and 18 20 l, respectively.

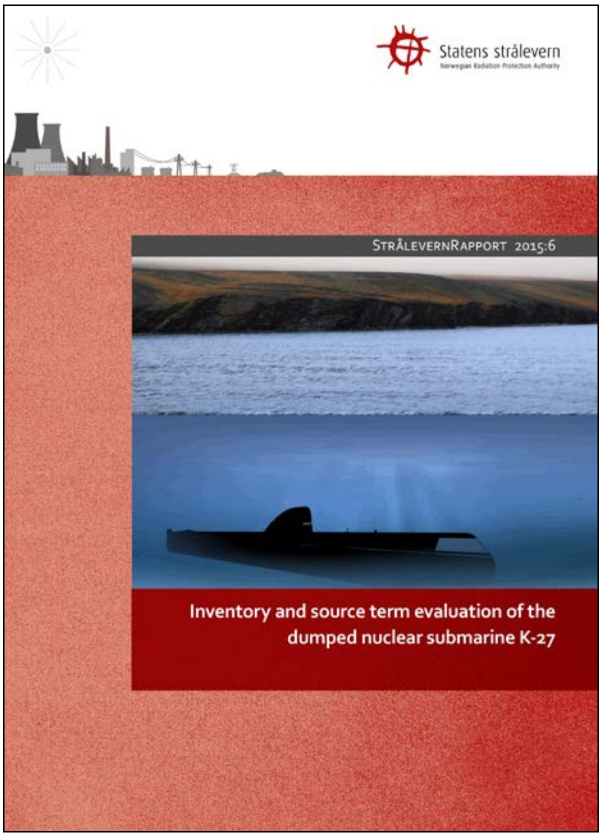
Depending on the scenario considered, analyses indicate that a total amount of up to 4.83E+14 Bq of short-lived fission products could be released to surrounding water and of this 2.51E+14 Bq might end up in to the atmosphere. For longer lived radionuclides, the amounts that could be released to atmosphere and water are 9.2E+11 Bq and 5.76E+12 Bq respectively. Full elaborations as to potential releases may be found in the report.

The report is the product of a collaborative effort between the Norwegian Radiation Protection Authority, the Nuclear Safety Institute (IBRAE) and the Russian Research Centre, Kurchatov Institute. Essential inputs for the second part of the study are provided in the first report where the focus will be on the modelling of radionuclide advection and dispersion in the environment and subsequent assessment of doses and associated consequences. The outcomes of the second part of the work will be presented in a follow-up report.

The Joint Norwegian Russian Expert Group (JNREG) has conducted several expeditions to dumping sites off the coast of Novaya Zemlya and the latest expedition to Stepovogo Fjord took place in August 2012. One of the observations from this expedition was: "Activity concentrations in seawater and sediment in the outer part of Stepovogo Fjord do not indicate that any leakage has occurred from the reactor units of K-27 since it was sunk in 1981." However, even though such observations indicated that the dumped objects containing SNF do not present an immediate radiological hazard, these objects rank as potentially hazardous objects in the Arctic which could pose a risk to the marine environment and human population in the future.

Summary of various potential activities present at both reactors of the nuclear submarine K-27 (Bq).

	Portside reactor		Starboard reactor	
	2015	2020	2015	2020
Fission products	1.49E+14	1.38E+14	1.59E+14	1.48E+14
Actinides	1.54E+12	1.40E+12	1.65E+12	1.50E+12
Tritium	3.96E+12	3.00E+12	4.26E+12	3.22E+12
Activation products	1.34E+13	1.25E+13	1.38E+13	1.31E+13
Europium in CPS rods	1.32E+13	1.01E+13	1.41E+13	1.07E+13
SUM	1.81E+14	1.65E+14	1.93E+14	1.76E+14



The front cover of the first report, available at *www.nrpa.no/en/publications*

Activity is defined as the rate at which a radioactive material disintegrates or decays per unit time. Becquerel (Bq) is the unit used for measuring *activity*.

1 Bq = 1disintegration/ second

1 TBq (terabecquerel) = 1 000 000 000 000 Bq = 10^{12} Bq

1 PBq (petabecquerel) = 1 000 000 000 000 000 Bq = 10^{15} Bq