RADIOACTIVE WASTE DUMPING IN THE KARA SEA:
A CRITIQUE OF THE JOINT RUSSIAN/NORWEGIAN SURVEY PROGRAMME

Paul Johnston, Ruth Stringer,
Greenpeace Exeter Laboratory,
Earth Resources Centre,
University of Exeter,
Exeter,
EX4 4QE

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Introduction

Russian sources have recently stated that large quantities of radioactive wastes have been dumped in the Kara Sea. This confirms a considerable body of anecdotal evidence which has accumulated, concerning the activities of the former Soviet Navy. This prompted a Greenpeace submission to the London Dumping Convention in 1991. The known dump sites, together with the wastes presently known to have been dumped at each site are shown in Figure 1 and described in the accompanying footnotes. The dumped material is thought to consist of both drummed wastes and complete reactors. Some of the reactors have been dumped as part of entire submarines and, of these, some still contain part or whole of the fuel inventory. Dumping operations are known to have taken place between 1968 and 1982, but dumping may have taken place until at least 1986. Russian authorities have, to date, confirmed that thirteen part or complete reactors have been dumped in the waters of the Kara Sea, close to the shores of Novaya Zemlya. This is cause for considerable concern given the potential for the escape of radionuclides in large quantities from the dumped material.

The Kara Sea is linked to the Barents Sea. The Barents Sea supports a highly important international commercial fishery, which is at risk from any leakage of radioactive material. The Kara Sea itself has lesser importance as a fishery, but nonetheless some fish species are routinely landed from its waters. In addition, the populations of the cities of Archangelsk and Murmansk may be at risk from any radioactive contamination. No data have been published of levels of radioactivity in the area. The risk to commercial fishing grounds, in particular those fished by the Norwegian fleet, has led to a survey programme being designed and initiated jointly between the Norwegian and Russian authorities.

The survey was conducted between August 14 and September 10 1992 as a joint programme between Russian and Norwegian scientists. It was designed to detect leakage of the dumped radioactive material. The full remit is given in the cruise report signed by Lars Foyn of the Marine Research Institute, Bergen and Anatoly Semenov of the Murmansk Area Department for Hydrometeorological and Environment Monitoring. This was as follows:

"To investigate alleged dumping of radioactive wastes in the Kara Sea and provide a general assessment of potential radioactive contamination in water, sediment and biota of the area"

The survey was an agreed and formally arranged programme between the Norwegian and Russian Governments involving the Environment and Foreign Ministry in Russia and the Foreign Ministry of Norway. Reuters, on Sept 10, 1992 reported on a radio interview given by a scientist returning from the survey which was broadcast on Norwegian national radio. This was followed up by a press release on Sept 16 1992 by the Norwegian Marine Research Institute. This confirmed the broad details of the interview. Significantly, the press release revealed that the joint survey team had been unable to sample within twelve miles of the coast of Novaya Zemlya. Sampling was prohibited on the grounds that the area is designated as a restricted area. This prohibition was made by the Russian Military Authorities after the survey team left to carry out the work.

According to the press release form the Marine Research Institute, initial results, have shown levels of the gamma emitter caesium-137 to be comparable with those found in the Barents Sea. This radio-isotope is a ubiquitous product of uranium fission which has been widely distributed in the environment as a result of nuclear reprocessing, nuclear accidents and the testing of nuclear weapons. The cruise report further states:

"We have further compared our preliminary results with the reported values from 1982 (12 cruise of research ice-breaker 'Otto Schmidt')......As can be seen from the various profiles, there is a defined decrease in the cesium-137 values on most stations. As a general and preliminary conclusion, there appears to have been a significant decrease in the cesium-137 content in water masses of the Kara Sea in the course of the last ten years."

The degree to which the 1982 results are comparable with those obtained in the 1992 survey is unknown. Nonetheless, the findings have been interpreted by the participating scientists as evidence that leakage of radioactive material has not occurred. The return of these negative results, however, cannot be regarded as definitive evidence that there has been no leakage. The sampling programme must be regarded as limited in power, particularly with respect to the number of samples taken. The certainty with which analytical results from these sites can be used to indicate local mobilisation or otherwise of radionuclides into the environment is extremely low.

The Norwegian/Russian survey originally comprised eleven designated sites arranged in a grid pattern across the Kara Sea, with three outlying sites designated in the Barents Sea on the approach to the Kara Strait. The position of the Kara Sea sites is shown in Figure 1. The protocol as originally published, called for analysis of water, sediments, and biological samples. This included samples taken in the near vicinity of the dumpsites. The analytical protocol called for the determination of a variety of nuclides, and according to the most recent information, the full suite of analytical results will be published in September 1993. Analyses will be conducted by a variety of research institutions including the IAEA. On the basis of Figure 1 of the Cruise report it seems that the Kara Sea sites were sampled as planned, but the Barents Sea sites were reduced to two: one at the mouth of the Kara Strait and another just offshore of Kirkenes. These were sampled on the return voyage.

Area Description

The Kara Sea is bounded by the Yamal Peninsula to the East and by Novaya Zemlya to the West. There is a restricted passage to the Barents Sea via the Kara Strait. To the North, the Kara Sea opens to the North Eastern Barents Sea. According to chart data the Kara Sea has a depth of between approximately 40-160 metres over much of the central area, falling rapidly from the coast. Deep water is present along the coast bounded by Novaya Zemlya, reaching almost 400 metres in the Novaya Zemlya Trench. The dominant circulation pattern is anticlockwise. The Novaya Zemlya current moves broadly from North to South, whilst the Yamal Current moves from South to North. The West setting Litke current exits the Kara Sea via the Kara Strait. Influent currents appear to enter the Kara and Yugorsky Straits, and join the predominantly North setting Yamal Current. The Barents Sea and Kara Sea connect in the North over the shoals between Frantsa Iosifa Zemlya and the North West of Novaya Zemlya. There is ice cover for much of the year, which is at a minimum from August through October and water temperatures range between -2 and +6 degrees C.

According to the Arctic Pilot, the tidal streams have not been extensively studied, but the currents are known to be highly complex due to mixing of warm Atlantic water with the colder water moving from the central Arctic basin. Predominantly counterclockwise eddies are set up which have marked local effects around the 200m contour. Marked discontinuities are set up in temperature and salinity profiles, but there is some vertical mixing. River outflow is also influential and may modify the broad circulation pattern, particularly in the North Eastern Kara Sea. The currents are therefore variable and highly influenced by external factors and the degree of severity of the seasons. The major current and circulation patterns, based on information from the Arctic Pilot are shown in Figure 1.

Limitations of the Joint Russian/Norwegian Protocol

a) Restricted Sample Numbers

As such, the sites designated in the published sampling protocol appear to have been selected on a judgmental basis with respect to the Barents Sea samples. A more formal systematic approach has been adopted in the Kara Sea itself where a grid pattern has been prescribed. A mixed sampling approach of this kind is common in environmental studies where a balance is perceived to be necessary between sampling effort and costs. Against this, however, must be weighed the likelihood of failing to gather important information. In this regard, the published sampling design typifies a programme designed to detect long term trends over a wide area. It is not suitable for the evaluation of a latent problem or a pervasive local problem with a potential to extend over the wider survey area.

The systematic approach enshrined in the protocol calls for the sampling of seawater at three depths, with recording of salinity and temperature, together with benthic sampling, repeated in triplicate at each site. The rationale is thus to reduce the effects of heterogeneity in the sample matrices at each site. This strategy ostensibly attempts to strike a compromise between the number of samples needed and the bias/error acceptable in the results. In general, random and systematic sampling programmes require large sample numbers to ensure statistical integrity. A key factor in the statistical reliability of these approaches is the selection of a number of sites appropriate to the size of the area. The Norwegian/Russian joint survey has been primarily designed around the far field detection of leakage of radionuclides from the dumped material. Nonetheless the intense replication of samples at relatively few sites is extraordinarily misguided. The exercise would have been more likely to achieve its stated aims by directing less effort at a much greater number of sites, located closer to the known potential sources of leakage.

Under the circumstances a more judgmental approach would have been far more appropriate to the task of determining whether leakage of dumped material is occurring. This would have entailed focussing the sampling effort more directly upon the known dumping areas. Ideally, relatively few samples taken in the wider field would supplement high sample density closer to the putative point sources. While such a survey would eventually need to be backed up by a more wide ranging effort, it would at the same time be more likely to detect any leakage of radioactive materials. Even given the restrictions on entering the twelve mile limit, greater sampling intensity closer to known point sources would have optimised the possibility of detecting local anomalies.

While the protocol, therefore, appears to be technically robust as regards securing and analysing the samples, this does not extend to the quality of the information likely to be provided by the sampling grid, which will inevitably be extremely poor. The number of sampling sites, given the area under consideration, is extremely limited. Sample sites are up to 300 km apart and this is insufficient to adequately resolve the levels of radioactivity present in relation to the to the known potential point sources. The unknown sediment types and the complex circulation patterns in the Kara Sea are further confounding factors. The relatively few sample sites together with their wide geographical spacing, must be regarded as a substantial limitation on the scientific integrity of the programme as a whole.

b) Circulation in the Kara Sea

A more highly focussed sampling programme is not only desirable on simple statistical grounds. Given the remit of the survey team to investigate leakage from the dumpsites, a consideration of the known prevailing currents also leads to the same conclusion. The area is oceanographical complex, with variable currents. The extensive temperature and salinity discontinuities observed in the area would also act to complicate the distribution of released radionuclides in a non-predictable manner. The outflow of freshwaters from rivers in the area will influence the behaviour of released isotopes. In addition, the Ob River, a major freshwater input, drains the highly contaminated Chelyabinsk facility and may contribute a substantial inventory of radioisotopes in its own right.

The protocol does not take into account potential transport pathways of nuclides in relation to prevailing or induced currents. The preliminary statements made by participating scientists of no evidence of leakage have been based on the analysis of caesium-137. This isotope is conservative to seawater and therefore considered likely to be rapidly transported considerable distances from the point of origin once solubilised. This presupposes an extensive knowledge of the currents and an assumption that movement of water masses is entirely predictable. This assumption is clearly unwarranted based on the limited information given in the description of the area in the Arctic Pilot and the prevailing currents shown in Figure 1.

Many of the selected sampling sites given in the published joint survey protocol are in areas isolated from the Novaya Zemlya current. Since most of the dumpsites are located in the coastal region of Novaya Zemlya, this current could be expected to dominate the distribution of radionuclides escaping from dumped material. This current interacts with the Litke current exiting the Kara Strait to the Barents Sea. The Marine Research Institute in Bergen, Norway has stated that the first signs of radioactive leakage are likely to be noticed first in the Eastern Barents Sea. The sampling programme does not accurately reflect this sentiment. Sample sites 4,5,6,7, are located in an area highly influenced by the outflow from the Rivers Ob and Yenisey and therefore unlikely to be highly contaminated by sites on Novaya Zemlya. Sites 9 and 11 are situated in areas dominated by components of the Yamal current which in turn is derived from the influent current through the Kara Strait. Only sites 8, 10, 1, 2 and 3 shown in Figure 1 are positioned such that they may be influenced by components of the Novaya Zemlya current. The utility of these sites, however, is questionable given the possibility of a south setting coastal jet stream circulation along the Novaya Zemlya coast. None of the selected sites in the Kara Sea, therefore, are ideally positioned with a view to detecting leakage of radiation and subsequent dispersion of seawater conservative elements on the basis of known setting of currents.

Numerical dispersion studies, using computerised mathematical models of passive tracers in the Barents and Kara Seas, have been carried out at the University of Hamburg by Ingo Harms and Jan Backhaus. The results of these modelling exercises were reported at the Second International Offshore and Polar Engineering Conference held in San Francisco, USA in June 1992. The basis for the study was a model originally developed for the North Sea. The model as applied to the Kara Sea is limited: It does not account for sea-ice nor does it incorporate potential influences of the Rivers Yenisey and Ob. Otherwise, it appears to be fairly robust as regards incorporation of topographical factors, and physico-chemical variability including discontinuities in salinity and temperature. The model generates strong North-east setting currents in the centre of the Kara Sea as a stable and permanent feature. The overall flow field, north easterly through the central Kara Sea, causes the model to predict a dispersion of seawater conservative material from point sources in the form of a broad tongue of contamination through the water body as a whole. Seasonal variation is additionally predicted to cause an annual pulsing of contaminated water masses into the north eastern Barents Sea.

There is clearly a need to reconcile local dispersion resulting from known surface current patterns as described in navigational literature with the more generalised patterns predicted by the mathematical modelling exercises. The known currents could be expected to carry radioactive material to the south west and into the Barents Sea with the Litke Current. This contrasts with the results of the modelling exercises for the area which predict that the flow is predominantly from the Barents Sea into the Kara Sea. The south westerly setting Novaya Zemlya current could effectively entrain contamination and result in considerable deviation from the modelled dispersion pattern. This possibility reinforces the view that a more locally directed sampling exercise is required in contrast to that executed by the joint Norwegian/Russian Survey.

While some water exchange would occur across the mass flows of these currents, leading to general contamination of the Kara Sea, the utility of the designated sites in detecting radioactive leakage would be highly dependent upon the nature and behaviour of any radioisotopes released and the interaction and mixing of coastal water masses with deeper water masses.

Behaviour of Radionuclides

The experimenters have made wide ranging assumptions relating to the likely behaviour of any radionuclides which leak from the dumped material. In particular, the Norwegian Marine Research Institute has stated that the radioactive element caesium would be detected relatively quickly even from outside the twelve mile limit as it would be carried by currents and absorbed by fish. The Institute has further stated that they expect the low levels of radio-caesium found in Kara Sea waters to be paralleled by low levels of other nuclides in the sediment and biota. These assumptions are not supportable and render the preliminary conclusions fundamentally unsound and grossly misleading.

Analysis of radio-caesium isotopes has been used to determine the influence of radioactive releases over wide areas. In particular, the discharges from the Sellafield and Cap-la-Hague reprocessing plants have been tracked by analysis of the caesium-137 isotope. This radionuclide has also proven a useful index of atmospheric emissions resulting from the Chernobyl reactor fire in the Ukraine and of atmospheric contamination resulting from the testing of nuclear weapons. In all these cases, however, the isotope has been introduced into the environment in large quantities and in a mobile form. The effluent from reprocessing contains caesium dissolved from fuel rods and introduced to the sea in soluble, ionic form. In the case of the Chernobyl accident and nuclear testing, the thermal atomisation of nuclear material introduced freely dissociated isotope into the atmosphere. In all these cases, the isotope has been freed from the original matrix rapidly and in substantial quantity.

The release of the dumped wastes is unlikely, at least initially, to result in such large scale emissions. Rather, releases could be expected to increase with time. Hence, radio-caesium levels attributable to these sources could take some time to become noticeably elevated above existing levels in the wider field as a result of systematic and other errors in the sampling and analysis, and hence may not be readily distinguishable analytically from existing background levels.

Little is known about the nature of the dumped substances and the inventory of radionuclides. The behaviour of the radionuclides following a breach of the vessels in which waste was dumped will be highly dependent on the nature of the wastes themselves. In the case of a fuel element, the inventory of isotopes will be distributed through the mass of the fuel element and release will be related to the solubilisation of the matrix as a whole. This in turn is likely to depend, for example, on the oxidation of uranium/uranium oxide to more soluble species and in turn on physico-chemical characteristics of the overlying waters. The release of drummed wastes will be dependent on the rapidity of corrosion/breach of the containment and the leachability of the matrix contained within the drums. Obviously, breach of a container of solid wastes will result in a different release scenario to breach of contained liquid wastes. Without knowledge of the nature and condition of the dumped material it is virtually impossible to predict the dynamics of the contained nuclides upon release to the environment.

If radionuclides are solubilised slowly from the dumped material as is likely, then caesium-137 is not reliable as an indicator of leakage. The expected pattern in this case would be of a highly contaminated sediment with isotopes which are non-conservative to seawater localised in the vicinity of the leak. Exchange with the overlying water would be dependent upon a number of factors including local sedimentation rates, and the depth to which wastes had become overlaid by sediment. Under these circumstances released caesium-137 might also be largely localised in the most highly contaminated areas. If dispersed into the overlying water, its use as a tracer depends upon any given source elevating background levels to a point where it can be distinguished from normal sampling variation and the associated errors. It follows that failure to detect an elevation of caesium-137 at the designated sampling sites cannot be regarded as *prima facie* evidence that leakage has not occurred. This can only be established by an intense sampling programme carried out in the vicinity of the dumpsite.

Conclusions

A Joint Russian/Norwegian Survey programme has recently been carried out in the Kara Sea with the intention of establishing whether or not radioactive contamination is taking place as a result of leakage from material dumped off the coast of Novaya Zemlya by the former Soviet Navy. Preliminary results of this programme have been released and it has been stated by participating scientists that no evidence of radioactive contamination has been found. The cruise report states that radio-caesium levels in the Kara Sea have fallen over the last ten years. The conclusion that the dumpsites are not leaking is unwarranted. The protocol suffers from a number of serious shortcomings which throw the preliminary evaluation into considerable doubt.

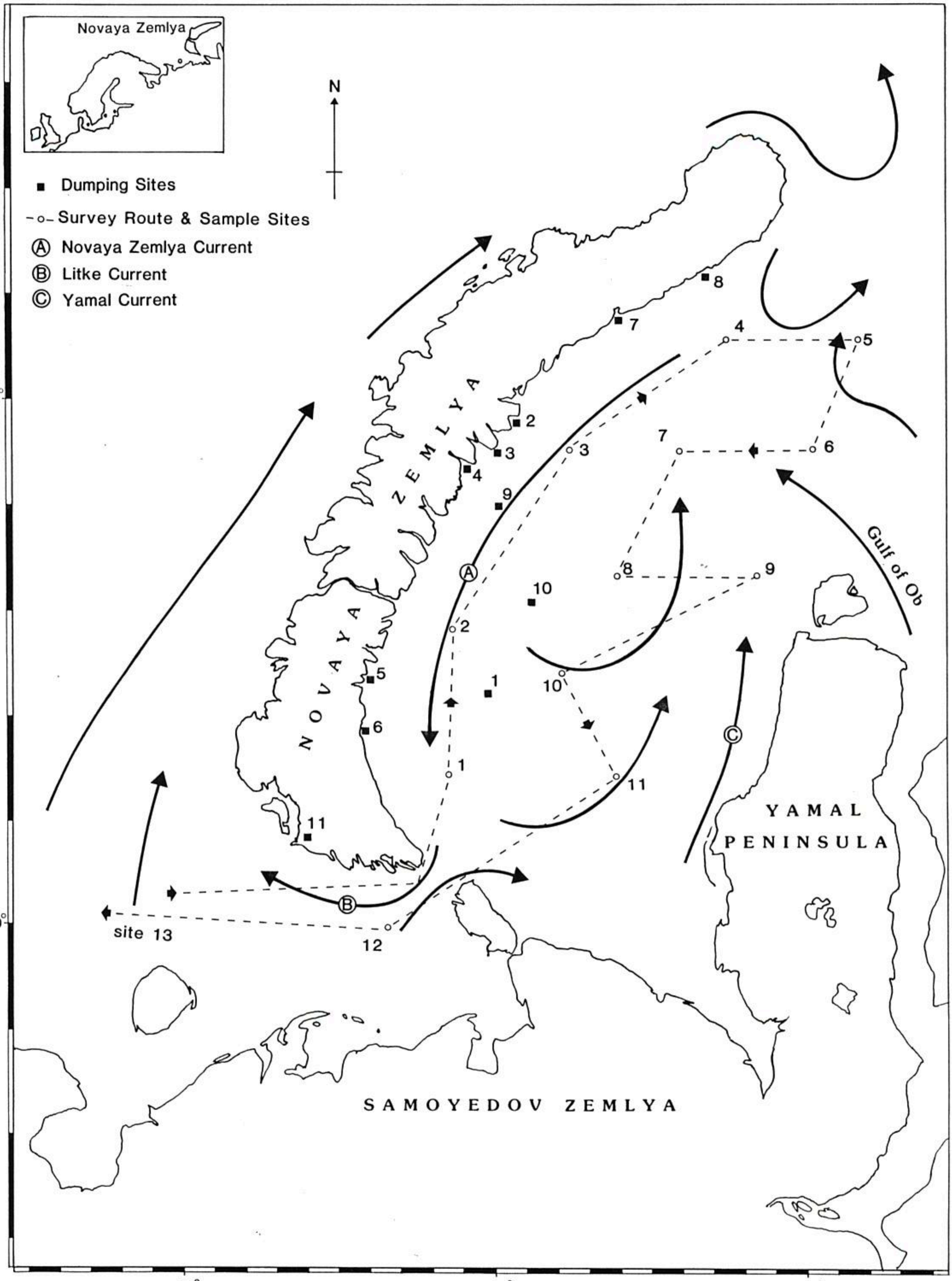
Samples were taken at sites up to 300km apart and only eleven sites were selected in the Kara Sea. Given the size of the Kara Sea, the use of few sites is statistically unsound and cannot be expected to resolve the question of whether leakage has occurred. In this case, the semi-systematic design used has no advantages, being more appropriate to the monitoring of long term trends. A judgmental approach to the sampling, with a higher degree of focus on areas where dumping is known to have taken place would have been a more appropriate approach.

This conclusion is reinforced by consideration of the known oceanographic complexity of the Kara Sea. Many of the sample sites chosen were in areas influenced by currents whose mass flow is not derived from the coastal areas of Novaya Zemlya where dumping is known to have taken place. On the contrary, many sample sites were located in areas which are likely to be influenced by currents deriving their water masses from areas distinct from the dumping areas in question and which are therefore least likely to provide evidence of radiation above existing background. The prevalent Novaya Zemlya current could largely restrict the transport of released radionuclides to a narrow area adjacent to the coast. Unless access was possible to waters inside the twelve mile limit, such mass transport would not be detected by the published Norwegian/Russian protocol.

The current exiting the Kara Strait continues in a northerly direction up the West Coast of Novaya Zemlya. Hence the sample sites selected on the approach to the strait are probably not the best places to identify radioisotopes entrained by the current. Significantly, recent statements by participating scientists incorporated in a press release, identify the Eastern Barents Sea as a priority for monitoring, This is not reflected in the sampling protocol.

The detection of elevated levels of radiation appears to have been predicated on the assumption that radio-caesium, an isotope conservative to seawater, would provide an adequate index of radioactive leakage. Failure to adequately consider possible release scenarios from the dumped waste, and a lack of knowledge of the precise composition of the wastes themselves throws this assumption into serious doubt, and therefore renders the utility of the sampling exercise highly doubtful.

On the basis of the sampling programme carried out by the joint Norwegian/Russian survey team, and the preliminary results for Cs-137, there would appear to be no justification for assertions that leakage has not occurred. The survey as conducted would, in all probability, not detect leakage from dumped material. The survey was restricted to areas outside the twelve mile limit around Novaya Zemlya. In order to fully evaluate the dumpsites, a more highly focussed sampling exercise within the twelve mile limit needs to be conducted. This should be concentrated around the areas where dumping has occurred and take into account other radioisotopes than Cs-137. Such an exercise would resolve uncertainties about leakage by allowing evaluation of the less mobile radioisotopes. In order to make a useful preliminary assessment, a need also exists for full disclosure of the inventory of dumped materials together with an evaluation of nuclides present in the area derived from other sources.


Novaya Zemlya
N
Dumping Sites
Survey Route & Sample Sites
Ⓐ Novaya Zemlya Current
Ⓑ Litke Current
Ⓒ Yamal Current
NOVAYA ZEMLYA
Gulf of Ob
YAMAL PENINSULA
SAMOYEDOV ZEMLYA
site 13
75°
70°
50°
60°
70°

Footnotes to Figure 1

Figure 1 shows Novaya Zemlya and the surrounding areas. Known dumping sites are shown marked as squares. The arrows show the major currents and circulation patterns as derived from Admiralty chart 2962 and data given in the Arctic Pilot. Sample sites designated in the published protocol from the joint Norwegian/Russian survey programme are marked by numbered circles. The materials dumped at the marked sites are as follows:

1: Novaya Zemlya Trench. 1450 containers including a barge with a damaged nuclear reactor and a barge carrier with liquid radioactive wastes. The inventory of radioactivity is estimated at 170,000 curies.

2: Nepokoyev Gulf. Solid radioactive wastes with an estimated activity of 3,400 Curies.

3: Sivolky Gulf. 4750 containers, the barge "Baumann" and the central section of the icebreaker "Lenin" including the screen assembly and three damaged nuclear reactors.

4: Oga Gulf. 850 containers.

5: Stepovov Gulf: 1850 containers together with a damaged nuclear submarine complete with two fuelled reactors.

6: Abrosimov Gulf. 550 containers. Sections of four accident damaged nuclear submarines with a total of eight reactors. Three of these still contain fuel elements.

7: Blagopoluchiyo Gulf. 650 containers.

8: Techenniyya Gulf. Defuelled, but accident damaged nuclear reactor.

9: Open Sea Area: 400 containers.

10: Open Sea Area: 250 containers.

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