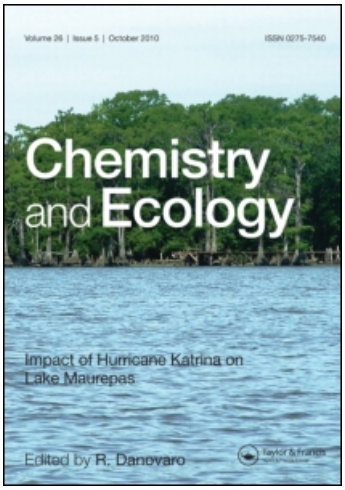

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NUCLEAR WASTES IN THE ARCTIC OCEAN. THE CONSEQUENCES OF PAST DUMPING AND OPPORTUNITIES FOR FUTURE PREVENTION

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The view is expressed that the assessment of disposal of nuclear waste in the ocean (specifically the Arctic and Kara Seas) is critical to understanding Arctic pollution. Much needs to be done in deciding what we should do, even though many wastes are long-standing and persistent. In 1993, disclosures about Russian dumping of submarine nuclear reactors, nuclear fuel, and other radioactive wastes into the Arctic Ocean brought this region and its problems into the world spotlight and raised public concerns about the resulting health and environmental risks. As a result of this concern, the Congressional Office of Technology Assessment published a 1995 study, *Nuclear Wastes in the Arctic* (US Congress Office of Technology Assessment, 1995). This paper summarises and updates that study.

Keywords: Nuclear waste; radioactive fuel; reactors; Arctic Ocean

INTRODUCTION

The OTA study examined the environmental and human health impacts from the dumped nuclear wastes, from discharged nuclear contaminants, and from both past and future nuclear activities in the region. The findings address three principal topics: research, monitoring and prevention. Research has provided initial facts about the dumped materials and migration of contaminants but more work is needed to fill data gaps and prepare a rigorous assessment of the risks to public health and the environment. Since the OTA study was completed in 1995

(US Congress of Technology Assessment, 1995), several individual research projects have continued and a risk assessment is underway but no new funding has been provided and no major new findings have been reported. While some initial planning has been done on approaches to monitoring, no specific systems have been developed, nor has the international community agreed to co-operate and fund future monitoring. Finally, the most urgent need is for initiatives to prevent future accidents, dumping or radioactive discharges. Certain projects in prevention have begun, but much work remains.

Protection of the environment and public health requires careful and responsible management and long-term control of nuclear waste. In recent years, as the Cold War and the nuclear arms race have abated, many nations, institutions and individuals have become increasingly concerned about the environmental legacy of the nuclear age and are working to seek solutions to these problems.

Soviet submarine reactors and waste products were dumped in the Arctic seas over the past several decades when the north-western coast of Russia was a hub of nuclear fleet and nuclear testing activities. The Arctic elicits images of vast frozen expanses with little human habitation or industry and a relatively pristine environment. These images are not always accurate, and contamination from both military and industrial activities has brought questions about its impact not only locally, but also in the wider Arctic region.

We now understand some of the environmental and human health impacts from nuclear wastes in the Arctic, nuclear contaminants discharged into these marine environments, and radioactive releases from both past and future activities in these regions. Although some information about waste and contamination is available in the Arctic, it does not follow that we know how, when and where they may affect people and their health. Because so many factors are involved and science cannot provide answers to many questions, there is a need for care and prudence as well as for a stable and continuing institutional framework for long-term observation and monitoring.

RUSSIAN NUCLEAR DUMPING

Rumours started to circulate in Russia in 1990 that dumping of nuclear waste had taken place in the Barents and Kara Seas. A con-

ference organised by Greenpeace International in September 1991, brought international interest and concern. At the press conference, Andrei Zolotkov presented a map showing dump sites used for radioactive wastes from 1964–1986, and local papers listed the sites and numbers of dumped objects (Zolotkov, 1991). The Soviet Union made no official denial of these allegations at the subsequent 14th Consultative Meeting of the London Convention in November 1991, and delegates were asked to provide information.

Meanwhile, Soviet dumping in the Arctic was causing concern in the United States. In August 1992, a hearing of the USA Senate Select Committee on Intelligence focused on USA and Alaskan perspectives on the problems (US Congress, 1992). The Government officials, scientists and some representatives of organisations stressed the need for more information and for co-operation with the Russian Federation to obtain it. At the London Convention, the new Russian Federation announced the formation (in October 1992), of a Presidential Commission under the direction of Alexei Yablokov so as to "ensure Russia's compliance with obligations under the international treaties", signed as a successor to the Soviet Union.

The report of the commission (Government Commission, 1993, the Yablokov report), was submitted early in 1993, contained inventories of both liquid and solid radioactive waste dumping that occurred between 1959 and 1992 (Gallager and Bloomstein, 1993). This was consistent with unofficial accounts and detailed the dumping of damaged submarine reactors, spent fuel from the nuclear fleet, and other waste into the Kara Sea, into the Sea of Japan, and in other locations. Other than the estimated inventory by an expert group with the IAEA (International Atomic Energy Agency, 1994), most of the information in the Yablokov report remains, a key source of data about the Russian's radioactive waste dumping in the Arctic.

The wastes dumped in the Kara Sea and along the coast of Novaya Zemlya included containers, barges, ships and submarines containing nuclear reactors, both with and without spent reactor fuel. A total of 16 reactors was disposed of at five sites both in fjords and the Kara Sea. Thirteen were from Soviet nuclear submarines and the others were from nuclear icebreakers. Six of the submarine reactors and the additional container from the icebreaker *Lenin* held spent reactors fuel in them. The total activity of these materials at disposal was 2 million

curies. USA and Russian scientists concluded today that only 5% remains at the Kara Sea sites. The Yablokov report described the nuclear accidents; solid, low-level waste dumping; extensive low-level liquid waste discharges (Barents Sea); sinking of the nuclear submarine, the *Komsomoletes*, in 1600 m depth of water in the Norwegian Sea. The *Komsomoletes* was powered by a nuclear reactor and also had two nuclear warhead torpedoes.

NUCLEAR DUMPING IN THE ARCTIC

Since the Yablokov report, data collection and investigations have been undertaken with USA investigators, Russia, Norway and others close to the Russian sites, and other agencies such as the IAEA. The United States has established agreements with Russia, Norway and others relevant. The United States is a party to the Declaration in Arctic Environmental Protection approved by the eight circumpolar nations (the United States, Canada, Norway, Russia, Finland, Iceland, Sweden and Denmark) in June 1991. The Arctic Environmental Protection Survey (AEPS), is a non-binding statement of co-operation on the development and implementation of programme to protect the Arctic environment. Radioactivity is one of several pollutants identified under the strategy for priority action.

The most significant US efforts have been the result of money set aside from "Nunn-Lugar" funds appropriated by Congress for the Department of Defense (DOD) in FY 1993–95. The $10 million annually has been assigned to DOD's Office of Naval Research (ONR) for the Arctic Nuclear Waste Assessment Program to study nuclear contamination by the Soviet Union in the Arctic. With these funds, ONR sponsored extensive research activities including 70 different field, laboratory, modelling, and data analysis projects; three major workshops on nuclear contamination of the Arctic Ocean, and extensive collaboration with Russia, Norway, Germany, Canada, Japan, Korea, the IAEA and the Arctic Environmental Protection Strategy. The initial results are to be expected to be published in scientific journals, but since FY 1995, no further funding has been provided.

Some tentative conclusions have been reached from the data collected by these efforts. Researchers have not found evidence of significant migration beyond the immediate vicinity of dumped radionuclides that might affect human health in the short run. However, some key problems included: (1) there has been no detailed inspection of many dump sites within the past two decades; (2) we have limited knowledge of possible release rates and the long-term viability of materials encasing the waste; (3) some of the critical pathways by which radionuclides can affect man, such as the biological food chain or transport on moving Arctic ice, have not been thoroughly investigated. Other possible sources of contaminants that could affect the Arctic environment are also only now to be investigated.

In the Kara Sea region, one potential source of contamination is from the large northward flowing Siberian rivers, at whose headwaters (more than 1,600 kilometres upstream) are located the Russian nuclear weapons production facilities. At some, such as Chelyabinsk, Tomsk and Krasnoyarsk, the largest releases of radioactive wastes have been recorded over the last few decades. Wastes of > 100 million curies were discharged into lakes and rivers at one site, and billions of curies have been injected directly underground. This has resulted in serious health problems among local populations. Whether contamination may migrate down rivers such as the Ob or Yensky into the Kara Sea and the Arctic Ocean is now under investigation.

In Russia today, nuclear waste management continues to be a problem. Liquid wastes are still discharged underground at some facilities, but nuclear dumping is now discontinued (but Russia is not a signator to the London Convention). Nuclear waste is still being accumulated due to the dismantlement of the submarine fleets. Reprocessing of spent fuel from reactors continues and is associated in Russia with increased waste and residues. Huge amounts of waste (especially from operations in the Urals) will remain uncontrolled for the future, with continuing risk of further migration.

While contamination in the Soviet Union is serious, it is the nuclear contamination of the Arctic and North Pacific that has attracted most attention in the United States. The north coast of the State of Alaska is adjacent to the Arctic Ocean, and the Bering Strait, on the western coast of Alaska, is a principal route for the exchange of surface waters and the Arctic and North Pacific.

POTENTIAL FUTURE CONTAMINATION

Although past radioactive contamination and releases in the Arctic, pose questions about future releases, dumping or accidents are also important. Where past dumping has received considerable attention, the risk of future releases has not been subject to the same scrutiny. Even though the potential of significant future release may be difficult to measure from existing data, the proverbial ounce of prevention would be worth a pound of cure. Two key areas pose future contamination risks from Russian nuclear activities: (1) the vulnerability to accidents during the downsizing and dismantlement of the nuclear fleet; and (2) the management of spent nuclear fuel and waste from this and concern about effective containment, safety, security and future releases.

The management of spent fuel and other wastes from the Russian fleet is of special concern. Serious problems with removal of spent nuclear fuel from submarine reactors; storage of spent fuel aboard service ships that are used for submarine defuelling; spent fuel handling and storage at naval bases in the north of Russia and in the Far East; the lack of capacity at land-based facilities; the management of damaged and non-standard fuels for which no reprocessing system exists; and the transport and reprocessing at distant sites such as Mayak.

During the past three decades, the Soviet Union built the largest fleet of nuclear submarines, and the only fleet of icebreakers. The Russian Navy has been retiring and decommissioning older submarines at an increasing rate. More than 120 submarines have been taken out of service, and many are in various stages of dismantlement. Only about 40 of these have had their spent fuel removed, and some have been out of service for more than 15 years. The following problems are: (1) spent fuel storage facilities are full, and little spent fuel is being transported to reprocessing sites to make room for the fuel removed; (2) there is a lack of fuel reloading and storage equipment (including service ships, transfer bases and land-based storage) and what is there is poorly maintained; (3) there are shortages of safe transportation containers, limited facilities for loading and moving them, problems at fuel transfer bases and lack of upgrades or railways. Many fuel storage vessels and facilities needing adequate maintenance and the number of

decommissioned submarines is growing; decommissioning will decline, and by that time there will be a large backlog of submarine reactor cores (> 300) with spent reactor fuel.

Non-standard and damaged fuel rods from submarine and ice-breaker reactors present other problems. Such fuel includes zirconium – uranium alloy fuel, fuel from liquid fuel reactors, damaged and failed fuel assemblies and fuel in damaged reactor cores. Removing this fuel for temporary storage and selecting or developing future treatments or storage are challenging and will require some technology not now available in Russia. The process is moving slowly, and there is a lack of resources. The question of risks from current or future operations to dismantled nuclear submarine and the management of spent fuel have now been considered separately in several studies.

CONTAMINATION FROM DUMPED WASTES

Since the release of the Yablokov report describing dumping in the Arctic, more has been found, but conditions and likely release rates are largely unknown. Current levels of radionuclides in the sea water and sediments in Arctic marginal seas do not suggest that significant releases have already occurred. Even though current risks would not appear to be increased as a result of the dumping, future release rates and pathways to people remain to be evaluated. Investigations of these transport mechanisms are now under way.

Scientists have developed models to approximate the behaviour of pollutants such as radionuclides in the environment. These require much site-specific information, much is unknown either for the Arctic environment, or for particular dump sites. Several efforts are now under way to model the transport of radionuclides dumped in the Arctic, as well as those released at sites within Russia along the rivers that drain into the Arctic.

The most likely route of human exposure to radionuclides in the seas is through the food chain. Thus, with radionuclide information through the physical movement, specific data are needed for the Arctic about biological pathways to man. The marine food web is complex, and most available data were collected in temperate climates, rather than in Arctic settings. Information about how radionuclides are

transferred and concentrated through the food chain under special local and regional conditions is required.

People of the world are not equally at risk from radionuclides dumped in Arctic seas or in the Russian Far East. Current and future investigations need to focus on gathering relevant information about the dietary habits and other characteristics of the populations who are most likely to be exposed, such as native northern populations and others who rely on Arctic marine resources. This information will be important for a thorough risk assessment to estimate the most likely effects on human health.

The Office of Naval Research (ONR) initiated a risk assessment project in mid-1995 under the Arctic Nuclear Waste Assessment Program (ANWAP). The goal of the project is to estimate a radionuclide dose to man and the environment, most in Alaska, from the Russian nuclear wastes in the Arctic. Data from the USA research and other international projects are being used. The project tasks include source characterisation; transport modelling (atmosphere, water, ice, sediments); biotransfer through Arctic food webs; future dose reassessments. This risk assessment is expected to be published in the summer of 1997 (Varela, pers. commun.).

Although Russian people have suffered health impacts from nearby radioactive releases, the situation is different when large regions such as the Arctic are considered, given the uncertainties of low-level exposures. There is not yet a clear answer to questions of what the future health impacts on a wider region will be from nuclear wastes dumped in the Arctic and North Pacific. Estimates and approximations of future impacts based on the information available do not suggest a noticeable effect on human health or on plant and animal populations. Many unknowns remain from the status of the dumped wastes, to the likely movement of radionuclides through the environment, to the dietary intakes of those most likely to be exposed.

The ANWAP risk assessment will be a final step in this ONR research programme although the publication of many of the individual research projects funded may not be completed until later. About 80 different projects of all types were finally funded from field surveys to laboratory experiments, modelling studies, and archival data analyses. Even though the specific research results are not published, programme summary documents are available for FY 1993,

1994 and 1995. These documents contain statements similar to that of previous years (Arctic Nuclear Waste Assessment, 1995). In addition to these annual summaries from ONR, several researches from the United States and overseas who are working in the field to summarise their work and results to date and interact with their scientific counterparts. In 1995, the Woods Hole Oceanographic Institute hosted a programme workshop (Office of Naval Research, with Gore-Chemomyrbin Environmental Committee, 1995) and in 1996 a similar symposium was held the University of Utah.

The research shows that radionuclide activity in the Arctic is low and river contamination in Russia has had only a small impact on the Arctic Ocean. There is apparently no immediate or widespread threat from nuclear waste dumping to the Arctic Ocean environment in general or to populations living in the region beyond the Russian borders. The major future concerns are related to possible accidents that could disperse large amounts of radionuclides, from possible long-term effects impacting of the Arctic food web, from possible future waste dumping, and from possible future catastrophic river releases. The 1995 ANWAP report also suggests that Arctic contaminantes other than radionuclides have not been studied adequately, and may be a problem worthy of future research.

Since no new funds have been allocated for the ANWAP programmes since 1995, the research work is coming to a close. The results will be reported as individual work is completed but without specific completion schedules. In an overall sense, the results will be reflected in the risk assessment report that is now being completed. And, some overall data collection and dissemination efforts, such as that of the Naval Research Laboratory, will attempt to summarise data from all survey and research efforts as they are completed and available. There is, in general, no central focus of these efforts in the United States because the termination of the ONR funding has left no-one with such responsibility.

INTERNATIONAL INITIATIVES TO ADDRESS ARCTIC NUCLEAR WASTE PROGRAMMES

Many national and international institutions are involved in initiatives to address solutions to the problems of nuclear waste dumping and

discharges into the sea. Some are addressing the threat of radioactive contamination to regional environments and human health. Others are working to ensure careful and safe future management of nuclear activities, materials and wastes. An open question is whether these institutions are effective and whether their initiatives can bring about improvements. The improvements needed, and other goals of many programmes, are not clearly defined and sometimes represent compromises among conflicting objectives. Because the problems are international, it is difficult to harmonise the policies and goals of each nation affected. In addition, many unilateral, and multilateral organisations have developed over the years, each with missions have evolved and changed to meet the challenges of the day and to reflect unique conflicts or co-operative moods of the time.

RESEARCH INITIATIVES

These have been the prime focus of most organised US efforts and this has been made the greatest advances in the research initiatives. There are some gaps in the ONR research programme (ANWAP) relating to regions covered, pathways investigated and other factors, but the programme evolving as a reasonably comprehensive investigation of key problems until it was terminated in 1996. The work still remaining would be enhanced by more co-operation with Russia, especially in the area of increased access to specific dump sites and dumped material. A radiological risk assessment that has been considered a last step in the current research programme is due to be completed soon.

On the other hand, research initiatives supported by several international organisations and specific European countries have been more consistently supported over time and have tended to bring international institutions, individual researchers and programmes together in productive ways to focus on Arctic nuclear contamination problems. The International Arctic Seas Assessment Project, under the auspices of the International Atomic Energy Administration, is one such effort. Russia, the United States and several European countries have worked co-operatively on projects to identify the characteristics of nuclear dumped material and the possibility of its future migration. Another effort to support both research and co-operation has been

fostered by both Arctic Monitoring and Assessment Programme (AMAP) and the Norwegian Radiation Protection Authority. The third AMAP symposium and Conference on Environmental Radioactivity in the Arctic is being held in Norway in 1997. At each of these conferences, results of the latest research is presented and new initiatives are encouraged. Several European countries, Norway especially, are funding research, data collection, monitoring and prevention programmes in the Arctic, and in Russia as well.

MONITORING AND WARNING INITIATIVES

This is an area of interest, but with little support. International co-operation in this area is imperative if an effective assessment and response programme is to follow. International institutions may be the most appropriate organisations to carry out such initiatives. However, long-term consistent support and the adoption of rigorous scientific implementation programmes must be ensured for these efforts to be effective.

PREVENTION INITIATIVES

These have received attention, particularly within the international community, and particularly over the past few years since 1995. The attention has not yet had a great impact on the major waste problems, because many of the needs require significant financial resources and long lead times to develop. Most of the key decisions must be made by Russia where pressures of other political and economic support have been overwhelming. In the United States, it is difficult to engender support for long-term substantial financial assistance in Russia. The joint projects that could benefit both United States and Russia and could be mutually supported are the ones that tend to have the greatest success. Other countries in Europe such as Norway have supported joint prevention projects and continue to do so.

One notable recent event organised to foster improved waste management was a NATO sponsored workshop in 1996 entitled: "Recycling, Remediation and Restoration Strategies for Contami-

nated Civilian and Military Sites in the Arctic Far North". This was held in Kirkenes, Norway, and was organised by the American Association of the Advancement of Sciences, the Russian National Research Centre Kurchatov Institute, the Norwegian Radiation Protection Authority and the US EPA. Recommendations from that workshop addressed co-operative programmes for the comprehensive decommissioning of nuclear submarines, support for continued co-operative work with experts from each country, improved management of spent fuel from submarine and icebreaker reactors, projects such as liquid or solid radioactive waste treatment technologies and facilities, and expanded work in environmental risk assessment.

The two nuclear waste management projects, with international co-operation, that have been underway for some time, are: (1) the development of a liquid radioactive waste treatment plant at the Atomflot facility in Murmansk, and (2) development of a system to remove or store or treat damaged and other spent fuel from the service ship **Lepse**. The liquid waste treatment plant is a joint US, Norwegian and Russian project that is now under construction (about 25% complete). This plant will treat contaminated water from both the Russian submarine fleet and the Murmansk Shipping Co., a nuclear icebreaker fleet. This liquid waste has been merely stored in tanks or treated with outdated facilities up to now. This is also the type of waste that (in the past) has been directly dumped into the Barents Sea according to the 1993 Yablokov report.

The **Lepse** is an old nuclear fuel storage vessel (built in 1934) that contains a large amount of highly contaminated damaged fuel from both submarines and icebreaker reactors. Some of the fuel has been encased in concrete to control radiation releases. The ship has been in dock in Murmansk without any fuel removals for 15 years. New equipment and processes are needed to safely remove damaged fuel and store or process it. The **Lepse** project has several country sponsors including the US, Norway, France, Russia and the European Union. An international advisory committee has been formed to recommend technological approaches and the above partners are committed to invest in several millions of dollars in the project (Dyer, 1997).

Spent fuel from submarine reactors and the icebreaker fleet is in temporary storage at several sites in the Russian Arctic. In the past,

most spent fuel was shipped to a Russian reprocessing facility in the Urals but shipments have slowed to only four per year and most storage sites are full. A project to develop safe interim storage containers for spent fuel has been promoted by the same international partners. This is part of a group of projects (including the solid waste modular storage facility) that is part of the Defense Department initiative to the United States known as the Arctic Military Environment Co-operative (AMEC) agreement. The parties to this agreement are the defence ministries and departments of the United States. The parties in this agreement are the defence ministries and departments of the United States, Norway and Russia. Many hope that co-operation at the military level will bring needed action to move these projects to completion and alleviate the severe problem of Russian nuclear waste management in the Arctic region. If the wastes and spent fuel are not safely managed on land, the risks of release into the water environment including the Arctic Ocean are bound to grow.

Environment advocates in Norway are most concerned about the nuclear waste management issue in the Kola region of northern Russia. The work on the **Lepse** is considered important and encouraging. Funds have been committed by the EU, France and Norway, and while problems remain with how to handle the fuel after it is removed from the ship, this is being addressed by competent experts. The projects under the Arctic Military Environment Co-operative (Russia, Norway and the US) are also considered important in that they could provide interim storage for spent nuclear fuel, treatment facilities for liquid rad waste, volume reduction for solid waste, and storage facilities for solid rad waste. The programme, however, is progressing slowly, and the problems of co-operation with the Russian military continues to hinder research. The Norwegians claim that an expedition planned to survey the fjords on the Kola Peninsula in the summer of 1996 was cancelled because the Russian military did not give them the needed permission (Boehmer, 1991).

Russian environmental advocates also indicate that there are difficulties in making progress with nuclear waste management within Russia and that financial and institutional barriers continue to be a problem. On March 29, 1997, there was a meeting of the Russian Commission headed by Yablokov, who is the environmental advisor

to President Yeltsin and the person who first published official Russian accounts of the Arctic nuclear dumping. At this meeting, issues were considered relating to the environmental impacts from nuclear submarine activities and the environment in the area of Mayak where spent fuel is now reprocessed. It was reported that co-operative work with the US and Norwegians is progressing slowly with more co-ordination needed among the many military and other agencies involved. Funds for building rail transportation cars for spent fuel and for constructing interim spent fuel storage facilities have been held up due to institutional co-ordination problems. Meanwhile, the reports are that more than 100 reactor cores remain with spent fuel aboard decommissioned submarines with no place to unload them, all northern fleet storage facilities for spent fuel and radioactive waste are 100% full, and the transportation of spent fuel from storage sites to the reprocessing plants is hindered by lack of equipment (Popova, 1997).

SUMMARY

In summary, three areas – research, monitoring and prevention – are critical to protect human health and the environment from widespread radioactive contamination in the Arctic. Poor waste management practices of the past have alerted the international community. Kara Sea dumping activities for the former Soviet Union have yet to show a direct connection to human health impacts but have none-the-less raised concerns and questions that will require years to answer even partially. Long-term dedication and planning, as well as comprehensive programme with both US and international institutions, will be necessary to protect the Arctic environment and the health of Arctic populations in the future. It is the future prevention of dumping and releases that is both the most important and the most difficult to resolve. Dedicated people in the international community are working on important projects but are hindered by lack of international co-operation in all countries. The cold war may be over, but the institutions that it created remain a barrier to improvements in the world environment.

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Mr. P. A. Johnson was formerly a Senior Associate with the Congressional Office of Technology Assessment and is currently a Senior Staff Officer with the Marine Board of the National Research Council in Washington, DC. The views expressed in this paper are solely those of P. A. Johnson and have neither been reviewed nor endorsed by the National Research Council.

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