STABILIZATION AND STORAGE OF SOLID RADIOACTIVE WASTE FROM THE RUSSIAN NAVY'S NORTHERN FLEET UNDER THE AMEC PROGRAM

Andrew Griffith[1], Patrick Schwab[2], Ashot Nazarian[2], Paul Krumrine[3], and Barry Spargo[4]

[1]*U.S. Department of Energy, Germantown, MD 20874*
[2]*Science Applications International Corporation, Germantown, MD 20874*
[3]*WPI, Germantown, MD 20874*
[4]*Naval Research Laboratory, Washington, DC 20375*

ABSTRACT

The Arctic Military Environmental Cooperation (AMEC) Program is a cooperative effort between the Kingdom of Norway, the Russian Federation, and the United States. This paper discusses joint activities over the past year among Norwegian, Russian, and U.S. technical experts on solid radioactive waste (SRW) treatment and storage technologies in the Arctic for the Russian Navy. The use of Western technology and technologies jointly developed between Russia, the U.S. and Norway will facilitate meeting Russia's needs for stabilizing and storing SRW from decommissioned nuclear submarines. Containers for transportation and storage of SRW are now under construction at a Russian shipyard. All work is directed at applications in northwest Russia where the Russian Navy is decommissioning large numbers of nuclear submarines. The missions of AMEC Projects 1.3 and 1.4 are to improve the Russian Navy's capabilities in SRW treatment and storage, respectively, and thus minimize the spread of radiological contamination (Griffith A. *et al.*, WM-99 and Griffith A. *et al.*, WM-98). Treatment decisions made in Project 1.3 will determine the scale of storage necessary in Project 1.4 and conversely, the safe storage requirements can affect the selection of treatment technologies in Project 1.3. The ultimate goal of these projects is a safe, secure, and self-sustaining SRW treatment and storage capability in northwest Russia.

INTRODUCTION

Figure 1. Solid waste compartment in Paldiski–photo courtesy T. Grochowski

A large volume (12,000 to 14,000 m^3) of SRW has resulted from the decommissioning of nuclear submarines and other nuclear related military activities at Russia's Northern Fleet bases on the Kola Peninsula (ICC Nuclide, 1998). Existing storage containers and facilities are full and deteriorating (see Fig. 1). Many more Russian submarines (ca.150) are awaiting accelerated decommissioning potentially as part of

Cooperative Threat Reduction activities or other multilateral cooperative programs. New waste is continuing to be generated and stored in an open-air environment. It is estimated that 25 to 30 percent of the SRW is presently uncovered and exposed to the elements. Estimated activity of the SRW is 37 TBq (1000 Ci). SRW consists of combustible materials (paper, wood, and fabric), pressable materials (plastics, rubber), sorbents, metal (equipment, fittings, pipes), and non-processable materials. The generation rate of SRW is about 1000 m^3 per year and is expected to increase as the rate of submarine decommissioning increases. Therefore the current situation presents a significant threat to the fragile Arctic environment and an impediment to ongoing deactivation and decommissioning goals.

AMEC Project 1.3 goals include assessing treatment options, selecting technologies, designing and constructing treatment systems for the SRW resulting from these decommissioning activities, and ultimately implementation of those technologies. The key focus at this time is on a Mobile Pretreatment Facility (MPF). AMEC Project 1.4 goals include development of self-sustaining production capabilities for metal and concrete waste containers, and in general storage systems and facilities such as modular units for SRW. A reinforced concrete container has been designed by a Russian firm with U.S. funding. Similarly, a procurement has been awarded to another Russian firm to design and build steel containers for SRW transportation and storage. This approach directly addresses the self-sustaining goal of the AMEC program. The steel and concrete containers will be used at the MPF for delivery of raw waste and removal of segregated high activity waste, respectively.

Therefore, coordination on key interface points (such as sharing of design specifications between the two projects) is important to ensure compatibility and efficient utilization of resources. Information on a variety of relevant technologies has been collected and discussed at AMEC Projects 1.3 and 1.4 meetings from early 1997 through 1999. At these meetings, which have been held in the U.S., Norway, and Russia, the parties have discussed specific, practical technologies for application at the Russian Navy facilities in northwest Russia.

AMEC PROJECT 1.3: SOLID WASTE TREATMENT

An early estimate of the cost to fully address SRW treatment was over $100 million for a facility that included incineration, metal melting, metal decontamination, super-compaction, size reduction and cementation. This approach was then reconsidered and limited to a central processing facility, consisting of metal decontamination and recycling, super-compaction of drummed waste, and cementation of liquid wastes and crushed drum pucks. Supplying waste to this central facility would be several satellite shipyard facilities where the SRW would be segregated and size reduced to minimize transportation costs. Even so, the cost estimate ranged from $20 million to $42 million (Spargo, 1998), which far exceeds the financial resources available to the project over the next few years from the participating countries. Therefore, the project was divided into phases.

Phase I

Phase I began in February 1997 and consisted of information exchange on the problem and the various technologies, which might be applied to it. From this exchange a number of technologies such as metal melting and incineration were evaluated, but eliminated as not cost effective given the expected resource limitations and regulatory environment. Completing this first phase, a set of recommendations were formulated for various implementation options, which centered around systems providing waste handling, super-compaction, cementation, and metal decontamination. These were determined to be the most cost-effective technologies and presented to the AMEC Steering Committee, resulting in a "limited implementation" option being selected for Phase II. By selecting limited implementation, the focus was placed on interim waste stabilization and volume reduction at the various shipyard sites as opposed to a central processing facility with capabilities for metal recycle and generation of a final waste form. However, AMEC support for selected aspects of a central waste management facility might still be considered in Phase III pending approval and funding release.

Further systems engineering analysis indicated that waste handling and assay, sorting/segregation, shearing/cutting, and low force compaction are the minimum technologies required at the sites to effectively pretreat and stabilize wastes until a central processing facility can be engineered and constructed. A system comprised of these technologies would facilitate and expedite interim waste segregation and storage, contain further release of radioactive species and integrate well with the more extensive planned capabilities of a centralized waste management facility.

Phase II

As a result of a joint Project Officers and Technical Experts meeting in March 1999, a conceptual

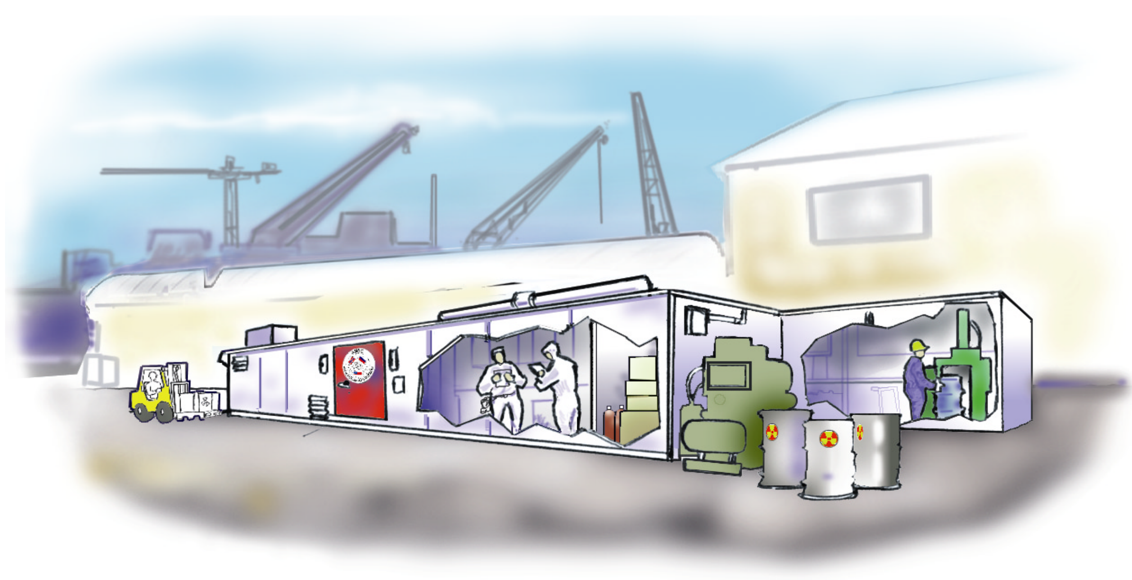

Figure 2. General View of Mobile Pretreatment Facility

solution for a novel Mobile SRW Pretreatment Facility was developed. A key feature of the concept is the mobility aspect, which will allow this system to be transported between the Nerpa shipyards and other intermediate storage sites such as Gremikha and Andreeva Bay (see Fig.2 and 3). These sites presently contain and are expected to generate the largest portions of SRW on the Kola Peninsula in the future. The proposed system can be set up in close proximity to the waste source and allow pretreatment unit operations of contaminant assaying, cutting/shearing, sorting/segregation, waste drying and shredding, and low force compaction.

The mobility concept will be achieved via the use of ISO type or equivalent containers as modular units to house the various unit operations. The containers will be designed in size and modularity so as to be easily disassembled and loaded onto ship, train or truck, and be moved to

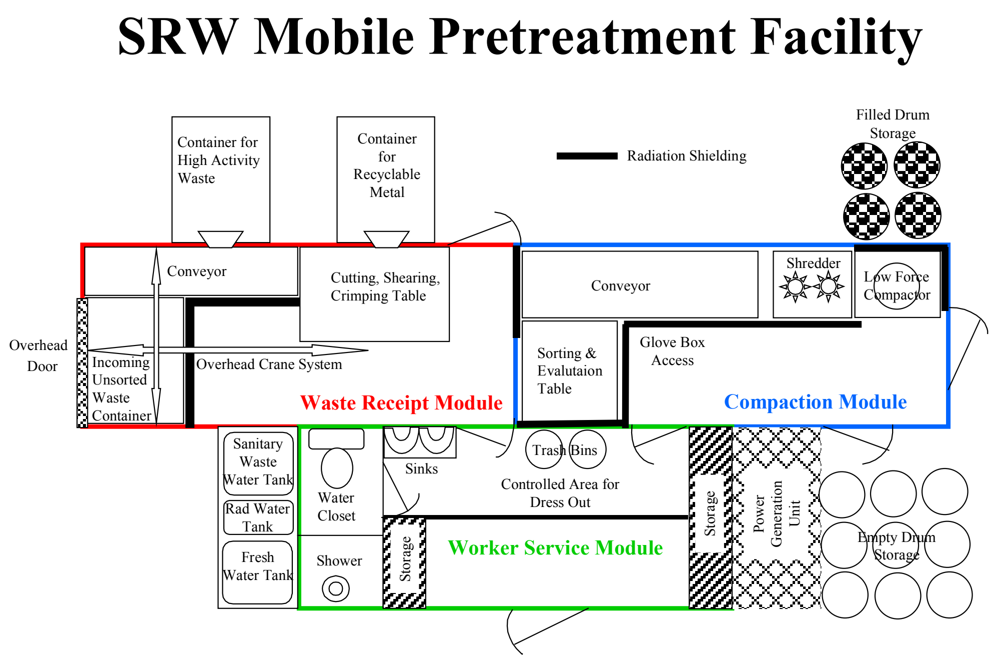

Figure 3. Modules of Mobile Pretreatment Facility

prepared sites at each of these facilities where they can quickly be reinstalled. Mobile does not imply these modules be on wheels or tracks, rather the modules can be disconnected and loaded onto whatever mode of transportation is required. While in operation at a site, the modules could be situated within another structure or outside, but in either case would be securely anchored to a concrete pad. Design specifications must include the ability to withstand up to 45 m/s (~100 mph) winds and snow loading of up to 2.5 kPa (~50 pounds per square foot). Also Arctic temperatures can range down to –40 ^{o}C. The initial concept (see Fig. 3) consists of three modules, two for the actual pretreatment operations and one for worker dress out and sanitation necessities. All equipment and components in this unique facility should be commercially available and proven technologies.

The first *Waste Receipt Module* addresses radiation level assessment, size reduction via cutting/shearing, and sorting/segregation. Workers in this area would be outfitted in full PPE. The most significant unknown is the actual state and variability of the waste to be processed, therefore this module must exhibit flexibility in configuration and functionality. It is expected that the waste would be brought into the module in a variety of reusable containers. The workers would be shielded from the containers via lead barriers and leaded glass. Waste from these containers would be removed via overhead crane with grapple or electromagnetic attachment and assayed for radiation activity. Depending on the result and classification criteria, it would be either rejected for further processing as high activity waste, or passed into the worker area, either directly via the crane, or via conveyor onto the sorting/cutting/shearing table for size reduction. If rejected as high activity waste it would be transferred directly into a designated concrete/metal container for segregation. Size reduction of metallic pieces would be accomplished via hydraulically operated cutters and shears. To avoid any fire hazard, it is not expected that any thermal cutting torches would be employed within the module, but could be accomplished outside for unusually large pieces. Low activity contaminated metal having potential scrap value would be size reduced and efficiently packed into a separate metal receipt container for latter decontamination at a central treatment facility. All compactable types of waste including cloth, rags, paper, wood, plastics, rubber, cans, pails, buckets, etc would be placed on an evaluation table for further sorting and classification by workers in the second module.

The second *Compaction Module* addresses radiation measurement and recording, waste drying and shredding, and in-drum compaction of wastes. Workers in this area would not require full personal protection equipment (PPE), since all operations would be carried out via glove box or without need for direct contact with the waste. Wastes placed on the evaluation and sorting table from the Waste Receipt Module would be hand sorted and classified via the glove box. Some disassembly such as required with HEPA filters could be carried out to separate recyclable metal from compactable waste. Decisions would be made as to suitability for shredding and compacting. Further radiation assay would be conducted and logged as a record for the drum contents and maximum radiation loading. Compactable waste would be placed on a conveyor belt and fed to a drier and shredder. Fluff from the shredder would fall into a hold bin from which it could be augered or conveyed to the in-drum compactor as needed. The low force compactor would volume reduce the waste resulting in reduction ratios of 5 to 7 or more. Filled drums would be removed and temporarily stored for eventual transportation to a central processing facility for eventual super compaction and entombment in cement.

The third *Worker Service Module* provides the required worker dress out and control areas to limit contamination spread. Also, provided should be toilet and shower facilities and storage for PPE and personal radiation dose monitoring and measuring devices. All workers would enter and leave the facility through this module as standard procedure, although emergency exits would be available in the Waste Receipt and Compaction Modules. A knee high barrier would separate the "clean area" from the "controlled area" where change out of contaminated PPE would take place. Trash bins would collect contaminated clothing for processing through the Compaction Module with other compactable wastes.

Attached to the outside of one end of the Worker Service Module would be a power unit (gasoline or diesel) for either direct generation of heat and electric power (250 volt/50 Hz) or as a back up if primary power available on site is lost. On the other end would be a series of water tanks for holding clean supply water for toilet/shower/sink, sanitary waste water, decontamination solutions and hold tank for any suspected radioactive water as a result of emergency wash down and decontamination procedures.

Each module would be outfitted with its own separate HEPA air filtration system since radioactive contamination and corresponding regulatory requirements are expected to vary considerably between the three modules. These systems would maintain each module under slight negative air pressure to ensure no further release or spread of contaminants.

The foregoing description embodies the initial concept for the MPF and the required unit operations. More detailed Russian Technical Requirements have been developed that encompass the need in regards to applicable Russian codes and regulations. Currently, a competitive procurement is being released for the design and construction of the MPF. A selected vendor will further combine the concept and Technical Requirements into a working design, which will then undergo certification and licensing through Minatom, Gosatomnadzor and Gosstandart of Russia.

Phase III

Concurrently our Russian partners have begun work on the systems engineering assessment for the central waste processing facility. Systems engineering needs to consider not only the treatment of SRW, but the whole decommissioning through disposal cycle, which may include various side and liquid radioactive waste (LRW) streams and the operations at a number of shipyard facilities on the Kola Peninsula. The approach has been to first evaluate the applicability of commercially available technologies within Russia and then available globally to control costs. Although high technology approaches may result in elegant and perhaps more effective solutions, simplicity of operation is a key consideration in the harsh Arctic environment, and the balance between labor and automation costs needs to be considered to maximize budget resources. These facilities would be operated by Russian personnel due to the sensitive military nature of activities at the bases and shipyards.

The final waste form from the central facility of Phase III is expected to be a cemented or grouted material consisting of the LRW generated from the metal decontamination process and the super-compacted drum pucks. Project 1.4 has selected a coated concrete container to hold these grouted wastes. The compacted pucks would be packed into the concrete container, and the cemented LRW slurry poured around the pucks to fill the void space, harden, and completely encase and shield the waste inside of the concrete container. These filled containers would serve as a stable waste form and storage system, which eventually can be transported to and emplaced in a final repository. Design considerations for the processes and containers are being coordinated to ensure efficient and cost effective operations throughout.

AMEC PROJECT 1.4: WASTE STORAGE

The various activities of AMEC Project 1.4 all fit together to develop a self-sustaining storage system, in which the Russian Navy manages its radioactive waste safely and securely, as shown in Figure 4.

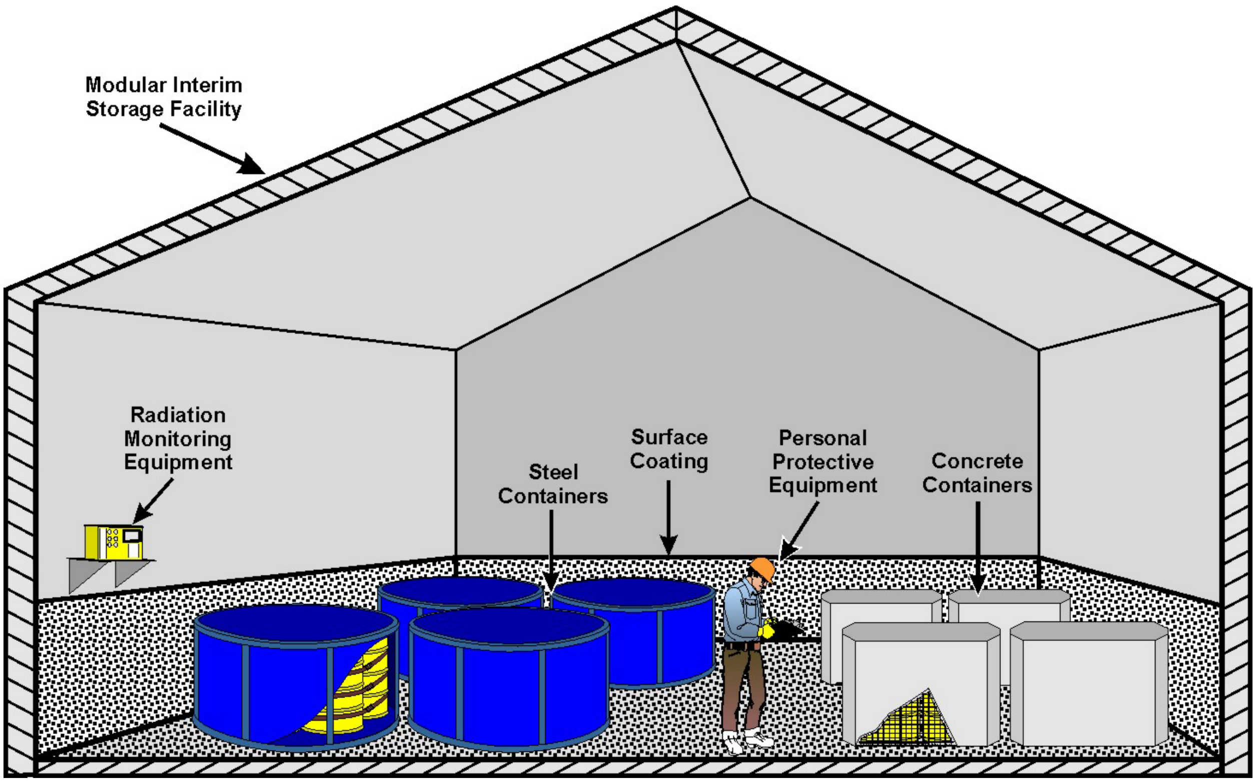

Figure 4. AMEC Project 1.4 Activities

Waste Storage Facilities

Our Russian partners have completed an SRW storage building. This facility will be primarily used to store old wastes that have been in the open air for years at Andreeva Bay. The storage facility has below-grade vaults with concrete lids and a 20-tonne bridge crane. The estimated Russian expenditure for this facility is $7.4 million, $800,000 of which has been provided since it was first proposed as an AMEC project.

Additional storage building(s) could be constructed in the 2002-2003 timeframe. The Project Officers are evaluating modular construction for these additional buildings. The design criteria for these buildings will include heavy snow loads, high wind loads, and low temperatures.

Coating Technology Demonstration

The coating material selected was Polibrid 705, a thermosetting elastomeric polyurethane supplied by Promatec Technologies, Inc. The chemical components and application equipment were shipped via air, barge, and truck to the RTP Atomflot facilities in Murmansk, Russia, arriving on May 25, 1998. The U.S. team followed, and, during the period June-August 1998, assembled and tested the equipment, and trained the Russian technicians. The Russians then sprayed a portion of the coating material on the concrete floor (Figure 5) of a loading bay of a radioactive waste handling building, an indoor passage in the same building, the external surfaces of a steel container, and 24 concrete and metal laboratory test coupons.

Figure 5. Coating Application

The coatings on the loading bay and indoor passage floors were exposed to the normal working environment over a period of one year and their conditions were monitored at regular intervals. The laboratory samples were taken to St. Petersburg where the coating material was subjected to a series of qualification tests. The Polibrid 705 coating demonstration was completed in August 1999 and the results were documented in the final report issued in September 1999. Based on this experience with the Polibrid 705 coating, it was recommended for the following purposes: application on concrete pads for interim storage, not subjected to intensive mechanical loading; application on floors and walls of personnel decontamination rooms; application on external monitored surfaces of floating and shore SRW management facilities; application on external surfaces of metal and concrete containers for SRW storage and transportation and application on the MPF under development in Project 1.3

Steel Containers

There is an acute shortage of high-quality certified containers for transportation and interim storage of SRW in Russia. To address this need, AMEC is sponsoring work on reusable containers made of steel. A request for proposals for certified steel containers was issued by the U.S. contractor in June 1999. Based on the tender results, a contract to

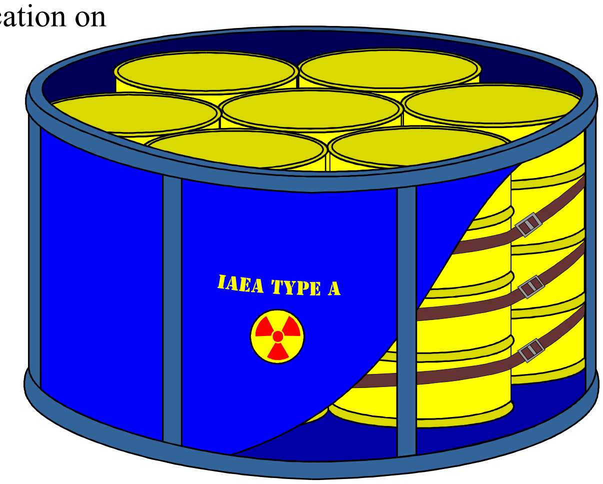

Figure 6. Steel Container

procure 100 containers has been signed with the Zvezdochka Shipyard in Severodvinsk, Russia, to be delivered to the Russian Navy this spring. These containers are intended for use as reusable transport containers meeting IAEA and Russian GOST standards. The containers will be large enough to hold seven standard 200-liter drums, as shown in Figure 6. The Project Officers plan to purchase more such containers in the next few years in order to develop a self-sustaining production capability in Russia.

Concrete Containers

AMEC Project 1.4 is also sponsoring work on single-use containers made of concrete, as shown in Figure 7. The objective of this task is to provide a long-term (up to 300 years) storage and handling package. It is also important that the concrete will be durable enough to satisfy the IAEA and Russian transport requirements for 50 years.

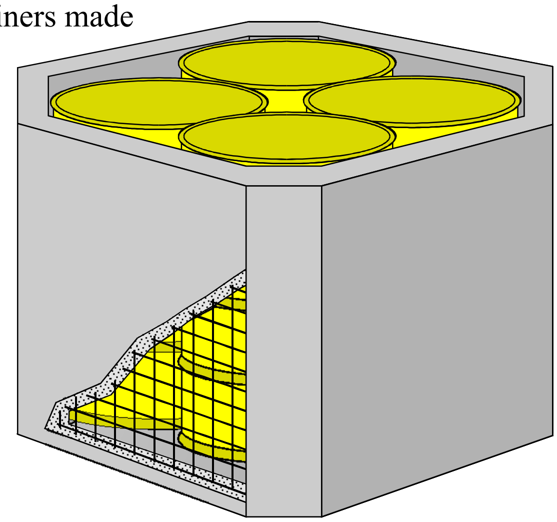

Figure 7. Concrete Container

Our Russian partners have finished the Technical Requirements for the concrete containers and begun the design process. The Project Officers have agreed to complete the design, and to fabricate ten prototype concrete containers for testing and certification. The Project Officers also plan to continue the work, including pilot production of sixty more containers. Serial production could start as early as late 2001, with several hundred units per year. The production rate could ramp up to over one thousand containers per year by 2003. This will allow the Russian Navy to put large volumes of radioactive waste in containers and thus minimize the spread of radiological contamination. With improved political and financial stability in Russia, the Project Officers estimate that the objective of a self-sustaining waste storage system in northwest Russia can be accomplished by 2003.

Radiation Monitoring Equipment

The objective of this task is to provide and install Russian-made radiation monitoring equipment that meets or exceeds all applicable Russian regulations and is at least consistent with Western standards for similar applications. For example the new waste storage building constructed by the Russian Navy at Andreeva Bay has no radiation monitoring equipment or alarms installed. This is not consistent with Russian or Western standards. Any new waste storage buildings that might be constructed under AMEC Project 1.4 will also need radiation monitoring equipment that meets Russian regulations and Western standards.

Personal Protective Equipment

The authors also plan to provide Western personal protective equipment to protect the workers from radioactive contamination. When the waste has surface contamination, handling it may lead to contaminated dust becoming airborne. Norway delivered some samples of personal protective equipment to the Russian Navy in June 1998. The Russian Navy evaluated this equipment during 1999 and stated that the two most useful items are protective/anti-contamination clothing with lining for cold weather and multiple-use full-face respirators. The project will therefore provide single-use disposable equipment for a limited test period as well as some multiple-use respiratory equipment and protective clothing in order to test the equipment's functionality relative to present equipment. A protocol defining the working conditions and procedures for application and/or decontamination will need to be developed in Russian.

CONCLUSION

The selected technologies will serve to support and enhance the Russian Navy's efforts to manage their SRW. This shift of practice from bulk, open-air storage to an approach that includes containerized waste placed in a facility with improved containment technology will be a challenge given the current Russian economy. With the trilateral cooperation of these projects, however, the waste will be treated and stored safely and securely.

REFERENCES

Griffith A., T. Engøy, A. Diashev, P. Schwab, A. Nazarian, and A. Ustyuzhanin, P. Moskowitz, and M. Cowgill, "Radioactive Waste Storage Technologies in the Arctic for the Russian Navy", Waste Management 99, February 28-March 4, 1999 in Tucson, AZ.

Griffith A., T. Engøy, and P. R. Schwab, "Solid Radioactive Waste Storage Technologies for the Russian Navy", Waste Management 98, March 1-5, 1998 in Tucson, AZ.

ICC Nuklide, "Designing and Creation of Systems of Processing of Solid Radioactive Waste (SRW), Obtained and Accumulated as a Result of Utilization of Russian Nuclear Submarines", Project 1.3 Internal Report, 1998.

Spargo, B., "Recommendations for Solid Radioactive Waste Processing Technologies", Project 1.3 Recommendation Paper, August, 1998.

ACKNOWLEDGEMENT

This work is funded tri-laterally by the U.S., Norway and Russian Federation under the Arctic Military Environmental Cooperation program. This work was also supported by the U.S. Department of Energy, Office of Environmental Management, under Contract Numbers DE-AC22-94PC92100, DE-AM26-99FT40575, and DE-AC21-96MC33241. The authors would like to thank Col. A. Diashev, the Russian Project Officer; Dr. T. Engøy, the Norwegian Project Officer; Gregory Polyanichko of WPI; Steinar Backe of the Institute for Energy Technology (Norway); and Mrs. Nina Yanovskaya and Dr. Lev Tchernajenko of ICC Nuklide (Russia) for their efforts in support of this project.