Remote Control

by Malgorzata K. Sneve

Russia's northwest coastline is dotted with hundreds of old and large radioactive sources. Known as RTGs, they mostly power remote lighthouses. Now the power packs are being safely dismantled. Norway is helping Russia do it.

Several hundred radioisotope thermoelectric generators (RTGs) are deployed along the Russian Federation's Arctic coast to power remote lighthouses and navigation beacons. Similar RTGs were also used as power sources in other remote locations in the Russian Federation and elsewhere in the former Soviet Union. All Russian RTG's have out-lived their lifespan and are in need of decommissioning. Radioactive incidents involving such sources, such as in Georgia, underscore the urgency of this task.

The RTGs typically contain one or more radionuclide heat sources (RHS) each with an activity of thousands of TBq of strontium-90. This means that they are Category 1 sources as defined in the IAEA international "Code of Conduct on the Safety and Security of Radioactive Sources". In fact they are among the largest single radioactive sources ever used.

According to the Federal Atomic Energy Agency of the Russian Federation (Rosatom), there are 651 RTGs at various locations in the Russian Federation which are subject to decommissioning or replacement with alternative sources of energy. In 1993, there were almost 200 RTGs in lighthouses in the Murmansk and Arkhangelsk regions of northwest Russia, relatively near the Norwegian border.

Due to the remoteness of these lighthouses, maintenance and security of RTGs is difficult to achieve. Most Russian RTGs are unprotected against intruders and there have been several examples of unauthorised interference. While there is no evidence of any intent to use the radioactive sources for malevolent purposes, there have been incidences of theft of shielding materials, presumably for their value as scrap metal, with the RHS being abandoned.

Naturally, concern has grown about the potential misappropriation of these radioactive sources as well as the broader issues of continuing maintenance and safe use of RTGs. This has become a matter of both national and international concern. The Norwegian Government has played a significant role in international efforts, fully cooperating with Russian authorities to safely decommission RTGs and provide alternative power sources.

Norway has actively supported improvement of nuclear safety and security in northwest Russia for more then ten years. Over this period, the Norwegian Government has spent approximately $150 million on a variety of industrial projects, including specific improvements in radioactive waste treatment and storage, physical security, and infrastructure support. The national authority, the Norwegian Radiation Protection Authority (NRPA), takes an active part advising the Government regarding prioritization and quality assurance of all these activities.

In addition, the Plan of Action places great emphasis on adequate regulatory supervision. Accordingly, the NRPA programme includes a variety of regulatory support projects. These are designed to assist the Russian authorities in ensuring that work is properly carried out within the framework of Russian law, taking into account international standards and recommendations from bodies such as the IAEA. The regulatory cooperation between NRPA and various Russian regulatory bodies is critical in maintaining an effective and efficient regulatory process.

Taking RTGs Out of Service: Industry Support

The Norwegian Government has been operating an industrial project to support decommissioning of RTGs in northwest Russia since 1997. Since project initiation, more than 60 RTGs have been removed from lighthouses on the Kola Peninsula. They are being replaced with solar panels and nickel-cadmium battery packs.

As part of this project, inspection and preparatory work took place before the RTGs were transferred by helicopter, boat and road to a temporary storage point at ATP "Atomflot" near Murmansk. The RTGs were then transported via road and rail to the dismantling point in the Moscow Region, where the heat sources (RHS) were removed. The RHS were then transported by road and rail to FSUE PA "Mayak", where they are stored pending final disposal.

While there are important security, environmental and radiological protection incentives for decommissioning RTGs (such as threats to the local environment, public safety, and possible misuse of the source of radioactive material), the decommissioning process is not without risks. Decommissioning itself could result in radiological and other environmental impacts and risks. In addition, the operational and regulatory responsibilities with respect to RTGs have evolved in the last few years, including changes from military to civilian control. It was necessary, therefore, to review the situation in order to weigh the associated risks.

The NRPA, in cooperation with Russian organizations, carried out a study to assess the environmental, health and safety consequences of decommissioning RTGs in northwest Russia. It was concluded that the decommissioning project should continue, since leaving the RTGs *in situ*, inadequately monitored, could lead to an undesired access to radioactive material.

It was also noted that the relevant authorities and organizations need to clarify their separate responsibilities throughout the entire process of inspecting, collecting, and dismantling RTGs, as well as the storage and disposal of radioactive waste so generated. Additionally, radiation protection guidelines should be reviewed and amended where necessary with correct procedures and checklists to ensure compliance. The need for regulatory support to help achieve this was recognised.

Regulatory Support

NRPA has provided support to regulators in the Russian Federation. The general goal of regulatory support is to help Russian bodies develop guidelines and require-

what is an RTG?

A Radioisotope Thermoelectric Generator (RTG) is a simple electrical generator which is powered by radioactive decay. In an RTG, the heat is released by the decay of a radioactive material and converted into electricity using an array of thermocouples. RTGs can be considered a type of battery and have been used as power sources in satellites, space probes and unmanned remotes facilities such as lighthouses. RTGs are usually the most desirable source for unmanned and unmaintained situations needing a few hundred watts or less of power for durations too long for fuel cells, batteries and generators to provide economically and in places where solar cells are not viable.

RTGs use a different process of heat generation from that used by nuclear power stations. Nuclear power stations generate power by a chain reaction in which the nuclear fission of an atom releases neutrons which cause other atoms to undergo fission. This allows for the rapid reaction of large numbers of atoms, thereby producing large amounts of heat for electricity generation.

Chain reactions do not occur inside RTGs, so a "nuclear meltdown" is impossible. In fact, RTGs are designed so that fission does not occur at all; rather, forms of radioactive decay which cannot trigger other radioactive decays are used instead. As a result, the fuel in an RTG is consumed much more slowly and less power is produced.

In spite of this, RTGs are still a potential source of radioactive contamination: if the container holding the fuel leaks, the radioactive material will contaminate the environment. To minimize the risk of the radioactive material being released, the fuel is stored in individual modular units with their own shielding.

Recovery mission in Georgia

Two abandoned and potentially dangerous radioactive devices have been successfully secured in the first three days of a summer 2006 campaign to trace lost radioactive sources in Georgia. Such abandoned sources are known as orphan sources.

A Georgian Ministry of Environment and IAEA team, scouring the isolated alpine region of Racha, found a powerful source in a pile of dirt on the floor of a derelict factory. The team also found a second smaller source inside a house—in a tin of nuts and bolts above a work bench. Just a thin, wooden wall separated the source from the family bedroom.

In the village of Iri, where the first source was located, background radiation levels were elevated 12 times above normal in the village centre.

"It could have resulted in serious injuries, or even death, if someone had picked it up and put it in their pocket for a period of time," said Carolyn Mac Kenzie, a radiation source specialist in the IAEA, who accompanied the start-up of the mission.

Villagers were shocked by the discoveries. "Of course no one had any idea it was here," said 14-year-old Salome Gagnigze, standing near the derelict factory in Iri as Georgian inspectors equipped with sensors combed the complex of ruined buildings.

An animal shelter is among the ruins but continues to be used as a place of storage for farmers. Neatly stacked bean poles stand a few metres from where the source was found.

In the second village, Likhaura, residents requested investigators to check their houses for possible sources after the discovery.

The radioisotope in both sources was caesium-137, a powerful gamma emitter, among the most common radioactive isotope in industrial use for instrumentation to check materials for flaws and for industrial measurements. New, powerful, backpack-mounted instrumentation with which the search team was equipped helped reveal and locate both sources.

Because records are not available, search team leaders said they had no clear knowledge of the origin of the sources. The first source may have been overlooked when the factory was abandoned—the second was presumably picked up and taken to the house where it was found. Both would originally have been contained in shielded containers.

As many as 300 radioactive sources have been recovered in Georgia since the mid-1990s and there has been at least one death and many injuries to the public as a consequence.

Among the most powerful orphan sources found have been unshielded strontium-90 sources that powered radioisotope thermoelectric generators (RTGs). Some RTGs, originally located in remote areas as stand-alone electrical generators, remain unaccounted for.

A legacy of Georgia's sharp economic decline after the break-up of the Soviet Union was a loss of control of radioactive sources used in industry. The collection and sale of scrap metal from abandoned factories has also provided a

ments for planning, licensing and implementing industry projects.

The NRPA's main partner in the RTG Regulatory Support Project (RSP) is the Nuclear, Industrial and Environmental Regulatory Authority of the Russian Federation (Rostechnadzor). However, it is important that all relevant organizations work together — for example, those organizations concerned with transport, operators and regulators from the Russian Federation and Western organizations. This is the "2 plus 2 approach." Russian and Western operators cooperate on the industry project, and Russian and Western regulators cooperate on licensing/approval of this industry project.

In order to provide the most relevant international inputs to Russian regulators, the NRPA involves regulators and technical support organizations from other countries, including France, Sweden and the UK.

Assessing the Threats

As a first step in the RSP, an Initial Threat Assessment was carried out to clarify the steps in RTG decommissioning and to identify priorities for regulatory action, based on the main radiological threats presented by each step. A series of steps were identified from the operator's inspection of RTGs at the point of origin through loading them means of livelihood and some orphan sources have been found in shipments of scrap. Many orphan sources have also been found on former military bases.

An added impetus to recovery operations is concern that some radioactive sources could be used for radiological dispersal devices (RDDs) if they fell into the hands of terrorists.

Since 1997 the IAEA has been working with Georgia to upgrade levels of radiation safety and to secure orphan sources. The latest search and recovery mission, funded by the United States through the IAEA's Technical Cooper-ation Program, scoured the mountainous region of Racha, about 300 km north-west of the capital Tbilisi, focusing on former industrial centres in the valleys of the Rioni River. It is the last area of Georgia to have gone unchecked for orphan sources.

But the problem of unaccounted for radioactive sources is not confined to Georgia, said Ms. Mac Kenzie. "Although there have been significant strides in improved security, there are frequent reports of incidents where sources go missing and accidents occur. This is a global problem, an indication that the control and management of radioactive sources still needs to be improved. Yet radioactive sources are an irreplaceable tool providing a huge benefit to society, in the practice of medicine, in industry and research."

The technical assistance provided by the IAEA to Georgia is part of its global effort to improve the security of radioactive sources and nuclear material. Georgia is nearing the final steps of commissioning a new secure storage facility where radioactive sources will be stored.

—Peter Rickwood, IAEA Staff Report.

Lerry Meski, a radiation specialist with the Georgian Ministry of Environment, inspects an abandoned factory where a powerful radioactive source was found during an IAEA-supported mission. (Photo: P. Pavlicek/IAEA)

onto the ship, placing them in temporary storage, transporting them via rail and road links to their final processing at FSUE PA "Mayak".

The risks associated with the steps must be addressed for each RTG. This is done through the preparation of a decommissioning plan, a safety analysis, and an environmental impact assessment (EIA), which should be developed for each RTG before work starts on decommissioning.

While there will be common features in the plans and assessments between different RTGs, plans should be tailored to take account of the specific characteristics of each RTG (location, history, condition, etc.) and the specifics of the decommissioning process for that RTG.

The physical form of the RHS is intended to make it very unlikely that significant dispersion or leaking of activity could occur—even under extreme conditions such as severe impact, intense fire, long-term immersion in water (e.g. in the sea) or explosion (presumably deliberate).

The primary radiological threat is direct exposure to radiation from the source in the event that shielding is removed or is no longer effective. The key operator must take actions to reduce the threats. These actions need to be systematically planned for all steps in the process and addressed in

RTG accidents

1999 Leningrad

An RTG was found ravaged by metal looters. The radioactive heat source (RHS) core was found emitting radioactivity at a bus stop in the town of Kingisepp. It was recovered.

2001 Kandalashka Bay, Murmansk region

Three radioisotope sources were stolen from lighthouses located in the area. All three RHS were found and sent to Moscow.

2001 Georgia

In December 2001, three woodsmen found two heat-emanating ceramic objects near their campsite in the remote Inguri river valley of Georgia. Two of the woodsmen involved in the accident carried the containers on their backs and experienced nausea, vomiting, and dizziness within hours of exposure. The third carried the source attached to a wire. At a hospital in Tbilisi, Georgia, the woodsmen were diagnosed with radiation sickness and severe radiation burns, and at least two of the three were in serious condition. A Georgian team recovered the sources in early 2002 with the assistance of the IAEA. They were the unshielded, ceramic sources of two Soviet-era RTGs each containing about 30,000 Ci of Strontium-90. Two of the victims were treated in hospitals in Paris and Moscow for many months before recovering from severe radiation burns.

2002 West Georgia

Three shepherds from the Tsalendzhikha region were exposed to high radiation doses after they stumbled upon a number of RTGs in a nearby forest. Shortly after the accident the IAEA established that, during the Soviet time, eight such generators altogether were delivered to Georgia.

2003 Cape Pihlissar, near Kurgolovo Leningrad region

An RTG was ravaged by metal scavengers and found 200 meters from the lighthouse, sunk in the shoals of the Baltic Sea. It was removed by a team of experts.

2003 Golets Island in the White Sea

The Northern Fleet service personnel discovered the theft of metal from an RTG-powered lighthouse on the small island of Golets. The door inside the lighthouse had been forced. The lighthouse contained a particularly powerful RTG with six radioactive heat sources, which were not taken.

Ref: The Bellona Foundation. These accident reports are drawn from a more comprehensive listing of accidents involving RTGs in the former USSR, Russia and the Commonwealth of Independent States.

the decommissioning plan and in the safety and environmental assessments.

Defining Tasks, Closing Gaps

Rostechnadzor has recognised that there is a need to upgrade the regulatory framework for the safe decommissioning and disposal of RTGs in the Russian Federation, taking account of the magnitude of the problem and the associated high hazards, as well as the lack of experience in this area.

The aim of the RSP is to upgrade the existing regulatory framework of the Russian Federation for the safe decommissioning and disposal of RTGs. The focus is on the following priority areas:

- Regulatory requirements based on the Initial Threat Assessment;
- Requirements for data, safety assessment and quality assurance;
- Supervision over radiological safety and security, including physical protection; and
- Requirements for emergency preparedness and response, based on environmental impact assessments made for each stage of RTG decommissioning.

Other areas of interest include preparation of an inspection handbook, training and certification of personnel, compliance monitoring; and providing information for the public.

The first task is to clarify the roles and responsibilities of the different organizations involved—particularly operators and regulators—with respect to the safety and security of RTGs. The aim is to ensure that there is clear allocation of responsibilities, consistent coordination of regulatory control and compliance requirements, effective transfer of responsibility at each stage in the overall management process and transparency within the Russian regulatory regime. There are gaps in these areas.

This task needs to address both the roles and responsibilities relating to RTGs *in situ*, but also those relating to the other stages involved in decommissioning. They include the transport of complete RTGs and RHS, the dismantling of RTGs, and the storage and ultimate disposal of RHS.

In addition, Rostechnadzor has responsibility for the regulation, control and supervision of all RTGs in Russian Federation, but the Defence Ministry is responsible for radiation and nuclear safety in military units. The Defence Ministry therefore has its own military nuclear regulatory body, and Rostechnadzor often does not have access to military sites with RTGs.

In line with the Code of Conduct requirement for a national register of Category 1 and 2 sources, the operating organizations are developing—through a parallel industrial project—a database containing comprehensive information related to each RTG. This includes their location, description, key characteristics (including size of radioactive source) and associated potential hazards. The database will also provide an assessment of vulnerability specific to each RTG. Based on analysis of information from this database, Rostechnadzor considers whether the types of data held are adequate for all locations and RTGs, and thus identifies gaps in information to be filled through the industrial project.

Another major task is to identify Russian Federation regulations relevant to the control of RTGs and to consider—taking into account international standards and recommendations and best practice in other countries—whether existing regulations need to be supplemented or modified and/or whether new regulations need to be developed. Again, this review needs to consider safety and security measures at the various stages of the RTG life cycle: use, recovery, transport, decommissioning, storage and disposal. Regulations identified through this process as 'missing' or requiring modification (and which fall within the remit of Rostechnadzor) will then be developed or modified.

Application and Enforcement

Once the basic regulatory infrastructure has been updated, it is proposed that further assistance will be provided in relation to some specific aspects of Rostechnadzor's role within the infrastructure.

Accordingly, support can be provided to Rostechnadzor in developing an assessment capability, independent of the operators, sufficient to perform its two main assessment functions for the various activities involving RTGs, namely:

- developing regulatory guidance for operators on conducting assessments that satisfy regulatory requirements for each stage of the RTG life cycle; and
- critically reviewing and evaluating safety and security assessments and EIAs submitted by operators in support of licensing and authorization applications at different stages, as a basis for regulatory decision-making.

While there are important security, environmental and radiological protection incentives for decommissioning RTGs, the process is not without risks.

Support is also provided to adapt inspection procedures, or develop new ones, to be applied to the various stages of an RTG's life cycle in accordance with the updated regulatory requirements. In addition an inspection handbook focusing on safety and security of RTGs is under development. This will provide a system for tracking and recording inspection findings and monitoring of the risks. The audit trail would ensure compliance with regulation and help promptly identify any irregularities, or potential problems.

Finally, support is provided for the development of regulatory guidance on requirements for emergency planning in relation to accidents or unauthorized actions involving RTGs at any stage of their life cycle, and to improve the capabilities of Rostechnadzor and technical support organizations to fulfil their functions in the event of such an emergency.

The Government of Norway continues to support the safe decommissioning of RTGs in northwest Russia. This involves close cooperation with Russian authorities and other countries supporting the wider programme on RTG decommissioning. So far about a third of the RTGs in the region have been removed with Norwegian support, and without incidents.

One lesson is clear: regulatory support is a vital adjunct to carrying out such industrial projects so that the whole process is safe and efficient for everyone involved.

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