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Environmental Impact Assessment of decommissioning radioisotope thermoelectric generators (RTGs) in Northwest Russia

Decommissioning radioisotope thermoelectric generators (RTGs) in Northwest Russia is a priority area under the Norwegian Ministry of Foreign Affairs Nuclear Action Plan. This NRPA Bulletin presents findings from a newly published NRPA Report that reviews environmental impact assessment (EIA) work undertaken as part of the joint Norwegian–Russian project to decommission RTGs in Northwest Russia.

Retired RTGs awaiting decommissioning on the Kola Peninsula (Photo: Office of the County Governor of Finnmark).

Environmental Impact Assessments (EIA)

In general, environmental impact assessment (EIA) is a process to predict the environmental effects of proposed initiatives before they are carried out:

- to identify possible environmental effects of proposed activities
- to propose measures to mitigate adverse effects
- predict whether there will be significant adverse environmental effects, even after the mitigation is implemented
- study alternatives to proposed activities and the likely environmental consequences of alternatives
- invite public participation in discussions about possible impacts
- conclude which activity is preferred and inform the public of this decision.

The main aims of EIAs are to minimize or avoid adverse environmental effects before they occur and to incorporate environmental factors into decision making processes. Here, adverse environmental effects are understood to be

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detrimental effects on local and distant human populations, fauna and flora.

The Russian regulatory framework

Information received about the Russian EIA process indicates that the regulatory requirements of the Russian and Norwegian systems are similar and accord generally with international practice (e.g., IAEA, 1996; JNREG, 2001).

The decommissioning process

The process of decommissioning the RTGs is carried out in several stages:

- an inspection and preparation of the RTGs *in situ* before transporting the RTG to Atomflot
- transferring the RTG by helicopter, boat and road to a temporary storage point near Murmansk.
- after temporary storage the RTGs are transported to the Moscow region
- RTGs are then transported by road and rail to VNIITFA by ARC Izotop
- the enclosed radionuclide heat source (RHS) is extracted from the RTG at VNIITFA, inside a special chamber.
- the enclosed RHS is then transported by road and rail from Moscow to Mayak PA, Ural.
- once at Mayak PA, the RHS containers are unloaded and the RHS is extracted from it's container for final storage.

RTG structure and properties

Briefly, an RTG is a radioisotope power device commonly used to provide electrical power to remote unmanned automatic systems such as lighthouses. Inside the RTG is a radionuclide heat source (RHS) that consists of one or several radioactive sources that decay, thereby generating heat which is transformed into electrical energy by a semiconductor thermoelectric converter (Figure 1).

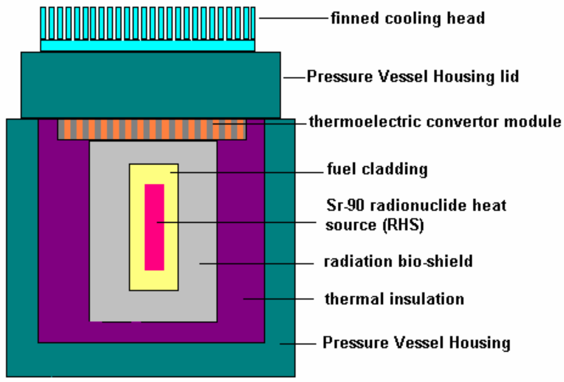

Figure 1*. Schematic illustration of a typical RTG*

The RTGs used in Russian lighthouses utilise the radioactive isotope ^{90}Sr (Strontium-90), a beta-emitter with a half-life of 29.1 years. The ^{90}Sr RHS consist of one or more compact, high-density solid fuel pellets, which are designed to be insoluble in both sea and fresh water, are non-combustible and very resistant to damage from fire. Together with the energy from ^{90}Sr radioactive decay, its beta-emitting daughter radioisotope, Yttrium-90 (^{90}Y is a radioactive by-product of ^{90}Sr decay and has a half-life of 64 hrs), also produces heat energy.

^{90}Sr and ^{90}Y emit beta particle radiation which does not penetrate far into exposed flesh, but may give very serious burns upon skin contact, depending on the strength of the source. X-rays, which can penetrate almost any material, are also emitted as bremsstrahlung when the beta radiation is absorbed in nearby materials. RTG cores (i.e., the RHS) are enclosed in a special capsule to reduce the radiation emissions (Figure 1). Radiation on the surface of an unshielded core can reach 10 Sv/h, which can provide a lethal dose to humans within half an hour of exposure.

The Russian RTGs have a lifespan of between 10 and 20 years and a maximum surface temperature of about 500 °C. Original RHS activities range from 740 TBq (20 kCi) to 14800 TBq (400 kCi), depending on the type of RTG. It is therefore critical to maintain the integrity of the RTG, during both normal operating conditions and under potential accident scenarios. RTGs are therefore designed with a multi-layer protective structure as illustrated in Fig. 1.

RTGs to be decommissioned

The current assessment covers the decommissioning of 23 RTG-powered lighthouses in the Northwest Russia. Nineteen RTGs were listed for decommissioning in 2004. Ten of these were in the White Sea region (15 RHS in total), while the rest were in the Barents Sea region.

Environmental status today

There are slightly elevated levels of radionuclides in the atmosphere and in both the marine, freshwater and terrestrial environments in the Barents Sea area. The elevated levels are mainly due to nuclear weapons tests, both in the atmosphere, in the sea, on the ground and underground. Levels peaked before 1980 and have decreased during the last 25 years, though the Chernobyl accident in 1986 lead to temporarily increased levels.

Environmental impacts related to normal decommissioning operations of RTGs

The different steps in the process in transporting RTGs from the operating site and to the disposal site have been described earlier. The dominant radioactive material used in RTGs is strontium-90 titanate. It is a chemically stable fuel element that is not affected by extreme weather conditions or high temperatures. It does not adhere strongly to soil particles or to sediment and potential radioactive contamination will most likely end up in the water phase. Being close to an intact RTG is considered a controllable health hazard as the radioactive material is well contained and shielded (AMAP, 2002). This conclusion has been verified by Russian scientists.

Decommissioning of RTGs using internationally accepted safe methods will not contribute to elevated levels of radionuclides in the environment or pose a threat to humans.

An RTG under helicopter transportation (Photo: Office of the County Governor of Finnmark)

Environmental impacts related to accidental releases

Three key accident scenarios have been studied:

1. Drop into sea
   1.1. RTG intact
   1.2. RTG partly or totally broken
2. Drop onto shoreline or in very shallow seawater
3. Drop onto or accident on land

Accidental releases to air

Accidental releases to air are unlikely to happen as the ^{90}Sr titanate RHS has a high melting point (~2060 °C) and a low evaporation rate. It is also stable when under conditions of burning / fire.

Accidental releases to soil

A dropped, or vandalized, RTG could in theory lead to exposure of the ^{90}Sr-titanate. It's very low dissolution rate (about 10^{-6} g/cm^2/day) gives negligible potential for major contamination, partly due to the fact that RTGs should be relatively easy to recover quickly once located on land.

Accidental releases to the sea

Two RTGs have been accidentally dropped during helicopter transport. Samples of sea water in the areas where these were lost have not shown any increased levels of ^{90}Sr (AMAP, 2002). In the very long term it is possible that sea water will penetrate the RTG such that local contamination could occur. This could result in accumulation of ^{90}Sr by sea organisms and finally be a potential source of doses to humans via seafood. Our independent assessment suggests that the low solubility of the RHS is not likely to result in large concentrations in edible marine foodstuffs.

Conclusions

As the ^{90}Sr heat source is well protected in a RTG of good stand it is deemed unlikely that a hypothetical accident connected to the planned decommissioning of RTGs will cause radiation exposures to the environment. If a breach to the RTGs multiple protective layers did occur during an accident, the resultant spreading of radioactivity will be very limited due to the low solubility of the ^{90}Sr titanate matrix. The ^{90}Sr titanate also has a high melting point, indicating that the risk of radioactive contamination due to fires is also negligible.

Considering the accident scenarios reviewed here, the likely worst-case for humans would be direct contact with an exposed ^{90}Sr heat source. However, in this instance it is also likely that the exposed RHS will be localised quickly and the proper authorities can then ensure the safe removal of the RHS.

The newly published NRPA report *"Assessment of environmental, health and safety consequences of decommissioning radioisotope thermal generators (RTGs) in Northwest Russia"* concludes that the decommissioning project should continue, as leaving the RTGs unmonitored and in situ could potentially lead to a risk of undesired access to radioactive materials. However, it is important to ensure that the relevant authorities and organisations are clear over their separate responsibilities throughout the entire process of inspecting, collecting, and dismantling of the RTGs, as well as storage and disposal of the radioactive waste generated from decommissioning. Radiation protection guidelines should be reviewed and amended where necessary with correct procedures and checklists to ensure compliance.

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