Issue Description

Committee: International Atomic Energy Agency

Issue of: Sustainable long-term solutions to nuclear waste allocation

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Introduction:

The operation and decommissioning of nuclear facilities and activities using radioisotopes in science, industry and medicine generate radioactive waste. Radioactive waste is hazardous to all forms of life and the environment, and is regulated by government agencies in order to protect human health and the environment. Therefore, it needs to be managed in a way that keeps people and the environment safe over long periods of time. The sustainable allocation of nuclear waste has been an issue of great importance in the past decades as radioactive waste can pose huge threats to human health, biodiversity and the environment, thus it is crucial to protect humans as well as the environment from the hazards caused by the inefficient and unsustainable allocation of such dangerous waste.

Definition of key terms:

Nuclear fuel cycle: The nuclear fuel cycle, also called nuclear fuel chain, is the progression of nuclear fuel through a series of differing stages. It consists of steps in the front end, which are the preparation of the fuel, steps in the service period in which the fuel is used during reactor operation, and steps in the back end, which are necessary to safely manage, contain, and either reprocess or dispose spent nuclear fuel.

Radioactive waste: Radioactive waste is waste that contains radioactive material. Radioactive waste is usually a by-product of nuclear power generation and other applications of nuclear fission or nuclear technology, such as research and medicine.

General overview:

Radioactive waste includes any material that is either intrinsically radioactive, or has been contaminated by radioactivity, and that is deemed to have no further use. Government policy dictates whether certain materials – such as used nuclear fuel and plutonium – are categorised as waste.

Although the amount of waste produced by nuclear power is relatively small, much of the waste produced is radioactive and therefore must be carefully managed as hazardous material. All parts of the nuclear fuel cycle produce some radioactive waste and the cost of managing and disposing of this is part of the electricity cost (*i.e.* it is paid for by the electricity consumers).

The fuel cycle involves the mining and milling of uranium ore, its processing and fabrication into nuclear fuel, its use in the reactor, its reprocessing (if conducted), the treatment of the used fuel taken from the reactor, and finally, disposal of the waste. Whilst waste is produced during mining, milling and fuel fabrication, the majority comes from the actual 'burning' of uranium to produce electricity. Where the used fuel is reprocessed, the amount of waste is reduced materially.

All toxic waste needs to be dealt with safely – not just radioactive waste – and in countries with nuclear power, radioactive waste comprises a very small proportion of total industrial hazardous waste generated.

Radioactive waste is not unique to the nuclear fuel cycle. Radioactive materials are used extensively in medicine, agriculture, research, manufacturing, non-destructive testing, and minerals exploration. Unlike other hazardous industrial materials, however, the level of hazard of its radioactivity diminishes with time.

Classification of radioactive waste:

The more radioactive an isotope is, the faster it decays. Radioactive waste is typically classified as either low-level (LLW), intermediate-level (ILW), or high-level (HLW), dependent, primarily, on its level of radioactivity.

Low-level waste:

Low-level waste (LLW) has a radioactive content not exceeding four giga-becquerels per tonne (GBq/t) of alpha activity or 12 GBq/t beta-gamma activity. LLW does not require shielding during handling and transport, and is suitable for disposal in near surface facilities.

LLW is generated from hospitals and industry, as well as the nuclear fuel cycle. It comprises paper, rags, tools, clothing, filters, *etc.*, which contain small amounts of mostly short-lived radioactivity. To reduce its volume, LLW is often compacted or incinerated before disposal. LLW comprises some 90% of the volume but only 1% of the radioactivity of all radioactive waste.

Intermediate-level waste:

Intermediate-level waste (ILW) is more radioactive than LLW, but the heat it generates (<2 kW/m^3) is not sufficient to be taken into account in the design or selection of storage and disposal facilities. Due to its higher levels of radioactivity, ILW requires some shielding.

ILW typically comprises resins, chemical sludge, and metal fuel cladding, as well as contaminated materials from reactor decommissioning. Smaller items and any non-solids may be solidified in concrete or bitumen for disposal. It makes up some 7% of the volume and has 4% of the radioactivity of all radioactive waste.

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High-level waste:

High-level waste (HLW) is sufficiently radioactive for its decay heat (>2kW/m^3) to increase its temperature, and the temperature of its surroundings, significantly. As a result, HLW requires cooling and shielding.

HLW arises from the 'burning' of uranium fuel in a nuclear reactor. HLW contains the fission products and transuranic elements generated in the reactor core and is contained within the used fuel. HLW accounts for just 3% of the volume, but 95% of the total radioactivity of produced waste. There are two distinct kinds of HLW:

– Used fuel that has been designated as waste.
– Separated waste from reprocessing of used fuel.

HLW is the focus of significant attention regarding nuclear power. In countries, which have adopted a closed cycle and reprocess used fuel, the fission products and minor actinides are separated from uranium and plutonium and treated as HLW. In countries where used fuel is not reprocessed, the used fuel itself is considered waste and therefore classified as HLW.

Nuclear reactors:

In the case of nuclear reactors, about 99% of the radioactivity is associated with the fuel. Apart from any surface contamination of the plant, the remaining radioactivity comes from 'activation products' such as steel components, which have long been exposed to neutron irradiation. Their atoms are changed into different isotopes such as iron-55, cobalt-60, nickel-63, and carbon-14. The first two are highly radioactive, emitting gamma rays, but with correspondingly short half-lives so that after 50 years from final shutdown their hazard is much diminished. Some caesium-137 may also be found in decommissioning wastes.

Some scrap material from decommissioning may be recycled, but for uses outside the industry very low clearance levels are applied, so most is buried and some is recycled within the industry.

Legacy waste:

In addition to the routine waste from current nuclear power generation there is other radioactive waste referred to as 'legacy waste'. This waste exists in several countries that pioneered nuclear power and especially where power programs were developed out of military programs. It is sometimes voluminous and difficult to manage, and arose in the course of those countries getting to a position where nuclear technology is a commercial proposition for power generation. It represents a liability which is not covered by current funding arrangements. In the UK, some £73 billion (undiscounted) is estimated to be involved in addressing this waste and about 30% of the total is attributable to military programs. In the USA, Russia and France the liabilities are also considerable.

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Non-power related nuclear waste:

In recent years, in both the radiological protection and radioactive waste management communities, there has been increased attention on how to effectively manage non-power related nuclear waste. All countries, including those that do not have nuclear power plants, have to manage radioactive waste generated by activities unrelated to the production of nuclear energy, including: national laboratory and university research activities; used and lost industrial gauges and radiography sources; and nuclear medicine activities at hospitals. Although much of this waste is not long-lived, the variety of the sources makes any general assessment of physical or radiological characteristics difficult. The relatively source-specific nature of the waste poses questions and challenges for its management at a national level.

Treatment:

Treatment involves operations intended to change waste streams' characteristics to improve safety. Treatment techniques may involve compaction to reduce volume, filtration or ion exchange to remove radionuclide content, or precipitation to induce changes in composition.

Conditioning:

Conditioning is undertaken to change waste into a form that is suitable for safe handling, transportation, storage, and disposal. This step typically involves the immobilisation of waste in containers. Liquid LLW and ILW are typically solidified in cement, whilst HLW is calcined/dried then vitrified in a glass matrix. Immobilised waste is then placed in a container suitable for its characteristics.

Storage:

Storage of waste may take place at any stage during the management process. Storage involves maintaining the waste in a manner, such that it is retrievable, whilst ensuring it is isolated from the external environment. Waste may be stored to make the next stage of management easier (for example, by allowing its natural radioactivity to decay). Storage facilities are commonly onsite at the power plant, but may also be separate from the facility where it was produced.

One of the problems with nuclear waste disposal that is still being discussed today is storage. Many different storage methods have been discussed throughout history, with very few being implemented, because of the problematic nature of storing such hazardous material.

Disposal:

Disposal of waste takes place when there is no further foreseeable use for it, and in the case of HLW, when radioactivity has decayed to relatively low levels after about 40-50 years.

The long timescales over which some ILW and HLW – including used fuel when considered a waste – remains radioactive has led to universal acceptance of the concept of deep geological disposal. Many other long-term waste management options have been investigated, but deep disposal in a mined repository is now the preferred option in most countries. The Waste Isolation Pilot Plant (WIPP) deep geological waste repository is in operation in the US for the

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disposal of transuranic waste – long-lived ILW from military sources, contaminated with plutonium.

To date there has been no practical need for final HLW repositories. As outlined above, used fuel may either by reprocessed or disposed directly. Either way, there is a strong technical incentive to delay final disposal of HLW for about 40-50 years after removal, at which point the heat and radioactivity will have reduced by over 99%. Interim storage of used fuel is mostly in ponds associated with individual reactors, or in a common pool at multi-reactor sites, or occasionally at a central site. At present there is about 250,000 tonnes of used fuel in storage. Over two-thirds of this is in storage ponds, with an increasing proportion in dry storage.

A current question is whether waste should be emplaced so that it is readily retrievable from repositories. There are sound reasons for keeping such options open – in particular, it is possible that future generations might consider the buried waste to be a valuable resource. On the other hand, permanent closure might increase long-term security of the facility. After being buried for about 1,000 years most of the radioactivity will have decayed. The amount of radioactivity then remaining would be similar to that of the naturally-occurring uranium ore from which it originated, though it would be more concentrated. In mined repositories, which represent the main concept being pursued, retrievability can be straightforward, but any deep borehole disposal is permanent.

Long half-life:

The products of nuclear fission have long half-lives, which means that they will continue to be radioactive for many thousands of years. Since hazardous nuclear waste is often not sent off to special locations to be stored, this means that it is relatively easy to find, and if anyone with ill intent were to look for nuclear waste to serve unpleasant purposes, they may well be able to find some and use it.

Effects on nature:

One of the biggest concerns regarding nuclear waste is its effect on human, plant and animal life. Although most of the time the waste is well sealed in drums of steel and concrete, leakages may occur, causing significant damage to the environment. Nuclear waste can cause cancerous growths or genetic problems for many generations to come.

Accidents:

Although guidelines are set for the safe disposal of radioactive waste, accidents still may occur. Throughout history there have been a number of examples to nuclear waste not being disposed in the proper way. These occasions had disastrous effects, as often water used by large populations of humans have got contaminated, as well. Even though bigger accidents happen quite rarely, their effects are huge, damaging many humans as well as the environment.

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Transportation:

Transporting nuclear waste from power plants may cause further problems. If poor shipping casks are used for the containment of radioactive material, a slight knock or bump or even crash could cause the contents to spill and affect a wide radius.

Previous attempts to solve the issue:

- Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management was adopted in 5 September 1997. It is the first international instrument that deals with the safety of management and storage of radioactive waste and spent fuel in countries with and without nuclear programs. ("The Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.")

- Convention on the Physical Protection of Nuclear Material is the only international legal binding that establishes measures related to the prevention, detection and punishment of offenses relating to nuclear material, which was adopted in 26 october 1979. The convention protects nuclear facilities and material in peaceful domestic use, storage as well as transport. ("Convention on physical protection of nuclear material.")

- Convention on Assistance in the Case of a Nuclear Accident and Convention on Early Notification of a Nuclear Accident or Radiological Emergency were adopted in 26 September 1986 after the disaster in Chernobyl, to provide assistance in case of an accident creating an international framework for support and cooperation. The convention made an international notification system that states the severity and any transboundary release of radiation for early precautions. ("Convention on Assistance in the Case of a Nuclear Accident and Convention on Early Notification of a Nuclear Accident or Radiological Emergency.")

- Commission on nuclear safety was adopted on June 17, 1994 aiming on establishing fundamental safety principles to maintain a high level of safety. This commission requires the parties involved to submit an annual report for discussion to the IAEA.

- Resolutions A/RES/64/45 (12 January, 2010) and A/RES/68/53 (5 December, 2013), in the topic of prohibition of dumping radioactive waste, were adopted by the General Assembly. Other programs include Integrated Review Service for Radioactive Waste and Spent Fuel Management, Decommissioning and Remediation (ARTEMIS) and Radioactive Waste Management Advisory Programme (WAMAP). ("Review Committee.")

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Possible solutions and approaches:

- The long timescales, over which some waste remains radioactive has led to the idea of deep disposal in underground repositories in stable geological formations. Isolation is provided by a combination of engineered and natural barriers (rock, salt, clay) and no obligation to actively maintain the facility is passed on to future generations.

- The radioactive waste from the Earth could be removed, for all time, by ejecting it into outer space. The waste would be packaged so that it would be likely to remain intact under most conceivable accident scenarios. A rocket or space shuttle would be used to launch the packaged waste into space.

- Liquid radioactive waste could be directly injected into a layer of rock deep underground that has been chosen because of its suitable characteristics to trap the waste (i.e. minimise any further movement following injection).

Bibliography:

- World Nuclear Organization, “Radioactive Waste Management”, April 2018
- Conserve Energy Future, “Dangers and Effects of Nuclear Waste Disposal”

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