(The Ghana Nuclear Power Programme Organization (GNPPO) is mandated with the task of coordinating, overseeing and administering the phase-to-phase implementation of the Nuclear Power Programme in Ghana until the commissioning of Ghana's first nuclear power plant.)

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GNPPO NEWSLETTER

RADIOACTIVE WASTE MANAGEMENT

BACKGROUND

Application of radioactive materials in the fields of medicine, industry, research and in the generation of electricity by nuclear fission provides significant benefits to society. However they generate radioactive waste materials that require management to ensure the protection of human health and the environment from the hazards associated with the waste materials. Radioactive waste also results from the processing of raw materials that contain naturally occurring radionuclides. The properties of these radioactive wastes vary, not only in terms of their radioactive content and activity concentration but also their physical and chemical properties. Radioactive waste may occur in liquid, gaseous or a solid form that may range from low radioactivity such as laboratory and medical waste, and certain mining waste to higher radioactive waste like spent fuel. Furthermore, radioactive waste may vary in volume from low volumes, such as spent radioactive sources, to large and diffuse volumes like tailings from mining. The fundamental safety objective in the management of radioactive waste is to protect people and the environment from harmful effects of ionising radiation and as a principle:

"Radioactive waste must be managed in such a way as to avoid imposing an undue burden on future generations; that is, the generations that produce the waste have to apply safe, practicable and environmentally acceptable solutions for its long term management" (IAEA Safety Fundamental Principle, 2006).

To achieve the objective of safe radioactive waste management requires an effective and systematic approach within a legal framework in which the roles and responsibilities of all relevant parties are defined. Radioactive Waste Management Policy and Strategy serve as a national commitment to addressing a country's radioactive waste issues in a co-ordinated and co-operative manner. In order to establish and operate a structured waste management scheme, it is of great practical value to classify the waste in a logical manner, according to the requirements on its handling and disposal. Several schemes have evolved for classifying radioactive waste according to the physical, chemical and radiological properties that are of relevance to particular facilities or circumstances.

WASTE ARISING FROM NUCLEAR POWER PLANTS

Nuclear power production gives rise to the generation of several kinds of radioactive waste, the most hazardous being the spent fuel (if it is declared waste) and other high level waste that is generated mainly from chemical reprocessing of spent fuel. In addition, very low level waste, low level waste and intermediate level waste are all generated as a result of reactor operations, reprocessing, decontamination/ decommissioning of nuclear facilities and other activities in the nuclear fuel cycle.

Adequate waste characterisation and protocols are essential for safety, regulatory and engineering purposes, particularly, for establishing the needed infrastructure in a waste management programme, and to facilitate recordkeeping and identifying potential hazards posed by various types of waste streams. The goal of characterising waste streams is to allow for estimation of radioactive inventory to support environmental safety and health provisions for work, and to properly assess packaging, transport and disposal for waste. This requires waste management processes that must be optimised, safe, compliant, minimised, characterised, classified, treated, packaged, transported, stored/disposed, cost effective and timely. Six classes of waste are derived and used as the basis for the classification scheme:

Exempt waste (EW): Waste that meets the criteria for clearance, i.e. it has been cleared from regulatory control, is not considered radioactive waste.

Very short lived waste (VSLW): Waste that can be stored for decay over a limited period of up to a few years and subsequently cleared for uncontrolled disposal, use or discharge.

Very low level waste (VLLW): Waste that does not necessarily meet the criteria of EW, but that does not need a high level of containment and isolation and, therefore, is suitable for disposal in near surface landfill type facilities with limited regulatory control.

Low level waste (LLW): Radioactive waste with only limited amounts of long lived radionuclides. Such waste requires robust isolation and containment for periods of up to a few hundred years, and is suitable for disposal in engineered near surface facilities.

Intermediate level waste (ILW): Waste that, because of its content, particularly of long lived radionuclides, requires disposal at greater depths, of the order of tens of metres to a few hundred metres.

High level waste (HLW): Waste with levels of activity concentration high enough to generate significant quantities of heat, or waste with large amounts of long lived radionuclides. Disposal in deep, stable geological formations, usually several hundred metres or more below the surface, is the generally recognised option for disposal.

Waste generated from routine operations includes contaminated clothing, floor s weepings, p aper a nd p lastic. W aste f rom p rocessing o f p rimary coolant water and the off-gas system includes spent resins and filters, as well as some contaminated equipment. Waste may also be generated from the replacement of activated core components such as control rods or neutron sources. These wastes are mainly VLLW or LLW, with small quantities of ILW. The LLW makes up around 90% of the volume of all radioactive waste from nuclear power plant operation, but constitutes only about 1% of the total activity. The ILW makes up some 7% of the volume and 4% of the radioactivity of all radioactive waste. These are mostly conditioned by solidification in cement (bitumen or polymers are other alternatives), using regular or specially formulated grouts. The process can be used to solidify liquid waste directly (sludge, concentrates) or to encapsulate solid waste (ashes, metallic components, compacted waste, etc.). The packages can be handled and stored in conventional warehouse type buildings. The necessary shielding of the packages during handling and storage is taken into consideration. Segregation of waste types and streams enhances application of clearance, delay and decay, and reuse/recycling principles, and combined with selection of effective treatment technologies, results in significantly decreased amounts of waste to be processed and disposed of. While management of raw waste is an integral part of a reactor complex, processing and predisposal storage facilities need to be constructed in parallel as a separate task. Figure 1 shows increasing levels of radioactive waste disposal for different classes of waste.

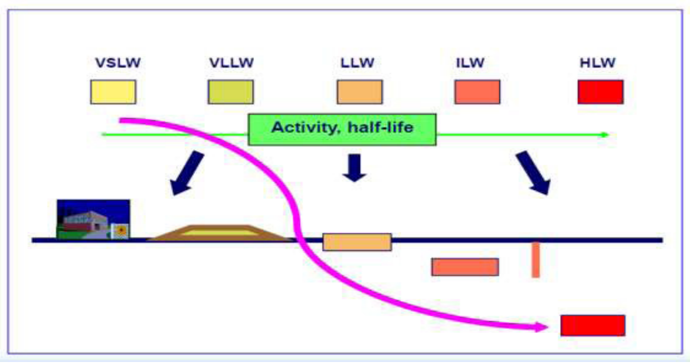

Fig. 1: Increasing Levels of Waste Isolation

Spent Fuel (HLW)

Fuel elements comprising pellets of ceramic uranium dioxide (UO_2) sealed within thin metal tubes form the reactor fuel and they are bundled together in a fuel assembly. The fuel becomes extremely radioactive, largely as a result of the formation of fission products in a nuclear reactor. After some years, the fuel must be removed from the reactor (spent fuel) and replaced. The removed spent fuel is normally stored under water for several years to allow cooling. The spent fuel can be reprocessed to get fresh fuel or transferred to longer term wet or dry storage before being encapsulated in preparation for emplacement in a geological disposal facility, if direct disposal is the chosen strategy. Spent fuel assemblies will be sealed into a metal canister for emplacement in a disposal facility. Spent fuel remains radioactive for long time. The quantities of spent fuel that are produced by modern nuclear reactors depend upon the reactor and fuel type and other technical parameters, operational history and the fuel burn-up (level of neutron irradiation of the fuel).

Waste from Decommissioning

Although decommissioning of a new nuclear power plant will start many decades after commissioning, it is important to have a decommissioning strategy from the outset, and to prepare estimates of the types and volumes of waste that will arise and will need to be disposed of. The activities involved in decontamination and dismantling of a nuclear facility and the clean-up of the site will lead to the generation of radioactive waste that may vary greatly in type, level of activity concentration, size and volume. This waste may consist of solid materials such as process equipment, construction materials, tools and soil. The largest volumes of waste from the dismantling of nuclear installations will mainly be VLLW and LLW, and can be disposed of like the operational waste. An exception involves some reactor internals with long lived radionuclides which are ILW that must be disposed of in a geological disposal facility. In most cases, the voluminous biological shield and all of the secondary plant either are short lived LLW or are so inactive that they are cleared as EW and can go to conventional disposal facilities.

WASTE MANAGEMENT OPTIONS

A waste management system/policy provides a framework / system for managing wastes from start up through decommissioning.

The system/policy should take into consideration, waste management options by addressing issues of appropriate technologies, designs, collection of waste (segregation and consequent clearance, recycling and/ or reuse) and processing of the remaining waste by employing efficient waste management technologies.

Managing HLW from Spent Fuel

Spent fuel gives rise to HLW which may be either the used fuel itself in fuel rods, or the separated waste arising from reprocessing the spent fuel. In either case, the amount (the volume) is modest – a typical reactor generates about 27 tons of spent fuel per year of vitrified waste. Both can be effectively and economically isolated, and have been handled and stored safely since the beginning of nuclear power plant operation. HLW generates a lot of heat and requires cooling. Storage is mostly in ponds at reactor sites, or occasionally at a central site. However, since HLW largely consists of uranium (with a little plutonium), it represents a potentially valuable resource and there is an increasing reluctance to dispose of it irretrievably. After 40-50 years of storage, the heat and radioactivity would have reduced to one thousandth of the level at removal. This provides a technical incentive to delay further action with HLW until the radioactivity has reduced to about 0.1% of its original level.

After storage for about 40 years the used fuel assemblies would be ready for encapsulation or loading into casks ready for indefinite storage or permanent disposal underground. Worldwide, about 90% of spent fuel is in storage ponds, much of it at reactor sites (smaller versions of that illustrated Figure 2).

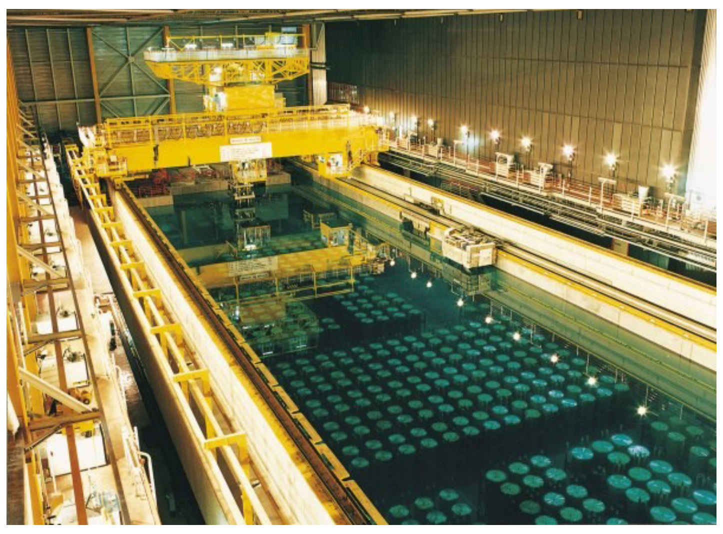

Fig. 2: Storage pond for used fuel at the Thermal Oxide Reprocessing Plant at the UK's Sellafield site (Sellafield Ltd)

Storage ponds at reactor sites, and those at centralised facilities such as CLAB in Sweden, are 7-12 metres deep, to allow several metres of water over the spent fuel. The circulating water both shields and cools the fuel. These pools are robust constructions made of thick reinforced concrete with steel liners. Storage ponds at reactor sites are often designed to hold all the used fuel for the life of the reactor. To ensure that no significant environmental releases occur over tens of thousands of years for final or permanent disposal of HLW, 'multiple barrier' deep repository geological disposal is the option. This immobilises the radioactive elements in HLW and some ILW and isolates them from the biosphere. Table 1 shows a summary of policy direction from various nuclear power operating countries.

Country	Policy
Belgium	Reprocessing
Canada	Direct disposal
China	Reprocessing
Finland	Direct disposal
Russia	Reprocessing
South Korea	Direct disposal, change possible
Spain	Direct disposal
Sweden	Direct disposal
Switzerland	Reprocessing
United Kingdom	Reprocssing
USA	Direct disposal but reconsidering

Managing Decommissioning Waste

It is increasingly expected that a decommissioning plan for a nuclear reactor is prepared by its designer and provided by a vendor before the start of operation. This necessitates producing estimates of the types and volumes of waste arising and deciding on end points for this waste. The amount and activity of waste depend on the selected decommissioning strategy (immediate or deferred action). Some reactors have been completely decommissioned and dismantled, with the sites released for unconditional use. The options for decommissioning nuclear power plants range from returning the site outright to a greenfield state through to entombing the structures for a hundred years or more in order to allow substantial decay of radioactive materials. The option chosen will depend on regulatory requirements, public and political opinion, and safety and economic considerations.

Disposal options for very low, low and intermediate level waste

Very low level waste and low level waste which consists largely of minimally contaminated clothing, machine parts and industrial resins, can be placed in containers and disposed of in trenches covered by soil. These wastes are less radioactive and might not require shielding during handling or transportation. However for radiation protection purposes, the waste can be isolated in engineered structures such as concrete lined trenches and vaults. Intermediate level waste, which includes reactor parts and contaminated equipment, is packaged in cement inside steel drums. In a similar way to low level waste, it can be safely disposed of in near surface facilities.

4. *Costs of Radioactive Waste Management*

Nuclear power is the only large-scale energy-producing technology which takes full responsibility for all its wastes and fully costs this into the product's financial provisions. The cost of managing and disposing of nuclear power plant wastes represents about 5% of the total cost of the electricity generated. Most nuclear utilities are required by governments to put aside a levy (e.g. 0.1 cents per kilowatt hour in the USA, 0.14 cent per kilowatt hour in France) to provide for management and disposal of their wastes. The actual arrangements for paying for waste management and decommissioning also vary. The key objective is however always the same: to ensure that sufficient funds are available when needed.

Regulation

The nuclear and radioactive waste management industries work to well-established safety standards for the management of radioactive waste. International and regional organisations such as the International Atomic Energy Agency (IAEA), the Nuclear Energy Agency (NEA) of the Organisation for Economic Co-operation and Development (OECD), the European Commission (EC) and the International Commission on Radiological Protection (ICRP) develop standards, guidelines and recommendations under a framework of co-operation to assist countries in establishing and maintaining national standards. National policies, legislation and regulations are all developed from these internationally agreed standards, guidelines and recommendations. Amongst others, these standards aim to ensure the protection of the public and the environment, both now and into the future. International agreements in the form of conventions have also been established such as the Joint Convention on Nuclear Safety and the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. Other international conventions and directives seek to provide for inter alia, the safe transportation of radioactive material, protection of the environment (including the marine environment) from radioactive waste, and the control of imports and exports of radioactive waste and transboundary movements

ENSURING SAFETY IN THE MANAGEMENT OF RADIOACTIVE WASTE FOR GHANA'S NUCLEAR POWER PROGRAMME

Ghana's nuclear power programme is divided into 3 Phases to address 19 different infrastructure issues including Radioactive Waste Management. In Phase 1 of the programme (Ghana is almost about to complete Phase 1), one condition is that the country develops an understanding and recognition of the requirements for management of radioactive waste from nuclear power plants. To address this condition, the GNPPO has developed a draft document on management of Spent Fuel and Radioactive Waste for a new nuclear power programme. This document outlines the nature and quantities of spent fuel and waste arising from the operation and decommissioning of a nuclear power plant and identifies options for management of different waste types. Gaps and any needed improvements in the legal and regulatory framework related to radioactive waste management will be addressed by the Nuclear Regulatory Authority. Currently arrangement have been put in place to review the existing "Policy and Strategy Guidance for Radioactive Waste Management" to come out with a more detailed radioactive waste management policy that will include radioactive waste from the nuclear power plants.

The other Phase 1 condition on radioactive waste management is whether the country understands the options for disposal of all radioactive waste categories. The GNPPO has developed detail understanding of the various options for disposal of radioactive waste and has documented them as "Management of Spent Fuel and Radioactive Waste for a New Nuclear Power Programme (Ghana)".

Further studies on technical options for the disposal of different waste types are currently ongoing. In addition, the GNPPO is studying the experience of other countries that are advanced in implementing disposal solutions.

Perspective

The fear of radiation health effects, particularly from severe accidents and radioactive waste, is central to public concerns about nuclear power activities. Nuclear wastes are a significant part of the nuclear power picture, and need to be managed and disposed of properly. However in more than 50 decades of civil nuclear power experience they have not caused any serious health or environmental problems, nor posed any real risks to people. Alternatives for power generation are not without challenges, and for a variety of reasons they – particularly those from coal combustion – have not always been well controlled. Managing nuclear power waste has distinct advantages as the quantities are remarkably small relative to the energy produced. The small quantities permit a confinement strategy, with the radioactive material, beginning with the nuclear fission process through to waste disposal, essentially isolated from the environment.