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Radioactive Waste Management

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Today one of the major challenges facing by mankind is to provide proper management for radioactive waste management. Any industrial activity results in generation of some waste material. Nuclear industry is no exception and the presence of radiation emitting radioactive materials which may have adverse impact on living beings and which is likely to continue to the subsequent generation as well is what sets nuclear or radioactive wastes apart from other conventional hazardous wastes. Another unique feature of the radioactive waste is the decay of radioactivity with time. This fact is gainfully exploited by the nuclear waste managers. The NRC regulates the management, storage and disposal of radioactive waste produced as a result of NRC-licensed activities. The agency has entered in to agreements with 32 states, called Agreement States, to allow these states to regulate the management, storage and disposal of certain nuclear waste. Any industrial activity results in generation of some waste material. Nuclear industry is no exception and the presence of radiation emitting radioactive materials which may have adverse impact on living beings and which is likely to continue to the subsequent generation as well is what sets nuclear or radioactive wastes apart from other conventional hazardous wastes. Another unique feature of the radioactive waste is the decay of radioactivity with time. This fact is gainfully exploited by the nuclear waste managers. The Department of Energy (DOE) is responsible for radioactive waste related to nuclear weapons production and certain research activities. The Nuclear Regulatory Commission (NRC) and some states regulate commercial radioactive waste that results from the production of electricity and other non-military uses of nuclear material. Various other federal agencies, such as the Environmental Protection Agency, the Department of Transportation, and the Department of Health and Human Services, also have a role in the regulation of radioactive material.

Keywords: Radioactive waste, Hazardous components, Recycle, Reduce, Reuse

INTRODUCTION

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. 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.

Radioactivity naturally decays over time, so radioactive waste has to be isolated and confined in appropriate disposal facilities for a sufficient period until it no longer poses a threat. The time radioactive waste must be stored for depends on the type of waste and radioactive isotopes. Current approaches to managing radioactive waste have been segregation and storage for short-lived waste, near-surface disposal for low and some intermediate level waste, and deep burial or partitioning/ transmutation for the high-level waste.

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A summary of the amounts of radioactive waste and management approaches for most developed countries are presented and reviewed periodically as part of the International Atomic Energy Agency (IAEA) Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. It is the first treaty to address radioactive waste management on a global scale in 1997.

Radioactive waste can be in gas, liquid or solid form, and its level of radioactivity can vary. The waste can remain radioactive for a few hours or several months or even hundreds of thousands of years. Depending on the level and nature of radioactivity, radioactive wastes can be classified as Exempt Waste, Low & Intermediate level waste and High Level Waste. Exempt wastes have levels of radioactivity too low to warrant any concern from the regulators. These can be disposed of to the environment and are not likely to cause any adverse impact.

The production of electricity by nuclear means has created radioactive residues, which have to be carefully managed and accounted for because they are potentially hazardous to human health. Similar residues have been generated as a result of the Defence Programmes in several countries. The residues include solid and liquid radioactive waste from civilian nuclear power production and from the production of nuclear weapons and residues from the above surface or underground testing of nuclear weapons.

INDIAN SCENARIO OF RADIOACTIVE WASTE MANAGEMENT

Management of radioactive waste in Indian context includes all types of radioactive wastes generated from the entire nuclear fuel cycle right from mining of Uranium, fuel fabrication through reactor operations and subsequent reprocessing of the spent fuel. Since the spent fuel is reprocessed with a view to recover and reuse the Uranium and Plutonium produced there, the fuel cycle is termed as ‘closed’, unlike in other countries like USA, Canada, etc. where the spent fuel is stored as waste.

Various units of the Department of Atomic Energy (DAE) provide fuel cycle and waste management services. Uranium Corporation of India Ltd., (UCIL), a public sector company of DAE, carries out mining and processing of uranium deposits surveyed by the Atomic Minerals Directorate of Exploration & Research (AMD) of DAE. Nuclear Fuel Complex (NFC), an industrial unit of DAE, utilizes the uranium concentrates supplied by UCIL to fabricate PHWR's (Pressurized Heavy Water Reactors) nuclear fuel assemblies. For the BWR's in Tarapur, NFC manufactures the fuel assemblies from imported uranium. NFC also supplies the required zircaloy components. Heavy water required for the initial charge and the Heavy Water Board of DAE supplies subsequent make-up requirements of the nuclear power plants.

Spent fuel from the PHWRs is reprocessed to extract the plutonium contained in it. Build up of plutonium inventory is vital for development of the second stage of the Indian nuclear power programme consisting of FBRs. The fuel reprocessing plants are set up by the BARC based on the technology developed by it. Power Reactor Fuel Reprocessing Plants at Tarapur and Kalpakkam are operational.

The primary objective of radioactive waste management is protection of human health, environment and future generation. The overall philosophy for the safe management of radioactive waste relies on the concepts of (i) delay and decay, (ii) dilute and disperse and (iii) concentrate and contain. Wide range of treatment and conditioning processes are available today with mature industrial operations involving several interrelated steps and diverse technologies.

TYPES OF RADIOACTIVE WASTE

According to the United States Nuclear Regulatory Commission more than 104 licensed nuclear facilities are located inside of the United States. These reactors total 20% of the energy consumption being used. There are five types of radioactive waste- high level, low level, intermediate level, mining and milling and transuranic waste. All types of nuclear wastes have their own separate storage and clean-up procedures.

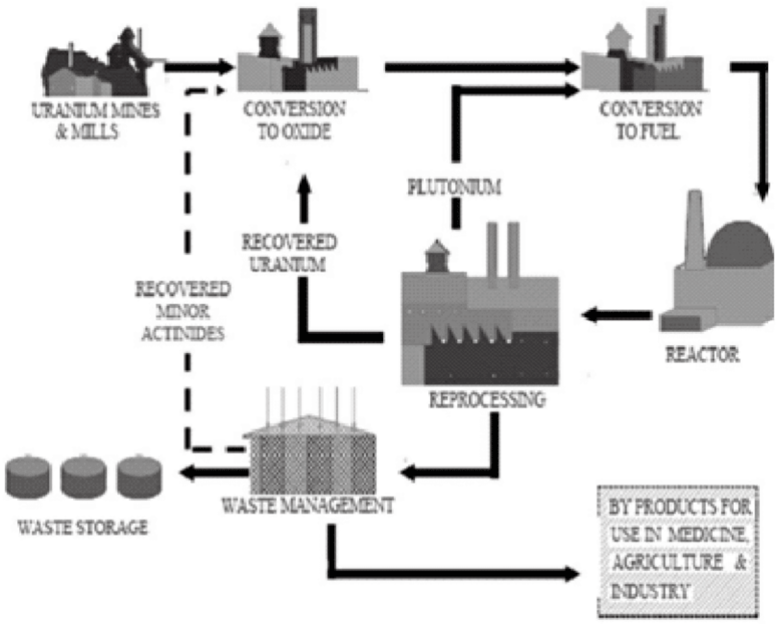

Figure 1: Nuclear Fuel Cycle

LOW AND INTERMEDIATE LEVEL WASTES

LIQUID WASTES

Low and intermediate level (LIL) liquid wastes are generated in relatively large volumes with low levels of radioactivity (few micro curie/l to millicurie/l). If a particular stream of radioactive liquid waste contains short-lived isotopes, it may be stored for adequate time period to ensure that majority of the radionuclides die down, thus, following the 'delay and decay' principles.

Low-level nuclear waste usually includes material used to handle the highly radioactive parts of nuclear reactors (i.e. cooling water pipes and radiation suits) and waste from medical procedures involving radioactive treatments or x-rays.

Depending on the nature of the waste, radionuclides present and level of contamination, the treatment scheme is chosen to concentrate bulk of the activity in a small volume and discharge the supernatant to large water bodies after further polishing and monitoring as per national and international standards. The discharges are only a small fraction of the allowed limits. The radioactive concentrate is conditioned and immobilized in highly durable matrices like cement, polymer, etc. fulfilling the objectives of 'concentrate and contain'.

SOLID WASTES

Significant quantum of solid LIL wastes of diverse nature gets generated in different nuclear installations. They are essentially of two typesas follows:

Primary Wastes: comprising of radioactively contaminated equipment (metallic hardware) spent radiation sources etc.

Secondary Wastes: Resulting from different operational activities, protective rubber and plastic wears, cellulosic and fibrous material, organic ion exchange resins filter cartridges and others.

Solid waste management plants in India are equipped with facilities for segregation, repacking, processing and embedment for radiation sources. Low active combustible wastes are incinerated and compactable wastes are reduced in volume by mechanical compaction.

The final packaged conditioned waste is then disposed off in near surface disposal facilities (NSDF), a few meters below the earth's surface. A multi barrier approach is followed in NSDF to ensure confinement and isolation of the wastes from biosphere. wastes which give out very low doses are disposed off in stone lined or brick-walled trenches, wastes having higher activity are disposed off in reinforced concrete trenches and tile holes. Special emphasis is laid on closure of such modules after it gets filled. These include appropriate closure such as clay for the stone lined trench and concrete cover for the other two. Provisions for monitoring and surveillance are also incorporated in the NSDF. Regular environmental monitoring ensures that radioactivity in air, water and soil in and around the disposal facility remains within the safe limits prescribed by the regulatory body. As a national policy, NSDF is co-located at each site of nuclear installations in India.

GASEOUS WASTES

The air in the working area and the environment is free from radioactive contamination. The off gas ventilation system in nuclear power plants play an important role in ensuring clean air. Radioactive gases and particulates carrying adsorbed radionuclides are the two pollutants in the gaseous waste. Various designs of scrubbers are deployed wherein off-gases are intimately contacted with suitable liquid media so as to retain the activity in the liquid phase. Specific adsorbersare also used to remove volatile radionuclides like iodine, ruthenium, etc. The off-gases are finally routed through high efficiency particulate air filters (HEPA) which are designed for an efficiency of >99.9% for sub micron size particles.

HIGH LEVEL WASTES

High-level radioactive liquid waste (HLW) containing most (~99%) of the radioactivity in the entire fuel cycle is produced during reprocessing of spent fuel. Planning for management of HL waste thus takes into account the need for their effective isolation from the biosphere and their continuous surveillance for extended periods of time spanning several generations. To meet this objective in the long term, waste isolation systems comprising multiple barriers are employed so as to prevent the movement of radionuclides back to the human environment.

Strategy for management of HLW takes into account the need for effective isolation from the biosphere and surveillance for extended periods of time spanning over future generations.

Thus the management of high-level liquid waste in the Indian context encompasses the following three stages.

1. Immobilization of high-level liquid waste into vitrified borosilicate glasses.
2. Engineered interim storage of the vitrified waste and other high level wastes with passive cooling and surveillance over a period of time, qualifying it for ultimate disposal.
3. Ultimate storage/disposal of the vitrified waste and other high active solid waste in deep geological repository.

India is one of the few countries to have mastered the technology of vitrification. Owing to the high radiation fields, various operations are carried out remotely in specially designed and state- of-the-art cubicles made of 1.5 meter thick concrete walls known as 'hot cells'. These hot cells are equipped with remote handling gadgets and systems. Some of the major remotisation gadgets include custom designed robots, remote welding units, remote inspection/surveillance devices and manipulators. Indigenous development of the remote handling equipment has been pursued in active collaboration with the Indian industries, academic and national institutions.

Development of glass matrix for HLW is interplay of its composition, specific glass additives and the processing temperatures. Solubility of the waste components and the decay heat limits maximum loading of waste into glass, though desirable. Glass forming additives should conform to chemical durability and acceptable processing temperatures. These processing temperatures are dictated by volatility of the specific radionuclide and compatibility of the melter material under corrosive environment of molten glass. Presence of certain chemical species like sulphate, aluminium, thorium, fluorine, platinum group metals, etc. in high level waste poses additional challenge for glass formulation development on account of their limited solubility/non-compatibility in glass composition. The vitrified products are evaluated for various properties like melt temperature, waste loading, homogeneity; thermal stability, radiation stability and chemical durability using advanced analytical instruments. The solidified waste form

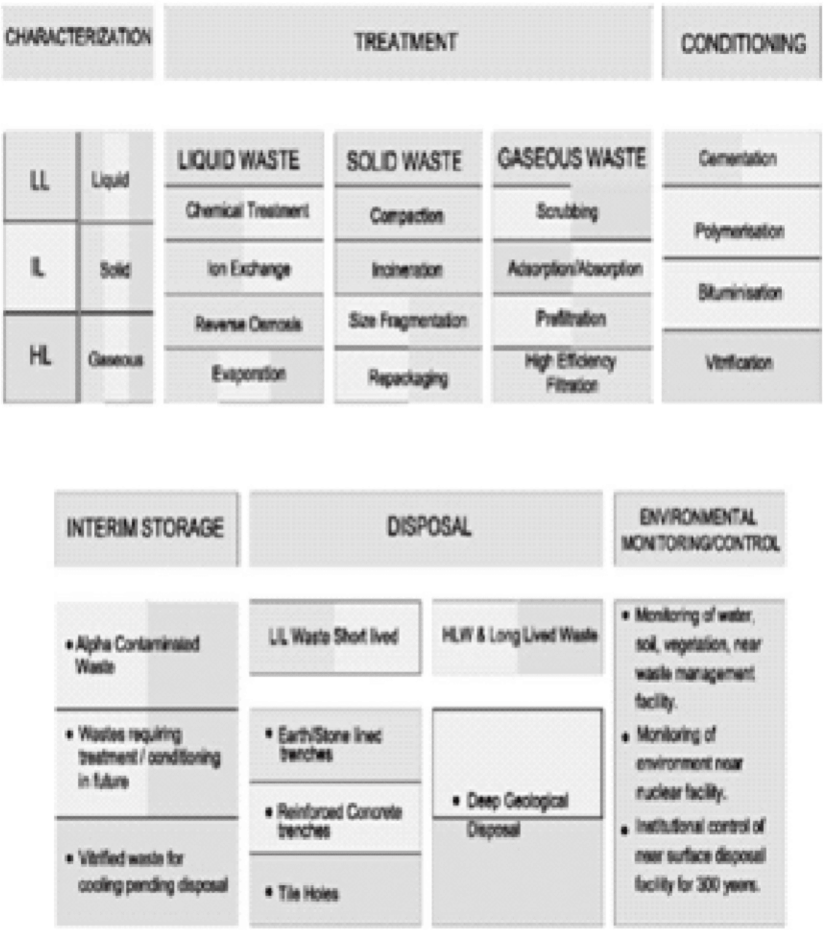

Figure 2: Summarizing of Nuclear Waste Management Practices

must also meet the criterion for its interim and long-term storage followed by its ultimate disposal in deep geological repository.

India has rich experience in operation of vitrification plants at Trombay and Tarapur. Figure shows the design of induction heated metallic melter operating at Trombay and the Joule heated ceramic melter operating at Tarapur. A third plant consisting of ceramic melter is nearing completion at Kalpakkam.

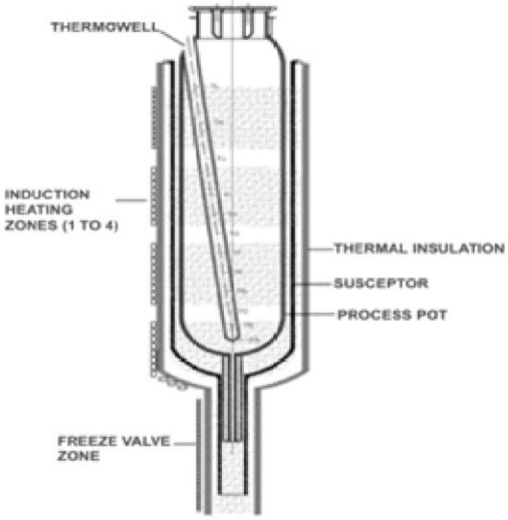

Figure 3: Design of POT Melter used for Vitrification of HLW

Cold crucible induction melting (CCIM) is emerging as the futuristic technology for the vitrification of high-level liquid waste at much higher temperatures. Besides being compact and advantageous as in-cell equipment, it offers flexibility to treat various wastes with better waste loading and enhanced melter life. Figure below shows the melting of glass in inactive engineering scale cold crucible at Trombay.

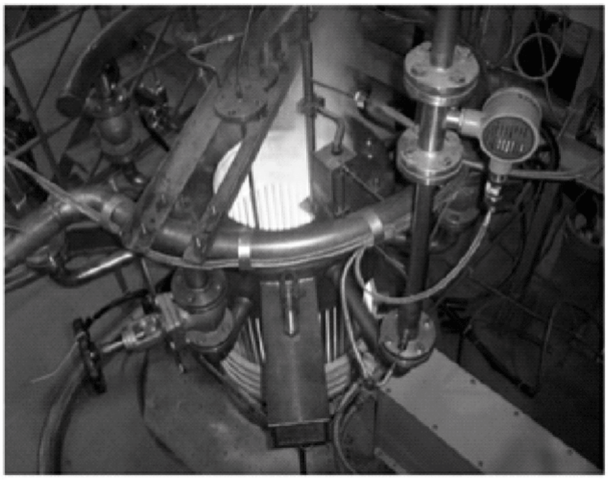

Figure 4: Glass melting in engineering scale cold crucible set-up.

On the basis of safety and detailed techno-economic considerations, natural draught air-cooling system has been designed for the storage vault. A solid storage and surveillance facility (SSSF) has been set-up at Tarapur for interim storage of vitrified high-level waste.

DEEP GEOLOGICAL DISPOSAL

Among the options considered for disposing of vitrified high level waste, international consensus has emerged that deep geological disposal is the most appropriate means for isolating such wastes permanently from man's environment. The basic requirement for geological formation to be suitable for the location of the radioactive waste disposal facility is remoteness from environment, absence of circulating ground water and ability to contain radionuclides for geological periods of time. India has wide spectrum of rock types especially those offering good potential as natural barrier for isolation and confinement of vitrified waste products. Granites, constituting about 20% of the total area of the country, could be the most promising candidates for deep geological repository. Even though the need for deep geological repository in India will arise only after a few decades, nonetheless, research and development work is in progress in the field of natural barrier characterization, numerical modelling, conceptual design and natural analogues of waste forms and repository processes. The overall safety against migration of radionuclides is achieved by a proper selection of waste form, suitable engineered barrier, back fill and the characteristics of the geo-environment of the site.

Backfills and buffer constitute most important components of multibarrier scheme adopted in a geological disposal system in hard rocks. These are placed as layers between the waste over pack and the host rock mainly to restrict the groundwater flow towards the waste form and to retard the migration of radio-nuclides to the biosphere in the unlikely event of their release from the over pack.

Model formulations, implementation and data are essential for safety assessment of disposal facilities under various scenarios. This is systematically assessed through predictive modelling of the gradual failure of the engineered barriers (i.e., the waste form, waste package, and backfill) and the subsequent transport to environment of radionuclides by circulating groundwater. Such safety assessments are based on a good physical understanding of the processes involved in the release and transport of radionuclides, and also those affecting the repository and the geological formation.

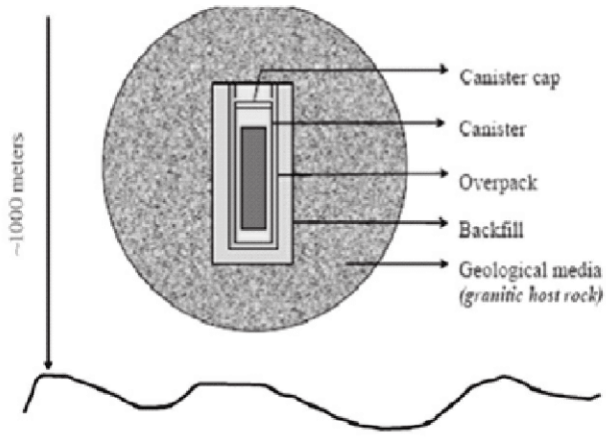

Figure 5: Schematic of Multi Barrier Disposal Concept

MINING AND MILLING

Tailings and waste rock are generates by mining and milling of uranium ore. The tailings material is covered with water and has the consistency of fine sand, when dried. It is produced by grinding the ore and the chemical concentration of uranium. After few months, the tailings material contains 75% of the radioactivity of the original ore.

Clean and mineralized waste rock is produced during mining activities which must be excavated to access to access uranium ore body. It has little or no concentration of uranium. While clean waste rock can be used for construction purposes mineralized waste rock could generate acid when left on the surfaced indefinitely that could affect surrounding environment.

TRANSURANIC WASTE

Transuranic waste, or TRU waste contains more than 3700 be per gram of elements. It is much heavier than uranium. This type of waste is produced through nuclear waste reprocessing procedures in most cases. This is one of the least worried about types of radioactive waste that is out there but it is worth mentioning since it is a part of nuclear waste.

RECYCLE AND REUSE

The need for resource utilization along with technological advancement has led to emerging scenarios of recycle options, which may also reduce the burden on future generation. Significant reduction in the potential radioactivity of the waste can be achieved through improved recovery and recycling of plutonium.

In the partitioning and transmutationtechnology, the long lived minor actinides (Np, Am, Cm) and fission products (129I, 99Tc, etc.) are isolated from the waste and transmuted by subjecting them to neutron bombardment whereby they either become non-radioactive or convert into elements with much shorter half-lives than the original. This transmutation may be achieved in Integral Fast Reactors (IFR) or Accelerator Driven Sub-critical Systems (ADSS), leading to either elimination or reduction of radioactive inventories. This would be a long-term strategy for themanagement of high-level waste and would provide both environmental and resource advantage.

FUNDING WASTE MANAGEMENT

Nuclear power is the only large-scale energy-producing technology that takes full responsibility for all its waste and fully costs this into the product. Financial provisions are made for managing all kinds of civilian radioactive waste. The cost of managing and disposing of nuclear power plant waste typically represents about 5% of the total cost of the electricity generated.

The actual arrangements for paying for waste management and decommissioning vary. The key objective is, however, always the same: to ensure that sufficient funds are available when they are needed. There are three main approaches:

- Provisions on the balance sheet. Sums to cover the anticipated cost of waste management and decommissioning are included on the generating company's balance sheet as a liability. As waste management and decommissioning work proceeds, the company has to ensure that it has sufficient investments and cashflow to meet the required payments.
- Internal fund. Payments are made over the operating lifetime of the nuclear facility into a special fund that is held and administered within the company. The rules for the management of the fund vary, but many countries allow the fund to be re-invested in the assets of the company, subject to adequate securities and investment returns.
- External fund. Payments are made into a fund that is held outside the company, often within government or administered by a group of

independent trustees. Again, rules for the management of the fund vary. Some countries only allow the fund to be used for waste management and decommissioning purposes, whilst others allow companies to borrow a percentage of the fund to reinvest in their business.

According to GE Hitachi, by 2015 funds set aside for managing and disposal of used fuel totalled about $100 billion (most notably $51 billion of this in Europe, $40 billion in the USA and $6.5 billion in Canada).

CONCLUSION

Radioactive waste disposal practices have changed substantially over the last twenty years. Evolving environmental protection considerations have provided the impetus to improve disposal technologies, and, in some cases, clean up facilities that are no longer in use. Designs for new disposal facilities and disposal methods must meet environmental protection and pollution prevention standards that are stricter than were foreseen at the beginning of the atomic age.Disposal of radioactive waste is a complex issue, not only because of the nature of the waste, but also because of the stringent regulatory structure for dealing with radioactive waste. India has achieved self-reliance in the management of all type of radioactive waste.In line with global scenarios, technologies are constantly upgraded for minimization of discharges to the environment.

RECOMMENDATIONS

Disposal volumes vary based on the chosen solution for waste disposal. In arriving at its estimate, the IAEA has made assumptions with respect to packaging and repository design for countries without confirmed disposal solutions based on the plans proposed by countries more advanced in the process. All hazardous waste requires careful management and disposal, not just radioactive waste. The amount of waste produced by the nuclear power industry is small relative to both other forms of electricity generation and general industrial activity. In over 50 years of civil nuclear power experience, the management and disposal of civil nuclear waste has not caused any serious health or environmental problems, nor posed any real risk to the general public. Alternatives for power generation are not without challenges, and their undesirable by-products are generally not well controlled. In addition to producing very significant emissions of carbon, hydrocarbon industries also create significant amounts of radioactive waste. The radioactive material produced as a waste product from the oil and gas industry is referred to as 'technologically enhanced naturally occurring radioactive materials' (Tenorm). In oil and gas production, radium-226, radium-228, and lead-210 are deposited as scale in pipes and equipment in many parts of the world.

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