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CHEMISTRY
M.Sc Sem-2
CC - V
Unit - V

A. Nuclear Waste Management
B. e-Waste Management
C. Recycling of Plastic

Radioactive Waste Management

(Updated February 2020)

- **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.**
- **The amount of waste generated by nuclear power is very small relative to other thermal electricity generation technologies.**
- **Used nuclear fuel may be treated as a resource or simply as waste.**
- **Nuclear waste is neither particularly hazardous nor hard to manage relative to other toxic industrial waste.**
- **Safe methods for the final disposal of high-level radioactive waste are technically proven; the international consensus is that geological disposal is the best option.**

Like all industries, the generation of electricity produces waste. Whatever fuel is used, the waste produced in generating electricity must be managed in ways that safeguard human health and minimise the impact on the environment.

For radioactive waste, this means isolating or diluting it such that the rate or concentration of any radionuclides returned to the biosphere is harmless. To achieve this, practically all radioactive waste is contained and managed, with some clearly needing deep and permanent burial. From nuclear power generation, unlike all other forms of thermal electricity generation, all waste is regulated – none is allowed to cause pollution.

Nuclear power is characterised by the very large amount of energy produced from a very small amount of fuel, and the amount of waste produced during this process is also relatively small. However, 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 internalised and paid for by the electricity consumers).

All toxic waste needs 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 all radioactive waste – its radioactivity – diminishes with time.

Types of radioactive waste

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.

Every radionuclide has a half-life – the time taken for half of its atoms to decay, and thus for it to lose half of its radioactivity. Radionuclides with long half-lives tend to be alpha and beta emitters – making their handling easier – while those with short half-lives tend to emit the more penetrating gamma rays. Eventually all radioactive waste decays into non-radioactive elements. 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 sludges, 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.

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. 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 has both long-lived and short-lived components, depending on the length of time it will take for the radioactivity of particular radionuclides to decrease to levels that are considered non-hazardous for people and the surrounding environment. If generally short-lived fission products can be separated from long-lived actinides, this distinction becomes important in management and disposal of HLW.

HLW is the focus of significant attention regarding nuclear power, and is managed accordingly.

Very low-level waste

Exempt waste and very low-level waste (VLLW) contains radioactive materials at a level which is not considered harmful to people or the surrounding environment. It consists mainly of demolished material (such as concrete, plaster, bricks, metal, valves, piping, *etc.*) produced during rehabilitation or dismantling operations on nuclear industrial sites. Other industries, such as food processing, chemical, steel, *etc.*, also produce VLLW as a result of the concentration of natural radioactivity present in certain minerals used in their manufacturing processes (see also information page on Naturally-Occurring Radioactive Materials). The waste is therefore disposed of with domestic refuse, although countries such as France are currently developing specifically designed VLLW disposal facilities.

Where and when is waste produced?

(See also information page on
The Nuclear Fuel Cycle
.)

Radioactive waste is produced at all stages of the nuclear fuel cycle – the process of producing electricity from nuclear materials. 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 and milling and fuel fabrication, the majority (in terms of radioactivity) comes from the actual 'burning' of uranium to produce electricity. Where the used fuel is reprocessed, the amount of waste is reduced materially.

Mining through to fuel fabrication

Traditional uranium mining generates fine sandy tailings, which contain virtually all the naturally occurring radioactive elements found in uranium ore. The tailings are collected in engineered dams and finally covered with a layer of clay and rock to inhibit the leakage of radon gas, and to ensure long-term stability. In the short term, the tailings material is often covered with water. After a few months, the tailings material contains about 75% of the radioactivity of the original ore. Strictly speaking these are not classified as radioactive waste.

Uranium oxide concentrate from mining, essentially 'yellowcake' (U_3O_8), is not significantly radioactive – barely more so than the granite used in buildings. It is refined then converted to uranium hexafluoride (UF_6) gas. As a gas, it undergoes enrichment to increase the U-235 content from 0.7% to about 3.5%. It is then turned into a hard ceramic oxide (UO_2) for assembly as reactor fuel elements.

The main by-product of enrichment is depleted uranium (DU), principally the U-238 isotope, which is stored either as UF_6 or U_3O_8. Some DU is used in applications where its extremely high density makes it valuable, such as for the keels of yachts and military projectiles. It is also used (with reprocessed plutonium) for making mixed oxide (MOX) fuel and to dilute highly-enriched uranium from dismantled weapons, which can then be used for reactor fuel (see pages on Uranium and Depleted Uranium and Military Warheads as a Source of Nuclear Fuel).

Electricity generation

In terms of radioactivity, the major source arising from the use of nuclear reactors to generate electricity comes from the material classified as HLW. Highly radioactive fission products and transuranic elements are produced from uranium and plutonium during reactor operations, and are contained within the used fuel. Where countries 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 (see below). In countries where used fuel is not reprocessed, the used fuel itself is considered a waste and therefore classified as HLW.

LLW and ILW is produced as a result of general operations, such as the cleaning of reactor cooling systems and fuel storage ponds, and the decontamination of equipment, filters, and metal components that have become radioactive as a result of their use in or near the reactor.

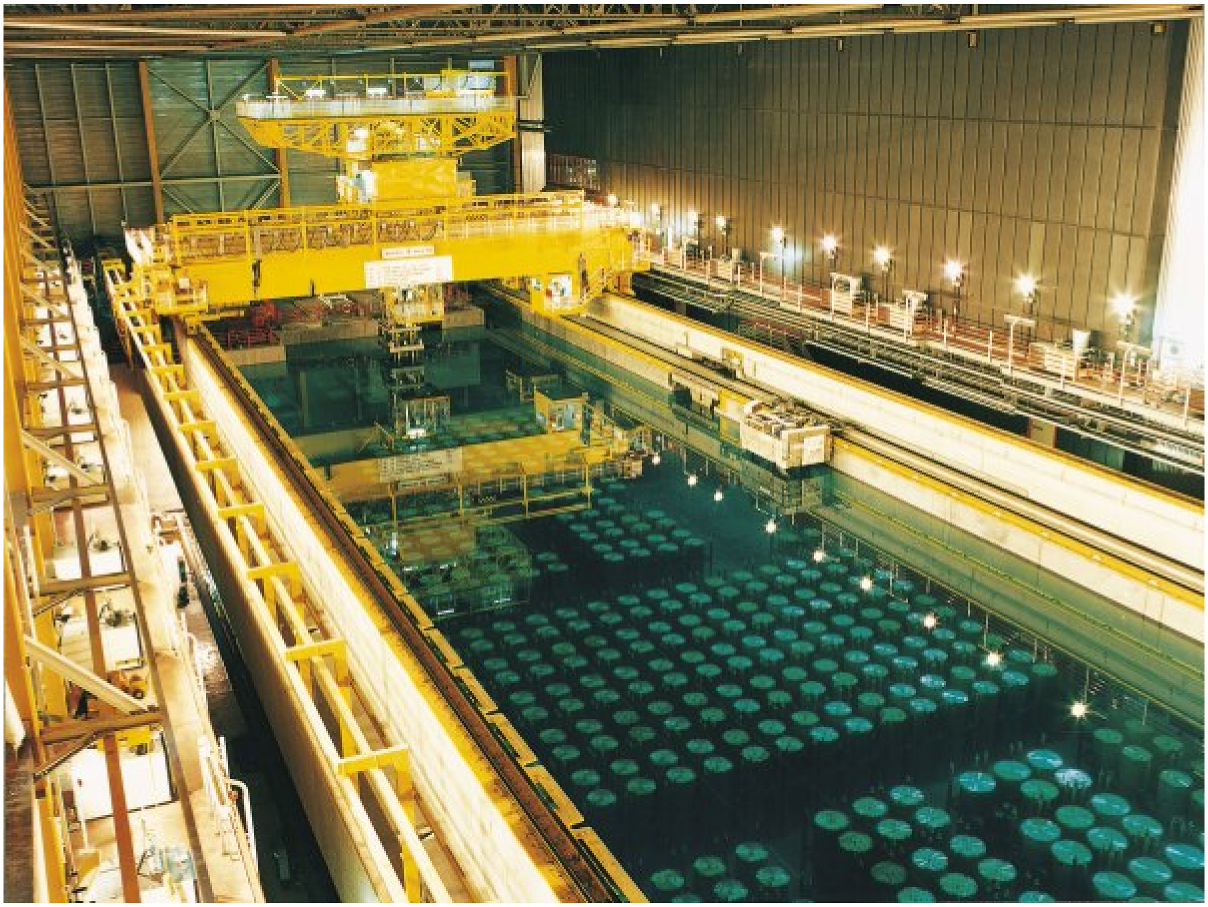
Reprocessing of used fuel

Any used fuel will still contain some of the original U-235 as well as various plutonium isotopes which have been formed inside the reactor core, and U-238. In total these account for some 96% of the original uranium and over half of the original energy content (ignoring U-238). Used nuclear fuel has long been reprocessed to extract fissile materials for recycling and to reduce the volume of HLW (see also information page on Processing of Used Nuclear Fuel). Several European countries, as well as Russia, China, and Japan have policies to reprocess used nuclear fuel.

Reprocessing allows for a significant amount of plutonium to be recovered from used fuel, which is then mixed with depleted uranium oxide in a MOX fabrication plant to make fresh fuel. This process allows some 25-30% more energy to be extracted from the original uranium ore, and significantly reduces the volume of HLW (by about 85%). The IAEA estimates that of the 370,000 metric tonnes of heavy metal (MTHM) produced since the advent of civil nuclear power production, 120,000 MTHM has been reprocessed.[1] In addition, the remaining HLW is significantly less radioactive – decaying to the same level as the original ore within 9000 years (vs. 300,000 years). (See also information pages on Mixed Oxide Fuel and Processing of Used Nuclear Fuel.)

Commercial reprocessing plants currently operate in France, the UK, and Russia. Another is being commissioned in Japan, and China plans to construct one too. France undertakes reprocessing for utilities in other countries, and a lot of Japan's fuel has been reprocessed there, with both waste and recycled plutonium in MOX fuel being returned to Japan. (See also information pages on Japanese Waste and MOX Shipments From Europe.)

The main historical and current process is Purex, a hydrometallurgical process. The main prospective ones are electrometallurgical – often called pyroprocessing since it happens to be hot. With it, all actinide anions (notably uranium and plutonium) are recovered together. Whilst not yet operational, these technologies will result in waste that only needs 300 years to reach the same level of radioactivity as the originally mined ore.



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

Decommissioning nuclear plants

(See also information pages on
Decommissioning of Nuclear Facilities
.)

In the case of nuclear reactors, about 99% of the radioactivity is associated with the fuel. Apart from any surface contamination of 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 £164 billion (undiscounted) is estimated to be involved in addressing this waste – principally from Magnox and some early AGR developments – and about 30% of the total is attributable to military programmes. In the USA, Russia, and France the liabilities are also considerable.

Non-nuclear power waste

E-Waste Management: As a Challenge to Public Health in India

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Introduction

In India, the quantity of "e-waste" or electronic waste has now become a major problem. Disposal of e-waste is an emerging global environmental and public health issue, as this waste has become the most rapidly growing segment of the formal municipal waste stream in the world.(1) E-waste or Waste Electrical and Electronic Equipment (WEEE) are loosely discarded, surplus, obsolete, broken, electrical or electronic devices.(2) In India most of the waste electronic items are stored at households as people do not know how to discard them. This ever-increasing waste is very complex in nature and is also a rich source of metals such as gold, silver, and copper, which can be recovered and brought back into the production cycle. So e-waste trade and recycling alliances provide employment to many groups of people(3) in India. Around 25,000 workers including children are involved in crude dismantling units in Delhi alone where 10,000–20,000 tonnes of e-waste is handled every year by bare hands. Improper dismantling and processing of e-waste render it perilous to human health and our ecosystem. Therefore, the need of proper e-waste management has been realized.(4) It is necessary to review the public health risks and strategies to combat this growing menace.

Burden of E-Waste

In India, solid waste management, with the emergence of e-waste, has become a complicated task. The total waste generated by obsolete or broken down electronic and electrical equipment was estimated to be 1,46,000 tonnes for the year 2005, which is expected to exceed 8,00,000 tonnes by 2012.(2) However, according to the Greenpeace Report, in 2007, India generated 380,000 tonnes of e-waste. Only 3% of this made it to the authorized recyclers' facilities. One of the reasons for this is that the India has also become a dumping ground for many developed nations. The Basel Action Network (BAN) stated in a report that 50-80% of e-waste collected by the USA is exported to India, China, Pakistan, Taiwan, and a number of African countries.(5) India is one of the fastest growing economies of the world and the domestic demand for consumer durables has been skyrocketing. From 1998 to 2002, there was a 53.1% increase in the sales of domestic household appliances, both large and small all over the world.(6) Another report estimated that in India, business and individual households make approximately 1.38 million personal computers obsolete every year,(7) accelerating the rate of e-waste generation, which is around 10%, annually(8) going to affect environmental health indicators.(9)

Health Impacts

Electronic equipments contain many hazardous metallic contaminants such as lead, cadmium, and beryllium and brominated flame-retardants [Table 1]. The fraction including iron, copper, aluminum, gold, and other metals in e-waste is over 60%, while plastics account for about 30% and the hazardous pollutants comprise only about 2.70%.(10) Of many toxic heavy metals, lead is the most widely used in electronic devices for various purposes, resulting in a variety of health hazards due to environmental contamination.(11) Lead enters biological systems via food, water, air, and soil. Children are particularly vulnerable to lead poisoning – more so than adults because they absorb more lead from their environment(12) and their nervous system and blood get affected. It is found that the e-waste recycling activities had contributed to the elevated blood lead levels in children living in China, which is one of the popular destinations of e-waste.(13) This was due to that fact that the processes and techniques used during the recycling activities were very primitive. Various studies have reported the soaring levels of toxic heavy metals and organic contaminants in samples of dust, soil, river sediment, surface water, and groundwater of Guiyu in China. In the same areas, the residents had a high incidence of skin damage, headaches, vertigo, nausea, chronic gastritis, and gastric and duodenal ulcers.(14) Further it was found that the blood lead levels of children were higher than the mean level in China, and there was no significant difference between boys and girls.(15)

EVERYTHING YOU NEED TO KNOW ABOUT RECYCLING PLASTICS

Plastic is one of the most popular and useful materials of modern times: we now use about 20 times more plastic than we did 50 years ago. Its popularity and widespread use is why handling it responsibly and correctly once it becomes waste is so vitally important. We can optimise the lifespan of plastics by re-using and recycling items as many times as possible.

Did you know?

- 99% of all UK local authorities now offer collection facilities for plastic bottles either through your household recycling collection or at recycling centres.

What about other plastics?

Mixed plastics packaging (trays, tubs, pots, films etc) can also be mechanically recycled, and it is both economically and environmentally effective to do so. Infrastructure for the collection, sorting and reprocessing of these valuable resources has increased in the UK in recent years.

Currently, 79% of councils collect other rigid plastic packaging such as pots, tubs and trays in household recycling collections.

Enter your postcode into Recycling Locator tool (//www.recyclenow.com/recycling-locator-0) to find out which plastics your council collects.

How is it recycled?

Plastics are:

- Sorted by polymer type
- Shredded
- Washed
- Melted
- Pelletised
- Made into new products.

It is a two-stage process:

- Sorting is mainly done automatically with a manual sort to ensure all contaminants have been removed

- Once sorted and cleaned, plastic can either be shredded into flakes or melt processed to form pellets before finally being moulded into new products.

Environmental impact

Plastic is a popular and highly versitile material, and we use a lot of it. Optimising the lifespan of plastics by re-using and recycling items as many times as possible, for example, by recycling used plastic bottles into new ones, we can therefore reduce our need to create new plastic.

This means we can:

- conserve non-renewable fossil fuels (oil)
- reduce the consumption of energy used in the production of new plastic
- reduce the amount of solid waste going to landfill
- reduce emission of gases like carbon dioxide into the atmosphere.

Problems and issues

There are many different types of plastic in use, some of which we can recycle in the UK and other types – including that used to make flexible pouches and black microwaveable trays – which will require new technology before we are able to recycle it effectively. This means that some plastic still goes to landfill, some is incinerated and some shipped abroad for recycling.

There are currently large investments being made in Britain to help our domestic plastic recycling sector cope with the variety of plastics in use and it won't be long before we operate a more efficient recycling system for all different types of plastic packaging.

In the meantime we can all do our bit to improve things now. Recycling plastic bottles is one easy way to help. They are usually made from two easily recyclable plastics – PET and HDPE – and can be recycled by most of us via our household recycling collections or local recycling centres.

Made from recycled

There is a wide range of products made from recycled plastic including:

- refuse sacks and carrier bags
- underground drainage systems for homes and national infrastructure
- flower pots, seed trays, watering cans and water butts
- wheel arch liners and bumpers on cars

- damp proof membranes, guttering and window profiles used in construction
- reusable crates and pallets
- wheel bins and food caddies
- composters and wormeries
- drinks bottles and food trays
- polyester fabric for clothing.

The different types of plastic

You may notice symbols on plastic packaging explaining the type of plastic they're made of and how to recycle them. Read Packaging symbols explained (//www.recyclenow.com/recycle/packaging-symbols-explained) for more information.

You may have seen an increase in businesses moving to different types of plastic packaging, but knowing your bio-plastics from your biodegradable plastics can be very confusing.

Plastic can be made from fossil-based or bio-based materials. Both can be used to make highly durable, non-biogradable plastics, or plastics which either biodegrade or compost.

Fact: Just because a plastic is made from bio-based sources, does not automatically mean it will biodegrade!

Only non-biodegradable plastic can be recycled, regardless of whether it is fossil-based or bio-based. Enter your postcode into our Recycling Locator tool (//www.recyclenow.com/local-recycling?rlw-initial-path=local-authority/search) to find out which plastics your council collects.

Compostable plastics can be composted at industrial scale composting facilities, so you can put these in with your green waste but **only if** it goes to one of these facilities - your council will be able to tell you where your green waste goes.

Some compostable plastics can also be home composted and should be clearly labelled if this is the case. **Compostable plastics should not go in with your dry recycling as they cannot be recycled in the same way as non-biodegradable plastic.**

Biodegradable plastics also cannot be recycled in the same way as non-biodegradable plastics. Some can be composted, but not all, and should be clearly labelled if this is the case.

Biodegradable packaging should be clearly labelled as such, and should not go in with your dry recycling.