National Inventory of Radioactive Materials and Waste 2012

The Essentials

ANDRA
Mastering radioactive waste

01 ISSUES AND PRINCIPLES OF THE MANAGEMENT OF RADIOACTIVE MATERIALS AND WASTE

WHAT IS RADIOACTIVE WASTE? RADIOACTIVE MATERIAL?

The use of the properties of radioactivity in various economic sectors produces waste, like any human activity.

A radioactive substance is a substance that contains radionuclides, natural or artificial, the activity or concentration of which justifies radiation protection.

Radioactive waste consists of radioactive substances for which **no further use** is planned or considered.

A radioactive material is a radioactive substance for which **further use is planned** or considered, after processing if necessary.

The large majority of radioactive waste is similar to conventional waste: tools, clothing, plastics, scrap metal, rubble, etc. However, it contains radionuclides which, because they emit radiation, constitute a health hazard. It cannot be managed in the same way as conventional waste, and needs special handling.

WHERE DOES THE WASTE COME FROM?

Radioactivity is used in many economic sectors. The five principal sectors are:

1 Nuclear power industry

Mainly nuclear power plants, along with fuel manufacturing and processing plants (mining and processing of uranium ore, chemical conversion of uranium concentrates, fuel enrichment and manufacturing, spent fuel processing and recycling).

2 Defence

Mainly activities related to deterrent forces and to nuclear propulsion of some ships and submarines, as well as defence research.

3 Research

Research in the field of civil nuclear power, laboratories for medical research, particle physics, agronomics, chemistry, etc.

4 Industry (apart from nuclear power)

Including rare earth mining, manufacturing of sealed sources and varied applications such as weld inspection, medical equipment sterilization and food product sterilization and preservation, etc.

5 Medicine

Treatment, diagnosis and research.

WHAT ARE THE DIFFERENT TYPES OF WASTE?

Radioactive waste generally contains a mixture of radionuclides (i.e. radioactive elements such as uranium, caesium, iodine, cobalt, radium, tritium). Depending on its composition, it is more or less radioactive, for a longer or shorter time.

DEFINITION

Radium-bearing waste, as its name suggests, contains radium. It is produced by:

- processing of minerals (rare earths, etc.);
- development of uranium mining methods by the CEA (French Atomic Energy Commission);
- the radium industry;
- clean-up of contaminated sites.

There are five categories of radioactive waste:

HLW	**High-level waste**	Mainly from spent fuel after processing. The level of radioactivity of this waste is of the order of several billion becquerels per gram.
ILW-LL	**Intermediate-level long-lived waste**	Also mainly produced by spent fuel processing. The radioactivity of this waste is of the order of one million to one billion becquerels per gram.
LLW-LL	**Low-level long-lived waste**	Mainly graphite waste from the first-generation natural uranium graphite gas reactors and radium-bearing waste. The radioactivity of the graphite waste ranges from ten thousand to several hundred thousand becquerels per gram. The radioactivity of the radium-bearing waste is between a few tens of becquerels per gram and a few thousand becquerels per gram.
LILW-SL	**Low- and intermediate-level short-lived waste**	Mainly produced by the operation and dismantling of nuclear power plants, fuel cycle facilities, research centres and, to a small extent, biomedical research activities. The radioactivity of this waste ranges from a few hundred becquerels per gram to one million becquerels per gram.
VLLW	**Very-low-level waste**	Mainly produced by the operation, maintenance and dismantling of nuclear power plants, fuel cycle facilities and research centres. The radioactivity of this waste is generally less than one hundred becquerels per gram.

FOR INFO

Some waste, mainly produced by the medical and research sectors, is very short-lived. It loses its radioactivity in a few years. It is therefore stored on the sites where it was used while its radioactivity decays, before disposal in a conventional waste disposal facility appropriate for its physical, chemical and biological characteristics.

DEFINITION

Storage consists in placing materials or waste temporarily in a purpose-built facility until they are recovered for recycling or disposal.

DEFINITION

Disposal consists in placing radioactive waste in a purpose-built facility designed to contain it under potentially permanent conditions.

HOW IS RADIOACTIVE WASTE MANAGED?

In order to isolate radioactive waste from people and the environment for the time necessary for its radioactivity to decrease and no longer constitute a hazard, France has chosen to manage radioactive waste, after interim storage, in dedicated repositories.

It is planned to manage radioactive waste in **three types of disposal facility with appropriate characteristics according to** the radioactivity level and lifetime of the waste:

> **surface repositories.** Andra operates two disposal facilities located in the Aube district for disposal of very-low-level waste (VLLW) and low-and intermediate-level short lived waste (LILW-SL);

> **the shallow repository;**

> **the deep geological repository.**

These two last repositories are currently being studied by Andra, in accordance with the prescriptions of the Planning Act of 28 June 2006, for high-level or long-lived waste (HLW, ILW-LL and LLW-LL).

Some waste is "legacy waste". It was classified when it was produced and placed in temporary storage. Before disposal, this waste will undergo detailed study and may be processed, and its management category might change. Moreover, some radioactive waste was managed using "historical" procedures (on-site disposal, sea-dumping, etc.) applicable at the time when it was produced.

02 INVENTORY OF MATERIALS AND WASTE AT THE END OF 2010

Andra compiles the inventory of radioactive waste and materials in France annually, on the basis of declarations from each holder, required to declare to Andra the stocks held on 31 December of the previous year. There are more than **one thousand holders, all economic sectors combined.**

The waste volumes obtained in this way are the volumes of waste once conditioned so that it can be stored and transported to the repository, constituting what is called primary package. Additional conditioning will be necessary in the special case of deep disposal for the purposes of handling, safety and reversibility. Only the volume of the primary packages is given in this document.

DEFINITION

Conditioning consists in embedding the waste in a container appropriate for its level of radioactivity and its lifetime, if necessary using an immobilizing material.

NOTE

At this stage of the deep geological repository design studies, the volume of the disposal packages is 2 to 3 times greater than the volume of the primary packages for HLW and 4 times greater for ILW-LL.

WASTE INTENDED FOR MANAGEMENT BY ANDRA

The tables and graphics below give the values resulting from the declarations made by the holders at the end of 2010 for waste already placed in the Andra repositories or intended for management by Andra.

Waste total volumes and volume changes

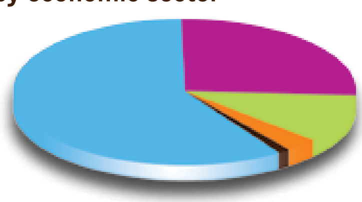
Category	Waste at end-2010 (m^3)	2007-2010 change
HLW	2,700	400
ILW-LL	41,000	- 800
LLW-LL	87,000	4,500
LILW-SL	830,000	37,000
VLLW	360,000	130,000
Total	**~1,320,000**	**~171,000**

Most of the differences observed between waste volumes at the end of 2007 and at the end of 2010 are due to routine waste production. The differences are also explained by:

> **optimization of the volume of the conditioning planned for sludge from La Hague,** leading to a reduction of the volume of ILW-LL;

IN FIGURES

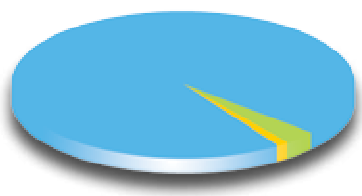
Volume breakdown by economic sector



Nuclear power industry	59%
Research	26%
Defence	11%
Industry (other than nuclear power)	3%
Medical	1%

IN FIGURES

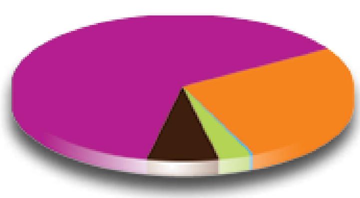
Radioactivity breakdown



HLW: ~ 2 x 10^{20} Bq	**96.8%**
ILW-LL: ~ 5 x 10^{18} Bq	**3.2%**
Other: ~ 10^{16} Bq	**< 0.01%**

IN FIGURES

Volume breakdown



HLW	**0.2%**
ILW-LL	**3.1%**
LLW-LL	**6.6%**
LILW-SL	**62.8%**
VLLW	**27.3%**

> **additional characterization of bitumen from Marcoule** enabling waste to be reclassified from ILW-LL to LLW-LL, leading to a reduction of the quantity of ILW-LL and an increase in LLW-LL;

> **increased volume of VLLW** produced during clean-up of engineered structures of facilities to be dismantled, as a consequence of reinforced clean-up target requirements.

WASTE MANAGED BY "HISTORICAL" MEANS

> **Uranium ore treatment residues** are disposed of on the mining sites. They amount to about 50 million metric tons (33 million m^3), on twenty sites. They are long-lived waste, with a level of radioactivity similar to that of VLLW.

> **Other waste has been disposed of in repositories not under Andra responsibility.** About 50 million metric tons has been identified, on some fifty sites: *in situ,* disposal sites, conventional waste repositories and certain mining sites. About 80% of this waste is waste with enhanced natural radioactivity, i.e. waste generated by conversion of raw materials containing radionuclides naturally but not used for their radioactive properties. This waste has very low activity but includes long-lived radioactive elements.

> **France** also **conducted two campaigns of radioactive waste sea-dumping** in the Atlantic Ocean, in 1967 and in 1969, totalling 14,200 metric tons of waste. In the context of the nuclear testing conducted by France in the Pacific Ocean, 3,200 metric tons of waste was also dumped at sea between 1967 and 1982.

RADIOACTIVE MATERIALS STORED AT THE END OF 2010

The holders of radioactive materials are also required to declare to Andra the materials stored on French territory.

Stocks of radioactive materials in inventory at the end of 2010 are summarized in the table below.

	Depleted uranium	Natural uranium	Enriched uranium	Recycled uranium	Spent fuel			Plutonium	Thorium	SM
					UOX	MOX	FNR			
Quantity (t)	272,000	16,000	3,000	24,100	17,000	1,700	200	80	9,400	23,500

DEFINITIONS

UOX: fuel composed of uranium oxide.

MOX: fuel composed of a mixture of uranium oxide and plutonium oxide.

FNR: fuel of the Phénix and Super Phénix fast neutron reactors; this may be UOX or MOX.

SM: suspended matter, by-products of processing of rare earths containing thorium.

03 FORECAST QUANTITIES OF RADIOACTIVE WASTE AT THE END OF 2020 AND 2030

THE LEGISLATION

Planning Act no. 2006-739 of 28 June 2006 on the sustainable management of radioactive materials and waste, and its implementation decrees.

The legislation requires holders to forecast waste production up to the end of 2020 and 2030, on the basis of assumptions specific to each economic sector. For example, for the nuclear power sector the following structuring assumptions are made:

> **an operating life of 50 years for all reactors:** this assumption has been made for the inventory because it reflects the strategic orientations of EDF with respect to extension of the operating life of the fleet; however, it does not pre-judge the decision of the authorities;

> **the processing of all the spent fuel,** corresponding to the current management policy.

Forecasts for the end of 2020 and the end of 2030

Waste volume (m³)	Forecast end-2020	Forecast end-2030
HLW	4,000	5,400
ILW-LL	45,000	49,000
LLW-LL	89,000	133,000
LILW-SL	1,000,000	1,200,000
VLLW	750,000	1,300,000
Total	**~1,900,000**	**~2,700,000**

COMPARISON OF FORECASTS BETWEEN 2007 AND 2010

Waste volume (m^3)	Forecast for the end of 2020 made in 2010	Forecast for the end of 2020 made in 2007
HLW	4,000	3,700
ILW-LL	45,000	47,000
LLW-LL	89,000	115,000
LILW-SL	1,000,000	1,000,000
VLLW	750,000	630,000
Total	**~1,900,000**	**~1,800,000**

Waste volume (m^3)	Forecast for the end of 2030 made in 2010	Forecast for the end of 2030 made in 2007
HLW	5,400	5,100
ILW-LL	49,000	51,000
LLW-LL	133,000	152,000
LILW-SL	1,200,000	1,200,000
VLLW	1,300,000	870,000
Total	**~ 2,700,000**	**~ 2,300,000**

The 2010 forecasts show changes from those made in 2007 (published in the 2009 edition of the national inventory). **These changes are consequences of:**

> **an increase in the annual spent fuel processing flow at the La Hague plant** (1,000 tHM instead of 850 tHM), resulting in increased volumes of HLW and ILW-LL;

> **taking into consideration a longer operating life of nuclear plants** (50 years instead of 40 years in 2007), resulting mainly in an increase in HLW, ILW-LL and LILW-SL;

> **better identification of the waste** that will be produced by dismantling, by further processing of legacy waste and by optimization of sorting, resulting for example in waste transfers from category ILW-LL to LLW-LL or LILW-SL and from category LILW-SL to VLLW;

> **the shift in the schedule for dismantling** of the natural uranium graphite gas series reactors, which delays the production of the associated LLW-LL (graphite waste);

> **an increase in the volume of VLLW:**

- the volume of VLLW produced during clean-up of engineered structures of facilities to be dismantled will be higher, as a consequence of reinforced clean-up target requirements,
- additional characterization leading to categorization as VLLW of waste previously considered suitable for disposal as conventional waste,
- waste in category LILW-SL is reclassified as VLLW following better identification or optimized sorting of this waste.

DEFINITION

tHM: ton of heavy metals, ton of uranium or of plutonium contained in the fuel before irradiation.

04 INVENTORY FORECAST

DEFINITIONS

UOX: fuel composed of uranium oxide.

MOX: fuel composed of a mixture of uranium oxide and plutonium oxide.

FNR: fuel of the Phénix and Super Phénix fast neutron reactors; this can be UOX or MOX.

tHM: ton of heavy metals, ton of uranium or of plutonium contained in the fuel before irradiation.

This section gives a prospective view of the waste and materials that would be produced by all the nuclear power plants up to the end of their life. These quantities are determined according to two deliberately contrasting nuclear power policy scenarios. This is not intended to pre-judge whatever will be decided in terms of French energy policy. The activity of economic sectors other than nuclear power is assumed to be the same in the two scenarios.

In both cases, **the inventory covers only waste produced by plants which were granted their licence by the end of 2010,** even though the "continuation" scenario assumes that new plants will be commissioned.

SCENARIO 1: CONTINUATION OF NUCLEAR POWER PRODUCTION

This scenario considers the continuation of nuclear electricity generation and of the present strategy with regard to spent fuel processing. It considers an operating life of 50 years for all reactors. All the fuel consumed by the reactors commissioned before the end of 2010 is assumed to be processed to separate the materials (uranium, plutonium) from the ultimate waste. No spent fuel is disposed of directly, and all the plutonium extracted from spent fuel is assumed to be recycled, in the current fleet or in a future fleet, in the form of MOX fuels. Given the number of reactors now authorized to use this type of fuel, the present nuclear power plant fleet will be capable of reusing separated plutonium until about 2029. Subsequently, the rate of processing of spent fuel, and consequently the production of plutonium, will depend directly on the rate of deployment of the new reactors that will consume it. **These spent fuels (UOX, MOX, FNR) from the existing fleet, up to the end of its life, would represent a total of about 30,000 tHM to be recycled.** Assuming that these operations are spread over 40 years, this would give an average annual processing flow of 700 to 1,000 metric tons of UOX and MOX fuel, resulting in an annual flow of 10 to 13 metric tons of plutonium.

SCENARIO 2: NON-RENEWAL OF NUCLEAR POWER PRODUCTION

This scenario assumes that the present nuclear fleet is not renewed, leading to shutdown of processing of spent fuel before the reactors are decommissioned, in order to avoid holding separated plutonium.

The operating life of the reactors is assumed to be 40 years. In this scenario, plutonium recycling is limited to the production of the MOX fuel necessary for operation of the reactors now authorized to use this type of fuel. In view of the shutdown dates for these reactors, their operation does not necessitate further plutonium separation by spent fuel processing beyond 2019. **In this scenario, about 28,000 tHM of spent fuel,** UOX, FNR and MOX, becomes waste and has to be disposed of (under the same conditions as HLW).

Estimation of waste produced by the two proposed scenarios

Waste		Continuation of nuclear power production	Non-renewal of nuclear power production
HLW	Spent UOX fuel	-	~ 50,000 assemblies*
	Spent FNR fuel	-	~ 1,000 assemblies*
	Spent MOX fuel	-	~ 6,000 assemblies*
	Vitrified waste (m^3)	10,000	3,500
ILW-LL (m^3)		70,000	59,000
LLW-LL (m^3)		165,000	165,000
LILW-SL (m^3)		1,600,000	1,500,000
VLLW (m^3)		2,000,000	1,900,000

The HLW and ILW-LL volume differences observed between the continuation scenario and the non-renewal scenario are a consequence of the different industrial strategies for spent fuel processing and of the different operating life of the plants considered in each scenario. The increase in LILW-SL and VLLW is due solely to the different operating life of the plants considered in each scenario.

MANAGEMENT OF RECYCLED URANIUM

In both scenarios, spent fuel processing also produces recycled uranium, a reusable material. Assuming maintenance of the present level of recycling (in the four reactors at Cruas until the end of their life), 40,000 metric tons of recycled uranium would remain in stock at the end of the life of the present fleet in the continuation scenario and 10,000 metric tons in the non-renewal scenario. In the second case, if it could not be reused in reactors outside France, the recycled uranium would become waste when nuclear power production stopped. However, complete consumption of this stock of material is technically possible in both scenarios. It assumes the production of fuel based on this recycled uranium which could, subject to the necessary administrative licences, be consumed in some or all of the existing or future reactors, in a similar manner to the recycling currently carried out at Cruas.

NOTE

* Today spent fuel is not considered to be waste, and is consequently not conditioned for management in disposal facilities. The average volume of a fuel assembly is 0.19 m^3 so, before conditioning, these assemblies account for a volume of 12,000 m^3. Andra verified the feasibility of disposal of spent fuel in 2005. The disposal container designs used for this demonstration resulted in a volume of disposal packages of about 89,000 m^3 (about eight times greater than the non-conditioned volume).

You can download the complete 2009 National Inventory
of Radioactive Materials and Waste
from the site **www.andra.fr**

The 2012 edition will be available from June 2012.

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