The Belgoprocess strategy for the managment of materials from decommissioning

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1 Purpose

Belgium started its nuclear programme quite early. The first installations were constructed in the fifties. Today, more than 55% of the Belgian electricity production is still provided by nuclear power plants. After 30 years of nuclear experience, the decommissioning of nuclear facilities was started in the eighties with two main projects: the BR3-PWR plant at the Belgian Nuclear Research Centre and the Eurochemic reprocessing plant.
Belgoprocess started the industrial decommissioning of the main process building of the former Eurochemic reprocessing plant in 1990, after completion of a pilot project. Two small storage buildings for final products of reprocessing were dismantled, decontaminated to background levels and demolished. The remaining concrete debris was disposed of as industrial waste and green field conditions restored [LT90]. In April 1998, Belgoprocess also started large scale decommissioning of obsolete facilities at the former waste treatment department of the Belgian Nuclear Research Centre (SCK-CEN).
The aims of the decommissioning projects are to limit radiation risks to the population according to the universal criteria of the ALARA principle, to bring the buildings into the non-nuclear category, i.e. to decommission up to a level where no controls on contamination and radiation are required any longer and the ventilation may be shut down, and to decontaminate the buildings completely in view of conventional demolition.
The paper highlights the specific Belgoprocess approach in this area. Belgoprocess is also the operator of the centralised waste treatment facilities and the interim storage for Belgian radioactive waste.

2 Methods and materials

2.1 Basic considerations

Some fundamental principles are considered for managing materials from the decommissioning of nuclear installations, mainly based on the guidelines of the IAEA-Safety Fundamentals with respect to radioactive waste management [IA95]. Two of the fundamental

principles indicated in this document are specifically dealing with the strategy for the management of materials from decommissioning: "Generation of radioactive waste shall be kept to the minimum practicable" (7th principle); "Radioactive waste shall be managed in such a way that it will not impose undue burdens on future generations" (5th principle).
The 5th principle is based on the ethical consideration that the generations that receive the benefits of a practice, should bear the responsibility to manage resulting wastes. An additional fundamental ethical principle can be added, stipulating conservation of primary resources for future generations.
Under the 7th principle it is indicated that "This (a set of measures) includes the selection and control of materials, the recycle and reuse of materials, ...". Advanced decontamination techniques may help to achieve this objective as decontaminated materials may be removed from the radioactive waste management system.
In a broader context, recycling of materials can be considered as a first order ecological priority to limit the quantities of radioactive waste to be disposed of, to reduce the technical and economic problems involved with the management of radioactive waste, and to make economic use of primary material and conserve natural resources of basic material for future generations. When analysing disadvantages and risks involved with a specific practice, it is recommended to consider the full life cycle of a practice, taking into account the disadvantages and the risks involved in the use of recycled materials, as well as the disadvantages and the risks involved in mining and conversion of new materials.
Based on these fundamental principles, Belgoprocess has made a straightforward choice for a strategy with minimisation of amount of materials to be managed as radioactive waste [LT99]. This objective is achieved using advanced decontamination techniques and the unconditional release of decontaminated materials. Unconditionally released materials are recycled, such as, i.e., metal materials that are removed to conventional melting facilities, or are removed to industrial disposal sites if they have no remaining value.
The selected techniques and equipment provide the required high degree of decontamination, while based on commercially available technology, and they meet the requirements about:

- *Safety*: application should not result in increased radiation hazards due to external contamination of workers or inhalation of radioactive dust/aerosols formed during its implementation.
- *Efficiency*: surface contamination should be removed to a level permitting recycle/reuse of the material.

- *Waste minimisation*: production of large quantities of secondary waste should be avoided, requiring excessive work power and costs for treatment and disposal, and cause additional exposure.
- *Cost-effectiveness*: decontamination costs should not exceed costs for waste treatment and disposal of the material.
- *Feasibility of industrialisation*: large quantities of contaminated materials are produced. The decontamination of these materials generally does not favour methods or techniques that are labour intensive, difficult to handle, or difficult to automate.

All tasks are carried out within the regulations for decommissioning activities and unconditional release of materials that are stipulated in a Royal Decree that was published on July 20, 2001.

2.2 Practical implementation of the Belgoprocess strategy

The practical implementation of the fundamental principles has been developed based on the following considerations:

- Keep the generation of radioactive waste to a minimum.
- Minimise the spread of radio-nuclides as much as possible.
- Optimise the possibilities for recycling and reuse of valuable components from existing and potential waste streams.
- Minimise the volume of the resulting radioactive wastes by applying adequate processing technology.

As an example, for concrete surfaces, where the contamination has not penetrated deeply, improvement in operational efficiency was achieved with dry hand held and automated floor and wall shaving systems [SB01]. These techniques use diamond tipped rotary disks, designed to give a smooth surface finish that is easier to monitor. They show a significant increase in efficiency and a 30% reduction in secondary waste production, and present less physical load on the operators due to the absence of machine vibration.

For dust-free decontamination of concrete, shavers were integrated into remotely and manually operated industrial systems that capture dust and debris at the cutting-tool surface, which minimises cross contamination. Industrial dust evacuation systems incorporate a cyclone to evacuate larger concrete particles and a filtering system with cleanable pre-filters and absolute filter.

It was also shown that it is economically interesting to decontaminate metal components to unconditional release levels using an automated industrial dry abrasive blasting installation as operated in the central Belgoprocess decontamination facility. Decontamination of metal components mainly requires the removal of a thin layer of structural material, which means that much more aggressive methods have to be used than during normal maintenance operations.

At the end of December 2002, after more than 7 years of operation, 602 Mg of contaminated metal has been treated. 182 Mg of this material was unconditionally released, having been measured twice by the in-house health physics department. About 420 Mg of the metal, presenting surfaces that could not be measured due to their shape, were packed in drums and melted for unconditional release in a controlled melting facility [RW01].
The suitability of the abrasive blasting system was verified. Impact of abrasives into the material surface, at the same time introducing contamination into the surface layer, was checked by means of two independent control actions on samples taken from the material. Contamination levels were monitored by non-destructive gamma measurements on samples before and after decontamination. In addition, chemical control monitoring was carried out by removing and dissolving surface material of samples after decontamination. A radiological characterisation of the chemical solution proved that there was no intrusion of contamination into the material surface.
The unit cost for decontamination proved to be less than 33 % of the cost for waste treatment, conditioning, storage and disposal [PL01].
At the end of 2002, after more than 3 years of operation, in the same installation, 237 Mg of contaminated concrete blocks were treated as well. 209 Mg of this material was unconditionally released, having been measured twice by the in-house health physics department. 28 Mg of concrete had to be removed as secondary waste.

Other materials such as heavy concrete, electrical cables and wooden pieces are decontaminated using techniques that are selected based on the type of material and the characteristics of the contaminants.
A specific approach was developed for taking representative samples and monitoring concrete material in view of the final demolition and unconditional release of the remaining structures of the various buildings after dismantling and decontamination.
For the small buildings in the pilot project, all concrete surfaces were monitored twice in view of unconditional release, and core samples were taken at the previously most contaminated places. For the remaining structures or larger buildings, this will result in a large number of samples to be taken and to be analysed. In addition, it will be very difficult or impossible to prove that these samples are representative for the remaining structures of the buildings. Though this methodology is not rejected as such, an alternative has been developed, considering at least one complete measurement of all concrete surfaces and the removal of detected residual radioactivity. This monitoring sequence is followed by a controlled demolition of the concrete structures and crushing of the resulting concrete parts

to smaller particles. During the crushing operations, metal parts are separated from concrete and representative concrete samples are taken, the frequency of sampling meeting the prevailing standards. In a further step, the concrete samples are milled, homogenised and a smaller fraction is sent to the laboratory for analyses.
After approval of the licensing documents, operations of the facility were started in June, 2001 [SB01]. At the end of December 2002, after 17 months of operation, 1,500 Mg of concrete were monitored. All this material could be unconditionally released and removed from site after analyses and agreement by the in-house health physics department and the authorities. The material is further used in conventional road construction.

Finally, contaminated materials that are not subject to the waste minimisation techniques as discussed before, have to be considered as radioactive waste. The final objective in waste minimisation during decontamination and decommissioning is to ensure that those volumes of remaining radioactive materials that cannot be released are reduced in volume as far as practicable. The methods for processing, conditioning, packaging, handling, storing, transporting and disposing of radioactive waste arising from decommissioning are in general similar to those used in other parts of the nuclear industry. Waste forms and packaging have to comply with national transport regulations, with the acceptance criteria at the centralised national waste processing facilities, and with the specifications of predefined, but not yet available disposal sites.
In general, radioactive waste from decommissioning is pre-treated to facilitate subsequent waste processing at the centralised waste treatment facilities. Pre-treatment steps comprise:

- Administrative steps, including documentation of waste details for accountability and operational purposes, with reference to specifications that are defined on a national basis.
- Segregation and sorting of wastes for suitable treatment.
- Decontamination for de-categorisation if economical interest.
- Packaging in bags/200 l-drums, suitable for transport to and for handling in the nationally centralised processing facilities.

Solid low and intermediate level waste is segregated into incinerable, compactible and non-compactible waste. Incineration of combustible waste results in a large overall volume reduction, and produces a stable waste product (ash) that can be immobilised using cement as a matrix. High force compaction is used to get acceptable volume reduction factors for waste material that cannot be incinerated. After processing, immobilisation of remaining material in 400 l-drums is mainly done using cement as a matrix.

3 Results

The total contaminated material production from decommissioning activities carried out by Belgoprocess from 1990 till the end of 2002 at the Eurochemic reprocessing plant and the former waste treatment facilities of the Belgian Nuclear Research Centre, is indicated in table 1. The figures clearly show the results of the Belgoprocess approach.

Table 1 Material production from decommissioning activities at the Eurochemic reprocessing plant and the former waste treatment facilities of the Belgian Nuclear Research Centre

	Metal		Concrete		Heavy concr.		Other material		Total	
	Product. (kg)	Free (%)	Product. (kg)	Free (%)	Product. (kg)	Free (%)	Product. (kg)	Free (%)	Product. (kg)	Free (%)
1989	53,124	85.6	65,750	100.0	3,165	100.0	0	0.0	122,039	93.7
1990	99,802	80.3	26,830	69.3	13,453	89.6	0	0.0	140,085	79.1
1991	50,469	42.2	370,723	96.9	6,293	53.6	0	0.0	427,485	89.8
1992	91,639	48.4	30,003	54.6	7,138	23.3	14,630	100.0	143,410	53.7
1993	59,069	38.0	80,082	44.3	3,563	44.6	27,528	92.5	170,242	49.9
1994	173,829	80,6	84,045	54.5	13,133	64.1	70,887	99.6	341,894	77.5
1995	123,003	59.2	104,581	33.4	12,364	37.4	42,508	96.0	282,456	54.2
1996	121,883	83.7	199,767	52.1	7,822	54.8	71,143	98.8	400,615	70.0
1997	161,698	76.2	133,150	47.3	10,576	24.5	19,649	96.7	325,073	63.9
1998	181,005	73.7	724,477	87.9	60,422	35.0	45,415	86.2	1,011,319	82.1
1999	139,488	75.7	655,322	74.4	19,822	43.1	10,539	84.6	825,171	74.0
2000	112,930	79.9	765,928	64.6	34,072	38.9	68,827	83.9	981,757	66.8
2001	135,480	67.9	432,997	56.7	38,505	37.0	104,967	88.8	711,949	62.5
2002	196,577	78.9	1,319,392	94.4	50,017	61.5	13,066	84.7	1,579,052	91.4
Tot.	1,699,996	72.3	4,993,047	77.2	280,345	46.3	489,159	92.2	7,462,547	75.9

All tasks are carried out within the regulations for decommissioning activities and unconditional release of materials that are stipulated in a Royal Decree that was published on July 20, 2001.

Considering the same Royal Decree, a new licence application was prepared in 2002, in order to enable further decommissioning and final demolition of the main process building and some peripheral buildings of the former Eurochemic reprocessing plant. At the same time, a global material balance was prepared, indicating the amount of material that should be unconditionally released and the materials that should be removed as radioactive waste, as shown in table 2. The figures indicate that more than 75% of the metal material may be unconditionally released for recycling. The concrete material that is produced during the decommissioning operations is mainly removed as radioactive waste. It is only a limited fraction of the total concrete material resulting from the unconditionally release of the building structures, however. On a global basis, about 95% of the concrete material will be unconditionally released and recycled.

As this concrete material is free of any polluting substance, it is well suited for reuse as secondary basic material in road construction. Only a limited fraction (< 1%) of other materials (all except metal and concrete) are produced. As a result of its low economic value and due to the absence of adapted recycling techniques, the non-radioactive part is mostly removed to an industrial dumping site. Only some 3% of the total material production will be removed as radioactive waste.

Table 2 Global material balance relating to the further decommissioning of the main process building and the peripheral buildings of the former Eurochemic reprocessing plant

	Metal (tons)	Concrete (tons)	Heavy concrete (tons)	Other material (tons)	Structural concrete (tons)	Total (tons)
Uncond. release	726	654	104	63	47.397	48,944
Radioact. waste	199	1,227	7	27	0	1,460
Total material	925	1,881	111	90	47,397	50,404
% Uncond. rel.	78.5	34.8	93.7	70.0	100.0	97.1
% Rad. waste	21.5	65.2	6.3	30.0	0.0	2.9
% Reuse	78.5	34.8	93.7		100.0	97.0
% Industr. dump				70.0		0.1

4 Discussion and conclusions

For managing the materials resulting from the decommissioning of nuclear installations, Belgoprocess considers some basic principles:

- The generation of radioactive waste shall be kept to the minimum practicable.
- Radioactive waste shall be managed in such a way that it will not impose undue burdens on future generations.

Based on these fundamental principles, Belgoprocess has made a straightforward choice for a strategy with minimisation of amount of materials to be managed as radioactive waste. The objective is achieved using advanced decontamination techniques and the unconditional release of decontaminated materials for recycling and reuse in the non-nuclear industry.

It should be clear that the Belgoprocess strategy is not only the right choice for the economical aspects. From the ecological viewpoint, it also provides maximum protection of the environment. In a broader context the recycling of materials can be considered as a first order ecological priority to limit the quantities of radioactive waste to be disposed of, to reduce the technical and economic problems involved

in the management of radioactive waste, and to make economic use of primary material and conserve natural resources of basic material for future generations.
In order to keep all decommissioning and decontamination activities within the required criteria for the protection of the public and the environment, all tasks are carried out under a certified Quality Assurance Programme. In March 1996, Belgoprocess obtained the ISO 9001 certificate for the decommissioning of nuclear facilities and the decontamination of contaminated materials.

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