Belgoprocess

The decommissioning of the Eurochemic reprocessing plant

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1. Introduction

The Eurochemic reprocessing facility at Dessel in Belgium, was constructed from 1960 to 1966. A consortium of 13 OECD countries operated this demonstration plant from 1966 to 1974, and reprocessed 180 tons of natural and low-enriched and 30 tons of high-enriched uranium fuels. After shutdown, the plant was decontaminated from 1975 to 1979 to keep it in safe standby conditions at reasonable cost. In 1984, Belgoprocess took over the activities on site. When it was decided in 1986 not to resume reprocessing in Belgium, the main Belgoprocess activities changed to processing and storage of radioactive waste and to decontamination and decommissioning of obsolete nuclear facilities.

The industrial decommissioning of the main process building of the former Eurochemic reprocessing plant was started in 1990, after completion of a pilot project. Two small storage buildings for end products from reprocessing were dismantled to verify the assumptions made in a previous paper study on decommissioning, to demonstrate and develop dismantling techniques and to train personnel. Both buildings were emptied and decontaminated to background levels. They were demolished and the remaining concrete debris was disposed of as industrial waste and green field conditions restored. The main conclusions of this pilot decommissioning project denoted that, in future, emphasis should be put on the automation of concrete decontamination, and the decontamination of metal components.

The main process building is a large rectangular construction of about 80 m long, 27 m wide and 30 m high (see Figure 1).

Figure 1. Main process building of the former Eurochemic reprocessing plant

The core of the building consists of a large cell block of 40 main cells, containing the chemical process equipment. Access areas and service corridors are located on 7 floor levels. About 106 individual cell structures have to be dismantled. Some cells have contamination levels up to 125 Bq/cm^2 (beta) and 200 Bq/cm^2 (alpha). Some hot spots give a gamma dose rate of several mS/h. About 1,500 Mg of metal structures and 12,500 m^3 of concrete with 55,000 m^2 of concrete surfaces have to be removed and/or to be decontaminated.

The aims of the decommissioning project are to limit radiation risks to the population according to the universal criteria of the ALARA principle, to decommission the building 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 remaining structures completely in view of a conventional demolition.

Decommissioning involves the removal and decontamination of equipment from each cell, the decontamination of cell walls, ceilings and floors, and the dismantling of the ventilation system. These activities are followed by a complete monitoring for unconditional release of the remaining structures. Most of the work involves hands-on operations under protective clothing tailored to each specific task. Tool automation and automatic positioning systems are successfully applied.

The specific Belgoprocess approach should be highlighted, considering that:

- The decommissioning activities are carried out on an industrial scale with special emphasis on waste minimisation, extensive decontamination to unconditional release levels and cost minimisation;
- Commercially available technology is used in good co-operation with the nuclear or non-nuclear industry;
- The decommissioning of a nuclear power plant mainly being characterised by radiation risks due to activation products, the alpha contamination on equipment and building surfaces in a reprocessing plant requires the use of adequate protective clothing. Specific breathing and cooling air systems are needed to enable the operators to carry out the decommissioning tasks in acceptable working conditions.

2. Decommissioning activities and equipment used

Dismantling of metal components is carried out by plasma-arc cutting. Pipes are cut with radio-controlled hydraulic shears, while dry or wet cutting of cast iron shielding blocks is done with hydraulically controlled saw blades.

Cutting and decontamination of concrete structures is carried out either hands-on, or by electrically powered, hydraulically controlled systems. Mini electro-hydraulic hammering units are used when contamination has penetrated deeply into the concrete surface, increasing the decontamination possibilities and reducing the work load for the operators. Cell entrances are created or enlarged with diamond cable cutting machines.

In the early days, concrete walls with limited in depth contamination, were decontaminated using commercially available pneumatic hand scabblers. In addition, 3-headed, 5-headed and 7-headed hand-operated floor scabblers were used. These pneumatic powered machines had adapted dust extraction systems around the scabbler heads. To improve the working conditions for the operators, and to increase capacity, scabblers were progressively automated.

Operation efficiency was improved when shaving machines were introduced, using a diamond tipped rotary head, designed to give a smooth surface finish and making monitoring easier. A floor shaver and a remote controlled diamond wall shaver were developed for decontamination of larger concrete surfaces, showing a threefold increase in efficiency and 30 % less secondary waste production. Due to the absence of machine vibration, the physical load to the operators was also reduced.

Two low weight handheld shaving tools were developed as an alternative for handheld scabblers. A handshaver uses a cupped disk with diamond segments bonded onto the face of the disk. It has a controllable dust extraction guard and produces very low hand-arm vibrations. Decontamination rates from 4 to 6 m^2/h machine time are obtained, compared to 1.5 m^2/h for a hand held DK1 scabbler. Operator's impressions are very positive, especially related to work load and hand-arm vibration levels.

To remove process equipment in a safe and ergonomic way from cells with heights up to 18 meters, movable platforms are used. On the movable platform a video survey system is installed, enabling the two operators in a cell to be monitored by an operator outside the work area. A communication system provides radio contact with the operators on the working platform. In other cells, lifting platforms with articulated axes are used.

3. Considerations about remote operation and robotisation

The feasibility of robotic systems was evaluated, considering that it should be possible to have the system equipped with hydraulic shears, plasma torches and other tools for size reduction of metal components. Collected information and demonstrations showed that:

- Available robot arms with lifting capacities up to 100 kg are adapted to specific tasks;
- Such robot arms may be used for decommissioning work in non-accessible areas;
- Force feedback is necessary to handle most of the required tools;
- Not so many adapted tools are available on the market for use with such systems;
- Working with a manipulator requires a lot of operator training;

- Using a robotic system requires a second one for operator training and tool development;
- Robotic systems do not necessarily increase work efficiency in planned dismantling tasks.

Considering the tests results, the equipment cost, the need for further development work, and the limited applicability and achievable efficiency in the planned decommissioning activities, it was preferred not to go to far in automation of decommissioning work in accessible areas or in areas that are made accessible by extensive decontamination. More emphasis was put on optimisation of commonly used and proven industrial techniques, adapting them to enable that decommissioning work is done in reliable, safe and comfortable working conditions.

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4. Management of contaminated material production

During the decommissioning work, a lot of emphasis is put on waste minimisation in order to cope with the increased costs for waste processing and disposal, and in order to meet the proposed planning. Some fundamental principles are considered which may be summarised as follows:

- Keep the generation of radioactive waste to a minimum;
- Minimise the spread of radioactivity;
- Optimise possibilities for recycling and reuse of valuable components;
- Minimise the volume of radioactive wastes based on adequate processing technologies.

Specific actions were defined in order to achieve these principles and to increase work efficiency:

- Improve concrete decontamination; use adapted techniques with higher and more efficient working rates and lower waste production;
- Put much effort in decontamination and unconditional release of metal components, including melting and related characterisation if the material cannot be measured due to its shape;
- Develop adapted systems for intervention work reducing the physical load on the operators resulting from the work carried out in plastic ventilated suits, and from the use of tools and equipment that cause important hand-arm vibrations;
- Increase the work efficiency by introducing adapted automated techniques and acceptable working circumstances, under the certified quality assurance programme.

As an example, the removal of surface contamination from concrete structures was significantly improved when dry hand held and automated floor and wall shaving systems were used as an alternative for scabbling. For dust free decontamination of concrete surfaces, shavers were integrated into remotely and manually operated industrial systems that capture dust and debris at the cutting-tool surface, which minimises cross contamination. For smaller systems, dust evacuation is carried out with industrial vacuum cleaners with capacities up to 500 m^3/hour, and equipped with absolute filtering systems at the outlet. Larger units are connected to vacuum systems with capacities up to 2,500 m^3/hour or higher. They incorporate a cyclone to evacuate larger concrete particles, a filter system with cleanable pre-filters and absolute filter, and a vacuum pump.

In a demonstration programme, it was shown that it is economically interesting to decontaminate metal components to unconditional release levels using dry abrasive blasting techniques, the unit cost for decontamination being only 33 % of the global cost for radioactive waste treatment, conditioning, storage and disposal. As a result, an industrial automated dry abrasive blasting unit was installed in the Belgoprocess central decontamination infrastructure. At the end of May 2001, after 6 years of operation, 523 Mg of contaminated metal has been treated. 182 Mg (35 %) of this material was unconditionally released, having been monitored twice by the in-house health physics department. About 303 Mg (58 %) of the metal, presenting surfaces that could not be measured due to their shape, were melted for unconditional release in a controlled melting facility.

The suitability of the abrasive blasting system was verified. The impact of abrasives into the material surface 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.

Other materials are decontaminated using techniques that are selected based on the type of material and the characteristics of the contaminants.

The final demolition of the main process building requires a specific clearance methodology. It has been evaluated that application of the methodology applied for the pilot project is complicated for several reasons, among which important ones are:

- The type and spread of contamination: at the end of the reprocessing activities, all cells were cleaned with high-pressure water jet, which caused in-depth penetration of contamination.

- The total surface is large, which will require extensive manpower if all surfaces have to be monitored twice in view of unconditional release.
- Taking core samples at the previously most contaminated places will result in a large amount of samples to be taken and to be analysed, and it will be very difficult or impossible to prove that these samples are representative for the remaining structures of the building.
- In view of the structural stability of the building, it will be impossible to remove all the pipe penetrations prior to the demolition of the building.

An alternative has been thoroughly studied, considering at least one complete measurement of all concrete structures and the removal of all 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. The concrete blocks containing the remaining pipe penetrations are sent to a controlled area in order to separate the tubes from the concrete. During the crushing operations, metal parts are separated from the concrete and representative concrete samples are taken. The frequency of sampling meets the prevailing standards. These concrete samples are further milled, homogenised, and a smaller fraction is sent to the laboratory for analyses.

A research and development programme was carried out in order to install the adequate crushing and milling technology so that the resulting concrete material can be reused in road constructions. A final report was prepared and agreement was obtained from the technical as well as from the financial point of view. The entire crushing installation, metal separator, transport and filter systems were installed in the middle of December 2000. Operational and cold tests were carried out in January 2001, and operational activities started in June, 2001.

Contaminated materials that may not be handled with the referred waste minimisation techniques are considered as radioactive waste. The final objective in waste minimisation is to ensure that the volumes of these remaining radioactive materials are reduced as far as practicable. The methods for processing, conditioning, packaging, handling, storing, transporting and disposing of radioactive wastes arising from decommissioning are in general similar to those used in other parts of the nuclear industry. The 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 appropriately pre-treated in order to facilitate subsequent waste processing at the centralised waste processing facilities. Pre-treatment steps comprise:

- Administrative steps including documentation of the waste material for accountability and operational purposes with reference to specifications that are defined on a national basis;
- Segregation and sorting of the waste materials for suitable treatment;
- Decontamination of wastes for decategorisation if economically interesting;
- Packaging in containers suitable for transport and for handling in the nationally centralised processing facilities, operated by Belgoprocess on the nuclear site of Mol-Dessel in Belgium.

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

5. Health and Safety - Working in ventilated suits

The decommissioning operations require the operators to use protective clothing and equipment, especially in areas with alpha contamination. To provide breathing and cooling air to the operators in their protective clothing, a specific personal protection system was developed, comprising an in-line breathing air filter, a distribution block to control breathing and cooling air, a low profile automatic, first breath activated, positive pressure demand valve, a special facemask with two standard connections, and a safety device, allowing breathing through an absolute filter when the normal air supply has dropped. A bypass on the positive pressure demand valve enables additional air supply to refresh the operator's face and to remove excessive moisture. Special attention was paid to minimise weight and dimensions of the components and to improve carrying comfort. Filtered breathing air is provided from specific units including emergency supply and alarm systems.

Physical condition tests and measurement of work load on the operators in the newly developed equipment were executed under normal working conditions of plasma cutting and hydraulic hammering or scabbling. Compared to similar tests with former systems, and although the physical condition of the operators had decreased by 7 %, the results of the measurements proved to be 20 % more favourable as compared to the proposed heat stress limits. Increases in heart rate and rectal temperature were less explicit as with the former systems, and operators' recuperation during lunch time break proved to be 100 %. The positive influence of the new combined breathing and cooling system was explicitly shown.

As in the metallurgical industry, in construction, and in forestry, exposure to hand-arm vibrations also occurs in the decommissioning of nuclear installations. Health effects induced by hand-arm vibrations are for instance 'white fingers', but also physical deformations of bones and joints, and other disorders. In different countries, alternative standards or target values have been proposed to limit vibration load on operators. A proposal for a general regulation, however, is not yet available. The current situation related to exposure of hand-arm vibrations during the decommissioning of nuclear installations at Belgoprocess has been submitted to a global representative evaluation method. The results of the analyses carried out do not give reasons to some concern. However, additional technical and organisational objectives were proposed, as well as precautions for personal protection and medical supervision, and for calculating and follow-up of the daily exposure to vibrations of the operators.

6. Data management system

A data management system was set up, based on the principles of the concept of 'Activity Based Costing', combined with the own Belgoprocess experience in data collection and data processing in decommissioning. The system is able to process a large amount of input data such as working hours, production factors (i.e., various waste productions per hour and per type of waste), various kinds of surfaces to be treated, and budgeting data for personnel performances, consumables, investments. All these data are collected and introduced in a computer database. Outputs give detailed overviews of costs, performed hours, produced wastes, production rates in relation to scheduled works and budgets. Part of the programme is used to prepare planning and cost estimates for future projects.

7. Quality Assurance programme

All decommissioning and decontamination tasks are carried out under a certified Quality Assurance Programme. The decommissioning and decontamination instructions are all integrated in a standard Quality Assurance Plan. In the beginning of 1996, the entire Quality Assurance system was audited by SGS European Quality Certification Institute as compared to the ISO 9001-requirements, and on March 21, 1996, *Belgoprocess obtained the ISO 9001 certificate applicable to the decommissioning of nuclear facilities and the decontamination of contaminated materials.*

8. Discussion on current situation of the decommissioning activities

The decommissioning operations at the main building of the former Eurochemic reprocessing plant have made substantial progress, and will continue till mid of the year 2006. The project was launched in 1990 with a limited crew which was enlarged in 1992 to 24 operators. Today, 39 operators are involved in the decommissioning activities, while 8 operators take care of the decontamination work. All activities are assisted, supervised and managed by 12 supervising and management people.

Decommissioning work has been carried out in 90 of the 106 individual cell structures to be dismantled. At the end of December 2001, 33 cells were decontaminated to background levels. After complete dismantling, concrete decontamination is carried out in 15 other cells. Components and materials are removed from another 42 cell structures.

The total contaminated material production from 1989 till the end of December 2001 is indicated in table 1 here above. The figures represent about 83 % of the contaminated material that were estimated to result from the decommissioning operations at the main process building. It is clearly indicated that, in view of the increased waste processing and disposal costs, much effort has gone into decontamination and unconditional release (clearance) of decommissioning materials.

In general, the main difficulties encountered during the last years were:

- High dose rates due to remaining liquids from former reprocessing activities, reducing access time to some cells, and to be removed before large scale operations could be continued;
- More material/equipment to be removed than considered in the inventory of several cells creating delays for planned decommissioning activities;
- Pipe penetrations between cells to be removed in order to obtain the low radiation background levels required for making release measurements, a type of work that was scheduled to be done just before or during building demolition;
- Contamination had penetrated deeper than expected into the concrete of cell structures.

	Metal			Concrete			Other material			Heavy concrete			Total		
	Product	Decont.	Free	Product	Decont.	Free	Product	Decont.	Free	Product	Decont.	Free	Product	Decont.	Free
	(kg)	(kg)	(%)	(kg)	(kg)	(%)	(kg)	(kg)	(%)	(kg)	(kg)	(%)	(kg)	(kg)	(%)
1989	53,124	45,480	85.6	65,750	65,750	100.0	3,165	3,165	100.0	0	0	0.0	122,039	114,395	93.7
1990	20,639	7,525	35.6	23,003	18,603	80.93	9,002	8,737	97.1	0	0	0.0	52,644	34,865	66.2
1991	37,466	17,890	47.7	9,050	6,937	76.7	2,933	2,113	72.0	0	0	0.0	49,449	26,940	54.5
1992	61,193	14.440	23.6	26,169	13,373	51.1	6,349	1.085	17.1	14,630	14,630	100.0	108,341	43,528	40.2
1993	52,775	21,836	41.4	69,902	33,607	48.1	1,785	640	35.9	27,528	25,451	92.5	151,990	81,534	53.6
1994	169,284	137,816	81.4	81,679	44,860	54.9	11,543	7,3987	64.1	70,587	70,587	100.0	333,093	260,661	78.35
1995	120,989	71,898	59.4	103,478	34,695	33.5	11,893	4,602	38.7	42,508	40,816	96.0	278,868	152,011	54.5
1996	114,118	96,993	85.0	197,436	101,866	51.6	6,923	4,289	62.0	71,143	70,287	98.8	389,620	273,435	70.2
1997	139,790	102,705	73.5	126,613	58,454	46.2	10,044	2,383	23.7	17,842	17,842	100.0	294,289	181,834	61.6
1998	86,420	48,088	55.6	161,607	84,038	52.0	32,662	1,393	4.3	45,415	39,164	86.2	326,104	172,683	53.0
1999	92,293	69,104	74.9	197,112	71,553	36.3	4,489	544	12.1	2,948	2,948	100.0	296,842	144,149	48.60
2000	29,944	19,142	63.9	120,605	42,5640	35.3	5,4412	2,249	41.3	52,453	42,953	81.9	208,443	106,908	51.38
2001	73,225	38,362	52.4	229,552	116,8957	50,9	6,826	1,970	28.9	104,3257	95,999	92.0	413,928	253,226	61.2
Total	1,051,260	691,279	65.8	1,411,956	693,195	49.1	113,055	40,568	35.9	449,379	420,677	93.6	3,025,650	1,845,719	61.0

Table 1. Contaminated material production from 1989 till December 2001 at the decommissioning of the Eurochemic reprocessing plant

The present experience shows a definite trend to reduce the physical load on the operators, to have the work done in comfortable working conditions, and to enhance the efficiency of hands-on operations in order to limit the required exposure time. This is mostly achieved by developing dedicated remotely controlled tooling and enhanced tool automation. The experience shows that more emphasis on the optimisation of commonly used and proven industrial techniques offers adequate solutions to most of the problems involved in the decommissioning activities.