Belgoprocess

Concrete crushing and sampling, a methodology and technology for the unconditional release of concrete material from decommissioning

1. Introduction

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 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 emphasis had to 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. About 106 individual cell structures have to be dismantled, involving the removal and decontamination of equipment from each cell, the decontamination of the cell walls, ceilings and floors, the dismantling of the ventilation system. These activities are followed by a complete monitoring to allow for unconditional release of the remaining structures. As such, 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.

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 in which decommissioning activities are carried out on an industrial scale with special emphasis on cost minimisation, a commitment to results within an overall planning, and the use of technology on an industrial representative scale. This approach includes specific actions to reduce standby costs. It takes great care to limit radioactive waste management costs, keeping the generation of radioactive waste to a minimum, minimising the spread of radioactivity as much as possible, and optimising the possibilities for recycling and reuse of valuable components from existing and potential waste streams. Extensive use of adequate decontamination techniques is made in order to allow dismantled components and materials to be unconditionally released, as is indicated in table 1 which can be seen in the "Strategy", taking into account the limited availability of funding.

Today, the decommissioning operations carried out at the main process building of the former Eurochemic reprocessing plant have made substantial progress. When the removal and decontamination of equipment from each cell will have been completed, and cell walls, ceilings and floors will have been decontaminated and the ventilation systems removed, a monitoring programme will be required in order to obtain the unconditional release of the remaining structures. It is the aim to demolish these structures and to remove the remaining concrete debris for recycle or reuse in the non-nuclear industry.

2. Final demolition of storage buildings for end products of reprocessing

As indicated before Belgoprocess started its decommissioning activities with the dismantling and decontamination of two small storage buildings for end products from reprocessing. Both buildings were emptied and after decontamination of the concrete structures down to a level of 0.04 Bq/cm^2 for alpha and of 0.4 Bq/cm^2 for beta-gamma emitters, two independent measurements of all building surfaces were carried out by the in-house Health Physics Department in order to confirm the above mentioned contamination levels. A third random control measurement was performed by an officially approved radiation protection control organisation. All three measurements gave the same results.

Core samples were taken on the previously most contaminated spots. The specific activities of these samples proved to be well below 1 Bq/g. Measurements and analyses on these samples only confirmed the presence of natural radioisotopes. Consequently, the buildings could be withdrawn from the controlled area.

The final steps in the pilot decommissioning project were the demolition of the two buildings, the removal of the demolition waste to an industrial dumping ground for inert wastes and restoration of the green field conditions. To enable this last step in the objectives of the pilot project, it was necessary to provide sufficient evidence to justify such action to the public opinion. In doing so, the actual absence of any Belgian regulation for unlimited reuse or uncontrolled dumping of suspected and/or decontaminated materials, other than the qualitative definition of radioactive waste, had to be taken into account.

The evidences to be supplied had to be evaluated in the context of a number of exceptive regulations, which were applied in other decommissioning projects, and in the context of available recommendations for recycling of materials resulting from the decommissioning of nuclear installations, by radiation protection experts of the European Community:

- Removable surface contamination in alpha <= 0.04 Bq/cm^2,
- Removable surface contamination in beta-gamma <= 0.4 Bq/cm^2,
- Total specific beta-gamma activity <= 1 Bq/g, mean value over an arbitrary mass of 1,000 kg with an individual maximum of 10 Bq/g.

The results of the multiple 100 % surface measurements in the two buildings and the additional controls on selective core samples (gamma-spectrometry and total alpha and beta measurements) showed that the requirements of the first two criteria were met, and that the third criterion, limited to the core samples taken, was also complied with. The only thing that remained to be demonstrated was, that also a possible alpha contamination was characterised by sufficiently low specific activities.

Based on experiences from the operational period of the plant (localised contamination) and on located contamination during decommissioning operations, it was decided not to take concrete core samples at random, but at the previously most contaminated spots. This should increase the probability on detection of possible remaining contamination.

By doing so, it was accepted in a conservative way that the collected core samples were representative for all concrete volumes, as if all of them had originally known the same history, and as if all of them were also brought to their actual characteristics in a similar manner. This also means that it was accepted that every part of both buildings was originally contaminated to the same degree as those parts where core samples were taken, and where before decontamination the highest degree of contamination was found, which, in reality was certainly not so.

This hypothesis, however, offered the possibility of extrapolating in a conservative way, the results of the analyses on the core samples, expressed in the mean value for the measurements and the standard deviation, to the whole of the building material. And for this hypothesis the core sampling carried out could be considered as random.

The total analysis of the core samples via gamma-spectrometry, by means of a 305 x 102 mm NaI(Tl)-detector in a screened bunker with low background radiation, revealed no indication of artificial contamination via low level activity measurements. The resulting spectrum offered a qualitative view with high sensitivity. In the core samples only natural nuclides were found.

A gamma-spectrometric monitoring (Ge-detector) of the individual core samples was carried out to obtain a quantitative measurement of the gamma emitters, and the results were compared to the results of similar measurements on a reference, non contaminated, core sample. This method has but little sensitivity. In fact a surface measurement is carried out which can only detect radioisotopes in the specimen at low depths. The detected radio-nuclides were:

- Natural radio-nuclides: ^{40}K, ^{226}Ra and daughters, which can normally be found in elements of concrete and other construction material. The mean values of the detected activities for both nuclides were comparable to the values found in the non contaminated reference core sample (x = 0.4 mBq/g, s = 0.3 mBq/g and x = 0.27 Bq/g, s = 0.34 Bq/g respectively). Operational history of the installations, and the fact that in the spectrum no peaks for ^{238}U or ^{235}U were found, do not give reasons to consider that the installations had ever artificially been contaminated with ^{40}K or ^{226}Ra. Moreover, this argument would only have been important if the detected values for ^{40}K or ^{226}Ra would have been inexplicably high.
- Nuclides due to artificial radioactivity: ^{137}Cs. Compared to the detected activity in the non contaminated reference core sample, the resulting total contamination in the core samples (2 mBq/g), for a homogeneous distribution of the specific activity, was not higher than 1 Bq/g, mean value over an arbitrary mass of 1,000 kg, taking into account the gamma penetration in concrete.

By means of the adopted gamma-spectrometry, no ^{241}Am was found. Considering the operational history of the installations, this was an indication for the absence of alpha contamination by plutonium. If there had still been some remaining contamination in the decontaminated floors or in other surfaces of both buildings, then, if the remaining material of the construction was still the original one, parts close to the surface would normally have shown the highest contamination concentration. Therefore some cross-sections of the upper part of the core samples were analysed for alpha and beta activity control.

The analyses carried out on six cross-sections of the core samples taken resulted in a mean value $x = 16.7$ mBq/cm^2 and a standard deviation $s = 8.2$ mBq/cm^2.

With the basic hypothesis of a generally spread maximum amount of contamination in the remaining structures as indicated at the beginning of this paragraph, probabiliorism tells us, that for a random sampling of N values from a normal population with calculated mean value x and standard deviation s, the most probable value for the mean will be somewhere between $x \pm t \times s / N^{0.5}$ where t represents the Student-factor, depending on one single parameter, the degree of freedom of the sampling problem. For a degree of freedom N - 1 = 5, and for a confidence interval of 99 %, it could be stated with 99 % certainty that the most probable mean value for the measurements carried out, would not be higher than 30.2 mBq/cm^2. In practice, considering the adopted hypotheses it would even have been lower.

It was furthermore accepted that the each of the fission products ^{90}Sr, ^{90}Y and ^{137}Cs were detected with equal activity (resulting mass-absorption coefficient for the medium 0.026 mBq/cm^2/mg) and a homogeneous distribution in a concrete layer of 1 mm thickness. It could then be calculated that the transmission due to self-absorption would be limited to 17.4 %. In this way the mean specific beta activity of the analysed concrete layers proved to be 0.44 Bq/g and the maximum for the mean value 0.79 Bq/g.

The evaluation of alpha measurements only made sense in case also other than natural alpha activity had to be considered. Indeed, it could not be the aim to prove that natural radioactivity in the remaining concrete was by coincidence lower than somewhere else in other constructions or concrete elements. In the evaluation carried out, it had therefore to be taken into account that an important part of the considered alpha contamination was coming from the radionuclide ^{226}Ra, due to natural radioactivity, as stated before.

To detect possible remaining alpha contamination in the core samples, the same six cross-sections that were analysed before were at both sides analysed on alpha-radiation, resulting in a mean value $x = 0.96$ mBq/cm^2 and a standard deviation $s = 0.54$ mBq/cm^2.

With the hypotheses a generally spread maximum amount of contamination in the remaining structures as indicated at the beginning of this paragraph, in the same way probabiliorism tells us, that for a random sampling of N values from a normal population with calculated mean value x and standard deviation s, the most probable value for the mean will be somewhere between $x \pm t \times s / N^{0.5}$ where t again represents the Student-factor, again depending on only one single parameter, the degree of freedom of the sampling problem.

For a degree of freedom N - 1 = 11, and for a confidence interval of 99 %, it could again be stated with 99 % certainty that the most probable mean value for the measurements carried out, would not be higher than 1.44 mBq/cm^2. In case of a homogeneous distribution of the activity in a concrete layer with thickness equal to the range R, it could be calculated that the transmission due to self-absorption, for 2π-measurements, would be limited to 50 %. With a value for R = 6.5 mBq/cm^2, the mean specific alpha activity in the analysed concrete layers proved to be 0.30 Bq/g, and the maximum for the mean value 0.44 Bq/g.

Figure 1. Demolition of buildings 6A/6B

Figure 2. Green field conditions after demolition of buildings 6A/6B

To check the indicated evaluations with reality, destructive analyses were carried out. By means of alpha-gamma spectrometry the total alpha-beta activity in a cross-section of the core sample with the highest detected activity was determined. The results of these direct measurements revealed respectively a beta activity of 0.78 Bq/g, and an alpha activity of 0.64 Bq/g. These practical analyses confirmed the evaluations carried out in calculating the specific values for possible alpha or beta activity in the core samples taken.

As such, by means of practical measurements, and by means of evaluations, confirmed by the results of destructive alpha and beta analyses, it was demonstrated in a conservative way that, for a possible alpha or beta-gamma contamination in the remaining structure of both buildings, sufficiently low surface activities and specific activities were obtained. Taking into account the hypotheses where it was accepted in a conservative way that all volumes originally showed the highest degree of contamination, despite the fact that an important part of the surfaces of the buildings originally showed no detectable contamination to the used detectors, the resulting specific activities are well below the proposed levels.

In this way, sufficient evidence was delivered to carry out the last part of the decommissioning project for the two buildings, i.e. the final demolition of the remaining structures and the removal of the demolition waste to an industrial dumping ground, as indicated in the pictures of Figures 1 and 2.

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3. Final demolition of the main process buildings

The final demolition of the main process building (see Fig. 3) 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 using the high-pressure water jet technique, 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.

The fundamental question also arises whether the authorities will accept that a building is released before all the pipe penetrations have been removed. In the same sense, it may be questioned whether a controlled demolition of a building will be acceptable once it has been released, but without additional monitoring during breakdown.

Although the application of the methodology used for the two small buildings in the pilot project is not rejected as such, an alternative has been thoroughly studied. It considers 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.

Figure 3. Main process building of the former Eurochemic reprocessing plant

During the crushing operations, metal parts are separated from the concrete and representative concrete samples are taken. The sampling frequency meets the prevailing standards. In next step, the concrete samples are milled and homogenised. A smaller fraction is sent to the laboratory for analyses.

Both methodologies, as mentioned above, were discussed with an independent radiation protection control organisation, prior to submitting one or both of them to the authorities.

In view of this proposal for the unconditional release of concrete material, a research and development programme was carried out in order to crush, mill, sample and monitor concrete dust similar to the procedure that is adopted for the melting of metal material. Discussions were organised with the independent radiation protection control organisation 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 licensing documents were prepared and approved.

The research and development programme resulted in a set of achievable goals that had to be met during the technical design. The most important goals and the relating achievements were:

- The definition of a representative sampling technique, based on prevailing standards from the mineral processing industry. A specific sampling unit was developed taking approximately 75 partial samples of 2 kg per processed batch of 7,000 kg of concrete blocks, comprising a crusher to bring the granulate dimensions to the requested level for measurement, and a sample divider to split the total sample into a reduced sample and a reference sample.
- The definition of a crushing technique, in order to separate the reinforcement bars from the concrete parts, but also to provide the right granulate dimension to both the sampling unit and the concrete processor. A typical electrically powered jaw crusher was installed, with automated feed rate control. A remote controlled hammering unit can be activated in case of obstructions on the inside of the crusher.
- The definition of a technique for removing reinforcement bars, in order to prevent these bars to block either the sampling unit or the sample crusher.
- The definition of the transport devices to and from the various components in order to smooth the complete process. A tilting device is used to load the installation. Vibration systems and conveyor belts are used for the internal transportation of the material.
- The definition of a ventilation system in order to prevent the release of dust into the environment. The complete installation is encapsulated and extracted via self-cleaning pre-filters and absolute filters. An additional dust sampling unit is provided in both the extraction circuits upstream and downstream of the crusher.

The orders for the practical installation of the various parts of the equipment in an existing building were placed in the first trimester of 2000. The building was partially dismantled and the area for the equipment was prepared. Concrete works for the supporting structures were finalised in September 2000. The entire crushing installation, metal separator, transport and filter systems were delivered in the beginning of September 2000 and installation of all systems was finalised in the middle of December 2000 (see Fig. 4). The complete installation is 48 m long, 10 m wide and 9 m high and represents an investment of about 2.5 million €. Its nominal capacity is set at 28 Mg per day. Operational and cold tests were carried out in January 2001, and training of the operators finalised.

Figure 4. General view of the concrete crushing and sampling facility

The required operational risk evaluation was carried out as well as the worker risk evaluation. The required documentation file has been submitted to the respective safety authorities in order to get the start-up permit. The conventional and nuclear safety inspection before start-up was carried out in the second week of June, 2001. As a result, operations could be started at the end of June, 2001. The first concrete batches could be officially released in October 2001 and removed from the site early in November.

At the end of April 2002, after some 9 months of operation, 390 Mg of concrete have been monitored. 266 Mg of this material could already be unconditionally released and removed from the site after analyses and agreement by the in house health physics department and the authorities. The time required to implement the radiological analyses is a limiting factor to enable faster release.

4. Conclusions

In view of the final demolition of the main process building of the former Eurochemic reprocessing plant, a clearance methodology has to be proposed. Application of the methodology applied for two storage buildings of a pilot decommissioning project is complicated for several reasons. Although this methodology is not rejected as such, an alternative has been studied thoroughly.

The alternative considers 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. 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. In a further step, the concrete samples are milled, homogenised, and a smaller fraction is sent to the laboratory for analyses.

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