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THE BELGOPROCESS STRATEGY RELATING TO THE MANAGEMENT OF MATERIALS FROM DECOMMISSIONING

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ABSTRACT

Belgium started its nuclear programme quite early. The first installations were constructed in the fifties, and presently, more than 55 % of the Belgian electricity production is provided by nuclear power plants. After 30 years of nuclear experience, Belgium started decommissioning of nuclear facilities in the eighties with two main projects: the BR3-PWR plant and the Eurochemic reprocessing plant. The BR3-decommissioning project is carried out at the Belgian Nuclear Research Centre, while the decommissioning of the former Eurochemic reprocessing plant is managed and operated by Belgoprocess n.v., which is also operating the centralised waste treatment facilities and the interim storage for Belgian radioactive waste.

Some fundamental principles have to be considered for the management of materials resulting from the decommissioning of nuclear installations, equipment and/or components, mainly based on the guidelines of the “IAEA-Safety Fundamentals. The Principles of Radioactive Waste Management. Safety Series No. 111-F, IAEA, Vienna, 1995” with respect to radioactive waste management. 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” (seventh principle), and “Radioactive waste shall be managed in such a way that it will not impose undue burdens on future generations” (fifth principle).

Based on these fundamental principles, Belgoprocess has made a straightforward choice for a strategy with minimisation of the amount of materials to be managed as radioactive waste. This objective is obtained through the use of 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 conventional industrial disposal sites if they have no remaining value.

In order to achieve these objectives, Belgoprocess uses techniques and equipment that enable the high degrees of decontamination to be obtained, while based on commercially available technology. As an example, for concrete surfaces, where the contamination has not penetrated deeply, significant improvement in operation efficiency was achieved when developing dry hand held and automated floor and wall shaving systems as an alternative for scabbling. As it was also shown that it is economically interesting to decontaminate metal components to unconditional release levels using dry abrasive blasting techniques, an industrial automated dry abrasive blasting unit was installed in the Belgoprocess central decontamination infrastructure. Moreover, a specific facility was developed and operations started for taking representative samples and monitoring concrete material in view of the final demolition and unconditional release of remaining structures of buildings after completing all dismantling and decontamination work.

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

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 (1).

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

When it is decided to finally shut down a nuclear installation, or when planning the operations for a final shutdown, a set of strategic, tactical and technical decisions have to be taken. In practice, these three types of decisions are all interlinked, and emerge from an iterative process of study and discussion.

Strategic decommissioning decisions refer to the decisions concerning the best time to fully dismantle the installation, and the stages prior to complete dismantling. Adequate choices have to be made, based on an examination of the various possible approaches and taking into account various technical considerations, with a comparison of the advantages, drawbacks and costs of each, but also taking into account the country's nuclear policy on decommissioning and waste management, including:

- The liability of official bodies;
- The relevant regulations governing nuclear safety and radiation protection;
- The employment code and the industrial safety rules;
- Social and economic considerations.

Tactical decisions take account of the regulatory constraints and the specific features of the installation to be decommissioned. It is necessary within a given strategy, to determine the tasks to be carried out, to manage these in order to optimise the balance of costs, time schedule and worker doses, and to determine the technical approaches in order to:

- Best meet the safety and protection conditions at least cost;
- Calculate the cumulative doses to workers;
- Minimise the quantity of radioactive wastes and effluents produced and optimise the cost of their management.

Technical decisions involve choosing the most appropriate technical facilities to carry out the operations as decided by the tactical decisions, including the choice of cutting tools and remotely-controlled systems, processes for decontamination and for management of radioactive materials and effluents, and methods of radiation protection and industrial safety.

Taking into account these general considerations, and depending on the chosen strategy, different kinds and amounts of contaminated materials will be produced during the decommissioning operations. For each option, it is necessary to consider the minimisation of activity and volume of wastes for storage and disposal and consequent environmental impact, as well as the total costs associated with contaminated material management. As a result, strategies and techniques for minimisation of wastes from decommissioning activities have a large impact when selecting adequate options.

FUNDAMENTAL PRINCIPLES OF THE BELGOPROCESS STRATEGY

In practice, some fundamental principles are considered for the management of materials resulting from the decommissioning of nuclear installations, equipment and/or components, which are mainly based on the guidelines of the IAEA-Safety Fundamentals with respect to radioactive waste management (2). Two of the fundamental principles indicated in this document are specifically dealing with the strategy for the management of materials from decommissioning:

- The 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 fundamental principle is based on the ethical consideration that the generations that receive the benefits of a practice should bear the responsibility to manage the resulting waste. An additional fundamental ethical principle can be added, stipulating conservation of primary resources for future generations.

Under the 7th fundamental 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, minimising the amount of remaining radioactive waste material.

In a broader context, recycling of materials can be considered as a first order ecological priority to limit the quantities of radioactive wastes to be disposed of, to reduce the technical and economic problems involved with the management of radioactive wastes, 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 cycle of a practice, taking into account the disadvantages and the risks involved with the use of recycled materials, as well as the disadvantages and the risks involved with mining and conversion of new materials.

Based on these fundamental principles, Belgoprocess has made a straightforward choice for a strategy with minimisation of the amount of materials to be managed as radioactive waste (3). This objective is achieved through the application of aggressive decontamination techniques and unconditional release of decontaminated materials. Unconditionally released materials are recycled, i.e., metal material that is sent to conventional melting facilities, or are removed to conventional industrial disposal sites if they have no remaining value.

The specific Belgoprocess approach should be highlighted, in which decommissioning activities are carried out on an industrial scale with special emphasis on (4):

- Cost minimisation;
- A commitment to results within an overall planning;
- The use of state-of-the-art technology on an industrial representative scale.

The decommissioning activities have to deal with the specific radiological characteristics of the facilities. While the decommissioning of a nuclear power plant is mainly characterised by radiation risks due to the presence of in depth activation products, the alpha contamination of equipment and building surfaces in a reprocessing plant requires that the decommissioning work is done using adequate protective clothing. Specific breathing and cooling air systems have to be provided to enable the operators to carry out the decommissioning tasks in acceptable working conditions (5).

PRACTICAL IMPLEMENTATION OF THE BELGOPROCESS STRATEGY

To cope with problems of increased waste processing and disposal costs, and to meet the proposed planning for the decommissioning activities, Belgoprocess puts a lot of emphasis on waste minimisation. 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 radionuclides as much as possible;
- Optimise the possibilities for recycling and reuse of valuable components from existing and potential waste streams;
- Minimise the amount of radioactive waste once it has been created by applying adequate processing technology.

Some specific actions have been defined in order to achieve these principles as well as to increase the 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 corresponding 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, **for concrete surfaces**, where the contamination has not penetrated deeply, significant improvement in operation efficiency was achieved when developing dry hand held and automated floor and wall shaving systems as an alternative for scabbling (6). These techniques use diamond tipped rotary disks, designed to give a smooth surface finish which is easier to measure. 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 dustfree 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. For hand scabblers and smaller systems, dust evacuation is carried out using industrial vacuum cleaners with capacities up to 500 m^3/hour, and equipped with absolute filtering systems at the outlet.

Larger scabbling or shaving machines 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 filtering system with cleanable prefilters and absolute filter, and a vacuum pump. The cleanable filtering system incorporates a fill-seal drum changeout method that allows the operator to fill, seal, remove, and replace the waste drum under controlled conditions. The unit may accommodate different drum sizes and several shavers at longer distances.

Since 1990-1991, various evaluations and laboratory tests were carried out to identify decontamination techniques that **remove surface contamination from metal components** such that unconditional release levels are met and the material can be reused without radiological restrictions. In many cases, this 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. It was concluded that selected decontamination techniques should include specific requirements about:

- **Safety**: application should not result in increased radiation hazards due to external contamination of workers or even inhalation of radioactive dust and 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, that require 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; and
- **Feasibility of industrialisation**: in decommissioning, large quantities of contaminated materials are produced and made available for decontamination, that generally do not favour methods or techniques that are labour intensive, difficult to handle, or difficult to automate.

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 (4). As a result, an industrial automated dry abrasive blasting unit was installed in the Belgoprocess central decontamination infrastructure. 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 were melted for unconditional release in a controlled melting facility (7).

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.

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.

In a specific experiment, 14,4 Mg of heavy concrete blocks were also decontaminated in the abrasive blasting installation. 12,2 Mg could be released after two specific measurements carried out by the in-house health physics department. Only 2,2 ton of dust material was recovered as secondary waste. This promising result was the start of a new and interesting decontamination technique, and at the end of December 2002, after more than 3 years of operation, 237 Mg of contaminated concrete blocks has been treated. 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.

A specific approach was developed for **taking representative samples** from and monitoring concrete material in view of the final demolition and unconditional release of the remaining structures after dismantling and decontamination of the main process building. It was evaluated that application of the methodology applied for the pilot project carried out from 1987 to 1990, i.e., the decommissioning of two smaller storage buildings for uranyl nitrate, plutonium dioxide and spent solvents from reprocessing is complicated for several reasons, among which the most important are:

- At the end of the reprocessing activities, the cells in the main process building were cleaned using high-pressure water jet techniques, which caused a general spread and in-depth penetration of contamination;
- The large total concrete surface will require extensive manpower if all these 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 arises whether an authority will accept that a building is released before all pipe penetrations have been removed. In the same sense, it may be questioned whether a controlled demolition of a building is 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.

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.

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 unconditional release of concrete material, a research and development programme was carried out in order to crush, mill, sample and monitor concrete material similar as the procedure adopted when melting metal material. Discussions were organised in order to install the adequate crushing and milling technology such 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 orders for the practical installation of the various parts of the equipment in an existing building have been placed, and operations of the facility have been started in June, 2001 (8). At the end of December 2002, after some 17 months of operation, 1,500 Mg of concrete have been monitored. 1,397 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 the limiting factor to enable faster release.

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 can not be released are reduced in volume 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 wastes from decommissioning are pre-treated to provide appropriate preparation of the wastes to facilitate subsequent waste processing at the centralised waste processing facilities. Pre-treatment steps comprise:

- Administrative steps including documentation of the details of the waste for accountability and operational purposes, with reference to specifications that are defined on a national basis;
- Segregation and sorting of wastes to classify them for suitable treatment;
- Decontamination of wastes for decategorisation if economically interesting;
- Packaging in containers (bags, 200 l-drums) suitable for transport to and for handling in the nationally centralised processing facilities.

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

PRACTICAL RESULTS FROM THE BELGOPROCESS DECOMMISSIONING OPERATIONS

From the beginning of 1990 till the end of December 2002, the total contaminated material production from the overall decommissioning activities carried out by Belgoprocess at the Eurochemic reprocessing plant and the former waste treatment facilities of the Belgian Nuclear Research Center is indicated in table I. The results of the specific Belgoprocess approach, showing the efforts in decontamination and unconditional release of decommissioning materials and limiting the remaining amount of radioactive wastes to a minimum, are clearly indicated.

Table I: Materials produced from 1989 to December 2002 during the Belgoprocess decommissioning activities at the Eurochemic reprocessing plant and the former waste treatment facilities of the Belgian Nuclear Research Center

	Metal material			Concrete material			Other material			Heavy concrete			Total		
	Product. (kg)	Decont. (kg)	Free (%)	Product. (kg)	Decont. (kg)	Free (%)	Product. (kg)	Decont. (kg)	Free (%)	Product. (kg)	Decont. (kg)	Free (%)	Product. (kg)	Decont. (kg)	Free (%)
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	99,802	80,113	80.3	26,830	18,603	69.3	13,453	12,060	89.6	0	0	0.0	140,085	110,776	79.1
1991	50,469	21,320	42.2	370,723	359,267	96.9	6,293	3,375	53.6	0	0	0.0	427,485	383,962	89.8
1992	91,639	41,294	48.4	30,003	16,373	54.6	7,138	1,665	23.3	14,630	14,630	100.0	143,410	73,962	53.7
1993	59,069	21,696	38.0	80,082	35,439	44.3	3,563	1,589	44.6	27,528	25,451	92.5	170,242	84,175	49.9
1994	173,829	98,710	80,6	84,045	45,843	54.5	13,133	8,417	64.1	70,887	70,587	99.6	341,894	223,557	77.5
1995	123,003	67,519	59.2	104,581	34,884	33.4	12,364	4,622	37.4	42,508	40,816	96.0	282,456	147,841	54.2
1996	121,883	93,543	83.7	199,767	28,298	52.1	7,822	4,289	54.8	71,143	70,287	98.8	400,615	196,417	70.0
1997	161,698	89,588	76.2	133,150	7,458	47.3	10,576	2,595	24.5	19,649	19,008	96.7	325,073	118,649	63.9
1998	181,005	67,346	73.7	724,477	571,468	87.9	60,422	21,120	35.0	45,415	23,429	86.2	1,011,319	683,363	82.1
1999	139,488	42,795	75.7	655,322	430,817	74.4	19,822	8,536	43.1	10,539	8,917	84.6	825,171	491,065	74.0
2000	112,930	44,800	79.9	765,928	442,104	64.6	34,072	13,239	38.9	68,827	57,739	83.9	981,757	557,882	66.8
2001	135,480	36,210	67.9	432,997	169,962	56.7	38,505	12,524	37.0	104,967	93,261	88.8	711,949	311,957	62.5
2002	196,577	88,157	78.9	1,319,392	1,118,745	94.4	50,017	29,687	61.5	13,066	11,070	84.7	1,579,052	1,247,659	91.4
Tot.:	1,699,996	838,571	72.3	4,993,047	3,345,011	77.2	280,345	126,883	46.3	489,159	435,195	92.2	7,462,547	4,745,660	75.9

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

FUTURE ACTIVITIES

Responding to the Royal Decree that was published on July 20, 2001, in 2001 a new licence application was prepared in order to enable the further decommissioning and final demolition of the main process building (101A) and the peripheral buildings (102X, 103X, 104X and 153X) of the former Eurochemic reprocessing plant. For the purpose of this new licence application a global material balance was prepared, indicated the amount of material that should be unconditionally released and the materials that are expected to be removed as radioactive material. The results are given in table II.

Table II: Global material balance relating to the further decommissioning of the main process building (101A) and the peripheral buildings (102X, 103X, 104X en 153X) of the former Eurochemic reprocessing plant.

	Metal	Concrete	Heavy concrete	Other material	Structural concrete	Total
	(tons)	(tons)	(tons)	(tons)	(tons)	(tons)
1 Unconditional release						
Building 101A	355	347	104	60	27,012	27,878
Building 102X	186	92			9,469	9,747
Building 103X	71	215		3	6,646	6,935
Building 104X	94				2,489	2,583
Building 153X	20				1,781	1,801
Subtotal uncond. release	726	654	104	63	47.397	48,944
2 Radioactive waste						
Building 101A	136	604	7	25		772
Building 102X	32	194				226
Building 103X	4	400		2		406
Building 104X	26	19				45
Building 153X	1	10				11
Subt. Radioact. Afval	199	1,227	7	27	0	1,460
3 Total material	925	1,881	111	90	47,397	50,404
% Unconditional release	78.5	34.8	93.7	70.0	100.0	97.1
% Radioactive waste	21.5	65.2	6.3	30.0	0.0	2.9
% Reuse	78.5	34.8	93.7		100.0	97.0
% Conventional dump				70.0		0.1

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 released building structures. On the whole, about 95 % of the concrete material is unconditionally released and recycled. As this concrete material is free of any polluting substances, 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 economical value and due to the absence of adapted recycling techniques, the non-radioactive part is mostly removed to a conventional public dumping site.

When considering the total material production, about 3 % will be removed as radioactive waste, more than 95 % will be reused and only a small fraction (< 1 %) will be removed to a conventional public dumping site.

It should be clear that the Belgoprocess strategy, based on advanced decontamination methods and unconditional release of materials, is not only the right choice from the economical point of view. From the ecological viewpoint it also provides maximum protection of the environment.

CONCLUSIONS

When a nuclear installation is finally shut down or when planning operations for a final shutdown, a set of strategic, tactical and technical decisions have to be taken. These three types of decisions are all interlinked and emerge from an iterative process of study and discussion.

The choice of a decommissioning strategy is mainly based on technical, safety and cost considerations, requiring an examination of the various possible approaches, with a comparison of the advantages and drawbacks of each. A country's policies on nuclear decommissioning and waste management may be a major factor in the decision making process.

Some fundamental principles are considered for the management of materials resulting from the decommissioning of nuclear installations, equipment and/or components, mainly considering that:

- 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 the amount of materials to be managed as radioactive waste. The objective is achieved through the application of advanced decontamination techniques and the unconditional release of decontaminated materials. Unconditionally released materials are recycled, i.e., metal materials that are sent to conventional melting facilities, or are removed to conventional industrial disposal sites if they have no remaining value.

In a broader context, the recycling of materials can be considered as a first order ecological priority to limit the quantities of radioactive wastes to be disposed of, to reduce the technical and economic problems involved with the management of radioactive wastes, and to make economic use of primary material and conserve natural resources of basic material for future generations.

In order to keep the 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 applicable to the decommissioning of nuclear facilities and the decontamination of contaminated materials.

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