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Management of sites and soils polluted by radioactivity

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Foreword

Eight years after the issue of *Contrôle* magazine devoted to the management of sites contaminated by radioactive substances, I wanted to take the opportunity of this review to shed new light on the changes made and the progress accomplished in this field.

As early as 2002, when the DGSNR[1] was created, ASN was tasked with the management of sites contaminated by radioactive materials. Ten years after the first interventions on the former Bayard clock-making site of Saint-Nicolas d'Aliermont (76), it became apparent that an initial inventory of national and international practices was needed, in order to identify the major obstacles and the changes that were required. Jointly with the ministry responsible for ecology, ASN thus organised the first national symposium entitled "Radioactive contamination: how to deal with polluted sites?". This symposium, held on 4 May 2004, demonstrated the technical, financial and psychological difficulties inherent in this subject. Various measures were however initiated, to allow even more transparent and efficient management of these forms of pollution, many of which constitute a heavy burden inherited from past practices.

I would like to mention the 2006 drafting of the first National Radioactive Materials and Waste Management Plan, highlighting the need to look for appropriate management solutions for radium-bearing waste from legacy contaminated sites, the creation in 2007 of the National Commission for Assistance in the Radioactive Field (CNAR), the November 2010 launch of Operation Radium Diagnosis and, more recently, the 2011 version of the Methodology Guide published by ASN, the DGPR[2] and IRSN concerning the management of sites potentially polluted by radioactive substances. This guide now aims to provide the various stakeholders with a common methodological basis for the simultaneous, joint management of all chemical and radiological hazards.

The tools and the approaches for the management of polluted sites and soils have thus changed, learning from the experience acquired by the public authorities over the past twenty years, moving on from action initially focused on surveying and securing the sites, to a more global management approach for the sites according to the established or planned usage. This global approach allows faster and more sustainable management of the sites, by involving all the stakeholders as early as possible in the polluted site management process.

ASN's prime goal is clean-up that is as complete as possible, aiming for removal of radioactive contamination, in order to allow free usage of the premises and land thus cleaned up. However, when this objective cannot be achieved, the relevant evidence must be provided and appropriate measures must be taken accordingly. These management principles are consistent with the position statements or texts concerning all activities regulated by ASN, from basic nuclear installations (BNI) to small-scale nuclear facilities.

This issue of *Contrôle* magazine also presents the management doctrine for sites and soils polluted by radioactive substances, recently approved by ASN.

Jean-Christophe NIEL
ASN Director-General

1. General Directorate for Nuclear Safety and Radiation Protection (ASN structure prior to the TSN Act of 13 June 2006).
2. General Directorate for the Risk Prevention, at the Ministry for Ecology, Sustainable Development and Energy.

Management of sites and soils polluted by radioactivity

Although it is important that the management of sites polluted by radioactive substances comply with the general principles defined by the public authorities for polluted site management, it must also take account of the particularly sensitive nature of radioactive pollution. The psychological impact is particularly strong when dealing with sites polluted by the radium used decades ago by industry, when these sites are today in the possession of private individuals!

Steps are being taken to protect the health of the population and the environment, by informing the stakeholders concerned through a process that aims to be as transparent as possible, and by taking account of all the constraints applicable at the local level.

Addressing these challenges is vital for ASN and the first part of this *Contrôle* magazine aims to clarify the regulatory framework and the national policy for management of sites and soils polluted by radiation. The second part of the review gives examples illustrating management methods for sites polluted by radioactive or chemical substances, such as first-hand accounts from managers and operators involved in remediation work. The reader may well be surprised by the duration of these polluted site and soil management operations which, before any decision can be taken, require detailed characterisation both on the surface of the sites and at depth.

Involving the stakeholders and publics concerned as early as possible in the polluted site remediation process is an essential aspect. This approach should lead to a joint solution being reached together, in complete transparency. This is why we approached the associations and local officials to obtain their views.

The editorial team also aims to enable the reader to compare the French approach with international practices employed in comparable situations.

We hope you enjoy this issue!

Lydie EVRARD and Odile PALUT-LAURENT
Coordinators of *Contrôle 195*

summary

Contrôle 195 :
Management of sites and soils polluted by radioactivity

Management issues for sites and soils

By Lydie Evrard, Director of the Waste Research Facilities
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What exactly is meant by "sites and soils polluted by radioactive substances" ?

According to the terms of the circular of 17 November 2008[1], *"a site of radioactive pollution is any site, either abandoned or in operation, on which naturally-occurring or artificial radioactive substances, have been or are being handled or stored in conditions such that the site entails health or environmental hazards. The pollution confirmed must be attributable to one or more radioactive substances[2], that is any substance which contains naturally-occurring or artificial radionuclides, the activity or concentration of which warrants radiation protection monitoring."*

1. The circular from the Ministries responsible for ecology, health and ASN, of 17 November 2008, concerns the responsibility for certain radioactive waste and sites polluted by radioactivity, as well as ANDRA's public interest duty.
2. Circular of 16 May 1997 concerning the administrative procedure applicable to sites polluted by radioactive substances.

polluted by radioactive substances

This definition in practice covers a very wide field and the actual management of such sites often proves to be complex. Several principles have to be taken into account in the remediation of sites polluted by radioactive substances. The optimisation principle in particular constitutes one of the fundamental principles enshrined in the Public Health Code with respect to radiation protection and entails a case by case examination of the clean-up objectives. The clean-up operations cover numerous aspects, both technical (ability to manage the volumes of excavated earth, etc.) and financial, as well as having to take account of local town planning measures.

In most cases, the clean-up operations are complex, lengthy and require intervention by many parties at the various stages.

Contrôle : **What are the guiding principles for management of polluted sites and soils?**

L. Evrard : The general principles[3] governing the management of sites polluted by radioactive substances were defined jointly by ASN and the General Directorate for Risk Prevention at the Ministry responsible for ecology. They are primarily based on the polluter-pays principle defined by the Environment Code[4]. When those in charge of these sites default, the National Agency for Radioactive Waste Management (ANDRA) is tasked with remediation of radioactive pollution sites further to a public requisition[5]. For most of the legacy polluted sites the party responsible had defaulted and they are thus managed by ANDRA as part of its public service duty.

Generally speaking, the polluted sites and soil management policy is based on three aspects: management of sites according to the actual or intended uses; conservation of a record of past pollution and remediation; providing the public with information concerning the associated hazards.

The entire site management and remediation approach is based on the diagnosis phase. This phase, involving collection of information and characterisation, is thus crucial. It must be precise and detailed in order to define the clean-up objectives and so that the site management or remediation decisions can be taken with a sufficient degree of confidence. It must also be able to determine the volumes of waste liable to be produced, as well as the sustainability and anticipated cost of the proposed solutions.

For sites and soils polluted by radioactive substances, the exposure of persons to ionising radiation as a result of the site management operations, must be kept to a level that is as low[6] as reasonably achievable in the light of the current technical knowledge and economic and social factors (ALARA[7] principle). The cost/benefit analysis of the various possible management options for the site must be such as to justify this optimisation by limiting residual exposure, but also by guaranteeing the robustness and permanence of the final management solution proposed.

What are ASN's remediation objectives?

ASN considers that the primary objective is to achieve a clean-up that is as complete as possible, aiming for removal of the radioactive pollution so as to allow free use of the cleaned premises and land. In some cases, the characteristics of the site do not enable complete clean-up to be achieved, in particular when the volumes of waste that would be involved in removal of the contamination from the site are too large for acceptance in dedicated disposal facilities[8] or when the management routes necessary for the waste produced are not yet available.

It can thus be acceptable to keep the contamination in-situ. In this case, the ALARA principle once again applies: clean-up must be as complete as reasonably feasible given the technical, economic, health and social constraints. In any case, it is essential to prove that the residual dosimetric impact remains acceptable for the intended use, as well as for any future use of the site, if necessary with the application of usage restrictions. Exposure scenarios must be developed and, for a given use, must be able to demonstrate that there is no risk for the persons frequenting these premises.

When the pollution remains on the site, justification must be provided. It may also be necessary to take action concerning the transfer pathways, in order to reduce the exposure pathways and ensure that the solution adopted leads to acceptable levels of exposure. In this case, it may be necessary to implement appropriate monitoring and, for example, ensure that the possible recovery of contaminated materials for subsequent management is not compromised, especially as a result of new construction. It may, in some cases, be important to prefer reversible technical solutions enabling the waste to

3. These general principles are specified in the ASN DGPR letter of 17 November 2011.
4. Article L. 110-1 of the Environment Code, whereby the party responsible for the pollution of a site must, if solvent and in the absence of prescription, finance the clean-out and remediation operations on the polluted site, up to and including removal of the waste and implementation of any measures specified by the competent administrative authority.
5. Pursuant to the provisions of Act 2006-739 of 28 June 2006 codified in the Environment Code.
6. In accordance with the principles of the Public Health Code.
7. As Low As Reasonably Achievable.
8. This is in particular the case with the phosphogypsum waste heaps and the uranium mining waste

be easily recovered once disposal routes become available. These situations could result in usage restrictions being imposed. Steps must also be taken to retain a trace and a record of the site and inform the public.

When and how are the first management steps for these sites taken by the public authorities?

The first steps were taken by the public authorities in the 1990s, with a survey of the sites concerned. This led to the production of two inventories: BASOL, listing the sites subject to management measures, and BASIAS, listing sites on which an industrial activity had taken place in the past.

The next step was the development of appropriate methodologies tools[9] to specify how to draft the historical surveys, the initial diagnosis and the simplified risk assessment. At the outset, the aim was to systematically rehabilitate the sites identified as sensitive. However, given the diversity of situations, it became apparent that it would be more appropriate[10] to manage the sites according to the intended usage, introducing new tools such as the detailed diagnosis and the detailed risk assessment.

In 1997[11], a circular intended for the Prefects clarified the approach to be followed to evaluate and process radioactive polluted sites, along with the regulatory steps involved. According to the terms of the circular, it applies to legacy pollution on a site already listed in ANDRA's national radioactive waste inventory, to the inadvertent discovery of a previously polluted site, accidental pollution of a site, or pollution caused by non-compliance with the regulations in force. It requests prior production of a health risk assessment, as well as a technical and financial assessment of the remediation work and the level of urgency involved.

Has the methodology drawn up in the 1990s changed since that time?

There have been several major changes over the past twenty years. The methodology has been fleshed out, moving on from the diagnosis phase to the operational management phase for these sites. In its 2000 version, the methodology guide therefore laid out the main principles for risk management, based on a graduated approach comprising several steps, from clearance of any doubts up to a detailed risk assessment and help with the choice of the remediation strategy for a given usage. After each of the five steps, the process could stop. Each step was proportionate to the issues and took account of the specific economic, social and cultural context of the site considered.

Since 2007, the methodology has again changed[12] to take account of learning from experience. The emphasis placed on site management according to its usage has been retained, but the gradual risk analysis approach has been replaced[13] by a global approach based on the interpretation of the environmental status (where usages have been determined) and on the management plan (where they have not).

Over the past twenty years, the public authorities have thus expanded their intervention procedures, moving from an initial approach focused on surveying and safeguarding the sites, plus targeted remediation measures, to global management of the sites according to the determined usage, based on precise and appropriate conceptual models.

The December 2011 version of the methodology guide for the management of sites potentially polluted by radioactive substances[14] reinforced the range of possible actions, by offering the various stakeholders a common methodological basis for the simultaneous, joint management of all the hazards (chemical and radiological) present on a given site. This global approach aims for more effective and more sustainable management of the sites.

The guide describes in greater detail the aim of the public authorities to increase involvement by the stakeholders as far upstream of the process as possible, through more systematic organisation of public meetings or the creation of local information committees around the polluted sites. The polluted sites management methodology guide explicitly recommends this, devoting an entire chapter to it. It follows on directly from the measures previously implemented.

In concrete terms what do these operations entail, how long do they last and who is involved?

The site characterisation phases, carried out prior to any clean-up operation, are lengthy and sometimes complex. They should give as precise a picture as possible of the sites to be cleaned and be able to define the most appropriate and the most robust management option for both the short and long term. The final verification operations, which are an essential phase in confirming that the clean-up objectives set have actually been reached, must be conducted rigorously and the databases updated accordingly. If the site could not be completely remediated, appropriate steps must be taken, as applicable, to ensure monitoring and take the necessary measures to guarantee that future usage is compatible with the residual level of pollution or, failing which, that additional clean-up operations are performed.

9. These methodological tools were presented in the circular of 23 April 1996.

10. This adaptation of the system was detailed in the circular of 10 December 1999.

11. Circular of 16 May 1997 intended for the Prefects concerning the administrative procedure applicable to sites polluted by radioactive substances.

12. These changes were clarified in the circulars of 8 February 2007 concerning the prevention of soil pollution and polluted site management and remediation procedures.

13. The circular of 16 May 1997 was abrogated and replaced by the circular of 17 November 2008.

14. Guide published by ASN, the Ministry responsible for ecology and the IRSN.

A number of essential players are involved: the site manager, the services of the Prefect and, depending on the regulatory regime covering the polluted site (Environment Code, Public Health Code), the classified installations inspection services, the regional health agencies (ARS), ASN, ANDRA - as part of its public service duties defined by the Environment Code should the party responsible have defaulted - and the public. The role of each of these players is defined in the circular of 17 November 2008[15].

In any case, the Prefect relies on the opinion of its services, of ASN and the ARS to validate the remediation project before it is implemented, to validate the clean-up objectives, but also to protect the populations and the workers pending removal of the pollution or following remediation of the site. He may also recommend the implementation of usage or public protection restrictions.

The involvement of the stakeholders and the public concerned, which has been explicitly introduced into the methodology guide, is required by the Environment Charter introduced in 2005 into the Constitution[16] and by the TSN Act[17]. Given the number of persons concerned and the initiation of this approach as early as possible in the polluted site remediation process, the time-frame involved may be lengthy but is necessary in order to reach a joint and fully transparent solution that is accepted in the site management or remediation process. Early dialogue contributes to the search for consensus regarding the best management solution to be adopted and makes it easier for the persons concerned to adopt it. Stakeholder involvement should not therefore be limited only to public information or awareness measures, but should aim whenever possible to ensure responsible engagement by the public.

15. The circular of 17 November 2008 from the Ministry responsible for the environment, intended for the Prefects, specifies the role of each of these players, describing the applicable procedure for management of the radioactive polluted sites subject to the regime applicable to installations classified on environmental protection grounds, or the public health code, whether the party responsible is solvent or has defaulted.
16. Constitutional Act 2005-205 of 1 March 2005, article 7.
17. Act 2006-686 of 13 June 2006 on transparency and security in the nuclear field, codified in the Environment Code.

National inventory of radioactive materials and waste

The Act of 28 June 2006 requires that ANDRA "establish, update every three years and publish the inventory and location of all radioactive materials and waste present in France". The national inventory presents the data declared by the producers of and those in possession of radioactive waste and materials and includes sites polluted by radioactive substances. The polluted sites are identified on the basis of information in the possession of ANDRA. Furthermore, pursuant to the interministerial circular of 17 November 2008 concerning ANDRA's public interest duties and its assumption of responsibility for certain radioactive waste and sites of radioactive pollution, the DREAL/DRIEE* and ASN notify ANDRA of any information liable to supplement or clarify the survey of sites polluted by radioactive substances.
This essentially concerns sites on which radium (or objects containing radium) were manufactured, stored or sold in the first half of the 20th century. It also concerns former industrial sites which utilised naturally radioactive ore, in order to extract rare earths, leading to pollution of the site by residues with technologically enhanced naturally-occurring radioactivity.

The sites which received a positive diagnosis were then listed in the form of data sheets in the national geographical inventory (www.andra.fr). The data sheets concerning these confirmed polluted sites give a brief history of the site. In terms of classification, there are three site categories:
– rehabilitated sites: sites which have been cleaned-up since the 2009 edition of the national inventory. The record of cleaned-up sites is kept in the Basias base developed by the French Geological and Mining Research Office (BRGM) (www.basias.brgm.fr). It should be noted that certain cleaned-out up were rehabilitated by containment;
– sites awaiting remediation;
– sites undergoing remediation.

The geographical inventory lists about fifty polluted sites as at the end of 2010:
– 16 sites remediated or partially remediated since the end of 2007;
– 11 sites undergoing clean-up;
– 22 sites awaiting clean-up. ■

Source : ANDRA

* Regional Directorate for the environment, planning and housing / Ile-de-France Interdepartmental regional directorate for environment and energy.

What significant operations are in progress and what are ASN's short and medium-term objectives on this subject?

In operational terms, a large-scale programme was started in September 2010 in the Ile-de-France region. This operation, called *Operation Radium Diagnosis,* aims to idenfity the sites which previously were home to activities liable to have utilised or handled radium. This operation, overseen by the region's Prefect, primarily concerns intervention in homes, with the agreement of the residents concerned, in order to check the condition of the premises. As underlined by articles in *Contrôle* 195 devoted to this subject, this operation also led to the creation of a specific organisation within the State services.

More generally, ASN formally defined its doctrine for sites polluted by radioactive substances, specifying the main principles that it feels should be implemented. These main principles apply to all sites, regardless of their regulatory status.

ASN in particular recommends that remediation is as complete as possible, should systematically be performed and, when this cannot be done, asks that all evidence be provided, and that the associated appropriate measures be taken. Moreover, it considers that polluted sites and soils management procedures must be part of a process that is transparent to the stakeholders and the public concerned and that the latter must be involved as early as possible in the approach to rehabilitate a site polluted by radioactive substances. It naturally underlines that the parties responsible for the pollution are also responsible for financing the polluted site clean-out operations and the removal of any waste resulting from these operations. ■

Basic principles of the radioactive substances

The following principles apply to all sites polluted by radioactive substances. They apply irrespective of any specific provisions, in particular those concerning basic nuclear installations and installations classified on environmental protection grounds, those of the Mines police and those of Operation Radium Diagnosis.

1 Any position statement issued by ASN concerning the management of a site polluted by radioactive substances is duly justified, recorded and presented in complete transparency to all stakeholders and the public concerned.

2 The stakeholders and the public concerned shall be involved as early as possible in the process to rehabilitate a site polluted by radioactive substances.

3 In application of the polluter-pays principle, those responsible for the pollution (if solvent) are also responsible for financing the polluted site remediation operations and the removal of the waste resulting from these operations. When those responsible for these sites have defaulted, ANDRA assumes responsibility for remediation of radioactively polluted sites after public requisition pursuant to article L. 542-12 of the Environment Code (article 14 of Act 2006-739).

ASN doctrine for management of sites polluted by

4 In accordance with the Public Health Code, the exposure of persons to ionising radiation during the operations involved in the management of sites polluted by radioactive substances and after said operations, shall be kept to a level that is as low as reasonably achievable in the light of current technology and economic and social factors. Thus, from an operational viewpoint, for ASN, the reference approach is, whenever technically possible, complete clean-up of the radioactively contaminated sites, even if the potential exposure to humans from the radioactive pollution appears to be limited. Even if, depending on the characteristics of the site, this approach were to pose implementation difficulties, one should nonetheless take the clean-up process as far as reasonably achievable and provide all technical or economic evidence to demonstrate that the remediation operations cannot be taken any further and are compatible with the established or envisaged usage of the site. Assuming that complete clean-up is not achieved, appropriate measures as specified in point e. below must be taken.

In practice:

a. In the event of residential or sensitive uses, the premises must be completely cleaned-up. If any residual pollution in the premises cannot be removed, a check must be run to ensure that the situation is acceptable and that the premises can be freely used.

b. If the waste volumes produced by complete remediation of the site would be too voluminous for handling in dedicated disposal centres, it could be acceptable to keep the radioactive pollution on the site, provided that it can be guaranteed that the residual dosimetric impact remains acceptable for the current and future uses of the site, if need be with the implementation of usage restrictions. This rule for example applies to the case of phosphogypsum waste heaps or combustion ashes, as well as to uranium mining waste.

c. In justified cases in which the waste volumes that would be produced by complete clean-up of the site remain manageable in dedicated routes, but which are not currently available, partial remediation may be acceptable. Technical solutions allowing easy subsequent waste recovery must then be preferred. Solutions which consist of keeping the pollution beneath buildings and managing the impacts by construction measures are to be prohibited, except in special, duly justified cases.

d. When a radon risk has been identified, it must be managed in accordance with the specific relevant regulations, taking account of the recommendations from the competent international organisations (ICRP[1], WHO[2]).

e. When the reference approach cannot be employed, in other words when the decision is taken to maintain the pollution in-situ, the following shall apply, as and when necessary:

– take steps concerning the transfer pathways in order to significantly mitigate the exposure pathways and ensure that the solution adopted leads to exposure that is acceptable in the light of the established or envisaged usage of the site,

– set up monitoring and specify the responsibilities for maintenance and oversight,

– inform the public,

– retain an archive and record and, as applicable, implement any utilisation or public protection restrictions,

– do not compromise the recovery of contaminated materials for subsequent management, in particular through construction work. ■

1. International Commission on Radiological Protection.
2. World Health Organisation.

BASOL site
http://basol.ecologie.gouv.fr

Regulatory framework and circulars governing the management of polluted sites and soils

By Laurence Roy and Estelle Chapalain, Nuclear safety and radiation protection delegation, General Directorate for Risk Prevention – Ministry for Ecology, Sustainable Development and Energy

General context

The regulations applicable to the management of polluted sites and soils were initially developed to manage those sites suffering from chemical pollution and were then adapted to the particular case of radioactive pollution. This is why the management of sites and soils polluted by radioactive substances is closely linked to the management of those polluted by chemical substances, while at the same time comprising a number of regulatory particularities.

Polluted sites and soils management policy is based on three general principles:
– management of these sites according to the established or planned usage,
– archive and record of past pollution and remediation work,
– the provision to the public of the available information on the potential hazards created by these sites.

From a policy of site surveying and classification to a policy of risk management according to usage

As of the 1990s and under the supervision of the Ministry for the Environment, French policy concerning the management of polluted sites and soils focused on identifying the scale of the issues and challenges by means of various site inventories. These inventories led to the definition of two databases which are now open to all via the Internet:
– BASOL (*http://basol.ecologie.gouv.fr*), which today lists about 3,900 sites subject to management measures to prevent risks to the surrounding populations and environmental damage;
– BASIAS (*http://basias.brgm.fr*) which now lists about 180,000 sites which in the past were home to an industrial or service activity.

To allow harmonised surveying and classification of the polluted sites, the ministerial circular of 23 April 1996 presented the first versions of the methodological tools used for:
– the historical surveys;
– the initial diagnosis and simplified risk assessment (ESR).

The aim then was systematic remediation of all sites identified as sensitive, considering only their inherent pollution level.

The polluted sites and soil management policy changed at the end of the 1990s, moving more towards a policy of risk management according to usage. Consequently, the circular of 10 December 1999 introduced appropriate tools and methodologies, in the form of the detailed diagnosis and the detailed risk assessment (EDR). Polluted site usage is now determined so that it is compatible with the levels of pollution or, conversely, the level of pollution clean-up can be determined according to the intended usage. The decision-making process is based on a cost/benefit analysis, which can sometimes lead to the pollution being left in-situ.

Many sites and soils are polluted owing to the operation of installations classified on environmental protection grounds (ICPE) in a context in which, in the 1990s, the regulations were unable to adequately prevent the occurrence of this pollution. The Act of 30 July 2003 concerning the prevention of technological and natural hazards and remediation of damage (initiated following the AZF accident) and its implementing decrees, thus modified the conditions for the end of operation of an ICPE, so that the polluted sites and soils management policy is above all based on pollution prevention measures. Furthermore, the principle of site management according to its usage, already in use in other European countries, is now enshrined in the regulations[1]. Finally, these texts clarify site remediation responsibilities:
– a licensee cannot be held responsible for a change in usage, not attributable to itself, after it has ceased its activity in compliance with the requirements;

1. Articles R. 512-39-3 for facilities subject to authorisation; R. 512-46-27 for facilities subject to registration; R. 512-66-1 for facilities subject to notification.

– the principle of consultation with the Mayor and the landowner concerning the future use of the site is now enshrined in the Environment Code, as are the steps necessary to make the site safe[2];
– the obligation to conduct an environmental analysis during the receivership phases is introduced by the Act. The Code of Commerce thus requires that the Receiver supplement the economic and social analysis of the company in difficulty by an environmental analysis comprising the information necessary for making the site safe and managing its impacts if the facility were to be shut down[3].

These legislative and regulatory provisions stipulate that the prevention of the hazards created by an ICPE is the responsibility of the operator of the facility, regardless of the nature of the hazard. It is not therefore up to the State to carry out risk prevention measures on a classified installation, whether in operation or shut down. In certain cases, in particular on sites where the activity was sometimes halted suddenly, the State must initiate and complete all possible administrative procedures against the responsible party or parties in order to achieve remediation of the site. However, the responsible party may default and be incapable of meeting its corresponding obligations or may even prove impossible to identify. In such situations, when there is a serious threat to the population and the environment, the public authorities must intervene as the guarantors of public health and safety.

Whether site remediation is carried out by the licensee or by the State, if all the polluting substances cannot be removed, it may be necessary to implement environmental monitoring and usage restrictions in order to maintain compatibility between the residual level of pollution and the usage, including for the long-term. Thus, for pollution caused by an ICPE, the Environment Code[4] makes it possible to institute public protection restrictions (SUP) on the site and on the land polluted by the licensee of an installation (ICPE) after it has closed down.

This policy is based on an examination and management of the hazard more than on an intrinsic level of pollution and means that a record and archive must be kept of past pollution and the remediation steps taken. The BASOL and BASIAS public databases already list sites which were home to an industrial or craft activity. In addition, the French National Radioactive Waste Management Agency (ANDRA) draws up and every three years updates and publishes the inventory of radioactive materials and waste present in France, along with their location[5]. In addition to waste, this inventory also lists the sites polluted by radioactivie materials. Article L. 125-6 of the Environment Code[6] also stipulates that the State must make public all information at its disposal concerning the risks of soil pollution. This information must be taken into account when producing and revising town planning documents.

The implementing decrees are currently undergoing the consultation process and make provision for the creation of:
– vigilance areas: sites on which there is confirmed pollution of the soil or groundwater, or sites which were home to activities known to be highly polluting;
– information areas: sites on which there is a possibility of soil or groundwater pollution.

These areas would be determined by the Prefect, after consultation with the Mayors or the public body with competence for town planning. The public would be informed via a geo-portal.

A number of circulars in turn defined the administrative and legal procedure with regard to the remediation of these sites polluted by chemical substances.

First of all, the arrangements introduced by the circular of 7 June 1996 led to public action being reinforced with the contribution of the French Environment and Energy Management Agency (ADEME) in the field of sites and soils polluted by chemical substances. The Prefect was then the competent authority, pursuant to the regulatory provisions of the Environment Code.
Then, learning from experience gained from State policy on management of polluted sites and soils, this circular was replaced by circular BPSPR 2005/371/LO of 8 February 2007 concerning the cessation of activity by a classified installation. This highlighted the role of the licensee in the prevention of pollution on active sites as well as the implementation of certain safety measures (access restrictions, limitation of the quantities of waste on the site). These measures, taken upstream of the cessation of activity, should help limit the need for ADEME financing to make the site safe.

Finally, these provisions were updated by the circular of 26 May 2011 concerning the cessation of activity by a classified installation with regard to the chain of responsibility-defaulting of responsible parties. It also decentralises to the Prefects authorisation to perform work financed by the ADEME, provided that its amount does not exceed €150 k.

The evaluation of polluted sites management policy carried out in 2007, at the same time led to the definition of new management processes for polluted soils. This is the subject of the circular of 8 February 2007 regarding polluted sites and soils and the processes for the management and remediation of polluted sites.

Regulations applicable to the management of sites and soils polluted by radioactive substances
The particular case of sites and soils polluted by radioactive contamination was taken into account in the interministerial circular of 16 May 1997 concerning the

2. Articles R. 512-39-2 for facilities subject to authorisation; R. 512-46-26 for facilities subject to registration; R. 512-66-1 for facilities subject to notification.
3. Article L. 621-54.
4. Articles L. 515-8 to L. 515-12.
5. Article L. 542-12 of the Environment Code.
6. Taken from article 188 of the Grenelle 2 Act of 12 July 2010

administrative procedure applicable to sites polluted by radioactive substances. It readopts the same principles as the circular of 7 June 1996, with ANDRA taking the place of ADEME as acting project owner in specific situations in which the party responsible is either insolvent or unknown.

The circular of 1997 was subsequently replaced by circular 2008-349 of 17 November 2008 concerning the assumption of responsibility for certain radioactive wastes and radioactive pollution sites and the public interest duties of ANDRA, which are still in force. It introduced a number of new elements into the management principles for sites polluted by radioactive substances.
First of all, it takes up the principles of the circular of 8 February 2007 concerning the cessation of activity by a classified installation, and highlights the fact that the management of sites polluted by radioactive substances must be consistent with the national policy on polluted sites and soils, as presented in the circular of 8 February 2007 concerning polluted sites and soils and the polluted sites management and remediation processes. It introduces the role of ASN, which must provide the Prefect with its opinion on the remediation objectives.
This circular of 17 November 2008 takes account of ANDRA's extended role, as introduced by Planning Act 2006-739 of 28 June 2006[7] on the sustainable management of radioactive materials and waste, which tasked it with the collection, transport and treatment of radioactive waste and the remediation of radioactive pollution sites after public requisition when the parties responsible for this waste or these sites have defaulted. To do this, ANDRA receives a subsidy from the State, which helps finance the public interest duties entrusted to it.

The circular also includes the procedures for calling on the National Commission for Assistance in the Radioactive Field (CNAR), the creation of which was decided on by an ANDRA board meeting of 27 April 2007, when the party responsible for a polluted site is either insolvent or has defaulted. The subsequent decree 2010-47 of 13 January 2010 concerning ANDRA and the creation of the radioactive waste industrial coordination committee, introduced this CNAR Commission into the Environment Code[8].

For the first time, this circular also specifies procedures for the management of sites polluted by radioactive substances which are not classified installations (private residences, ICPEs which closed more than 30 years previously, for example). The legislative and regulatory framework which applies in these cases[9] is specified in the Public Health Code. The articles concerned are:
– article R. 1333-13 if steps can be taken to reduce human exposure;
– article R. 1333-41 when the site is located within the perimeter of a nuclear facility (as defined in article L. 1333-1) which is no longer in operation;
– articles R. 1333-89 and 90 if the site is liable to entail long-term exposure. In this case, the party responsible is required to implement measures to monitor exposure and proceed with clean-up of the site.

Finally, the circular specifies the procedure to be applied according to whether the party responsible for the site is solvent or not. In both cases, the remediation objectives identified for management of these sites are validated by ASN.

Methodologies and tools for management of polluted sites and soils

To help the various players involved in the management of polluted sites and soils, the Ministry responsible for the environment has developed tools enabling its relevant policy to be implemented operationally. These tools are available on-line from the website of the Ministry for Sustainable Development, dedicated to polluted sites and soils, under the "toolbox"[10] heading.

In particular, the circular of 8 February 2007 concerning polluted sites and soils and the methods for managing and remediating polluted sites, for the first time introduced methodological tools appropriate to polluted sites in the broadest sense of the term. The two management approaches proposed in this circular, applicable to chemical pollution, are referred to as "interpretation of the status of the environment" and "management plan".

In order to extend these two approaches to sites and soils polluted by radioactive substances, but also to take account of experience and changes to the regulations, the Ministry for Sustainable Development and ASN tasked IRSN with the drafting of a new methodology guide for management of such sites (to replace the existing guide dating from 2001). This revised guide was published in December 2011[11]. Management of sites and soils polluted by radioactive substances is now also based on these "interpretation of the state of the environment" and '"management plan" approaches. One of the important points to be underlined concerns the analysis required to evaluate the level of clremediation to be achieved, particularly in the light of the planned uses of the site. This analysis is based on a cost/benefit analysis which must present the various elements, such as the management of radioactive waste, the expectations of the stakeholders, the cost to the State, the residual exposure of the public following the clean-up process, the continuity and robustness of the solution adopted.

To conclude, the general principles and the methodologies currently in force, concerning the sites and soils polluted by both chemical and radioactive substances, benefit from more than a decade of experience and harmonisation. ■

7. Articles L. 542-12 et L. 542-12-1 of the Environment Code.
8. Article R. 542-15.
9. In book III "protection of health and the environment", section III "prevention of environmental and occupational health hazards", chapter III "ionising radiation".
10. *www.developpement-durable.gouv.fr/-Sites-et-sols-pollues-.html*
11. Available on the *www.asn.fr; www.irsn.fr* and *www.developpement-durable.gouv.fr* websites.

From management of radioactive waste to management of the sites and soils polluted by radioactivity:
A few considerations concerning the public interest duties entrusted to ANDRA

By Bertrand Oudry, Special Adviser, office of public policy and oversight, General Directorate for Energy and Climate – Ministry for Ecology, Sustainable Development and Energy

The remediation of radioactive pollution sites is today clearly identified as a public interest duty entrusted to the French National Agency for Radioactive Waste Management (ANDRA).

The management of sites and soils polluted by radioactivite material is a relatively recent policy in France, at least in its current configuration, even though the activities which originally caused this pollution often date back many years.

The planning Act of 28 June 2006 on the sustainable management of radioactive materials and waste officialised the role of ANDRA on this subject, explicitly identifying among the duties entrusted to it, that of "collecting, transporting and ensuring responsibility for radioactive waste and remediating radioactively polluted sites at the request of and at the expense of the parties responsible or following public requisition when the parties responsible for this waste or these sites have defaulted" (article L. 542-12-6 of the Environment Code).

The Act also stipulates that the Agency "receives a State subsidy which contributes to financing of the public interest duties entrusted to it pursuant to the provisions of 1[1] and 6 of article L. 542-12" (article L. 542-12-1 of the Environment Code). Among the duties entrusted to ANDRA, the legislator thus identifies those of public interest (also sometimes called "public service duties") which justify specific financing, provided by a subsidy from the State's general budget.

It is now clear that ANDRA, as a public establishment responsible for the long-term management of radioactive waste, is tasked with intervening to remediate radioactive pollution sites, which means not only taking responsibility for the waste or the land polluted as a result, but also for safeguarding these sites and ensuring that all the pollution is removed, or is removed to an extent compatible with the future use. ANDRA's legitimacy and competence in this field are today recognised, as clearly demonstrated by its role in Operation Radium Diagnosis run by ASN and officially launched in September 2010.

A quick look back shows that a system such as this was not initially a foregone conclusion, when ANDRA was first created, and that the process which led to the Act of 28 June 2006 had its fair share of trial and error, hesitation and even fluctuation in the positions adopted by the various administrations concerned. In the end, the choice made in 2006 can be explained far more by pragmatism than by theoretical considerations with regard to the best answer to the problem posed.

The Agency's original road-map did not deal with this subject.

The 30 December 1991 Act on research into the management of radioactive waste, which created ANDRA (article 15), entrusted it with a list of duties which, even if not restrictive, left no room for the management of polluted sites and soils. The Agency was then tasked with taking responsibility for all radioactive waste produced nationwide, regardless of the origin, and for operating the corresponding management routes, or for designing, siting and building the new disposal centres that became necessary and for performing all relevant studies necessary.

When defined in this way, this duty meant that ANDRA had to concern itself not only with waste produced by the nuclear power generating industry and by the hospital/university and research sector ("small producers") but also with that relating to the diffuse nuclear sector (those occasionally in possession of a wide variety of radioactive objects) and, finally, that produced on the sites polluted by radioactive substances.

With regard to the latter, ANDRA gradually moved away from management of the waste itself, to management of its production[2], and then to management of remediation of the site itself. This change is the result both of ANDRA's desire to intervene as far upstream as possible, as soon as the waste package is produced, and of the requests – if not the requisition – by the public authorities in the absence of other competent and/or solvent parties.

1. This concerns the drafting and publication of the national inventory of radioactive materials and waste.
2. In other words, management of the flow of waste produced by the clean-out work.

Faced with a real case, the public authorities had to improvise.

In the early 1990s, the case of the Bayard facilities in Saint-Nicolas d'Aliermont (Seine-Maritime *département*[3]) illustrated the limits of the existing legal framework – based in particular on the regulations applicable to classified installations – and the need to design operational regulatory and financial tools to enable such situations to be dealt with.

This case concerned a company which had first used radium and then tritium for the application of radioluminescent paint to clock and watch faces and hands. The Bayard company went into receivership in March 1987 and no longer had either the legal capacity or the means to perform the necessary remediation work required for the possible reuse of its site. As for the receiver in whose hands the company had been placed, he rapidly proved incapable of undertaking this work, given its scale and the scarcity of resources that he could hope to have at his disposal.

ANDRA intervened on the Bayard site in 1994, following a requisition by the Prefect of the Seine Maritime *département*: orders from the Prefect authorised it on the one hand to temporarily operate a disposal and packaging facility for the radioactive waste produced by the clean-up work and, on the other, to carry out decontamination work "at the expense of the natural or legal persons responsible for the contamination". In the absence of any plans for reuse of the site, it simply carried out surface clean-up, with the excavation of about 1,050 tons of contaminated earth, which were taken away as waste to CEA's BNI 56 in Cadarache for storage. The financing of this work, which cost about € 2 M exclusive of taxes, was covered by an exceptional subsidy from the Ministry responsible for industry, by financing from the ERDF[4] with the rest being covered by the "orphan polluted sites" patronage agreement concluded subsequently between ANDRA and the main French nuclear licensees (see further on in this document). This one-off funding covered the cost of the work, but left unresolved the question of financing the cost of the storage and future disposal of the waste. Nothing came of the procedures initiated against the receiver of the Bayard company.

The circular of 16 May 1997 provided an initial answer, albeit legally uncertain and with insufficient financing.

The lessons learned from the clean-up work on the Bayard site and the need to deal with other polluted sites made the distribution of an interministerial circular (labour, environment, industry) to the Prefects essential. This circular of 16 May 1997 specified the procedures to be followed in dealing with such sites and the respective responsibilities of the various parties involved, as defined by the 19 July 1976 Act on classified installations and its implementing decree[5]. It also clarified those cases in which the Prefects could automatically require remediation work to be performed at the expense of the party or parties responsible, appointing ANDRA as acting project manager for this work.

The circular of 16 May 1997 represented a significant step forwards, but proved to be uncertain from the legal standpoint because on the one hand it in practice extended the scope of the 19 July 1976 Act to polluted sites, even if they did not contain any classified installations[6] and, on the other, it gave ANDRA the role of acting project manager – in addition to its primary duty of technical appraisal regarding the waste management conditions – which could not be clearly and unambiguously considered to be one of its duties. Furthermore, it did not provide a totally satisfactory answer to the questions raised by the remediation of radioactive sites, particularly that of the financing of the operations. Focusing on application of the "polluter-pays" principle, it asked ANDRA to take legal action in order to obtain from those responsible for the site the reimbursement of the expenses it had incurred. In the absence of any identified or solvent responsible party, which was often the case, no provision was made beyond dealing with emergency situations, which forced ANDRA

3. Administrative region headed by a prefect.
4. European Regional Development Fund.
5. Provisions today codified (Environment Code).
6. In this respect, it was found to be illegal by a decision of the Administrative Court of Versailles on 17 December 2002.

to look for remedial solutions from the main French nuclear licensees (EDF, CEA and COGEMA, which subsequently became AREVA NC).

In September 1996, under the aegis of the public authorities, these licensees concluded an agreement with ANDRA on the financing of clean-out operations for "orphan polluted sites" (SPO). This 5-year agreement entered into force with the publication of the circular of 16 May 1997. The intervention by the licensees on this subject was in practice more a case of patronage, as they were clearly not responsible for the legacy pollution of sites caused by activities from the past (radium extraction) or unrelated to the nuclear sector (clock/watch-making and others).

A second agreement was signed in 2003 for a further three years. While the scope of the first SPO agreement was relatively broad and covered all the costs linked to the pollution clean-up operations, that of the second was restricted only to work necessitated by a health emergency. The experience of making safe the Orflam-Plast[7] industrial site in Pargny-sur-Saulx (Marne *département*) had also shown that in their capacity as the sources of funds, the nuclear licensees had a tendency to try to assume a more influential role in the place of the public authorities. Even though it had enabled a certain number of pressing needs to be addressed, resorting to the nuclear licensees was not therefore a sustainable solution.

After the experience of the radium fund, the preparation for the 2006 legislative deadline enabled a long-term solution to be found.

The creation in June 2001 of the "radium fund" run by the Ministry for the Environment, financed by an allocation from the ADEME's budget and actually managed by ANDRA, aimed to address a specific situation, distinct from the derelict industrial sites such as Bayard or Orflam-Plast: this time, the situation concerned premises, usually residential, built on land contaminated by radium[8] as a result of the former presence of activities historically linked to the "radium saga" during the first half of the 20th century. The Coudraies district in Gif-sur-Yvette (Essonne *département*), a residential area built on land contaminated by a radium extraction firm which went into receivership in 1957 and was subsequently inadequately cleaned up, is a prime example of this type of problem.

As the party responsible for the pollution had disappeared, the landowners, primarily private individuals with sometimes modest incomes, found themselves forced to bear the often insurmountable cost of clean-up (works and removal of the resulting waste) failing which they would be obliged to live in a contaminated environment, with a serious drop in the value of their assets. Faced with such a situation, the need for public aid was recognised, but the level of the radium fund subsidy, capped at 50% of the actual cost of the work, was often an obstacle to carrying out the pollution clean-up operations, as the remaining cost to be borne by the landowners was felt by them to be too high. It then became inevitable to accept the possibility of a higher subsidy rate, of up to 100%.

Visit by CNAR members to Gif-sur-Yvette (Essonne)

Although inadequate, the radium fund arrangements, which included the creation of a national committee reporting to the director for the risk prevention at the Ministry for the Environment, was the precursor to the solution that was to be adopted several years later.

The idea whereby the pollution clean-up of sites contaminated by radioactivity required an appropriate intervention system, in other words both public financing of the requisite amount and a competent operator, was slowly becoming accepted, although not without a degree of reticence, not only because the idea of public financing came at a time of already strict budget constraints, but also because the role assigned to ANDRA exceeded the scope of its traditional duties. The Agency's supervisory administrations were unfavourable to intervention in a field that they felt lay outside ANDRA's core activity and one that could even place it in conflict of interest situations.

The first four-year State-ANDRA contract, covering the period 2001-2004, did not set any particular objective for dealing with radioactively polluted sites; it simply recalled that the interministerial circular of 16 May 1997 had given the Agency a role of assessment and assistance to the public authorities for the diagnosis and remediation of these sites.

The second four-year contract, covering the period 2005-2008, dealt more explicitly with the topic of processing polluted sites for which the responsible party had defaulted. It made provision, as of 2005, for a framework

7. Until 1996 this site had housed a facility producing lighter flints from monazite, the processing of this ore having led to the production of waste contaminated by thorium.
8. Or even premises redeveloped and converted for other uses.

for action to overhaul the existing system and take account of lessons learned from the implementation of the circular of 16 May 1997. The preparation of the contract has particularly helped raise the question of the financing of the agency's "public interest" activities which, in addition to producing the national waste inventory[9], included the collection of diffuse nuclear waste and pollution clean-up of radioactively contaminated sites. The principle of a public subsidy paid to the Agency, topping up its own resources as and when needed (in other words the resources financed by the margin achieved on its industrial activities) was explicitly envisaged.

These considerations were incorporated into the preparation of the radioactive materials and waste management bill.
The initial drafting of the bill, tabled in March 2006, made it possible for the State to entrust ANDRA with the management of radioactive waste for which the party responsible was either unknown or defaulting, with a subsidy contributing to the financing of this public interest duty, without prejudice to any legal action being taken against the party responsible. It is clear that this cautious drafting made no explicit mention of the remediation of polluted sites. It was only during the Parliamentary debates, in this case at the initiative of the Senate, that the drafting of the text was supplemented, extending ANDRA's role to the remediation of polluted sites.

The system created by the Act is operational but, for certain waste from polluted sites, a management solution still had to be put into place.
The provisions of the 28 June 2006 Act were the opportunity for a fresh look at the skills and responsibilities of the various parties involved and for clarifying the procedures applicable to the processing of polluted sites, whether subject to the regime on classified installations, or the Public Health Code. This was the subject of the interministerial circular[10] of 17 November 2008 sent out to the Prefects, the effect of which was to supersede the circular of 16 May 1997.
In budget terms, the clarification resulting from the 28 June 2006 Act concerning ANDRA's duties and resources in this field, led to a credit allocation corresponding to the financing of the Agency's public interest duties being included in the finance Act. For 2012, this allocation amounts to €4.162 M. This means that about €3 M can be assigned to processing of polluted sites (including financing of the cost of storage of the waste following site clean-up) and financing of the national inventory of radioactive materials and waste and the collection of diffuse nuclear waste (with regard to that receiving aid).

One consequence of this Act was to set up a pluralistic oversight body (representatives of the State, associations, experts, local officials) within the Agency's governance, tasked with defining priorities for allocation of public funds, determining polluted site treatment strategies and ruling on the individual dossiers submitted to it. Since its first session in July 2007, the National Commission for Assistance in the Radioactive Field (CNAR) has carried out a considerable amount of work, as presented elsewhere.

The treatment of radioactively polluted sites is thus today covered by a consistent and coherent system, similar to that applicable to non-radioactive polluted sites, with the duties assigned to ANDRA being in this respect similar to those of ADEME for non-radioactive sites.

Although much has been achieved, ANDRA today remains faced by a major obstacle to the performance of its polluted sites duty, that is the fact that the Agency does not currently have at its disposal all the industrial tools needed to process and take responsibility for the waste resulting from the remediation of these sites. The insufficient storage solutions – despite the forthcoming commissioning of a facility on the site of the Morvilliers very low level waste disposal centre in the Aube *département* – and the absence of disposal solutions for radium-bearing waste classified as low level, long-lived waste (or LLW-LL), are a significant handicap: on the one hand, ANDRA may be obliged to propose remediation scenarios limiting the volume of waste removed and thus leaving residual pollution[11] in-situ; on the other, the uncertainty surrounding the future cost of disposal of this waste makes it hard to evaluate the total cost of a pollution clean-up operation and entails a certain financial risk for the Agency, in that it will have to subsequently cover costs which may not have been correctly evaluated. This subject demands particular attention on the part of the competent Authorities, especially with regard to the work to update the national radioactive materials and waste management plan (PNGMDR). ■

9. For which financing by public subsidy was obtained as of 2002.
10. Co-signed by the DGEC, the DGPR, the Director General for Health and the Director General of the ASN.
11. Independently of the fact that setting a clean-out objective that is consistent with the intended use of the site may, after an overall analysis taking account of the notion of acceptable cost for the community, lead to the adoption of a partial pollution clean-up scenario.

Incident in Lyon during recovery of old radium-based objects intended for medical uses

During the course of 2011, a private individual in Lyon contacted ANDRA asking it to collect some old radium-based objects intended for medical uses (ORUM) which had belonged to his grandfather, a doctor who had died in 1956 and who had used radium-based objects for his professional activity. For several decades, these objects had been kept in a box in the basement of a building in the centre of Lyon.

On 29 February 2012, ANDRA sent a contractor out to collect the old ORUM from the basement of the building concerned. During the operation, radium dust was found to be in suspension in the building's entrance hall, in particular owing to the damaged condition of the objects. Two of the operators and a part of the hall received very slight contamination. The ASN Lyon division was immediately informed of the situation. The operators closed down the operation and called in the fire department's mobile radiological intervention unit (CMIR).

This unit immediately went to the site and managed the situation, liaising with the office of the Prefect and ASN. The two very slightly contaminated persons were given care and treatment. The fire department confirmed the presence of slight traces of contamination in the common parts of the building (entrance hall, stairwell).

To facilitate removal of the slight traces of radium and prevent any dispersal of the radioactive dust as a result of comings and goings by the occupants, the Prefect of the Rhone *département*, at the suggestion of ASN, decided to evacuate the residents of the building. They were rehoused by the Lyon local authority for 3 days, which was the time needed to have the common parts of the building cleaned by specialist contractors. ASN suggested that the Prefect of the Rhone *département* issue an order regulating the cleaning of the premises and requiring safeguarding of basements still containing ORUM. This order stipulated a final check on clean-up of the common parts of the building by a third-party company. On 3 March 2012, after receiving the results of this check, confirming the radiological cleanliness of the common parts concerned, the Prefect followed the ASN proposal to allow the occupants to return to the building.

From March to July 2012, ANDRA and its contractors prepared a second ORUM recovery operation. Pursuant to the order from the Prefect, the procedure and the preparation of this operation were subject to approval by ASN and the office of the Prefect. The ORUM were thus removed to an authorised facility.

In June 2012, radioactivity measurements were taken inside the apartments, to look for any presence of radium. They concluded that there was no radium in the private areas of the building. Access to the basements is still secured. An exhaustive inventory of basement contamination is to be carried out in the next few months. ■

CMIR intervention on 29 February 2012

The approach and general principles for management of sites and soils polluted

by radioactive substances, recommended by the public authorities in November 2011

By Odile Palut-Laurent, Waste Research Facilities and Fuel Cycle Facilities Department – Autorité de sûreté nucléaire, Laurence Roy and Estelle Chapalain, Nuclear safety and radiation protection delegation, General Directorate for Risk Prevention – Ministry for Ecology, Sustainable Development and Energy

The management of sites and soils (potentially) polluted by radioactive substances falls within the general framework of the national management policy for (potentially) polluted sites defined by the circulars of 8 February 2007, even if some modifications are necessary in practice, given that the pollution concerned is radioactive. The perception of the radiological risk is particularly acute and requires management measures appropriate to this perception. Thus, in response to these circulars, ASN, IRSN and the Ministry responsible for sustainable development, in close collaboration with the stakeholders, drafted the methodology guide for the management of sites potentially polluted by radioactive substances. This new guide, which was published in December 2011, replaces the methodology guide for the management of industrial sites potentially contaminated by radioactive substances, issued in 2001 and then updated in 2008.

video on asn.fr

■ L'Orme des Merisiers (CEA): a pollution clean-up site

Although the primary objective is the removal of the maximum amount of pollution, in order to aim for complete clean-up, management sometimes needs to be adapted to the particular situation of each site, in particular in the light of current technical knowledge and economic and social factors. Thus, on the occasion of the publication of the guide, and given the large number of parties involved in the management of a site polluted by radioactive substances, the public authorities felt that it was essential that this guide be supplemented by a supporting letter on 16 November 2011, which specifies the general principles shared by ASN and the Ministry responsible for sustainable development.

The approach to the management of sites polluted by radioactive substances is thus based on the four general principles and on application of the 2011 guide. The four general principles are as follows:

The polluter-pays principle

By virtue of the polluter-pays principle defined in article L.110-1 of the Environment Code, the party responsible for the pollution of a site must, if solvent and if there is no prescription, finance the clean-up and remediation operations on the polluted site, up to and including removal of the waste and the implementation of any measures specified by the administrative authority (environmental monitoring, access ban, usage restrictions, etc.).

Since the Planning Act 2006-739 of 28 June 2006 and its article 14, codified in article L. 542-12 of the Environment Code, if the party responsible for the pollution defaults, ANDRA then takes charge of remediation following a public requisition. For this purpose, ANDRA set up the National Commission for Assistance in the Radioactive Field (CNAR). This financial system, which had been requested by all stakeholders for a long time, now ensures that appropriate financing is available and that the necessary steps can be taken for management of polluted sites referred to as

View from a phosphogypsum waste heap: residues kept in-situ provided there is monitoring and usage restrictions, as applicable

"orphans". These arrangements are specified in article R. 542-15 of the Environment Code, as well as in circular 2008-349 of 17 November 2008.

A precise diagnosis of the site for management appropriate to its current or future usage

The diagnosis phase is the foundation on which the entire management approach to a potentially polluted site is built and assesses the compatibility between the levels of pollution and the established or envisaged uses. It entails drawing up an inventory of a potentially polluted site and evaluating the hazards for man and the environment. This information collection phase is crucial and must be conducted in enough detail to allow precise characterisation of the pollution and definition of the clean-up objectives and so that the decisions regarding management of the site can be made with a sufficient degree of confidence. It must also allow definition of how the waste liable to be produced is to be dealt with, evaluation of the anticipated cost of the various management solutions proposed, and evaluation of the robustness and sustainability of these solutions. It would appear to be essential that the solution proposed and the arrangements envisaged be evaluated with respect to how their performance is maintained over time.
In practice, two typical situations can be encountered:

– the usage has been established. In this case, the question is that of the compatibility of the environment with the usage. The approach recommended by the guide is to conduct an interpretation of the state of the environment (IEM), which makes it possible to compare the measurements taken on the site and in its environment with the management values applicable to the population or the environment. If usage is incompatible, the site would have to be rehabilitated through a management plan;
– usage has not been established and the possible uses can thus be influenced. In this case, the question is to evaluate the compatibility of the biotopes[1] with the new planned uses. The approach recommended by the guide is to produce a management plan able to determine what work is needed in order to ensure that the environment is compatible with the planned uses.

The principles of radiation protection: optimisation

Article L.1333-1 of the Public Health Code states that human exposure to ionising radiation as a result of these activities or interventions must be kept as low as reasonably achievable in the light of current technology and economic and social factors.

When adapted to the management of radioactively polluted sites, this optimisation or ALARA principle indicates that as

1. The biotopes are the various compartments of the environment (water, air, soil and subsoil) liable to be affected by the pollution of a current or former industrial site.

soon as exposure is brought to light, reasonably practicable steps to mitigate the exposure must be sought and whether or not it is worth implementing them must then be examined on the basis of their cost, their technical feasibility and the effectiveness that could be expected.

Thus, in the case of established uses (IEM approach) and even if the compatibility between these uses and the biotopes is confirmed, simple, appropriate steps should be taken as applicable, in a manner proportional to the issues, thus reducing the exposure as reasonably as possible.

In all other cases and once a management plan is in place, it is important that a cost/benefit analysis be completed and must first of all aim to reduce human exposure to ionising radiation as a result of the use of the site and the remediation operations as far as is reasonably practicable. This cost/benefit analysis must also take account of the robustness of the management solutions envisaged and highlight the most appropriate one. Thus removal of a maximum amount of pollution, with the aim of achieving complete clean-up, is the primary objective to avoid having to perform repeated subsequent pollution clean-up operations.

In particular, if the site is to be used for housing, the reference approach is a removal of the pollution that is as complete as possible.

However, in specific cases, the decision may be taken not to carry out maximum pollution clean-up if the residual dosimetric impact remains acceptable for the intended use, for example, when too much waste would be generated or if there is no disposal route for it. In any case, in this type of situation, steps must be taken concerning the transfer pathways in order to minimise exposure, to set up appropriate environmental monitoring of the site and, as applicable, the zone affected by it, to prefer reversible technical solutions allowing possible subsequent pollution clean-up, to implement usage restrictions and to take all measures to retain a permanent record of the site and ensure appropriate information of the public.

Validation of the clean-up project and targets by the public authorities concerned is necessary prior to implementation of the chosen solution. This is done on the basis of the diagnosis, the cost/benefit analysis and the justifications of the option chosen by the site manager.

Stakeholder involvement

The stakeholders and the public concerned must be involved as early as possible in the management approach for a site polluted by radioactive substances, in order to achieve a management or remediation solution that is jointly defined and, whenever possible, accepted. It is important that this involvement not be limited simply to information or awareness raising measures and that the highest possible level of public involvement be examined as and when necessary.

This principle is described in detail in the December 2011 guide.

Conclusion

Faced with the diversity of sites polluted by radioactive substances (sites on which the activity causing the pollution is still in progress, or has ceased with or without site redevelopment), the stakes involved (land development pressure, historical sites linked to the history of Marie Curie, leisure centres, etc.), and their specific constraints (industrial or private and residential sites, or rural sites), the public authorities decided to retain a case by case approach based on appropriate management according to the established or intended uses of the site as defined by a national policy for polluted site management and the above-mentioned common management principles. ■

New baseline requirements for the management of sites potentially polluted by radioactive substances

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December 2011: the Ministry for Ecology, Sustainable Development, Transport and Housing (MEDDTL), the Autorité de sûreté nucléaire (ASN) and the French Institute for Radiation Protection and Nuclear Safety (IRSN) published an updated guide to the management of sites potentially polluted by radioactive substances.

This new document is the updated "methodology guide for management of industrial sites potentially contaminated by radioactive substances" published by IRSN in 2001. It aims to bring the existing document into line with the general policy for management of polluted sites specified in the texts published in February 2007 by the Ministry responsible for the Environment[1]. The new version of the guide supplements the methodologies issued by the Ministry[2] and helps provide the players concerned with a joint methodological basis that is essential for joint and uniform management of chemical and radiological hazards. This update was also an opportunity to clarify the clean-up targets and to integrate the provisions introduced by Act 2006-739 of 28 June 2006 on the sustainable management of radioactive materials and waste and the circular of 17 November 2008 on taking responsibility for certain radioactive waste and sites of radioactive pollution, as well as the public interest duties of ANDRA. In its new version, the guide emphasises the importance of involving the stakeholders, by identifying them and proposing forms of interaction, in particular with the public.

This new guide was drafted in two stages. Initially, a working group consisting of the IRSN, INERIS, the MEDDTL and ASN drafted a guide including the objectives mentioned above. This draft also benefited from the conclusions of a pluralistic think tank (GRP) tasked with defining the clean-up objectives. This pluralistic think tank comprised representatives of ASN, the MEDDTL, the public authorities, French and foreign experts, environmental protection associations and elected officials. The first phase in the drafting of the guide ended with the public consultation of the draft guide at the end of 2010. A total of more than 400 comments were received and analysed by IRSN, ASN and the MEDDTL during the second phase of the work. Incorporation of these comments led to the final version of the document, which is today available on the internet[3].

Adapting the approach to the uses

The approach adopted in the new version of the guide reinforces the management approach according to the usage, introducing a clear distinction between two types of situations:
– those for which it is possible to influence both the condition of the site and the uses, which can be chosen or adapted. This is the case with the cessation of activity or conversion of former industrial sites;
– those for which the uses are already established. The uses are qualified as "established" when the polluted zone is home to clearly defined activities (industrial, commercial, residential, agricultural, etc.) and there are no redevelopment projects which could entail their modification. This is, for example, the case when the activity at the origin of the pollution is still on-going or when it has ceased and new uses have been developed on the site without adequate clean-up having been performed.

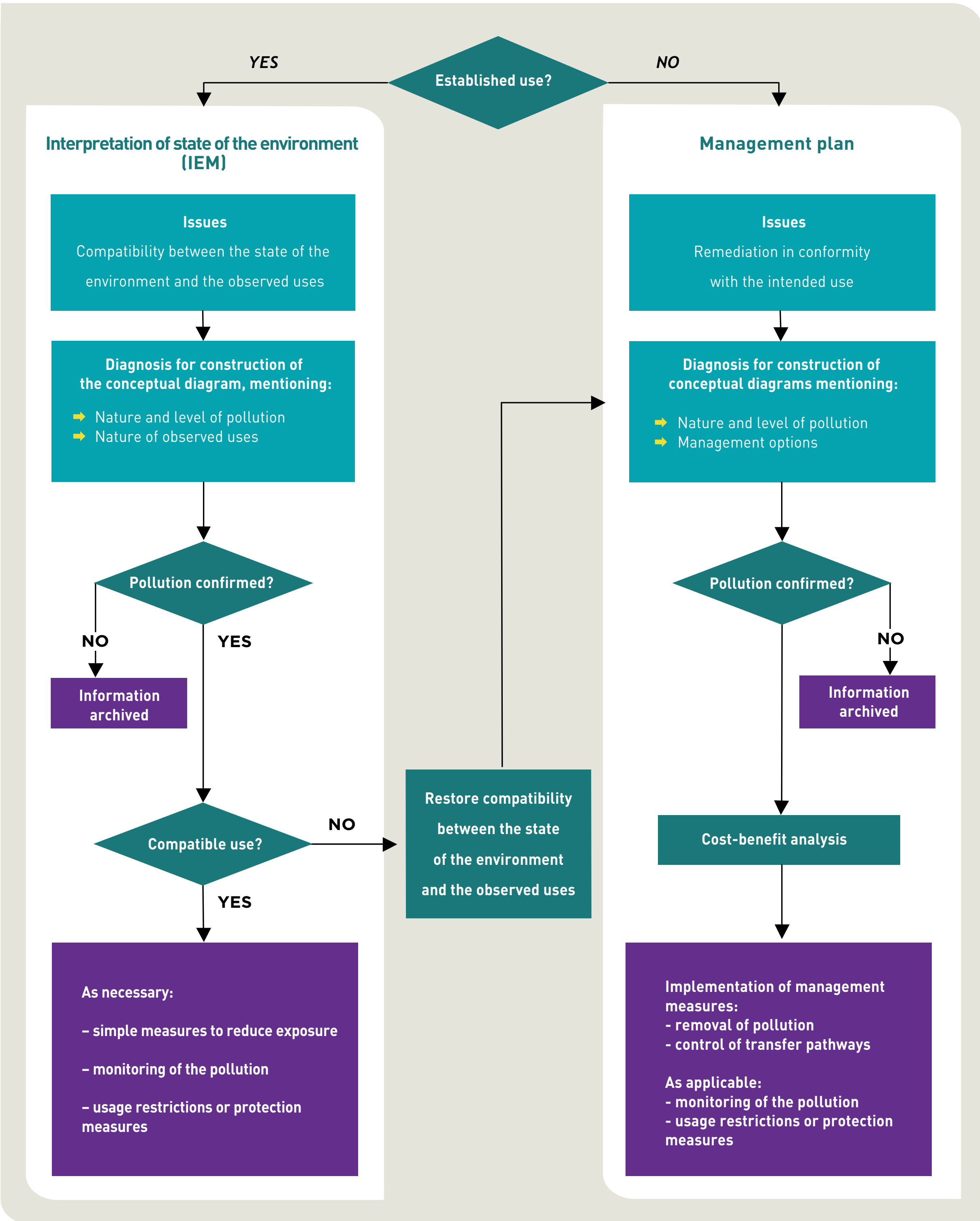
In practice, it is not rare to have to manage both of the above situations simultaneously. This is the case when, during redevelopment of a polluted industrial site, pollution is brought to light that goes beyond the perimeter of the project and affects neighbouring land on which people live or work.
When the uses are established, the primary objective of the management approach is to examine the compatibility between the level of pollution and the uses defined. This compatibility examination takes the form of a step known as interpretation of the state of the environment (IEM). When the uses have not yet been established, the approach entails the definition of a management plan. This consists in defining a site clean-out and redevelopment project taking account of the status of the pollution and the various economic and technical constraints, but also the expectations of the various

1. Circular from the Ministry of the Environment to the Prefects of the regions and *départements* dated 8 February 2007.
2. *www.developpement-durable.gouv.fr/-Sites-et-sols-pollues-.html*
3. *www.irsn.fr; www.asn.fr* et *www.sites-pollues.developpement-durable.gouv.fr*

stakeholders. Within this context, examination of the options allowing removal of the sources of pollution as completely as possible requires particular attention. A management plan can also be implemented following an IEM, when this determined incompatibility between the level of pollution and current uses.

Characterisation is the basis of any management approach
Whether or not a use has been established in the polluted zone, the management approach is systematically based on the performance of a diagnosis proportional to the issues. This diagnosis comprises a documentary study and

Management approach



field investigations which must initially either confirm or rule out the presence of the suspected pollutions. To do this, the approach is to compare the level of radioactivity on the site with the level of radioactivity representative of its initial condition – when known – or with a natural environmental reference status. When no pollution is found, the management process ends after consultation with the various stakeholders concerned, ensuring that the data acquired and the interpretations made are conserved.

When pollution is found, the information collected during the diagnosis must, in addition to determining the level of pollution, allow a definition and implementation of a situation management strategy. Thus, for interpretation of the state of the biotopes, the diagnosis must provide the information necessary for assessing the compatibility between the level of pollution and the observed uses.
In the case of the management plan, the diagnosis must enable the redevelopment options to be defined, along with the associated clean-out objectives. This can lead to the diagnosis being performed in various stages, following an iterative approach.

When uses are established in a polluted zone; evaluating compatibility through an interpretation of the status of the environment
The interpretation of the status of the environment consists in comparing the levels of pollution with the existing pertinent management values. These management values are those defined by the public authorities to ensure the general protection of the population and the environment.

The values to be considered can define either a level of quality for a biotope and a given usage, or a level of exposure. Thus, concerning water intended for human consumption, the orders of 12 May 2004 and 11 January 2007 set guideline values for total α, total β and tritium activity levels and for an exposure indicator called the total indicative dose (TID). From the radiological viewpoint, water with activity of less than 0.1 Bq/l total alpha, 1 Bq/l total β or which is associated with a TID of less than 0.1 mSv/year is considered to be compatible with consumption usage. In addition to the previous regulatory requirements, with regard to the uranium concentration, the assessment of the degree of pollution may also be based on the guideline value of 30 µg/l recommended by the World Health Organisation (WHO) for drinking water.

Concerning radon, the existing regulation management values concern the activity concentration in buildings and in workplaces. In geographical areas where naturally occurring radon is liable to be measured in high concentrations, decree 2002-460 of 4 April 2002 and the order of 22 July 2004 set at 400 Bq/m^3 the activity concentration as of which corrective measures to lower the activity concentration of radon is required in certain premises open to the public (schools, hospitals, etc.). Similarly, ASN resolution 2008-DC-0110 dated 26 September 2008 adopts this value for the workplace. In addition, Act 2009-879 of 21 July 2009 imposes an obligation of radon screening in certain categories of buildings constructed in geographical areas where the exposure to naturally occurring radiation is liable to compromise human health. The conditions for implementation of this new arrangement must be specified by the implementing decrees currently under preparation. It should also be pointed out that the international organisations (ICRP, WHO) recommend action being taken at levels of between 100 and 300 Bq/m^3 which could constitute a basis for evaluating the compatibility between the level of pollution in situations that do not strictly fall within the regulatory frameworks mentioned above.

When the management values concerning the quality of the biotopes are not sufficient to allow an evaluation of the compatibility between the pollution levels and the observed uses, it is necessary to use radiological exposure evaluations and have a management value with which to compare the results obtained.
To do this, the guide proposes a tool for quantitative evaluation of radiological exposure (EQER) based on eleven standard scenarios characteristic of the various conceivable uses of a site:
– one scenario deals with the use of buildings and land (unregulated access);
– one scenario deals with temporary usage of buildings and land (construction site);
– two scenarios deal with the defined use of buildings (building for professional or private use);
– seven scenarios deal with the defined use of the land (car park, allotments, professional activity, residential, school, sports centre, leisure centre).

The guide also defines the value of 1 mSv/yr as the management value to be considered in addition to the natural exposure in order to assess compatibility between uses and pollution levels. However, by virtue of the optimisation principle in the Public Health Code applicable to exposure to ionising radiation, as soon as exposure is brought to light, an attempt must be made to define reasonable mitigation measures and an examination conducted as to whether it is worth taking these measures, based on their cost, their technical feasibility and the effectiveness that could be expected. Moreover, depending on the context, more restrictive management values than those previously mentioned could be adopted by the public authorities. This could in particular be the case when the site is used for sensitive uses (kindergarten, school, playground, etc.) or when a significant level of uncertainty surrounds the hypotheses used for the quantitative evaluation of radiological exposure.
When the IEM concludes that the pollution observed does not compromise the established uses, then the approach can be interrupted. First of all however, an examination should however be made on the one hand of the possible reduction of hazards for man and the environment and, on the other, the possible steps to be taken to prevent any changes to the pollution or the uses that could compromise the conclusions of the IEM.

Whether they concern the pollution or the usage, the steps which could be envisaged to reduce exposure must be appropriate and proportional to the issues at hand. These steps could be taken on the occasion of development of or routine maintenance of the sites concerned. They can entail removal of pollution hot-spots, application of a coating to a polluted soil, or improved ventilation or sealing of the interfaces with the soil (filling of cracks, pipe penetrations, etc.) when the radon activity concentration in a building is higher than the natural levels expected in the geographical area concerned.

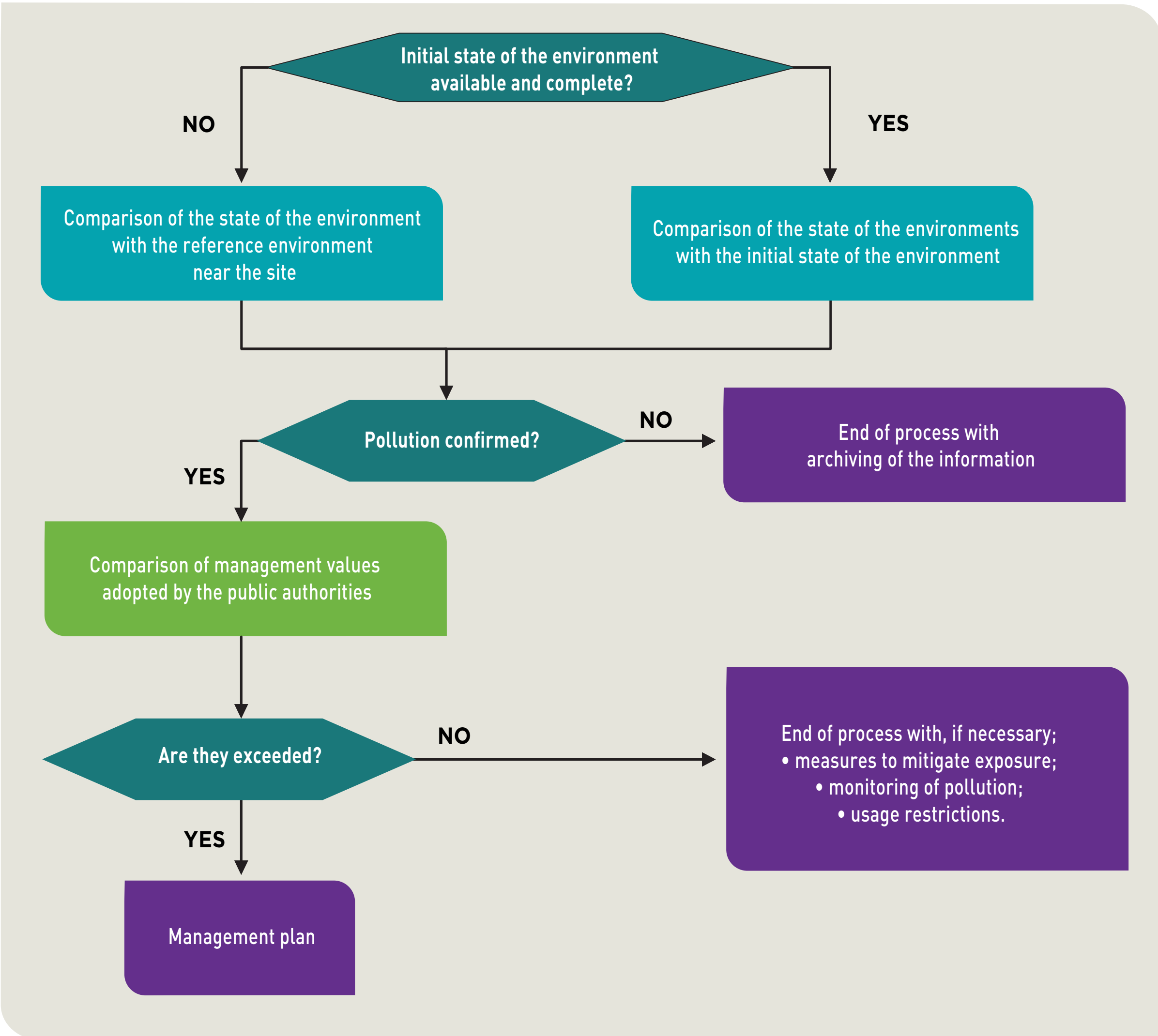
In addition to the steps taken regarding pollution, it may be worth setting up monitoring to ensure that the compatibility between the pollution and the uses is maintained over time. This is, for instance, necessary when changes in the pollution are liable to entail a deterioration of the biotopes, leading to the management values being exceeded. Usage or public protection restrictions should also be applied to future uses of the site which could prove to be incompatible with the existing pollution.

When, following the IEM, is it established that the uses observed are not compatible with the pollution, the approach requires the implementation of a management plan, the minimum aim of which is to restore compatibility between the uses and the pollution. The management plan must be appropriate to the pollution characteristics, the exposure of the population and the environmental impacts. In practice, its nature and scale can vary widely.

When the pollution affects a zone being redeveloped or when the levels of pollution observed are incompatible with the uses observed: restore compatibility by means of a management plan

The management plan is the approach to be initiated in the event of redevelopment of the site concerned (for example cessation of activity or redevelopment of a derelict industrial site), but also when the level of pollution is found to be incompatible with the use following an IEM.

Interpretation of the state of the environment flowchart



On the basis of the elements of the diagnosis, the management plan must make it possible to envisage various redevelopment options which will be compared in a cost-benefit analysis and will allow optimisation of the management strategy to be implemented in the light of the various issues involved. Whenever possible, this work must be done in consultation with all the stakeholders concerned.

The complexity of a management plan can vary significantly, particularly according to the characteristics of the pollution. The management options must, however, systematically envisage the possibility of removal of the sources of pollution. Whenever possible, this removal is the preferred solution because it leads to a general and sustainable reduction in pollution, thus participating in ensuring continuous improvement of the biotopes and reducing the risk that supplementary measures may subsequently prove necessary.

When the pollution is limited in scale and easily accessible, removal may be simple. In this case, the management plan will simply define the clean-up targets and procedures chosen, estimate the physical-chemical characteristics and the volumes of waste anticipated and identify the envisaged disposal routes.

In the other cases, the nature of the pollution or the technical and financial constraints may mean that the option of removing all the pollution sources will be considered disproportionate or even unrealistic. This is in particular the case when the management plan follows on from an IEM, owing to existing uses. The existence of uses on or near the polluted areas is a major constraint liable to restrict the possibility of access to the pollution, for example when situated underneath buildings. It then becomes necessary to envisage measures to reduce, or even eliminate the transfer and exposure pathways. They may be accompanied by the adoption of usage restriction or public protection measures. We then talk of impact control. These arrangements must be supplemented as necessary by monitoring of the evolution and spatial distribution of the pollution or verification of the level of exposure.

If the pollution is left in place, its location and characteristics then become essential data to be considered when defining the site redevelopment project. The strategy adopted must systematically avoid the appearance of transfer pathways or limit the risks of exposure. Playgrounds shall thus whenever possible be kept away from polluted areas and buildings will whenever possible be constructed away from land polluted by radium in order to prevent the risk of a radon build-up. The redevelopment of the site must also be envisaged with a view to preserving the possibility of additional clean-out if it subsequently become feasible as a result of changes in treatment techniques or waste disposal conditions. This prospect may lead to a design for the planned developments that would allow easy access to the most heavily polluted areas, for example by building a parking area rather than erecting a building.

If the pollution is left in place and can lead to exposure, a quantitative evaluation of radiological exposure must be conducted to check that the chosen clean-out targets enable exposure to be limited to acceptable values in the light of the intended uses.

Conclusion

The success of any polluted site management strategy is based primarily on the ability to comprehend the spatial dimensions of the pollution and take account of the diversity of associated risks simultaneously and uniformly. With this new guide to the management of sites potentially polluted by radioactive substances, the MEDDTL, ASN and IRSN provide all players involved in the management of sites potentially polluted by radioactive substances with a common methodological base enabling them to tackle situations as a whole and stake steps based on long-term optimisation and effectiveness.

The alignment of the approach specific to radioactive substances with the general policy for the management of polluted sites, published in 2007 by the Ministry responsible for ecology, did not lead to any sudden questioning of existing practices. It is the result of a logical evolution tending to bring the pragmatism of the measures adopted in the field of chemical pollution into line with the requirements arising from the principles of radiation protection and the particularly sensitive nature of radioactive pollution. The new version of the document thus aims to meet the needs expressed by the various stakeholders, in particular by specifying the management values applicable and by proposing an evaluation method appropriate to the diversity of situations encountered. The considerable importance given to stakeholder involvement aims to raise awareness and change practices on this essential point, in order to lead to the implementation of solutions that are more robust because they are more widely shared and accepted. ■

ANDRA's public service duties: Learning from Experience and summary of sites either cleaned-up or undergoing clean-up

By Eric Lanes, Head of Public Service Delegation – French National Agency for Radioactive Waste Management (ANDRA)

The 28 June 2006 Act on the management of radioactive materials and waste entrusts ANDRA with public interest duties with three objectives:
– the production and publication every three years of the national inventory of radioactive materials and waste.
This is *a reference tool for the management of radioactive waste and gives as exhaustive a view as possible of its nature, quantities and location, and also gives a forward-looking assessment of the waste that will be produced in the future.* The last edition came out in June 2012;
– collection and taking responsibility for old radioactive objects in the possession of private individuals.
This usually concerns objects containing radium, marketed to doctors and private individuals over the period 1920-1940 and still today owned by the families of these people: medical and paramedical accessories, luminescent objects, cosmetics, etc. ANDRA collects about a hundred of these every year, free of charge;
– clean-out of sites polluted by radioactivity, when the party responsible for the pollution has disappeared and the polluter-pays principle cannot therefore be applied.
The majority of these sites are those on which, between the wars, there were workshops manufacturing objects with radium, as well as plants extracting the radium itself from uranium ore.

The State finances ANDRA's public interest duties from a public subsidy, amounting to about €4 M per year. Some operations are the subject of an additional subsidy, such as Operation Radium Diagnosis or the repair of the hydraulic structures at Pargny-sur-Saulx.

ANDRA has intervened on or is currently working on about thirty sites in metropolitan France. The duration and cost of the work varies over several orders of magnitude depending on the size of the site, the scale of the pollution encountered and the intended use after remediation. Some examples:
– recovery of an object containing radium buried in a private garden in Chivres (Côte-d'Or *département*): 1 day, €15,000;
– clean-out of a house at Gif-sur-Yvette (Essonne *département*): 6 months, €450,000;
– remediation of a former industrial site in Pargny-sur-Saulx (Marne *département*): 9 years, €4.2 M (operation still in progress).

The CNAR

In April 2007, the Board of ANDRA decided to create a National Commission for Assistance in the Radioactive Field (CNAR). This pluralistic commission is a tool for oversight and for helping with decision-making concerning allocation of subsidies. The various remediation projects are presented to it for its opinion on:
– the site management strategy, including the social issues and the technical and financial constraints;
– whether or not it is appropriate to use the public subsidy to finance the remediation projects.

The commission is chaired by the ANDRA Director General and comprises:
– State representatives: ASN, General Directorate for Energy and the Climate, General Directorate for the Risk Prevention, General Directorate for Health;
– technical public organisations: IRSN, ADEME[1];
– two environmental protection associations: Robin des Bois, France Nature Environnement;
– an elected official;
– two qualified individuals: a specialist in the remediation/decommissioning of nuclear facilities and a representative of a public land management agency.

Since its creation, the CNAR has met sixteen times, approximately every quarter. The files are examined individually, so that the opinions issued are specific to the individual projects. For example, the CNAR takes account of the level of sensitivity of the polluted area (school, home, etc.) or the interest for the local community to reclaim polluted land so that it can be reused (land situated in the centre of town, etc.).

The CNAR does however aim to ensure that its opinions on recurring subjects are fair, by adopting a certain number of generic doctrines. These doctrines concern the procedures for free collection of old radioactive objects, the financing of renovation work after clean-out, the temporary rehousing of persons whose homes are being cleaned of pollution, or clean-up work performed as part of Operation Radium Diagnosis.

Finally, the CNAR also monitors the dossiers on which it has issued an opinion. A regular review of the work in progress is therefore presented to it during its sessions.

The sites of Nogent-sur-Marne and Ile-Saint-Denis (see below) receive an exceptional State subsidy, granted as part of the economic revival plan launched by the Government in 2008-2009.

The financing mechanism is different from that of the sites mentioned earlier, in that the funds are not taken from the public subsidy given to ANDRA, but are directly paid by the ADEME to the project managers.

Isotopchim building – exterior view

Laboratory in 2008

Laboratory in 2010

However, before the projects could be considered eligible for the recovery plan, the ADEME[1] approached the CNAR to obtain its opinion on the technical and economic pertinence of the projects. The CNAR returned a favourable opinion in both cases.

Since its creation in 2007, the CNAR has ruled on numerous dossiers. The most high-profile cases are reviewed below.

Ganagobie - Alpes-de-Haute-Provence (04) – Former Isotopchim laboratory

The Isotopchim company was in operation from 1986 to 2000. Its production of molecules marked with carbon 14 was subject to authorisation as an installation classified on environmental protection grounds (ICPE). During its operation, it was found guilty on a number of occasions of breaches of the terms of the Prefect's authorisation and of unauthorised radioactive discharges into the environment.

The company went into receivership in September 2000 and the facility was abandoned by the parties responsible, who were the subject of legal action and found guilty of criminal charges.

At the time it was abandoned, the site still contained a very large number of containers of liquid and solid chemical products, contaminated with carbon 14, but for which there was no available characterisation. From 2004 to 2007, ANDRA carried out a series of studies to define the means of removing the radioactive waste representing the most severe safety hazard, in particular the waste which needed to be kept chilled in refrigerators on the site.

The latter was removed in 2008 to authorised processing routes, which enabled electrical power to the building to be finally cut, thus reducing the risk of fire. However, many unrefrigerated chemical and radioactive products still remain on the site, in both liquid and solid form. This is why, in 2009, the site was secured by the installation of a fire detection system and a fence to keep out any intruders.

In 2009, a study performed by IRSN of the immediate environment of the former Isotopchim laboratory, confirmed that the site's environment posed no hazards for the population, regardless of the soil utilisation considered and that pollution clean-up could therefore be limited to removal of the radioactive waste still present on the site and demolition of the building.

An extensive further characterisation campaign for the liquid chemical waste still present was thus launched in 2010. At the same time, about 40 m^3 of VLL (very low level) waste was removed.

ANDRA is now focusing on identifying management solutions for the remaining liquid and solid waste, with a

1. French Environment and Energy Management Agency.


Making La Peupleraie safe in Pargny-sur-Saulx

Forestry clearance then covering with a layer of containment clay

view to demolition of the building. In 2011 it initiated a draft study on the future decommissioning of the site.

The total management budget for this site is estimated at € 3M.

Pargny-sur-Saulx - Marne (51) - Orflam-Plast plant and outside land (see article p. 50)
The Orflam-Plast company manufactured lighters until February 1997, when it went into receivership.

The ores used (monazite) to manufacture the flints meant that the plant generated large quantities of waste contaminated with thorium, a naturally radioactive element, which polluted not only the site of the plant itself, but also the banks of the Saulx, the river running along the edge of the site.

As of 1997, the most urgent safety work was performed by ADEME and ANDRA at the request of the Regional Directorate for the Environment, Planning and Housing (DREAL). This work consisted in confining the contaminated banks under a clay covering in order to stop any exposure of the public liable to spend time on these banks (fishermen).

In 2008 and 2009, two polluted areas outside the site were discovered a few hundred metres from the plant: the Peupleraie (zone on which, according to the statements of a former employee of the site, processing waste rich in thorium 232 had been buried, and Gravière lake. These zones were immediately and urgently secured (signposting and fencing). To complete the contamination search, an extensive radiological survey was carried out in June 2009 over a perimeter of 60 km2 around the site, using the HÉLINUC helicopter-borne mapping system. This survey revealed no other contaminated zones.

Demolition of a home built on radioactive polluted soil in Gif-sur-Yvette

The State became the owner of the site in 2009 further to a "vacant and ownerless property" procedure instigated by the offices of the Prefect, as the registered owner – the Orflam-Plast company – had in the meantime ceased to exist.

In December 2009, the CNAR approved a programme of work involving remediation of Gravière lake, making the Peupleraie site safe, demolition of the plant buildings and confinement of the demolition rubble in place by means of a long-term, sustainable system.

The decontamination work on the banks of the Gravière river took place from mid-June to mid-July 2010. It consisted in excavating the polluted earth around the lake. The least active earth (about 200 m^3) was taken to the originating site. It will be confined in-situ with the plant demolition rubble. Slightly more radioactive waste was shipped to the very low level waste disposal facility (CSTFA) (about 40 m^3). Finally, about 30 m^3 of LLW-LL waste (low level waste, long-lived) was stored in the ICPE operated by the SOGEDEC company in Pierrelatte (30).

The work to make the Peupleraie area safe took place from August to November 2011. The very slightly contaminated trees were cut down, the branches removed and left lying on the ground. A sufficiently thick layer of clay was placed over the surface of the Peupleraie in order to limit the residual surface dose rate.

Demolition of the plant and construction of the rubble containment structure should begin in Spring 2013 and last one year.

The total budget for remediation of the site and the outside land, as approved by the CNAR, amounts to € 4.2M.

Gif-sur-Yvette - Essonne (91) – Private house-owners in the Coudraies district
From 1904 to 1957, the commune of Gif-sur-Yvette (Essonne *département*) was home to the Société nouvelle du

Radium (SNR) which carried out industrial radium extraction activities and operated a research laboratory. The Coudraies district was converted into a residential zone in 1959 and retained traces of these activities.

From 1969 to 1984, some of the properties underwent partial pollution clean-up. However, in 2000, the persistence of radon in one of the homes, at levels higher than those allowed by the health recommendations, encouraged the local authorities to carry out a diagnosis of all the properties in the district in order to analyse the hazards and take the necessary protective measures. The diagnosis revealed that in addition to the property in question, a further three required pollution clean-up of the buildings.

The first property was purchased by the State in 2005 and demolished in 2010. remediation of the land is scheduled for 2012. Two other homes were cleaned-out in 2008-2009 and they were once again made compatible with use for residential purposes. The file was closed by the CNAR in September 2010.

The last property was purchased by ANDRA in 2010. A remediation project to requalify it as a green space for public or private use was presented to the CNAR in 2012.

Since 2007, the local planning scheme has been revised and specifies the health measures to be taken in the district in question (usage restrictions on deep ground, excavation work to be carried out under radiological monitoring, etc.).

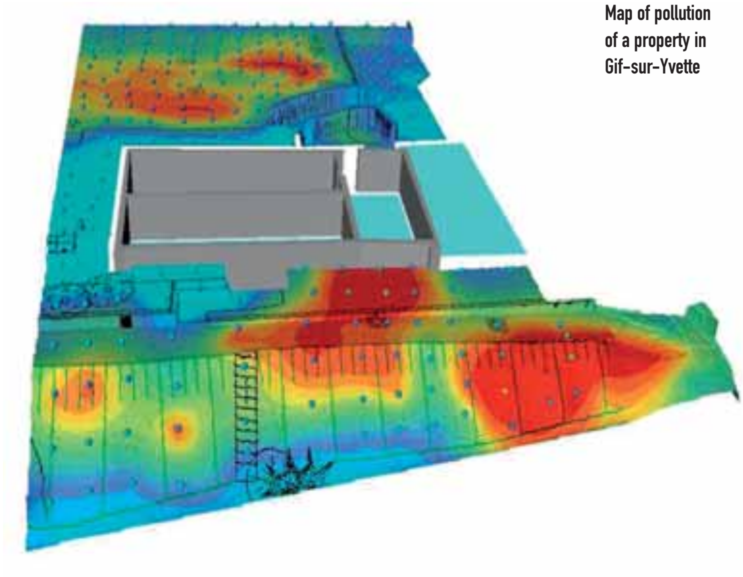
Nogent-sur-Marne - Val-de-Marne (94) - Former Marie Curie school

The Marie Curie school in Nogent-sur-Marne was built in the late 1960s on the site of a former radium extraction plant, which operated between 1904 and 1927. After a series of soil insulation works, performed as of 1987, the school was closed for good in 1998.

In 2009, the CNAR issued a favourable opinion on its remediation project consisting of partial clean-up of the site, with limited volumes of LLW-LL waste produced, but allowing safe use of the site. The envisaged use, in this case the construction of gymnasia built on stilts, means that any subsequent pollution clean-up operation would be possible, for example once a final management route for the LLW-LL waste becomes operational. The project owner is the commune of Nogent-sur-Marne, which receives a 40% subsidy under the economic recovery plan.

At the same time, the CNAR recommended studying an alternative scenario enabling more extensive clean-up of the site. This alternative scenario was drawn up in 2011 and validated by order of the Prefect. Its aim was to achieve more complete clean-up of about half the site, which could then be used for construction of a gymnasium at ground level, with containment of the radioactivity present in the other half, for construction of a car park. The amount of the remediation work was estimated at about € 2.8M, excluding construction work (gymnasium and car park).

The work began in October 2010. As the excavation work continued on the part of the site intended for extensive



Map of pollution of a property in Gif-sur-Yvette

pollution clean-up, it became apparent that the quantities of radioactive waste produced would significantly exceed the initial estimates and that the planned budget for the operation would not be enough to see the process through to completion. In the Spring of 2012, the Nogent-sur-Marne town hall decided to abandon the plans to build a gymnasium on the site, and began to look at alternatives allowing reuse of the site compatible with the remediation levels already achieved (see interview with Mayor of Nogent-sur-Marne, p. 75).

Ile-Saint-Denis - Seine-Saint-Denis (93)

Between 1913 and 1927, the SATCHI company operated a plant for chemical extraction of radium salts in the commune of Ile-Saint-Denis.
Since then, a number of companies have occupied the site, totally unaware of its radioactive past.
This site is still owned by one of them. In 1997, the Office for Protection against Ionising Radiation (OPRI) brought to light the radiological pollution of the site and its immediate vicinity. Various studies were then carried out to produce a clear map of the site's pollution status. In 2006, in the light of the results of the various studies, an order was issued by the Prefect, asking that the land be secured and the radiological pollution managed.

The remediation scenario was approved by the CNAR in 2009.

The initial work phase was carried out under the project management of the firm currently owning the site, with ANDRA acting as assistant project manager. This allowed the sorting and characterisation of nearly 700 m^3 of demolition rubble, part of which was contaminated and contained asbestos. This rubble has now been removed.

Following this initial phase, the site will become the property of the Établissement public foncier Ile-de-France (EPFIF) which is overseeing an urban requalification operation on behalf of the local stakeholders (commune and local authority). The second phase should start in 2013 and is expected to last 12 months.

Apart from treatment of the site itself, this operation includes treatment of the banks, removal of the contaminated areas from the neighbouring companies, as well as the examination and protection of the site groundwater, which is contaminated not with radium but with uranium (no doubt related to the processing of pitchblende ores on the site in the past).

The plan is eventually to develop the site as an urban park closed to the public and containing photovoltaic panels. This reuse would make it possible to carry out more complete remediation subsequently, given that significant volumes of LLW-LL materials would remain confined on the site.

The total budget for the operation is € 3.7 M exclusive of taxes. This sum is covered 50% by the recovery plan and 50% by the current and future owners

Operation Radium Diagnosis

Operation Radium Diagnosis (ODR) concerns 134 addresses in metropolitan France, known to house activities involving radium (and possibly thorium 232, or even tritium). In most cases, there is no information to indicate if these sites have been or still are actually contaminated.

The ODR aims to produce a diagnosis of each of these addresses and rehabilitate the sites which prove to be polluted.

The project was presented to the CNAR in September 2010. Several doctrines were announced, concerning the conditions in which the work would be initiated, the rehousing of people during the work, the technical and financial monitoring of the work by a CNAR body and the assigned clean-out objectives.

The operation was started at the end of 2010. So far, 26 addresses have been inspected or are still under investigation, involving more than 175 diagnoses. 15 of them proved to be polluted and are the subject of a remediation programme that is either in progress or under preparation. However, the pollution levels revealed are slight and entail no health hazards (see article p. 62).

Conclusion

With the 28 June 2006 Act defining ANDRA's public interest duties and the principle of a public subsidy to finance them, the State has created a framework and provided the means enabling it to follow a proactive policy of remediation of sites polluted by radioactive materials which, although few in number, each represent very real challenges. ■

Isotopchim Site in Ganagobie

Involvement of the Isotopchim site stakeholders in Ganagobie (Alpes-de-Haute-Provence *département*)

As defined in the circular of 17 November 2008 concerning responsibility for certain radioactive waste and radioactively polluted sites, the roles are distributed as follows:

– the competent Authority for this facility is the DREAL;

– under its public interest duties, ANDRA is tasked with site remediation;

– ASN supports the DREAL concerning technical matters.

The sub-prefecture of Forcalquier regularly convenes meetings of the town hall and the various departments involved in the dossier and deals with the health and safety of the population with regard to the accident risks as related to the site. The fire and emergency services are thus regular participants in the meetings and are involved in the pollution clean-up operations performed on the site. ANDRA systematically organises an exercise during each operation for the fire service crews liable to be called out to any accident in the contaminated building.

As soon as ANDRA schedules any significant operation, a public meeting is held to inform the population of what the intended operation entails, to present the progress of the pollution clean-up work and to answer any questions. These meetings are also an opportunity for the administration to present the studies conducted into the chronic or accidental health consequences of the radioactive pollution.

Finally, during the operations performed on the site in 2008 and 2010, ASN carried out occupational radiation-protection inspections. ■

What are the health issues involved in the management of sites and soils polluted by radioactivity

Interview with Michel Bourguignon, ASN Commissioner

Contrôle : **Mr Bourguignon, could you explain the real or potential health hazards involved in the management of polluted sites?**

Michel Bourguignon : I start from the assumption that we are dealing with residual rather than any large-scale, intense pollution, which would already have been dealt with. The first point to be considered, whether the site is occupied by private individuals or is a derelict former industrial site, is that this type of pollution is never uniform.

I remember the example of a house built on the site of a former radium plant, in which significant radon contamination was discovered in a small unventilated bedroom in the basement, close to the rest of the cellar with a beaten-earth floor. The quantity of radon in this room, occupied by a young boy, was very high, far higher than in the rest of the house.

A similar problem was found in a house built in the Limousin region, on granite rock naturally rich in uranium, without any particular precautions having been taken in terms of crawl space or ventilation. Here again, the potential hazard was related to radon.

It is therefore always necessary to ensure that there is not a more active zone somewhere leading to a rescaling of the problem. The purpose is to ensure that individual exposure remains at an acceptable risk level.

What do you mean by acceptable risk?

The health issue here is that of "low doses". A low dose is the dose level below which epidemiological studies are unable to highlight any adverse health effect. This effective dose level is about 50 millisieverts (mSv) for children and 100 mSv for adults. As a precaution, an effective dose limit of 1 mSv is set by the regulations for the general public, in order to remain acceptable, in other words a level far below the significant epidemiological levels.

The problem lies in the fact that, even at low doses, ionising radiation has clastogenic[1] effects, in other words it breaks the DNA and thus contributes to cell ageing, which we know to be at the heart of long-term cancer phenomena. It should be recalled in this respect that natural radiation, even at very low levels, also contributes to DNA breakage.

In any case, the dose continuously received as a result of radioactive pollution is very small, below one mSv. The principle to be applied however, is not so much scientific as moral. It is based on the fact that it is not legitimate to expose anyone to ionising radiation, regardless of the type or dose, when one can do otherwise.

The idea is not to wait for a true scientific demonstration of the carcinogenic effect of ionising radiation at low doses in order to protect the population. This is also true for the two main causes of population exposure, which are radon (naturally occurring or otherwise) and medical exposure, which on their own account for 80 to 90% of all exposure. The principles of the justification and optimisation of medical exposure are therefore applied and, if there is radon in the home, steps must be taken (laying of slabs in the basement, additional ventilation) to mitigate its effects.

When dealing with sites historically polluted by radium, ASN's stance in Operation Radium Diagnosis is to clean-up the pollution to the extent that one would not need to come back and repeat it, thus limiting the risks related to any loss of records concerning these sites.

ASN therefore recommends identifying and dealing with sites liable to contain one or more hot-spots, without waiting until a problem is identified or until there is no responsible party left to deal with. It thus recommends systematically processing the sites. The aim is not to bring the site to level 0, because this does not exist owing to natural radioactivity, but to maximise pollution clean-up to return the site to a level equivalent to the average background level in the region, because we know that this background level is not uniform nationwide. In any case,

the idea is to remain below an added one mSv.
Over and above treating sites with legacy pollution, the idea is also to minimise future pollution, which broadens the scope to include technologically enhanced naturally occurring radioactivity. The principle is then to consider that any activity whereby man transforms natural radioactivity generates a potential pollution hazard, in particular by concentrating the radioactivity. For any industrial activity involving radioactivity, it is therefore necessary to ensure that it does not lead to a situation creating a pollution problem to be managed.

What are the health hazards for the public: workers on clean-up sites, families living on or in the immediate vicinity of sites polluted in the past?

As already mentioned, the health hazard from low doses concerns the ageing and breakage of cell DNA. Given the doses in question, there is no deterministic hazard such as burns, but a slight probabilistic risk, such as a cancer, cannot be ruled out. We know that cancer is linked to an accumulation of particular DNA damage, but just because there is DNA damage does not mean that a cancer will occur. However, the long-term prevention of cancer involves limiting exposure to clastogenic hazards (tobacco, alcohol, ionising radiation, etc.), because the greater the accumulation, the greater the long-term statistical risk of developing a cancer.
For those living near polluted sites, appropriate treatment of the land by extracting the polluted earth and of the dwellings by clean-out operations, or structural modification and natural or assisted ventilation considerably mitigates the hazard.
For the workers carrying out these operations, the hazard is also very limited because, even if the dose received is potentially higher, their exposure time on a hot-spot is far shorter. It naturally increases if there is an accumulation of hot-spots treated. In any case, these workers receive radiation protection training, specific medical and dosimetric monitoring, with a regulation dose limit of 20 millisieverts per year, which is not a danger threshold but a management threshold which already applies the precautionary principle.
The problem on derelict industrial sites would be more a concern for non-specialist workers carrying out long-duration work on polluted sites without being aware of the problem. They thus become exposed to the same potential hazards as the inhabitants.
Over and above collective reference thresholds, I would point out that there is a shortcoming in this risk assessment, in that we are not all equal when it comes to radiation, owing to the phenomenon referred to as individual radiosensitivity[2]. This has been known about for a long time and was brought to light in radiotherapy where, provided that there is no error in the delivery of the therapeutic dose, it was observed that certain persons who are more sensitive to ionising radiation suffer complications and side-effects. We do not all react to radiation in the same way, including at low doses in research laboratories. This parameter would therefore have to be taken into account for the residents and workers concerned by polluted sites.

Is the medical profession (GPs, hospital staff and occupational physicians) aware of these issues?

There is no doubt that the medical profession is not sufficiently aware of nor trained in understanding the issues and hazards related to exposure to ionising radiation, regardless of the origin, especially when this origin is radiological pollution. These notions are looked at in the first and second years of medical studies and that is all. Physicians are therefore relatively ill-equipped to answer their patients' questions and concerns on the subject.
For example, let us imagine the case of a patient who had a thyroid problem in 1988, two years after the Chernobyl accident. This patient asks his doctor whether, as he had read in the press, this problem could be linked to the radioactive fall-out. If the doctor hesitates even for a moment, because he needs time to think about the question owing to a lack of information, then whatever the answer, the patient will interpret this hesitation as confirmation of his original suspicion or will believe that the doctor is looking for an argument to mask the truth. This example could also apply to the discovery of radioactive pollution on a site or derelict industrial site premises. If the local physicians have not been made aware of the problem, have not received clear and instructive documentation, they will not be able to provide their patients with the necessary support.
This is a wide-ranging issue for ASN, both with regard to radioactive polluted sites and for all subjects relating to the effects of ionising radiation. Closer work with the physicians will be needed, so that they are regularly informed, take part in professional events and are given practical and informative data sheets.

What is ASN's role in the management process for polluted sites, in particular in terms of health? When and on what basis does ASN intervene? Has this role changed over time?

ASN's first interventions were triggered by the discovery of polluted sites. They were thus carried out "under pressure", in order to manage acute events and/or incidents and mitigate their health impact on the populations or personnel living in or working on the site. ASN dispatched inspectors to the site for an immediate assessment of the situation and to recommend appropriate measures.
Much pollution proves to be "chronic", affecting derelict industrial sites or sites polluted in the past. The approach therefore had to change. This was a long-haul process, because it was necessary to trace the history of the site and track down those involved. Faced with this situation and the risk of losing all history and records of the site and being unable to locate the parties concerned, ASN recommended that one should not wait for the situation to get worse before intervening. Moreover, if one applies the polluter-pays principle, the longer one waits, the fewer responsible parties there will be, because most of the licensees will have disappeared.
This is exactly the case with Operation Radium Diagnosis, proposed by ASN to the Ministry for Ecology, which approved it and entrusted overall oversight to the

Prefects, with operational verification going to ASN and in-situ performance to ANDRA.
I feel that ASN's role in the management of polluted sites is appropriate to the stakes and issues, because on the basis of events which may well have been isolated, ASN helped define an overall programme, rather than waiting for the next event, leading the various parties concerned (public and private) to become involved in the system. ASN's intervention brought to light the fact that management of sites polluted by radioactive substances was lagging behind what is done to clean up sites polluted by chemical products for example, even though much still remains to be done in this field.
ASN's role was thus to sound the alert, coordinate the response by the various stakeholders and then monitor implementation of the measures decided. It has so far mainly performed this role in dealing with incidents or the unexpected discovery of radioactive pollution.
ASN's current doctrine is to see the reference approach through to the end "to avoid having to come back", while leaving a record of what has been done, for example so that no plans are for example made to put up a sensitive building such as a kindergarten on the site of a former radium plant because, as we all know, total pollution clean-up is not possible.
The role of ASN has also changed over the years in two very important respects:
– the increasing involvement by the stakeholders (operators, institutions, associations, etc.), which ensures that they take part in the process, enables them to understand the issues and more easily accept the idea that perfection is impossible but that all areas that can be treated, have been treated;
– in terms of information of the public and professionals, but also local authorities, ASN has also made a real effort at transparency on this subject, in the same way as all the subjects for which it is responsible.
This approach is essential when attempting to counteract the suspicion generated, if not by secrecy, then at least by the silence or omission which has often been the case on these subjects.
It is perfectly legitimate for questions to be asked, but it is important to provide answers that are clear, informative and which also have the benefit of demonstrating the rigorous nature of the approach. In this respect, developing transparency is a way of encouraging trust. ■

Private site in Bandol (Var) cleaned up thanks to financing through ANDRA's public interest duties

1. These effects can be highlighted using new immunofluorescence methods. The threshold of these techniques is 1 milligray, which represents a threshold 100 times lower than the lowest of the previous techniques.

2. Individual radiosensitivity is the result of anomalies in the signalling and repair of DNA damage. Individuals affected by serious genetic diseases with individual radiosensitivity of a factor of about 10 in relation to the normal population, are rare and have been identified. Those affected by individual radiosensitivity of a factor of 2 to 5 could represent about 10% of the population. In these people, the same dose of radiation creates 2 to 5 times more DNA damage and thus greater difficulty in repairing it. They are therefore subjects who are potentially more susceptible to radiation and thus probably to cancers. Eventually, individual radiosensitivity will no doubt modify the notion of radiation protection, which will gradually change from collective to individual, once routine screening becomes available.

Clean-up of soil outside the
of the CEA's basic nuclear installations in

by Didier Dubot, senior expert, head of the clean-out section for the CEA site in Fontenay-aux-Roses

In general, the initial radiological inventory is based on local historical land data and on a few analysis samples, frequently too few in number to enable a remediation scenario to be drawn up that would guarantee project costs and deadlines.

This context means that it is of vital importance to take representative samples of an area of soil or of civil engineering structures.

The questions have always been the same:
– how many samples are needed to characterise the area being studied?
– down to what depth and using what sampling pitch?
– what technique (raw, auger, crushing, etc.) to use?
– how to estimate the contaminated volumes?

In the absence of any free release threshold in France, remediation values are proposed to the Authorities concerned on a case by case basis. For the soil of the site outside the perimeter of the basic nuclear installations (BNI) at CEA/Fontenay-aux-Roses, a target of 10µSv/year was set according to the envisaged reuse.

However, for soil located within the perimeter of the CEA/Fontenay-aux-Roses BNI, following a cost/benefit analysis, the plan could be to clean-out the soil to a reasonable level in compliance with international regulations (OECD, IAEA, etc.) and to implement utilisation restrictions.

Introduction

CEA/Fontenay-aux-Roses, the first CEA site, created in 1946 in Châtillon Fort, has been home to three generations of nuclear facilities. It was the birthplace of French nuclear research and the first "ZOE" pile went critical in 1948. Several generations of facilities then succeeded each other on the site, the pilot plant for processing fuel and isolating plutonium then, from 1960, several facilities devoted to spent fuel research (radiometallurgy and radiochemistry). Since the 1990s, research at the centre has focused on the life sciences.

The past activities of the site, the topographical changes due to the use of the Fort as the first generation of nuclear research facilities, then the successive construction of several generations of facilities, led CEA/Fontenay-aux-Roses to conduct clean-out work as early as 1958. The first pilot plant was completely cleaned-out according to the rules in force at the time, to make way for new facilities. The soil was thus cleaned out until a total residual activity of < 74 Bq/g was reached, which was the target to be achieved before remediation or clean-out could be stopped. More recently, in the 80-90s, clean-out was carried out on areas of interest related to the operation of the second and third generations of facilities devoted to the fuel cycle. The question posed was always the same: what should be the target residual activity level? During this period, the activity limits were set on the basis of the nature and scale of the pollution: 1 Bq/g, or sometimes 5 Bq/g usually only applicable to caesium 137, with the other radionuclides often simply being ignored. At the end of the 1990s, CEA decided on complete remediation of the CEA/Fontenay-aux-Roses site: gradual shutdown of all the BNIs, followed by clean-out and decommissioning. At the same time, clean-up operations were conducted on the soil of the site outside the perimeter of the current BNIs.

Methodology applied

In 2000, a methodology was applied to remediate the CEA/Fontenay-aux-Roses site on the basis of lessons learned from prior experience on the site and the existing methodologies (IRSN guide to management of sites with localised contamination by radioactive substances, 2001 version, directive Euratom 96-29, etc.).

The methodology comprises several steps, as shown in the flowchart opposite.

Historical and functional surveys are an essential starting point and of great importance in determining the initial radiological status. Without these surveys, the steps necessary for production of the initial status would require far more investigations, samples and analyses, all of which entail significant costs. This step should allow identification of all the activities which have taken place on the site, the various perimeters of the facilities, the radionuclides handled, the events, etc. The history of CEA/Fontenay-aux-Roses was finalised in 1999 and entailed five years of archive searches, collection of testimony and on-site measurements. It is periodically updated.

As of the beginning of this step, the use of drawings combined by a surveyor with existing aerial views is essential. It should not be forgotten that the precision of the surveys and maps must be less than one metre if, on the occasion of the final remediation, one wishes to avoid creating unnecessary cubic metres of waste. In this context, CEA/Fontenay-aux-Roses developed KARTOTRAK®, a geographical information system (GIS) able to use all types of geo-referenced media, including vector and non vector types.

Thanks to a GPS with continuous sub-metric differential correction, the position of the sample points and in-situ measurements is recorded which, throughout the site remediation process, gives drawings that can be used by everyone with the same level of precision.

perimeter
Fontenay-aux-Roses

Radiological measurements of surface soils

The second step is to characterise the surface soil, with the areas to be investigated varying from a few hundred square metres to, on sites other than CEA/ Fontenay-aux-Roses, several tens of hectares. In most cases, the pollutants are gamma emitters, measurable with the usual detectors (NaI, Gamma Spectrometry, Plastic Scintillators). The combination of GPS positioning and in-situ measurement and/or sampling is a minimum requirement. CEA has developed real-time measurement systems (VEgAS®, KRP®, KRT®) associated with the KARTOTRAK software platform, currently manufactured by the Géovariances company. With a device moving at 2.6 km/h, this enables measurements to be collected from the various detectors every second. Geostatistical analysis of these data, often collected exhaustively from the site, makes it possible to produce a 2D map highlighting the areas of interest where the gamma flux is different. When initially supplemented by a few samples, the maps are rapidly usable. If it is impossible to take in-situ gamma measurements of certain radionuclides, samples are collected using an appropriate sampling mesh. The iterative approach used is explained in the boxes on p. 37 and 38.

Sampling plan in areas of interest

To address these issues, CEA/Fontenay-aux-Roses in 2008 set up a process of learning from experience from all the sites evaluated by the Site Clean-Out Section (about 90). The purpose of this learning from experience was to identify all the sites for which the sampling plan made the use of geostatistics possible for processing of the data.

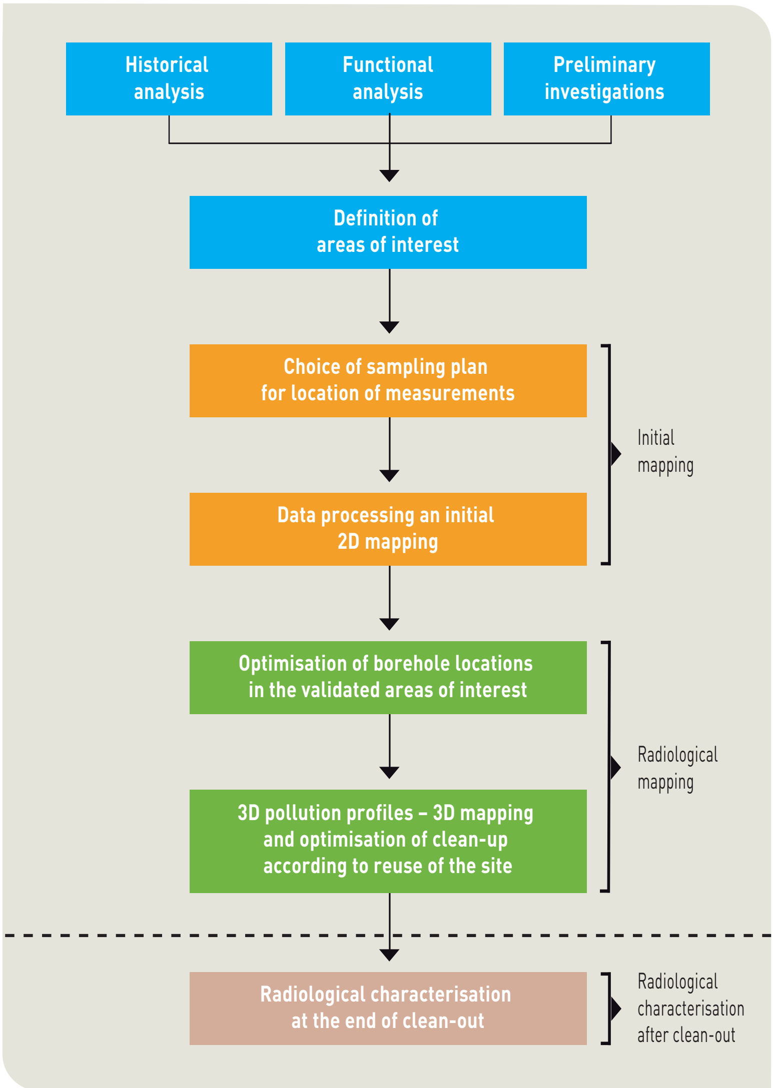
Based on these lessons learned it is now possible to determine the number of bore-holes necessary for a pertinent radiological evaluation of the soils at depth. This step enables the bore-holes to be sited in areas of significant uncertainty and variability, unlike what had usually been done in the past, when nearly all the bore-holes were situated in the areas of highest activity.

Analysis of pollution profiles

When the boreholes are made, usually with techniques involving no water in order to minimise leaching of the sample, representative samples of the core or core section must be collected. This operation is first of all generally preceded by scanning gamma measurement of the core in 10 cm steps, in order to identify the presence of any hot-spots, and then secondly by samples from the core. These are generally at 20 to 30 cm intervals for cores 2 to 3 m long, and at 50 cm intervals for cores less than 10 m long and then every metre when the core reaches about twenty metres.

Each sample undergoes gamma spectrometry and/or radiochemical or pure beta emitter measurements, in the laboratory. The results are used to plot the profiles of the

General methodology applies for soil clean-out



various radionuclides. As of this step, it is possible to validate the functional analysis of the site and attempt to understand the mechanisms governing the penetration of each radionuclide into the soil, whether backfill or natural ground.

As of 2004, the radiological measurements were supplemented by chemical measurements in order to identify any chemical pollution associated with the radiological pollution. Apart from permanent monitoring of the borehole operations by a geologist and visual inspection of the cores, these samples are analysed in the laboratory using the "TerraTest" method.

3D radiological mapping

In the same way as when producing 2D maps, the production of a three-dimensional map uses geostatistics as the technique for data analysis and estimation of the activity levels.

Geostatistical data processing

This technique, initially used to characterise mining seams, was developed in the 1950s by D. Krige and then by G. Matheron. The completion of their work and developments in computing have expanded the scope of application to include site chemical pollution data and, more recently (since 2004) it has been used by CEA for application to radiologically polluted sites and soils.
This method consists in taking account of the spatial continuity of the phenomenon. The first step, an exploratory analysis of the data, is used to produce a data position plan identifying the low and high activity zones as well as the background level, and a conventional statistical analysis of the values (average of median activity levels, dispersion around this central trend, quantile, etc.).
During this exploratory phase, it is also interesting to study the relationships that exist between the various parameters considered, such as the gamma activity, ambient irradiation or the activity of several radionuclides, in order to identify the singular zones (multiple contamination, change in matrix, variations in ambient environment, etc.).
The next step consists of analysing the spatial structure of the data. The interest of using geostatistics is based on the spatial continuity of the phenomenon: intuitively, for a non-random phenomenon in a space, two nearby measurements will have similar values, whereas the difference between the values of two measurements that are further apart will be more variable. In order to conduct an experimental evaluation of this spatial continuity, a variogram is plotted form the distance between the measurement points and the variance in values.
This is then adjusted using a mathematical model, which will enable the estimation calculations to be made. Variogram adjustment is a very important step and it in particular allows identification of the scale of short-range variability and determines whether or not additional measurements need to be taken.
The third step concerns the interpolation of data using the Kriging method. Kriging differs from the other interpolators by including, between the data and the target, the distances separating the data from each other and from the spatial structure of the phenomenon (via the variogram). This interpolator is built to guarantee that the estimate is not biased and to minimise the variance of the estimation error.
Moreover, the added value of geostatistics is to be able, from the Kriging maps, to quantify the uncertainties associated with the interpolation but also to establish maps of the probability of exceeding a given activity level.
On the strength of lessons learned from this experience, the Site Clean-out Section (SAS) created a decision-making tool in 2008 (STRATEGE®) dedicated to determining and optimising sampling plans based on the objective to be attained according to the allocated budgets. STRATEGE® can be used to adapt the sampling plan:
• to be able to perform a geostatistical survey on the basis of the data;
• according to the reuse of the site.
It can also be used to adapt the sampling plan according to the expected level of confidence. It will not be the same if the site is rehabilitated for construction of a kindergarten or if it is to be used for a park or the erection of a building. ■

J. Attiogbe, Kartotrak: a GIS platform for real-time characterization of radiological contaminations, STATGIS, Milos 2009.

This map will be used to obtain drawings based in particular on the probability of the activity level being exceeded. These results are used initially to compare the various zone remediation scenarios from the technical and financial viewpoints. For several years now, the Site Clean-Out Section has included these 3D surveys in its specifications, so that the contractors consulted for the remediation work can prepare in the best possible conditions.

Cost/benefit analysis – Remediation and associated health impact

Based on the result of the various steps and for an impact which depends on the envisaged reuse of the site, a cost-benefit analysis is carried out for each pollution profile. Depending on the depths to be reached in order to clean-out the site, the cost may rise very quickly. All these data will enable a summary

Radiological evaluation of the ground beneath a building

This illustration concerns the evaluation of the ground beneath the foundation raft of an installation outside the perimeter of the BNIs at CEA/Fontenay-aux-Roses.
This study is a part of a 2009-2010 project consisting of evaluating the level of residual activity in the soil beneath the foundation raft of accessible facilities. The building was erected above a part of the soil of the former Plutonium plant decommissioned at the end of the 1950s.
The clean-out levels achieved in accordance with the regulations in force at the time, considered that the waste removed to conventional disposal routes could not exceed 74 Bq/g. This value was commonly applied to the remediation of soil or facilities. The historical and functional surveys showed the existence and position of the various separation processes. They revealed that caesium 137 is the predominant radionuclide, with traces of plutonium 239 and strontium 90.

Methodology

The general methodology applied is that described in the first part of this article, with regard to site remediation.

Radiological evaluation of the ground beneath a facility

The subsoil covering an area of about 700 m² was initially mapped, during the course of which more than 200 in-situ measurements were made using an NaI detector (with a sampling mesh of 1.5 x 1.5 m), supplemented by 59 GeHP gamma spectrometry measurements. The NaI (8x8'') is positioned on a table at a height of 70 cm above the ground. A 100s counting time is used in order to record the emergent gamma flux. The number of points was optimised to be able to perform geostatistical processing of the data. These measurements were processed by Kriging and the γ spectrometry measurements were positioned on the areas of interest highlighted by the NaI mapping. The device used is a GeHP detector collimated by 10 cm of lead.
The associated modelling takes account of the 14 or 20 cm thickness of the concrete foundation raft (considered to be contamination-free) and uniformly distributed pollution in the sand to a depth of 30 cm. The results of the 59 γ spectrometry measurements were processed using geostatistics in order to obtain an estimated activity map (fig. 1).
Following this processing, 27 boreholes were positioned in the areas of interest and in the areas with a high degree of uncertainty (fig.2).
The boreholes were made by piledriving to depths of 4 to 15 m. The work was constantly observed by a geologist who recorded the lithology of the soil and took VOC (volatile organic compounds) measurements on contact with the core sample. Each core was sampled in segments of 25 cm. More than 470 samples were produced and analysed using gamma spectrometry in the laboratory, with an acquisition time giving a detection limit of about one Bq/kg of caesium 137. The activity profile for caesium 137 is plotted for each of the cores.
About fifty samples were analysed by radiochemistry in order to identify the pure α and β emitters. All the results are processed by geostatistics using the ISATIS software, in order to obtain 2D and 3D activity estimation maps by Kriging, as well as maps of the probability of a given level of activity being exceeded (fig. 3).
The surface of the polluted area was estimated at 180 m².
The study of the profiles for each of the boreholes enabled pollution migration in the soils to be studied. The dominant radionuclide is caesium 137 with a maximum localised activity of 17 Bq/g and 8 of the 27 boreholes showed a caesium 137 activity in excess of 1 Bq/g on one or more

core segments.

Radionuclides other than caesium 137 are present in certain boreholes, primarily plutonium 239+240 and strontium 90, (as expected from the historical and functional surveys) but at low activity levels (< 1.5 Bq/g) and were measured on samples where caesium 137 pollution was present.

Most of the pollution is situated at a depth of between 15 cm and 2 m. The absence of americium 241 and plutonium 238 confirms that the origin of the pollution is the activity of the pilot plant.

Each of the zones was the subject of a cost/benefit analysis in order to define an optimised excavation depth (fig. 4) according to the remediation scenario.

Following the complete study of the migration profiles and the impact assessments, three zones were defined for clean-out (A, B and C) with respective areas of 20, 30 and 130 m² (fig. 5).

In zone A, the pollution is located on the surface, over the first 50 centimetres and the large number of boreholes means that the zone can be clearly identified. In zone B, the pollution is situated at a greater depth than the rest of the subsoil (significant caesium 137 activity down to about 3 m). Zone C comprises the remainder of the polluted areas, with pollution down to a depth of up to 2 m.

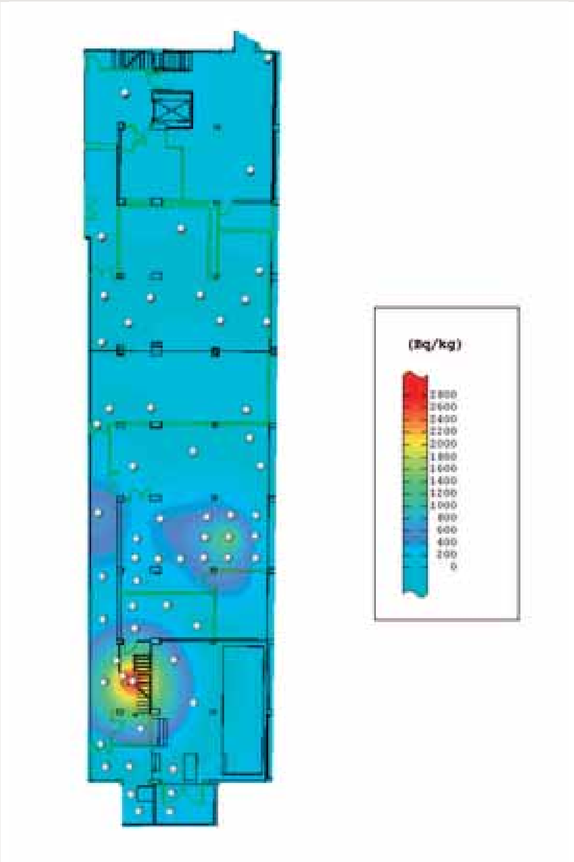


Figure 1 : map produced by in-situ gamma spectrometry measurements

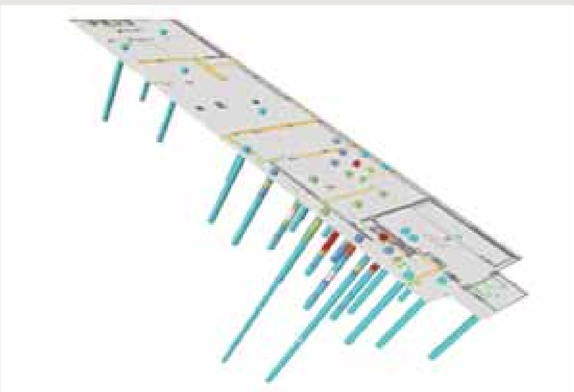


Figure 2 : location of boreholes

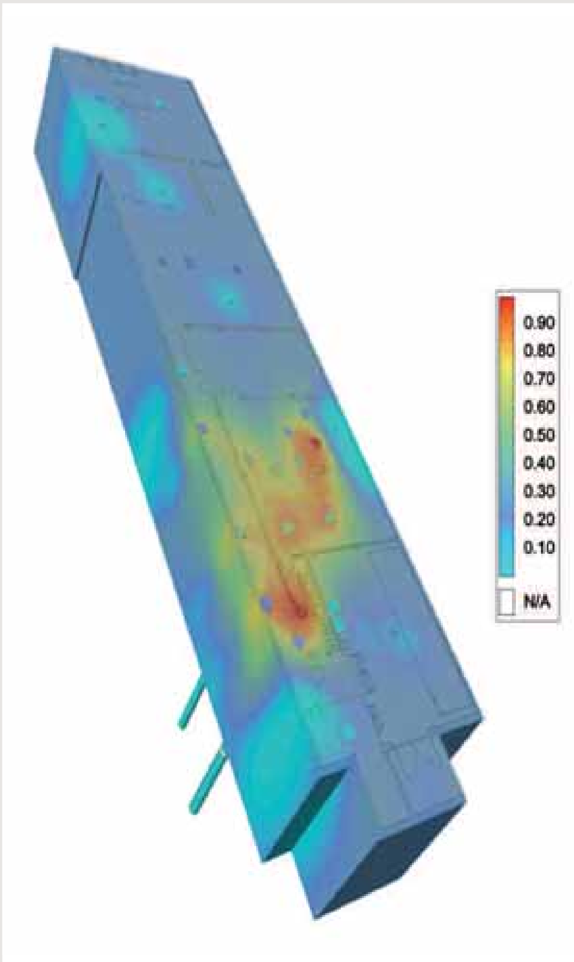


Figure 3 : 3D pollution map

The total source term is estimated at 0.75 GBq (zone A: 0.03 GBq; zone B: 0.33 GBq; zone C: 0.39 GBq).

The envisaged use of this part of the site is the construction of a building. According to this scenario, the current impact without clere mediation would entail an impact > 300 µSv/year in localized areas.

Assuming that the building were to be demolished before soil clean-out, all the pollution could be removed with no particular constraint, thus enabling a very low clean-out target to be reached. The scenario adopted is to retain the building as-is and keep a record of the results of this assessment. ■

E. Aubonnet, Soils radiological characterization under a nuclear facility, ICEM, Reims 2011.

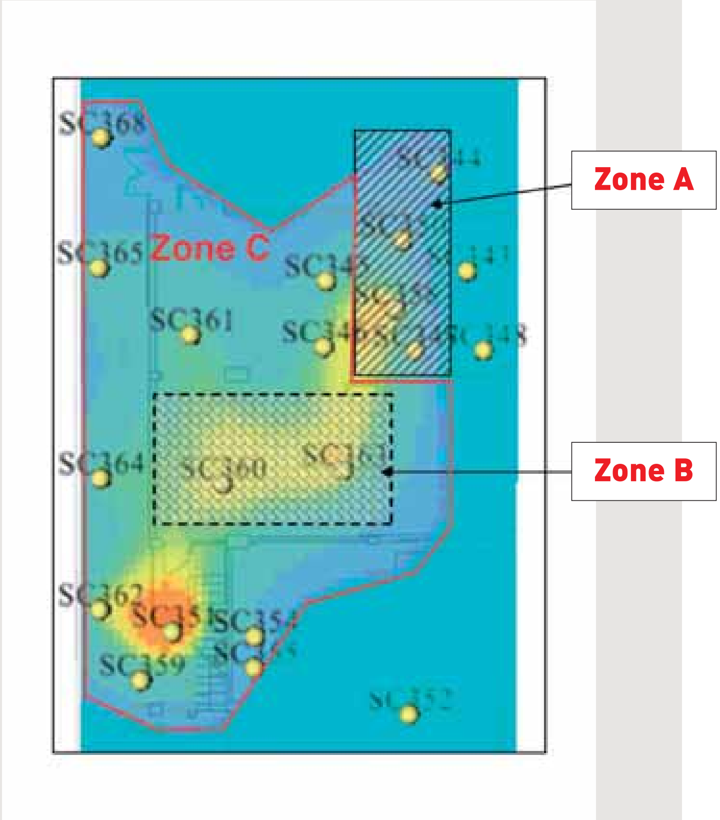


Figure 5 : views of zones A, B and C to be cleaned-out (overhead view)

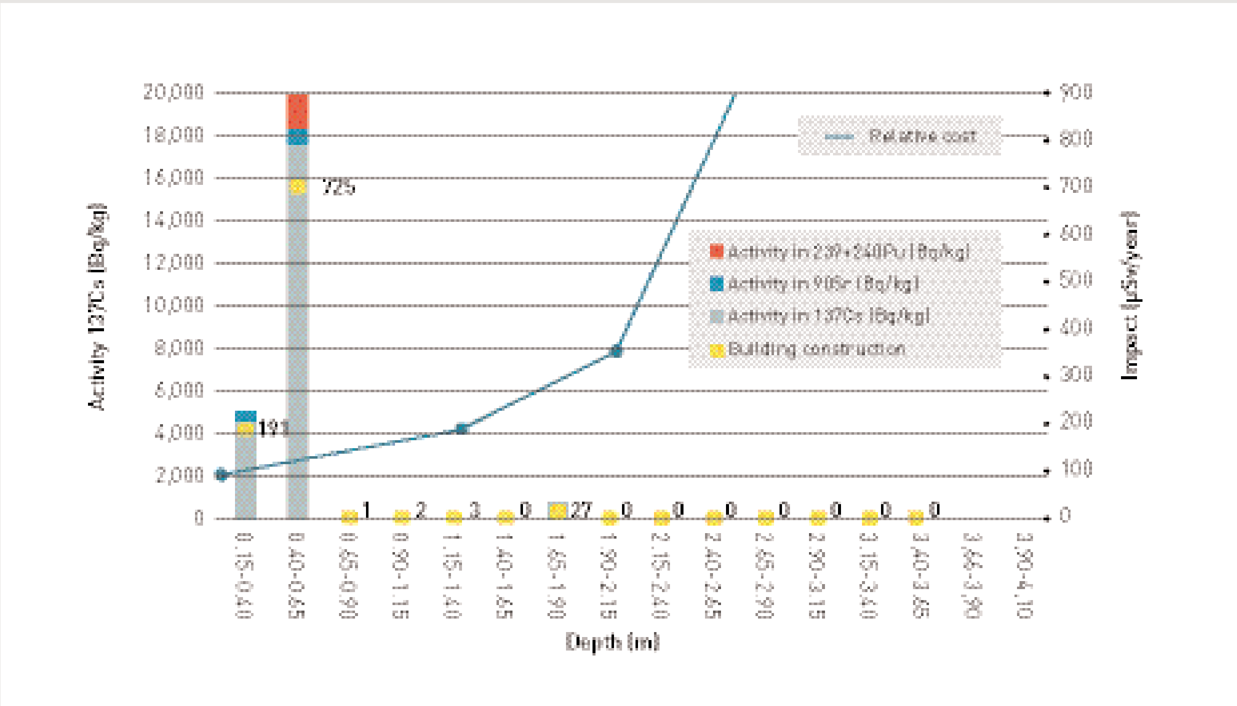


Figure 4 : cost/benefit analysis – Impact of zone C according to a remediation scenario involving construction of a building

Characterisation of a backfilled pit

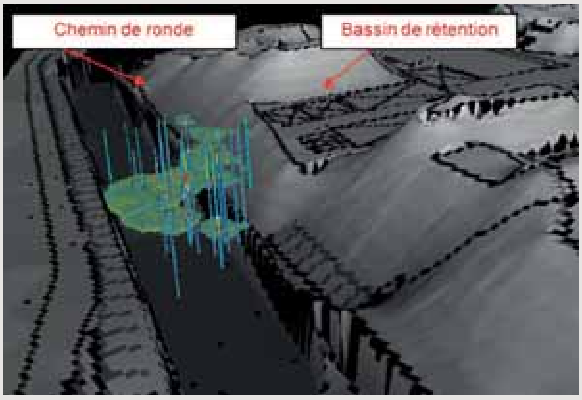


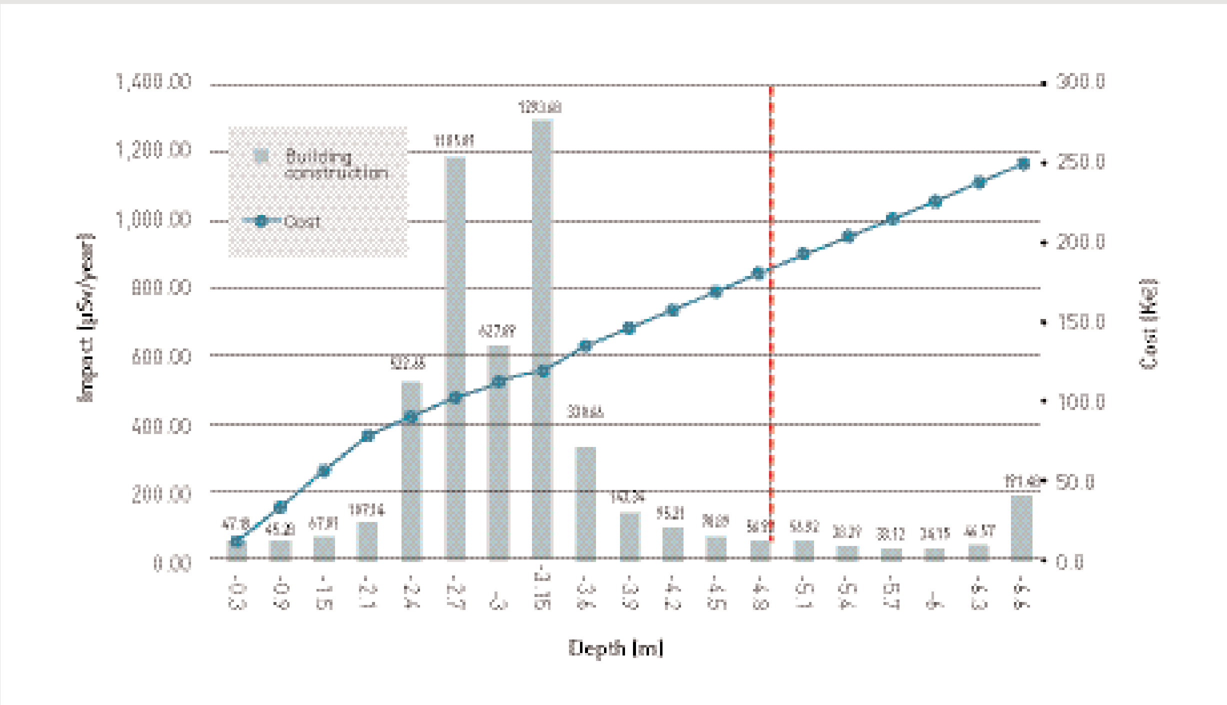
Figure 6 : modelling of contamination after geostatistical processing

The historical survey and functional analysis identified that two ponds had been used to process the mother liquor from the pilot plant (1955-1958). The mother liquor was processed by lime flocculation and the sludges were left to dry along the wall of the pond and then disposed of via the routes available at the time. This process therefore left traces of activity at the bottom (depth of 10m) and on the sides of the pit.
The characterisation clarification operations carried out in 1999 on the areas of interest of the site, showed the presence of pollution as of a depth of 3.5 m. A borehole campaign was organised starting in 2007 in order to produce a 3D map of the scale of the pollution.

Radiological evaluation

Surface measurements are not pertinent for this contamination at depth. The radiological evaluation at depth was performed using three borehole phases. These were made at a depth of between 15 and 20 m, in confined mode using a "sonic" technique. The high cost of boring of this type led CEA to optimise the number of bores. The approach involved a first campaign of bores, followed by analysis of the samples and processing of the data allowing calculation of the probability maps for a level of pollution in order to identify those areas where the pollution is not circumscribed.

Figure 7: cost/benefit analysis – Impact of zone C according to a building construction scenario



Two successive operations were necessary to circumscribe the pollution with a high degree of confidence.
The activity levels measured are of several tens of Bq/g of caesium 137 and about one Bq/g of plutonium 239.

Reuse of the land

The reuse of the land envisaged for the next twenty years is construction of buildings for the service or industrial sector, with an underground car park.

Cost/benefit analysis

The radiological evaluation led to the plot investigated being divided up into six zones of different depths and technically excavatable shapes. For each zone, a cost/benefit analysis was carried out, in order to check that remediation was necessary in the light of optimisation of radiological exposure and the cost of the corresponding clean-out work. This analysis ruled out the remediation of a zone with pollution of about 1.4 m^3 (outside the margin) located at a depth of nearly 9 m, for which the health impact was assessed at 15.5 µSv/year and for which the cost of clean-out would be about € 200K.
Following the cost/benefit analysis, five zones covering a total surface area of 170 m^2 and at a depth of between 5 m and 10.5 m, determined by the radiological evaluation, will be cleaned out.
A source term of 2.8x109 Bq will be removed, corresponding to 99% of the source term of the area investigated.

Soil clean-out

In order to perform this clean-out, five shielded shafts will be dug. The work will take place over 12 months (in 2012-2013). 974 m^3 of VLL waste will be produced and disposed of in the very low level waste repository (CSTFA). A further 1,000 m3 of conventional earth will be excavated and removed in order to reach the contaminated layers.

The total cost of this project is € 1.5M. ■

P. de Moura – Y. Desnoyers, Characterization of a deep radiological contamination: integration of geostatistical processing and historical data, ICEM, Reims 2011

of the cost/benefit approach to be produced via a graph showing which objective could be reasonably achieved. It can also show whether the removal of additional soil is effective in terms of reducing the health impact as of a certain depth. On the other hand, when pollution is clearly delimited and shallow, the study generally concludes that total removal of the contamination is preferable.

Final checks following remediation

At the end of clean-up, given that there is no spatial structuring of the pollution, statistical tools will be used to ensure that the final objective has been reached (PESCAR method, Wilks formula, Student test, etc.).

Account must also be taken of the analysis of profiles and the existing α and β ratios after treatment of the pollution, in order to adapt the type of inspection and analysis to be performed on the samples in order to estimate the residual activity. It may for instance be possible that caesium 137 is no longer the predominant element and that only traces of pure α and beta emitters exist.

Conclusion

Remediation of the soils on the CEA/Fontenay-aux-Roses site, located outside the perimeter of the BNIs, began in 1999 and will be completed in 2013, with the issue of a technical memorandum.

The use of a rigorous methodology for radiological characterisation as of the beginning of the project and the development of efficient soil measurement tools enabled this project to be completed on-time. The quantities of waste created and removed to appropriate disposal routes are as follows:
– 25,000 tonnes of conventional waste;
– 15,000 tonnes of very low level (VLL) waste);
– 20 tonnes of low-level (LL) waste).

The total cost of remediation, including waste, is about € 50M.
■

An example of radiological characterisation of a polluted site: the case of the Ile-Saint-Denis

By Olivier Chabanis, Intervention and Radiation Protection Assistance Department – French Institute for Radiation Protection and Nuclear Safety (IRSN)

The context and the goals of the studies conducted by IRSN at Ile-Saint-Denis

From 1913 to 1928, the SATCHI company carried out the industrial extraction of radium from uranium ore on a site located on the Ile-Saint-Denis, in the Seine-Saint-Denis *département*. The premises of the SATCHI company produced the radium used for industrial and medical purposes and housed a laboratory used by Marie Curie for her research work.

After the radium extraction activities ceased in 1928, and until 2005, the site was used by a series of companies recovering animal bones and carcasses. During this period, the site was mainly used as a storage platform before the material was sent to industrial processing plants.

This former industrial site, covering an area of about 6000 m², is currently derelict. It is located within a dense industrial environment and is surrounded by the two arms of the Seine.

Several radiological investigations were carried out in 1997 and 1998, in particular by the IRSN, on this former industrial site and its immediate vicinity, as part of an initial site diagnosis and road network redevelopment works. These studies revealed the existence of radiological pollution by elements of the natural decay chain of uranium, but were unable to determine the geographical extension.

Aerial view of the polluted site (red circle) and its environment (2009)

For a number of years now, the entire Ile-Saint-Denis island has been the subject of a redevelopment project, including this former industrial site, hereinafter referred to as the polluted site. In this context, the prefecture of Seine-Saint-Denis, which is responsible for this dossier, wished to supplement the existing information and obtain a clearer picture of the condition of the biotopes in the vicinity of the polluted site.
During the course of 2009, the IRSN thus carried out a survey at the request of the Ministry for the Environment, in order to evaluate the compatibility between the current uses of the site and the pollution present, so that it could be characterised on the basis of the available diagnostic data. This survey, which was part of the interpretation of the status of the environment defined in the new version of the methodology guide for management of sites and soils polluted by radioactive substances (December 2011), led to a first evaluation of the site's health and environmental impact, with identification of the risk management and environmental monitoring steps taken.

At the same time, the current owner of the site asked the IRSN to carry out another study, this time to establish a detailed radiological and chemical diagnosis in order to acquire more extensive data on the pollution in place, to help define the various possible management options for the site conversion project. The location and characteristics of the pollution would therefore have to be integrated as a fundamental constraint in the development project. This second study was part of the management plan production approach defined in the new version of the methodology guide for management of sites and soils polluted by radioactive substances.

Definition of the scope of the study performed by IRSN around the polluted site

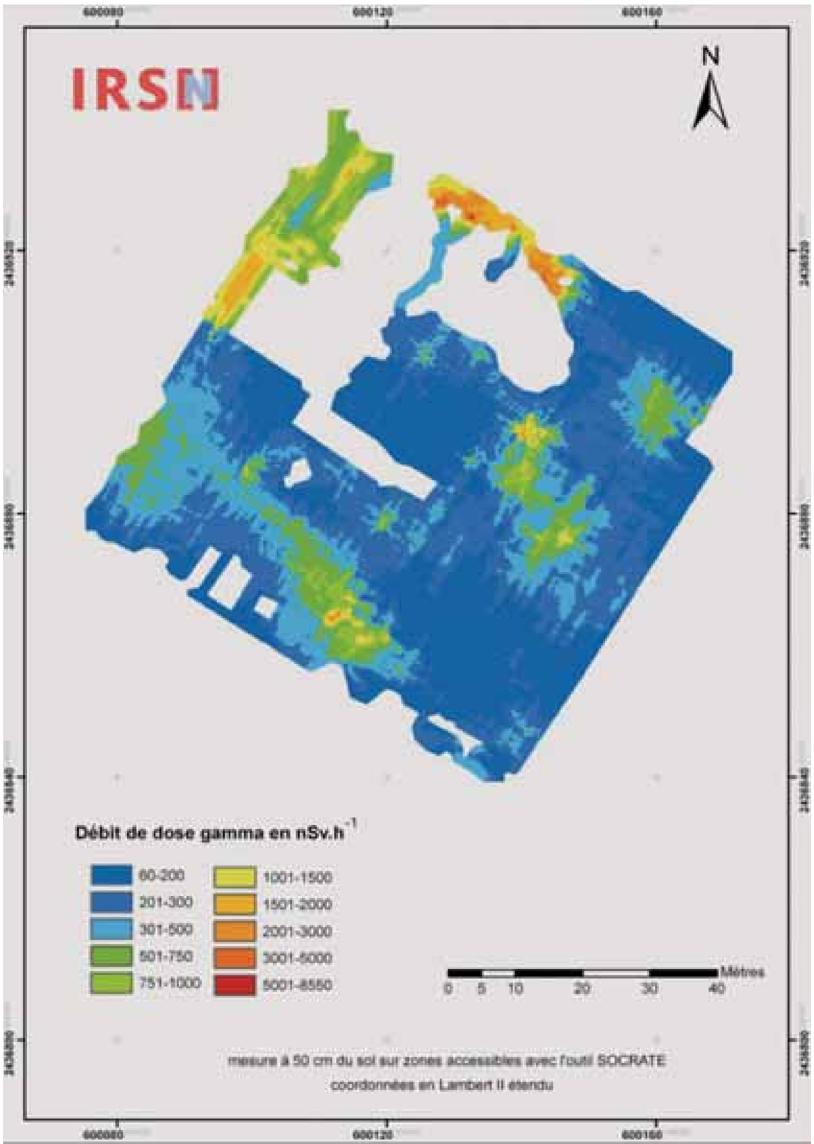
The first step in this study was to define the scope of the investigation around the former radium production site. Based on a documentary analysis and in particular old aerial photos obtained from the French national geographical institute (IGN), a study was carried out into the changing land occupancy. Analysis of the various photos available enabled the history of the former radium extraction site and its environment to be traced from 1934 to the present day, thus helping to guide the radiological investigations. These photos show that the land adjoining the polluted site, currently covered by warehouses, had been used to dispose of the residues generated by the activity. A study perimeter of about ten hectares around the former radium extraction site was thus identified. This study perimeter comprises circulation areas (roads, footpaths), car parks and land occupied by industrial activities (warehouses, workshops).

Aerial view of the polluted site (red circle) and its environment (1934)

The types of radiological investigations carried out by the IRSN for the radiological diagnosis of the polluted site and its environment

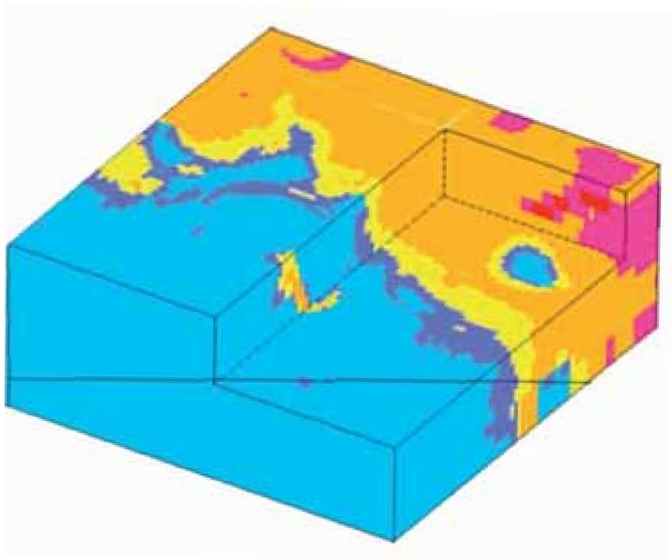
According to the historical survey of the site, the environmental context and the available data on the radiological status of the polluted site and its environs, the IRSN carried out various radiological investigations involving dose rate measurements, analysis of soil and groundwater samples and measurements of radon in the buildings.
The SOCRATE tool, which is used to obtain a dose rate measurement coupled with a GPS location, was used to produce surface radiometric maps. The maps were produced with a regular mesh of one metre, the dose rate being measured at 50 cm from the ground. The value used to assess whether or not a dose rate increase is significant, and thus define areas of interest, was about twice the characteristic reference environmental value (background level). If an area of interest is detected, then in-depth radiological investigations are carried out in this area, in particular with the collection of samples.

Based on the surface dose rate measurement results and the field constraints, a borehole location diagram was drawn up for the polluted site and its environment, in order to obtain in-depth soil characterisation data. The aim was to have a uniform distribution of the bores, focusing on the areas of interest identified during the surface radiometric survey. About 120 bores were thus drilled on the polluted industrial site and in its environment. These bores provide pertinent data for evaluating the scale of the contamination at depth, in particular with a view to a redevelopment project. For the polluted site, a finer mesh was applied, because the aim was to obtain as precise an estimate as possible of the volume and radioactivity of the polluted earth, in order to dimension the remediation work. The core samples were subject to visual examination and contact radiological measurements. The approximately 350 samples taken were analysed by gamma spectrometry in the IRSN's laboratory vehicle present on the site throughout the duration of the drilling campaign. The elements looked for belong to the decay chains of uranium 238, uranium 235 and thorium 232.
To obtain information on the radiological quality of the groundwater, seven observation wells were also drilled upstream and downstream of the polluted site. The



Map of dose rates recorded using the SOCRATE tool

Polluted site – 3D representation of the pollution at depth (Estimages company)



position of the wells was determined on the basis of a hydrogeological survey performed beforehand by IRSN. Water samples were collected during two campaigns, a first during the Seine river high water period and a second during the low water period. All the samples underwent total alpha and beta counting and radium measurement by means of emanometry and alpha spectrometry, in IRSN's laboratories.

Finally, as the radium pollution of the soil could lead to a build-up of radon in the buildings located within the perimeter of the study, IRSN supplemented the diagnosis by a campaign to screen for this radioactive gas generated by the decay of radium. This led to about fifteen measurements being taken in five buildings within the investigation perimeter. These measurements were taken using solid-state nuclear track detectors (SSNTD), and quantified the integrated radon activity concentration over a period of three months.

The results of the diagnosis performed by the IRSN on the polluted industrial site

Mapping of the dose rate and an analysis of the soil samples by gamma spectrometry enabled a detailed radiological inventory to be created, which is vital when drawing up a site redevelopment project.
The map of the dose rates is presented above. On the polluted site, it shows that the dose rates at 50 cm from the ground are extremely heterogeneous and can reach 8 µSv/h, or more than one hundred times the local

background value. About 25% of the site has a dose rate at least twice as high as the characteristic background value, and is thus considered to be an area of interest.

More than 70 bores (about 4 m deep) were made on the polluted site. 190 samples were thus collected and analysed in-situ in IRSN's laboratory vehicle. The results of the analyses revealed radiological pollution down to the natural soil at a depth of about 3 m, and even beyond. The pollution levels measured are on the whole between 750 and 10,000 times the background level, estimated at about 40 Bq/kg (for example, 100 Bq/g of radium 226 at a depth of 3.5 m). On the basis of all the measurement results, an estimate of the volume of polluted earth was made, along with a 3D representation of the pockets of pollution. The estimate of this volume over the entire industrial site is between 15,000 and 20,000 m^3, about 4,000 m^3 of which has a radon specific activity of more than Bq/g.

The results of the diagnosis made in the environment of the polluted industrial site

Concerning the radiological measurements taken within a perimeter of about 10 hectares around the polluted site, 5 areas of interest were brought to light by the surface radiometric measurements. These highly localised areas are situated within the perimeter of the neighbouring industrial sites as well as on the West and East banks of the Seine. The dose rate values are between 2 and 25 times the background level.

The drilling campaign (about 50 boreholes) carried out within the perimeter of the study enabled about 150 samples to be collected and analysed in-situ by gamma spectrometry. The results of these analyses confirm the presence of radium pollution at depth (of up to 1.5 m) in the areas of interest identified during the radiological surface surveys. The levels measured are about 10 to 250 times the background level of the region. The analysis results on the samples taken outside the areas of interest revealed no pollution.

The results of the surface and deep soil radiometric measurements confirm occasional dispersion of the pollution in the vicinity of the site concerned.

Analysis of the water samples revealed radiological marking of the aquifer downstream of the polluted site. Isotopes 234 and 238 of uranium are the main contributors, leading to a total alpha activity higher than 0.1 Bq/l.

Finally, radon activity concentration measurements taken in the buildings on the sites adjacent to the polluted site are higher than the average level measured for the Seine-Saint-Denis *département* (about 30 Bq/m^3) although without exceeding the 400 Bq/m^3 value adopted as the action level by the regulations in the case of premises open to the public and workplaces. Only one of the buildings contained a radon activity concentration higher than 400 Bq/m^3 with, in certain rooms, the levels measured reaching even more than 50 times this value. In the light of these results, an order from the Prefect was issued to take account of this specific situation of radon exposure in this building, for example by imposing access restrictions; further investigations were also conducted on this site in order to study the ingress and transport routes for this gas and thus define remediation options.

Conclusions and outlook

The studies performed by IRSN led to a detailed diagnosis of the radioactive pollution present on the former radium extraction site and its immediate environment, thus giving a clearer picture of the scale and levels of the pollution. The vast majority of the pollution is situated within the perimeter of the former industrial radium extraction site. A few small spots of pollution were identified in the immediate vicinity of the polluted site, at levels far lower than those recorded on the actual former industrial site. In the current configuration, exposure to ionising radiation, added to the natural background level, can be considered to be negligible on the Ile-Saint-Denis as a whole, other than on the polluted former industrial site and an adjacent building in which there are high radon activity concentration levels.
Finally, this study also revealed transfer of the radiological pollution present on the site to the groundwater. This water is currently not used for any private or industrial purpose.

On the basis of the findings of the diagnosis and for the purposes of the redevelopment project, IRSN recommended:
– implementing measures to ensure that a record of the polluted areas is kept (access or usage restrictions), in particular if polluted residues and soils remain on the site after the redevelopment phase;
– the performance of radiological checks on the materials excavated during the redevelopment work, in particular in the event of any demolition of buildings;
– the performance of a more detailed hydrogeological survey and the implementation of a surveillance programme for long-term monitoring of the groundwater quality.
With regard to the former industrial radium extraction site which is at present secured, the study conducted by IRSN enables the site owner and future parties responsible for the Ile-Saint-Denis remediation project to be provided with factual information about the radiological status, enabling various management strategies to be envisaged, with a search for the optimum management options. In

1. IRSN Radon Atlas – national campaign to measure natural radioactivity in the French *départements* - IPSN /DPHD-SEGR-LEADS (January 2000).

addition to the radiological diagnosis, IRSN also included in its approach a diagnosis of the chemical pollution present on the site. This revealed the existence of pollution by metals, hydrocarbons and chlorinated solvents. The co-existence of chemical and radiological pollution will thus need to be taken into account when rehabilitating the site.
Finally, the approach adopted with regard to the release of results led to these results being sent individually to the owners of the locations studied and to a public meeting being held in March 2010 under the responsibility of
the Mayor of Ile-Saint-Denis, to present all the results of the study and the remediation project for the area in question. ■

One company's experience of radioactive pollution clean-up projects

Interview with Yves Duranton, Clean-out/Decommissioning Sales Director,
Elia Binet and Jean-Jacques Freudenreich, Project engineers – Onet Technologies

All-terrain radiological inspection system (CRTT)

***Contrôle*: How does a company such as Onet Technologies intervene in managing a polluted industrial site? What is its role?**

Yves Duranton: Onet Technologies, the nuclear industry engineering, services and works subsidiary of the Onet group, has been treating polluted sites for about twenty years now. Onet Technologies and its specialised subsidiaries, Onectra and Sogedec, carry out radiological diagnoses and decommissioning and clean-out work. For the larger projects, Onet Technologies is a turnkey contractor: we coordinate the various trades (demolition, earthworks, inspection, transport, etc.). For smaller pollution clean-up projects, Onet Technologies can carry out investigations and provide rapid response processing of contaminated areas, thanks to a framework agreement signed with ANDRA just over a year ago.

What does a radioactive pollution clean-up project consist of?

The projects involve several stages: first of all, a radiological diagnosis which identifies the areas to be processed, the depth of contamination and its characteristics (type of radionuclides encountered, etc.). A "radiological target" is then submitted to the public authorities for validation. The clean-out scenario is defined on the basis of the radiological target. This scenario in particular includes the intervention methodology, waste management and the radiological monitoring programme. The work can then begin: Onet Technologies takes charge of the coordination, radiation protection, waste management and premises clean-out. At the end of the work, a "radiological characterisation" step confirms that the radiological target has actually been reached.

Are the techniques and equipment used specific to this type of work?

The techniques employed, which are derived from the nuclear industry, are ideal for these highly particular worksites: rigid or flexible vinyl containments, air extractors with high-efficiency (HEPA) filters, investigation cameras, etc. The sensitivity of the radiation protection instruments must allow them to take measurements close to the natural background level (70 to 120 nSv/h); monitors are also used to provide instantaneous measurements of the radon concentration in the air. Onet Technologies has also developed measurement systems tailored to the specific nature of pollution clean-up worksites. This is for example the case of the all-terrain radiological inspection system (CRTT). This equipment, fitted with large surface area detectors, is mounted on a wheeled chassis. It measures the radiation from the soil along with the corresponding GPS positions. This assembly can be towed or carried depending on the condition of the ground and the access. It is used either in the initial diagnosis phase, or in the final radiological characterisation phase to ensure that the radiological target is reached.

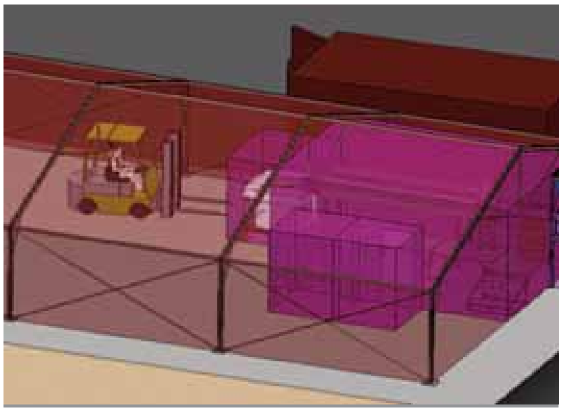
To localise and quantify the volume of radiologically polluted material, we often have to make a large number of boreholes in the three dimensions of the land to be treated (surface and depth). The materials extracted are

1. Inside the core sample processing unit (UTC)

2. Overview of the UTC

3. Radiological inspection and transfer of rubble by conveyor under confinement

4. Confinement of the filling hopper for the waste packages, equipped with a misting system



sampled and analysed. We have designed a core sample processing unit (UTC) consisting of three independent gloveboxes, dedicated to characterisation, cutting and sampling. This assembly, installed in a road transport container, is stand-alone and can be installed close to the worksite.

Is there any special treatment for the waste?

Yes. The waste is required to comply with all the rules defined by ANDRA (packaging, activity measurement, absence of prohibited waste, etc.) so that it can be accepted by the disposal facility. It must be optimised (in terms of mass and volume) in order to reduce the environmental and financial impact of the project.
In the pollution clean-up phase, we need specific equipment, which we define in order to optimise and make safe the work done by our technicians.
For example, for management of earth and rubble, we use a site installation which is a conveyor combined with a loading hopper and a scintillation counter. This chain is able to reach the throughput necessary to process the large volumes of waste generated by this type of operation. Downstream of the process, our technicians then perform the final checks and inspections.

How do you identify the nature and scale of the pollution?

We usually have to use old documents (photos, drawings, interviews, archives, etc.), which help us determine the zone to be investigated and define an initial clean-out scenario. To validate this, we perform in-situ measurements: samples, geo-radar measurements, boreholes. We sometimes have to call in companies using highly specialised techniques. For example, for work on very high structures that are hard to access, we had to call in a company using mountaineering techniques to take core samples from inside and outside a stack prior to its demolition.

What difficulties do you encounter on this type of project?

There are numerous difficulties when dealing with this pollution. The first one lies in the fact that the historical owners had little if any awareness of the hazardous nature of the product being handled. They did not confine and store the substances in the conditions which we today employ. Consequently, some of the pollution extends beyond the physical limits of the site and migration into the soil sometimes reaches considerable depths. In order to make an accurate quantification of the volumes to be treated, a whole range of investigations is required (mapping, core sampling, measurements, etc.); these latter are costly, complex and sometimes lengthy and are not always exhaustive, which makes it complicated to accurately size the worksite. A good estimation of the volumes is crucial on this type of project and it allows optimum definition of the flows, storage requirements and duration of the work.

The second difficulty is psychological and media-related; the occupants, having often worked or lived in the premises, completely unaware of the radioactive pollution present, are naturally worried, sometimes even outraged. In certain cases, campaign groups were set up.
When we intervene on sites which are still in operation or still inhabited, our role is to reassure and to explain to the residents or staff on the site the work done and the means used to manage the various risks.
The third difficulty is the presence of radon, which

site machinery), divide up the operations using strict sequencing or zoning, enabling these companies to intervene without any additional constraints. Every year, Onet Technologies performs numerous radioactive pollution clean-up operations throughout France. The lessons learned from this valuable experience enable us to offer proven and appropriate solutions for these very special types of operations. ■

sometimes creates complications. This radioactive gas resulting from the decay of radium, easily builds up in basements, ducts or pipes, thus disrupting the measurements and complicating the working conditions. As this is a noble gas, the filtration cartridge on the protective breathing apparatus is not effective: the only ways of combating this radionuclide are isolation and good ventilation of the premises. Particular dosimetry is required in order to effectively measure the exposure of the personnel involved.

Determining the activity of the samples to be measured can also be disrupted by the presence of radon.

Other potential difficulties are the fact that some derelict sites present safety hazards (ruined buildings) and a risk of intrusion. We then implement logistics appropriate to the situation (permanent security on the premises, creation of new water and electricity supply networks, fencing, worker camp for the personnel, etc.).

We also have to take account of the constraints related to the operations performed outdoors. Pollution clean-up work is often done in the open air or under light containment. Weather conditions are in this case a potential source of difficulties. This is a key factor to be considered when running a worksite.
Finally, intervention by a trade which in general has no dealings with the nuclear industry is a recurring problem. These companies (demolition, security, etc.) usually have neither the training nor the medical authorisation to intervene on this type of site. Three solutions are commonly used: help the company obtain the necessary permits (medical file, allocation of dosimeters, training, etc.), perform the services concerned using our own personnel (several of our employees are trained to operate

Clean-out under containment in a home

Orflam-Plast, a site undergoing remediation by the public authorities

By Sylvie Cendre, sub-Prefect of the arrondissement of Vitry-le François – office of the Prefect of the Marne *département*
Benoît Rouget, deputy head of the Châlons-en-Champagne Division – Autorité de sûreté nucléaire and Bruno Laignel, polluted sites and soils engineer – Champagne-Ardenne Regional Directorate for the Environment, Planning and Housing

Origin of the pollution: a misunderstood problem

Between 1931 and 1997, U.T.M. (Usine de Traitement de la Monazite) and then Orflam-Plast were companies that carried out industrial activities in the commune of Pargny-sur-Saulx (Marne *département*) involved in the manufacture of lighters. Between 1931 and 1967, these activities in particular concerned the processing of ore (monazite) for extraction of the cerium needed to make lighter flints. Several hundred tonnes of monazite were processed in this way. These extraction operations also led to the production of residues containing thorium 232, a naturally radioactive substance, by concentrating the fraction initially present in the monazite, imported primarily from Sweden and Madagascar (we then talk of technologically enhanced naturally occurring radioactive materials (TENORM)). Although some of these residues were reused in the form of thorium nitrate, mainly by other industries abroad (manufacture of gas mantles, television screens, etc., use of the properties of thorium other than its radioactivity), the rest was considered as an "inert" mineral product subject to no particular management rule, especially radiation protection. These residues were thus reused as backfill for the extension of the plant and development of the banks of the Saulx, a watercourse feeding the plant's mill, or on private land situated in the vicinity. This reuse, which was to cause radioactive pollution identified only later, was not specifically monitored, which would have enabled the geographical situation and volumes of materials used to have been identified.

Identification of pollution: rewriting history ...

In February 1997, the Orflam-Plast company went into receivership. During the operations to liquidate the plant's assets, chemical analyses were carried out on drums of waste in order to identify the contents and thus the appropriate disposal route. These analyses revealed the presence of radioactivity in the drums discovered in an abandoned building. In the light of this discovery, an inspection visit was conducted in April 1997 by the Champagne-Ardenne Regional Directorate for Industry, Research and the Environment (DRIRE), which is the inspectorate for installations classified on environmental protection grounds, the regulatory system applicable to certain activities of the Orflam-Plast company which required notification. The office for protection against ionising radiation (OPRI) and the French national agency for radioactive waste management (ANDRA) are also associated with this inspection. In addition to the small number of drums containing thorium salts, which will be removed by ANDRA, this inspection visit revealed unbound contamination in the oldest buildings on the plant near the mill (area where monazite had historically been processed) and fixed contamination spots on the banks of the Saulx and in the soil of certain of the plant buildings. Given the context of receivership and thus insolvency, the Orflam-Plast site is now registered as a polluted site and soil for which the party responsible has defaulted, requiring action by the State to make it safe. The public authorities, under the aegis of the Prefect, then delegate ANDRA to ensure the immediate safety of the site (fencing, access ban and monitoring of groundwater quality) and to conduct additional investigations necessary for precise characterisation of the radioactive pollution with a view to its treatment. The exceptional flooding of the Saulx river in 1999, which eroded part of the banks, thus revealing a hot spot of about 200 µSv/h contact dose rate, combined with additional diagnosis operations performed after the initial discoveries in 1997, led to the definition of the following schedule of work:

– stabilisation of the banks of the Saulx to prevent their erosion, with covering to guarantee a surface dose rate of about 1 µSv/h;

– demolition of the plant buildings, keeping the contaminated materials *in situ*, with a cover such as to achieve a dosimetric target similar to that adopted for the river banks.

Against a backdrop of complex public financing, relying to a large extent on a mechanism involving contributions by the nuclear power generating industry licensees, only the work concerning the river banks was carried out by ANDRA and completed in October 2003. In the following years, ANDRA continued to perform work to maintain the security of the site (bricking up of the openings in the former plant's buildings to keep out intruders, repair of the roof of one of the buildings, and so on).

In 2007 and in order to consolidate ANDRA's public service duties, in particular for treatment of polluted sites and soils for which the party responsible has defaulted, the French Government created the National Commission for Assistance in the Radioactive Field to provide a procedural framework and clearly established financing (annual budget allocated to ANDRA). In early 2008, the CNAR was contacted in order to reactivate the Orflam-Plast dossier and thus ordered studies to finalise the plant buildings demolition project. In the autumn of 2008, on the occasion of work falling within the context of the above-mentioned studies, the Orflam-Plast dossier took on a completely new dimension. A former employee of Orflam-Plast living in Pargny-sur-Saulx informed the ANDRA personnel that plant production residues had been used as backfill on a communal plot of land now planted with poplar trees (plot known as *la Peupleraie*). Brief radiometric checks conducted immediately by ANDRA personnel confirmed this local resident's claims (hot spots of about 15 µSv/h at 50 cm from the ground). A municipal order was immediately issued to ban access to *la Peupleraie.* The local resident went on to indicate two further zones which in the end showed no radiological anomaly further to surface measurements. As of the end of 2008 and under the terms of the agreement of principle for financing by the CNAR, the duties entrusted to ANDRA were broadened so that the studies included the search for other contaminated plots and so that the programme of works now included *la Peupleraie,* in addition to the former Plant. At the local level, the institutional monitoring of this dossier by the services of the Prefect now involves the recently created Champagne-Ardenne regional directorate for the environment, planning and housing (DREAL), which took over the duties of the DRIRE with regard to installations classified on environmental protection grounds, and the Autorité de sûreté nucléaire (ASN), represented by its Châlons-en-Champagne division, which is an independent administrative authority created in 2006, supporting the Prefect through its expertise in the field of radiation protection.

In April 2009, ANDRA carried out radiometric checks on the edge of a lake located close to *la Peupleraie* in order to clear up any doubt. This zone was chosen because, in addition to its proximity to *la Peupleraie*, an examination of aerial photos before and after the working of monazite on the Orflam-Plast site, showed that significant earthworks had been carried out. The measurements taken confirmed the presence of radioactive residues (hot spot of about 30 µSv/h at 50 cm from the ground). This zone, known as Gravière lake, was a very popular fishing spot and was immediately fenced off, with a municipal order barring all access.

The developments in the Orflam-Plast dossier between the end of 2008 and April 2009 revealing hitherto unknown areas of pollution, significantly altered the nature of the potential stakes of this dossier and led to major changes in the treatment strategy identified in the early 2000s. Faced with the gaps in the historical data and in addition to the immediate security measures taken for la Peupleraie and Gravière lake, the public authorities decided that the Orflam-Plast dossier should be treated as a whole and that to do this, all the polluted zones should be rapidly identified beforehand for subsequent management (securing then treating). In order to meet this objective, wide-ranging measures were taken as of June 2009:

– public meeting held in Pargny-sur-Saulx in particular to collect testimonies from former Orflam-Plast employees and local residents in order to direct the investigations aimed at identifying all the contaminated areas. This meeting attracted from 80 to 100 participants;

– after the above-mentioned meeting, two-day overflight of an area covering 60 km2 centred around the commune of Pargny-sur-Saulx by a helicopter fitted with a radioactivity measurement system (HELINUC system).

The helicopter overflight confirmed the significant thorium 232 contamination of the areas covered by the former plant, *la Peupleraie* and Gravière lake, but revealed no new areas. The testimonies collected during the public meeting identified five additional areas for investigation. Although these areas had been overflown by the helicopter without revealing any significant thorium 232 contamination, the public authorities nonetheless decided to conduct additional investigations in said areas, using human-portable measuring instruments. These inspections, performed by the Institute for Radiation Protection and Nuclear Safety (IRSN) revealed slight, isolated areas of contamination, the intensity and surface area of which were nothing like the scale of the pollution identified in the three main areas mentioned above.

HELINUC airborne measurements system

In addition to these actions, numerous measurements were taken by IRSN in the aquatic environment (Gravière lake and Saulx river) starting in April 2009. These measurements revealed slight sedimentary contamination with thorium 232 in Gravière lake but no contamination of the surface waters, fish and plants, entailing no restrictions being imposed on the usual practices.

Pollution treatment: a necessarily ALARA approach

In late 2009, the considerable amount of investigative data accumulated to back up the information collected at the public meeting in June 2009 led to the conclusion that the handling of the Orflam-Plast dossier could be summed up as involving management of three main areas, that is the former plant, including the banks of the Saulx river, the Peupleraie area and Gravière lake. Various treatment scenarios were then defined by ANDRA (total or partial excavation of the contaminated earth, confinement in-situ) producing a summary of the long-term management costs and prospects for each of the solutions proposed. After presenting these scenarios to the local information committee (CLI) set up specially in November 2009 to involve and inform the local populations, the dossier was submitted to the CNAR. Given the uses and the level of contamination of each of the zones, the financial resources available and the physical-chemical properties of thorium, which is characterised by little mobility in the environment and virtual insolubility, thus allowing confinement solutions, the following treatment principles were adopted, for an estimated cost of € 3.5M:

– Gravière lake (surface to be managed of about 250 m^2, maximum thorium 232 contamination of a few hundred Bq/g): excavation of contaminated earth to allow collective recreational use of the site (fishing, walking, etc.);

– Peupleraie (surface to be managed of about 3,000 m^2, maximum thorium 232 contamination of a few hundred Bq/g): in-situ confinement of the contaminated earth with multi-layer covering (geotextile, clay, topsoil) to achieve an exposure level everywhere of less than 0.5 µSv/h at 50 cm from the ground;

– Former plant (contamination not exceeding the characteristics of the very low level radioactive waste category): demolition of the buildings and in-situ confinement of the contaminated rubble by a multi-layer cover (geotextile, clay, topsoil).

Following these decisions, the work on Gravière lake was carried out in 2010. The pollution clean-out targets were on the whole met, even if unanticipated difficulties had to be resolved during the operation (excavation depth, temporary storage of the contaminated earth before disposal to an appropriate route).

The work on the Peupleraie was carried out in 2011. After the decisions by the CNAR, the project was readjusted to include felling of the poplar trees, with the chips being kept in-situ after grinding, on the one hand to prevent any transfer of contamination which would have prolonged the problem of managing said poplars and, on the other, to facilitate the shaping of the confinement layers and manage their long-term integrity by eliminating the problem of cutting down and uprooting the poplar trees.

The work on the plant, which started in 2010 on the uncontaminated buildings, continued in 2012 and will be completed in 2013.

Conclusions and outlook

The Orflam-Plast dossier is subject to four fundamental constraints:
– pollution generated by a legacy activity and discovered several decades after the cessation of said activity. This implies specific measures to counter the lack of knowledge concerning areas in which residues containing thorium were reused (i.e. radiologically polluted zones); measures that can comprise a degree of uncertainty in terms of the exhaustiveness of their results;
– a historical activity carried out in ignorance of the radiological aspects and therefore with no monitoring or oversight of radiation protection. This implies a potentially complex exercise to subsequently inform the populations concerned (former employees, local residents);
– pollution with thorium 232, a long-lived radionuclide, requiring that consideration be given to methods for durable monitoring of the areas treated by in-situ confinement, without completely ruling out the prospects for possible reuse of the land;
– pollution for which the party responsible has defaulted, thus affecting the possibilities for financing of the treatment operations.

In the face of these constraints, the public authorities mobilised significant resources to optimise the response:
– confirmation of oversight of the dossier by the office of the Prefect, in close collaboration with the public stakeholders participating in the decision-making processes (DREAL, ASN, ANDRA) in order to guarantee that the most appropriate decisions are taken in a situation subject to considerable constraints;
– take essential steps (public meeting, HELINUC inspection, multiple manual radiometric inspections) to fill in the gaps in historical knowledge;

1. Peupleraie before the work

2. Shaping of the clay during the work

3. Final condition after the work


1


2


3

Performance of pollution clean-up work on Gravière lake

– public meeting and creation of a CLI which meets annually to take part in informing and involving the local populations in addition to the numerous direct exchanges with the municipality of Pargny-sur-Saulx and the private householders directly concerned. One should also mention the epidemiological survey between 1997 and 2001 of the former employees of Orflam-Plast [Challeton de Vathaire, 2002]. This survey concluded that there was no link between the thorium contamination and the excess of cancers observed in the communes of Pargny-sur-Saulx and the environs;
– creation of public protection restrictions in the town planning documents of Pargny-sur-Saulx to ensure durable monitoring of the zones treated by in-situ confinement (conservation of a collective record, surveillance of the development work carried out). Additional consideration is being given to assessing the suitability of physically posting this information on the site and to identifying compatible developments which could make it easier to conserve this record;
– significant request for funding from the CNAR (about € 5M, an amount greater than its annual allocation and higher than the initial estimates) to guarantee the financing of the pollution treatment operations.

The 2006 confirmation of ANDRA's public service duties and the 2007 creation of the CNAR, clearly identifying the financing possibilities, especially for polluted sites and soils for which the party responsible has defaulted, marked a real turning point in the ability to manage the Orflam-Plast dossier, especially at a time when further areas of pollution were being identified (Peupleraie, Gravière lake). For the public authorities, the CNAR thus proved to be an essential tool in managing these issues. The Orflam-Plast dossier, which was one of the first major dossiers handled by the CNAR, revealed that the way the CNAR and the local authorities worked together needed to be improved. On a dossier such as that of Orflam-Plast, the actions of the CNAR and the local authorities are not always on the same scale (macroscopic and microscopic respectively) nor on the same time-scale. Similarly, the respective objectives and constraints may differ. Schematically, the services of the Prefect have decision-making prerogatives for managing all aspects of the dossier (emergency measures, technical requirements, communications, etc.) while remaining dependent on the financing granted by the CNAR. The CNAR thus becomes an additional investigative and decision-making body. This decision-making "overlapping" should not be such as to confuse matters but should enable decisions to be taken in consideration of all informed opinions and with the aim of reconciling the health issues, the interests of the parties affected by the pollution and the rationalisation of public financing.

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The lessons to be learned from pollution clean-up of a site polluted by chemical substances

by Philippe Bodénez, head of the soil and subsoil office, General Directorate for Risk Prevention – Ministry for Ecology, Sustainable Development and Energy

There has only really been true awareness of soil pollution by industrial activities for a relatively short period of time, no more than about twenty years, as compared with more than two centuries of industrial activity. Under the legislation on classified installations, a policy has been developed in France over the past ten years. Its principles and implementation are close to what is practiced in the other European countries.

This policy is built around two main concepts:
– focus more on examining and managing the risk on a given site, rather than on an intrinsic level of pollution;
– management of the risk depends on the usage of the site.

It is extensively transcribed into the circulars of 8 February 2007, which redefined the methodologies used to manage polluted soils.

This methodology has been utilised since 2007 in numerous cases, an example of which will be presented here.

The case of intervention by the ADEME on the UFP (Petrocarbol) plant in Dieulouard (Meurthe-et-Moselle *département*)

The UFP company *(Union Française des Pétroles)* operated a black oil regeneration plant from 1959 until 1992. This plant was built on the site of a tannery destroyed by fire in 1958, on the edge of the village of Dieulouard, 25 km north of Nancy. The Bouillante stream runs alongside the site before flowing into a backwater of the Moselle river 300 m downstream of the site. This company was unable to meet its debts and entered receivership on 2 November 1992.

TABLE 1 : WASTE IDENTIFIED

NATURE OF THE WASTE	TYPE OF PACKAGING
Used oils at various stages of regeneration	Numerous different containers: more than 70 vessels, tanks, tankers on and off the site and numerous drums, cans
Oils polluted with PCB	
Various chemical products (filtration sediments, acids, etc.)	
Non-hazardous industrial waste, packaging	Bulk
Transformers	Off-site premises

A number of accidents had occurred on this site (explosion, fire in 1986 and 1988). Chronic pollution took place during its period of operation. Waste was abandoned outside the site during its activities. At receivership, other waste was present on the site, in perilous storage conditions (buildings and containers in a state of advanced deterioration (see table 1).

The administrative procedures initiated against the former licensee for management of the environmental hazards generated by this site could not be completed. The lack of funds arising from the winding up of the company required the use of public funds to ensure that the site was made safe.

The objectives set by the various orders of the Prefect, instructing the ADEME to carry out work, were as follows:
– decontamination of a tank car located in Dieulouard station, on a siding dedicated to UFP, containing used oils contaminated by PCBs, including removal and disposal of these latter (1993);
– fencing of the site, emergency intervention following oil spillage into the stream, with removal and treatment of all the waste and products stored on the site - radioactive sources, drums of oil contaminated by PCBs (1997);
– removal of the transformers, strengthening of the fencing and a study of the environment outside the site (2009);
– monitoring of the groundwater, demolition of the buildings and a detailed diagnosis of site pollution (2010).

The site was fenced off and all access points locked. Some tanks were cleaned and degassed while others were partially cut open to ensure satisfactory ventilation. The total quantities of waste removed are detailed in table 2.

Following the initial waste removal operations, the status of the environment was characterised in 2009. This revealed the following:

For the soils off the site:
– no pollution with phenols;
– relatively slight hydrocarbon pollution, with the reference value only being exceeded in a surface sample from one collection point;
– pollution with polycyclic aromatic hydrocarbons (PAH) on the surface at three collection points;
– very slight pollution with volatile halogenated organic compounds (traces at one collection point);

UFP (Petrocarbol) plant in Dieulouard (Meurthe-et-Moselle *département*)

– trace pollution with PCBs also at one collection point;
– slight metals pollution with the geochemical background level being occasionally exceeded for copper and lead at three collection points.

For the sediments of the Bouillante stream:
– no pollution with phenols;
– slight pollution with hydrocarbons, PAH and metals (lead, zinc) with little potential impact on the site between upstream and downstream;

For the backwater sediments:
– no pollution by phenols;
– significant pollution with hydrocarbons, PAH and PCBs;
– metal pollution.

For the groundwater, the quality recorded was on the whole satisfactory downstream of the site, with the presence of VHOC at one sample collection point. The picture was however worse up-gradient, with the presence of hydrocarbons and metals.

This characterisation thus revealed no significant impact by the site on the environment off the site, other than the sediments on the banks of the backwater of the Moselle, with significant levels of organic pollutants (polycyclic aromatic hydrocarbons (PAH), polychlorobiphenyl (PCB), hydrocarbons) and metals (lead, zinc). Water wells did not appear to be exposed.

In 2010, the Ministry responsible for sustainable development gave the Prefect its approval for ADEME to continue its groundwater and surface water investigations, by means of three six-monthly analysis campaigns for metals, hydrocarbons, PCBs and PAH at four sample collection points around the site (groundwater and surface water). If any incompatibility is found between the level of pollution brought to light at the site and the biotopes exposed, given the observed usages off the site, steps will have to be taken to manage this pollution.

Following the observation that the buildings were in very poor condition, the decision was taken to demolish them. This demolition was also necessary in order to perform the additional detailed site pollution diagnoses, in acceptable safety conditions.

Once all the measures described have been taken, it will be possible to envisage reusing the site, possibly by the Lorraine *département* public land use agency.

The data sheet for the UFP Dieulouard site is available on the BASOL website.

This example is relatively representative of the situations inherited from the past and which have to be managed primarily by the former licensees, according to the polluter-pays principle. However, if the old industrial sites are to undergo pollution clean-up, it is primarily with a view to reuse for purposes comparable with the previous uses. However, including in the case of Dieulouard, it is clear that the local government may be interested in redeveloping these derelict sites for other purposes.

On the basis of this example, it is possible to draw the following conclusions:

TABLE 2 : WASTE DISPOSED OF

NATURE OF THE WASTE	QUANTITY DISPOSED IN TONNES
Transformers containing PCB	1.5
Oils polluted with PCB	
Oil, earth, washing water, polluted with PCB	158
Acid oils and tars	126
Polluted earth, sawdust	111
Polluted water, washing water	377
Non-hazardous industrial waste	24
Waste containing asbestos	1
Other miscellaneous waste	53

Preventing soil and groundwater pollution

It is worth recalling that soil pollution does not simply mean managing legacy issues. It also involves ensuring that current activities do not generate any new pollution. The steps taken in the past twenty years to improve the verification of potentially polluting activities, whether from installations classified on environmental protection grounds, or from mining activities, have on the whole led to improved prevention of any new pollution. Similarly, stricter verification of the conditions in which an activity is closed down has also resulted in end situations that are more satisfactory in terms of soil pollution.

Demolition of UFP plant buildings

However, the cost of pollution clean-up is in the end a difficult burden for companies which, as they close down, sometimes do not have the means to carry out the minimum safeguarding work, especially if it is the parent company of certain subsidiaries which themselves arrange for these subsidiaries to go bankrupt.

A draft decree setting up financial guarantees was thus prepared by the Ministry responsible for sustainable development, which should enable the necessary funds to be available, when the time comes, for making classified installations safe once they are finally closed down. These arrangements already existed for quarries or waste repositories and will be extended to the chemical and refining sectors, but also to surface treatment facilities.

Furthermore, article 227 of the 13 July 2010 Act, known as the Grenelle 2 Act, makes it possible for parent companies to help their subsidiaries carry out site remediation operations. This same article also gives the Prefect, the public prosecutor or the receiver the power to take the parent company to the commercial court in the event of a clear responsibility on the part of the parent company for the loss of the subsidiary’s assets, such that it is unable to carry out the remediation operations.

Maintaining a record and providing information about soil pollution hazards

Like the other types of hazards, such as technological or natural hazards, soil pollution must be a part of an overall management approach to ensure that the level of soil pollution is known, which implies the existence of soil pollution databases. These data today exist, at least in part, whether in the BASOL base for polluted sites requiring remediation oversight by the services of the State, or in BASIAS, a database for land that has hosted industrial or service activities. Furthermore, in recent years, some sites have been the subject of public protection restrictions designed to retain a historical record and archive of the presence of soil pollution.

When preparing the implementing decree for article 188 of the 13 July 2010 Act on information by the State concerning soil pollution hazards, it became clear that there was a need for better identification of and information about these hazards. Work was initiated, with other Ministries and public organisations, to create a system to improve identification of the locations on which there was a risk of soil pollution, with regard to plans for future urban redevelopment of areas that had for a long time been occupied by industrial activities and which are now slated for housing or public or commercial buildings. ANDRA and IRSN are taking part in the working group initiated by the Ministry responsible for sustainable development, with regard to the sites containing radioactive pollution.

These measures should lead to improved consideration of the soil pollution hazards when drawing up the local development plans and should ensure that in the highest

risk areas, specific precautions are taken by the project owner to manage this pollution.

For priority zones, a process of anticipation

The publication of maps mentioning the existence of confirmed or assumed soil pollution is not in itself sufficient. In some cases, anticipation is needed to ensure that health problems do not occur if the presence of pollution is suspected.

The Ministry responsible for sustainable development, pursuant to article 43 of the 3 August 2009 Act, known as the Grenelle 1 Act, thus launched a soil diagnosis campaign in establishments receiving vulnerable populations, as of July 2010. This approach concerns about 1000 schools in 70 *départements* and will as of 2012 be extended to about twenty other *départements*. The aim is to ensure that the environments to which the children are exposed do not pose any problems as a result of the possible soil pollution. This step is similar to those taken by ASN, ANDRA and IRSN concerning former radium handling sites.

Reserving State interventions for making sites safe, possibly extended to remediation work in certain circumstances

The system used for making safe those sites polluted by chemical substances, which was the inspiration for the system applicable to sites polluted by radioactive materials, is mainly used to guarantee public health and safety. It therefore entails removal of waste, elimination of the fire or explosion hazards, environmental monitoring and restriction of access to old industrial buildings.

The changes to the system, introduced by the circular of 28 May 2011 regarding interventions in the event of a defaulting responsible party, aim to optimise pollution treatment, without recourse to systematic inspection by the Ministry for small-scale safeguard actions. However, it opens the door to remediation measures when simple safeguarding is not enough to prevent public health risks, or when the sites are in particularly sensitive locations (presence of housing, schools, etc.).

In circumstances such as these, it is above all important to ensure that the system allows rapid and effective action according to the available resources.

Improving the skills of those involved in pollution clean-up

Starting from the assumption that soil pollution clean-up requires a mix of various skills (hydrogeology, toxicology, civil engineering, geochemistry, etc.) and that there is no actual training course in this field, the Ministry responsible for sustainable development took steps to set up a system for certification of soil pollution clean-up professionals. Standard NFX 31-620 concerning soil pollution clean-up was modified in 2011. The national metrology and testing laboratory (LNE) established certification baseline requirements and audited the first companies in the second half of 2011. The first certificates were given out in December 2011.

This certification concerns design services, engineering and actual works. The companies can receive certification in one or more of these three areas, depending on their activities.

The Ministry responsible for sustainable development is continuing its efforts to ensure that the professionals can receive high-quality training able to meet the new skills requirements identified in the certification process.

Conclusion

Polluted sites in fact lead the public authorities to take steps that are in fact relatively similar, regardless of the nature of the pollution, whether chemical or radioactive. First of all there is prevention, then treatment of legacy situations, maintaining a historical record and archive of the presence of the former activities which may have led to the pollution, in particular when there is residual pollution, because it is relatively difficult to achieve the pollution clean-up levels offering guarantees for the future in all circumstances. Finally, improving information and thus knowledge of the risks and hazards should lead to both an improvement in the prevention of these hazards in the event of property development on former polluted waste ground and anticipatory measures in situations to be prioritised.

As we have seen, experience so far has contributed and will continue to contribute to enriching the doctrine implemented by the various players, irrespective of whether the pollution they have to deal with is radioactive or chemical. The boundaries between the two sectors in fact prove to be highly permeable.

The doctrines will therefore inevitably converge, whatever the type of pollution encountered. ■

Operation Radium Diagnosis
The approach by the public authorities

By Florence Gabillaud-Poillion, Head of Operation Radium Diagnosis, Waste, Research Facilities and Fuel Cycle Facilities Department – Autorité de sûreté nucléaire, Estelle Chapalain and Laurence Roy, Nuclear Safety and Radiation Protection Delegation – Ministry for Ecology, Sustainable Development and Energy

Operation Radium Diagnosis poster

Radium, a natural radioactive element, was discovered by Pierre and Marie Curie in 1898, and has been used in a number of medical and craft activities (clock-making) since the beginning of the 20th century.

For many years now, the services of the State have been involved in the management of sites and soils polluted by radioactive substances. The State first of all concerned itself with sites which had housed radium research and extraction activities in the early 20th century.

In 2009, a survey was taken to identify the sites on which radium had been used. This survey identified 134 sites potentially polluted with radium, including 58 in Paris itself, 26 in the Paris area and 54 in the provinces, including 25 in the Franche-Comté *département*, the centre of the French clock-making industry. The Ministry for Ecology, Sustainable Development and Energy decided in June 2010 to finance a diagnosis and remediation operation at these addresses.

On the basis of this list of sites, a working group consisting of the French Institute for Radiation Protection and Nuclear Safety (IRSN), the French national radioactive waste management agency (ANDRA), the Ministry for Ecology, Sustainable Development and Energy and the Autorité de sûreté nucléaire (ASN) was set up to prepare the operational and budgetary aspects of the operation. The initial diagnoses were carried out in the Ile de France region at the end of September 2010.

Even if the services of the French Government have significant experience in the management of sites and soils polluted by radioactive materials, Operation Radium Diagnosis differs from the usual management framework in several aspects.
For instance,
– the actual pollution of the sites is not confirmed and the approach consists of proposing undertaking a diagnostic investigation to the occupants of the premises corresponding to these addresses, without them being in any way bound by the regulations to accept;
– local information and explanation to those directly concerned are thus essential in order to obtain access approval for the purposes of the diagnosis;
– the health issue is not of prime importance – lessons learned from experience show that the possible pollution levels have no health impact – yet the perception and reaction of the persons concerned may differ widely and must be taken into account;
– the diagnosis is totally free of charge for the occupants and any remediation and renovation work is covered by the State in the majority of cases.

Oversight bodies

A national steering committee was set up in order to prepare and decide between the various project options. The National Commission for Assistance in the Radioactive Field (CNAR), which manages the financing of remediation of polluted sites for which the responsible party has defaulted, is also consulted on the key aspects of the project. The CNAR thus adopted generic principles for the treatment of sites which prove to be polluted and which require remediation work. This body created a small specific organisation designed to monitor the remediation operations to be performed according to criteria associated with these generic principles.

The operation began in the Ile-de-France region, a dense urban area with a large number of sites (84). An operational regional steering committee and a local communication unit were set up.

Diagnosis

The diagnosis phase is run by ASN. An ASN coordinator makes contact with the occupants in order to present the operation and obtain their approval for IRSN to carry out a diagnosis. This consists in identifying the areas of interest through measuring and systematically recording the equivalent dose rate in each room, using a portable radiometer.

An area of interest is identified whenever unbound contamination is measured or the gamma radiation is more than twice the background level, which has first been measured outdoors.

The discovery of an area of interest does not necessarily mean that the area is abnormal, but does lead to additional characterisation identifying the nature and origin of the increase in the dose rate. This can be of "natural" origin, for example owing to the materials used. Otherwise, a portable gamma spectrometry measurement is taken to detect the presence of radium.

As tritium replaced radium in clock-making applications, a search is carried out for tritium contamination on the sites with areas of interest involving radium.

When an area of interest is revealed, radon measurements are also continuously taken and integrated.

Following the diagnosis, if the conditions so warrant, precautionary measures can be taken, such as the removal of radioactive objects, the installation of shielding, or signposting.

The occupants are given a verbal presentation of the results on-site, based on the initial results. As soon as all the results are known, they are sent to and explained to the occupants. At the same time, the occupants are offered a dosimetric assessment.

Although no real health issues are expected, a protocol for addressing health questions is provided for, using a graduated approach, with four response levels being proposed according to the measurement results: a dosimetric evaluation, an individual consultation with an ASN physician specialising in ionising radiation, contact with specialist physicians from outside the operation, whole body radiometry examinations.

Remediation and restoration

In the event of confirmed pollution, the remediation phase can be initiated, under the supervision of ANDRA. A precise map and additional measurements are then produced in order to optimise preparation of the clean-out operation, define its perimeter and assess the cost.

When the occupants have to be rehoused for the duration of the works, this expense is covered. Following clean-out, ANDRA performs a first radiological inspection, followed by a final inspection by the IRSN. ASN is then consulted on the clean-out status achieved, following which ANDRA can begin the remediation work.

Initial summary

Two years after the operation was launched in the Ile-de-France region, 18 of the 84 sites identified in the region have been fully diagnosed, along with one site in Annemasse.

Five of these sites were given a complete green light, because the buildings are too recent, by comparison with the period during which radium may have been handled, for there to be any radioactive pollution.

Of the thirteen other sites, more than 175 IRSN diagnoses were performed. A site can correspond to a building with numerous apartments, or several individual plots. Of the 175 diagnoses performed, ASN was only denied access one time, which tends to confirm that the campaign to inform the occupants about the objectives of this operation and the conditions in which it is carried out was successful.

Three sites received a negative diagnosis and nine sites showed signs of pollution, but on which there were no health issues. These nine sites correspond to 19 remediation and then renovation projects.

Twenty five dosimetric assessments were performed in the Ile-de-France region and one in Annemasse. The maximum dosimetric evaluation is 2.4 mSv/year excluding radon. An individual consultation with a specialist physician, associated with two whole body radiometry examinations were performed, with the purpose of reassuring the occupants of a site.

The number of worksites is higher than initially planned, because on one site on the list, several homes could be concerned. Moreover, the worksites are more complex than anticipated and require considerable preparatory work and a sometimes lengthy clean-out phase involving several successive steps, depending on the pollution locations discovered. ■

Franche-Comté, cradle of the clock-making industry

A brief history

Franche-Comté is the cradle of clock-making in France. This activity, which has existed in the region since the end of the 17th century, in particular with the manufacture of the famous local grandfather clock, evolved over the years towards the manufacture of alarm clocks and watches, with a range of high-street but also luxury brands.

Radium was used in the clock-making and instrumentation industry for its photoluminescent properties in the first half of the 20th century. It was in particular used to manufacture watch hands and dials, which were then painted with radium until the end of the 1960s, after which it was gradually replaced by tritium, another radioactive element, with the same photoluminescent properties, but less radiologically toxic, the use of which ceased in 2002.

Today, the use of radioactive elements in the clock and watch-making industry is no longer authorised. However, the sites on which radium or tritium were used and handled can potentially show traces of radioactive contamination, if no pollution clean-up has been carried out. *Contrôle* magazine takes a look at the management of radioactive pollution on two industrial sites in Franche-Comté.

From the evacuation of Morteau technical college to treatment of the former Mercier plant (Doubs *département*)

In the late afternoon of 7 December 2006, the Edgard Faure technical college in Morteau was entirely evacuated. This precautionary measure by the head of the college followed a security guard's discovery by of a certain amount of waste in the grounds of the college, including a flask marked "Rado Poison". This was in fact radium from the former Mercier clock-making plant, the premises of which were being renovated for conversion into apartments.

Apart from the need for medical check-ups on about ten people who had come into contact with this waste (the results of which proved negative), this event led to the recovery and disposal of various radioactive objects found at the home of one of the student's parents, a check on the presence of and elimination of any residual contamination in the home (washing machine and clothing), and initiation of the pollution clean-up operation in the former Mercier plant.

Once this specific event management process was over, the process to treat the Mercier site began. ASN initially focused on informing the current owner and the lawyers in charge of selling the premises, which were still being converted into apartments. The transactions were then interrupted until an initial radiological inventory of the premises could be conducted. A first radiological environment inspection identified the presence of two radium contamination spots, for which clean-out was requested. This contamination is the result of dust and dust clusters deposited between and under the floorboards. This was followed by complete vacuum cleaning, which unfortunately was unable to achieve an ambient dose rate compatible with the intended use for residential purposes. The wooden floor in the end had to be entirely removed, with a concrete slab several centimetres thick being poured in order to confine the dust and other small pieces of clock-making residue still liable to be present in the premises. It was only then that the premises could be released in mid-2009 from all subsequent administrative or technical constraints.

Flask containing radium salts found in the former premises of the Mercier plant

From discovery of pollution to clean-out of a site

In September 2009, ASN was informed that a radiation portal monitor at the entrance to a scrap metal collection facility in the Doubs *département* had been triggered. This turned out to have been caused by a container of waste from a clock-making plant which had been closed down and for which production was being relocated to other units of the industrial group.

As the site was subject to notification as an installation classified on environmental protection grounds (ICPE), a reactive inspection was immediately initiated by ASN and the Regional Directorate for the Environment, Planning and Housing (DREAL). This industrial site, consisting of various buildings from various periods of the industrial operation, had been owned since 2002 by an operator who was not the cause of the radioactive pollution present.

Following this inspection, the Prefect of the *département* recommended that the operator cease the relocation operations, requiring it to begin a radiological diagnosis of all the buildings and recovery of all the radioactive waste (on or off the sites), to identify the locations where the relocated equipment had been sent, along with the waste, and to check that there was no contamination on the equipment reused. Given the costs incurred by these operations and the consequences for the working of the company, the clean-out process was staggered.

The first radiometric mapping campaigns revealed the presence of various radium and tritium contamination spots in various areas of the plant and on some of the equipment still present. Rapid decontamination of this equipment was possible, so that it could be reused. With regard to the actual buildings themselves, the clean-out target adopted was set with a view to allowing residential reuse of these premises.

The involvement and responsiveness of the industrial firm in the treatment of this site led to decontamination of the majority of the buildings in just under a year. ■

Operation Radium Diagnosis: the role

Lessons Learned from implementation of the two years after its launch

By Delphine Ruel, Paris Division head – Autorité de sûreté nucléaire

Operation Radium Diagnosis was officially launched in the Ile-de-France region by the Prefect of the region on 21 September 2010.

Even if ASN's Paris division has considerable experience of managing sites and soils polluted by radioactive materials, Operation Radium Diagnosis differed from the usual management of these sites, as there is no proof of actual pollution of the sites. There are also large numbers of these sites: 84 for the Ile-de-France region alone. Finally, and above all, most of these sites are today occupied by housing or commercial premises. The target public is therefore not that with which the radiation protection inspectors normally come into contact, that is professionals fully aware of the radiation protection issues, but the general public, whose awareness of the hazards related to ionising radiation varies widely.

This latter point is what makes this activity so unusual for the division and what confers such particular importance on its "information of the public" component, with regard to at least two aspects:

– educational, to ensure that the stakes involved in the operation are understood and enable the diagnosis to take place. This operation was voluntary, so it was therefore essential to inform the persons concerned in order to obtain access authorisation to enable the diagnosis to be carried out;

– clarity and precision, particularly with respect to the health issues: according to previous lessons learned from experience, these issues were not expected to be significant. However, this does not reduce the need for clear and transparent information of the persons concerned by the subject.

The aim of this article is to present the lessons learned gained from implementation of this operation by the ASN Paris division, two years after its launch.

Results of the operation in figures

Two years after the operation was launched, 13 of the 84 sites inventoried in the Ile-de-France region have been investigated. Some sites actually corresponded to several present-day addresses or have been extended to neighbouring sites. In total, so far, 26 addresses have been or are still being investigated, representing more than 175 diagnoses (one diagnosis per apartment, house, commercial premises or isolated plot of land).

The following sites were diagnosed:
– residential buildings comprising common areas, apartments and/or commercial premises: in Paris 2 (two sites), Paris 3, Paris 5, Paris 6, Paris 7, Paris 8 (two sites), Paris 17 (two sites).
– a derelict industrial site being demolished, its annexe occupied by a kindergarten and the surrounding plots (Rueil-Malmaison);
– houses (Chaville, Le Perreux sur Marne).

In addition to the 13 sites investigated, five additional sites were declared to be free of pollution owing to their recent date of construction. These are sites on which the buildings were put up after the date on which radium ceased to be handled. Checks on drawings in close collaboration with the town halls revealed that no part of the old building or its annexes, and therefore no radium pollution, was still present on the premises.

Of the more than 175 diagnoses performed by the IRSN, 15 revealed pollution: three apartments (Paris 3, Paris 5, Paris 17), the derelict industrial site (Rueil), six houses and/or gardens (one in Le Perreux and five in Chaville), four commercial premises (Paris 5, Paris 2, Paris 7 [two premises]), common areas in a residential building (Paris 7). This exercise shows that most of the premises diagnosed are clear of radiological pollution, which is what was anticipated when preparing for the operation.

# of ASN
operation in the Ile-de-France region,

The remediation operations are nearing completion in three apartments (Paris 3, Paris 5, Paris 17) and on the abandoned site in Rueil-Malmaison. They are under way in three houses (Chaville and Le Perreux). Other sites are currently undergoing preliminary studies prior to pollution clean-up operations which have not yet started.

The remediation worksites proved to be more complex than anticipated, as described in the ANDRA article on page 70.

Lessons learned from the diagnosis operations

Operation Radium Diagnosis consists in conducting a systematic search, using measurements, for any traces of radium or to confirm its absence and, as necessary, to rehabilitate the premises concerned, free of charge.

For each site, there are two main phases: the "diagnosis" phase, run by ASN; if pollution is detected, then this first phase gives way to the "remediation" phase, run by ANDRA.

The "diagnosis" phase itself involves three steps: prior investigations, contact and finally performance of the diagnosis.

Prior investigation

The survey of sites on which radium was used enables historical addresses to be identified. Prior to initial contact, work must be done to identify the corresponding present-day addresses. The person in charge of the site within the division, who will then be the ASN coordinator during the contact phase, also carries out a search to identify the current occupants as well as to find out the particulars of the owners and any building management agencies. These sometimes lengthy investigations are nonetheless essential for the smooth running of the operation.

Experience from these preliminary investigations shows that an address on the historical inventory may actually correspond to a number of present-day addresses. This accordingly multiplies the number of parties to be convinced and the number of diagnoses to be performed. On this point, the involvement of local players such as the town halls and offices of the Prefect is an advantage, owing to their local knowledge of the sites, with the town halls being able to provide valuable information about the history of the plots of land and their current occupancy. One of the addresses on the list turned out to correspond to five current addresses, with three others corresponding to two current addresses.

The contact phase

Once the current occupants / owners have been identified, the ASN coordinator makes contact with them to present the operation and obtain their authorisation to perform the diagnosis. At present there is no regulatory obligation to have this diagnosis performed, given that the pollution is not confirmed. The operation is thus based on the willingness of the persons contacted.

This contact phase can take various forms, depending on the situation of the site and its occupants: posting or hand-delivery of a letter, phone call, organisation of an information meeting, etc. The procedures are adapted to each case according to the type of site and the information obtained from the building manager as applicable.

Given that there is no regulatory obligation to have the diagnosis performed, this explanatory stage designed to convince the parties concerned is absolutely vital. The aim of the operation is to perform all the diagnoses on a site, so that it can be given a green light in its entirety. Experience shows that although the ASN coordinators are generally well received, in particular owing to their skill in clearly explaining the context, the issues and the performance of the operation, this phase can sometimes be lengthy and difficult. It is generally successful because, in two years, only one private individual of the 175 contacts made by the inspectors from the Paris division has refused to open his apartment to the diagnosis, because he was not legally obliged to do so.

The diagnosis

Once contact has been made and agreement obtained from the occupant /owner (depending on the situation encountered), a date is set for carrying out the diagnosis.

This is done by a team from the French Institute for Radiation Protection and Nuclear Safety (IRSN). This team is accompanied by the site's ASN coordinator who has obtained authorisation to access the premises and remains the principal point of contact for the occupant or the owner concerned, answering any questions they may have.

The diagnosis consists in identifying the areas of interest by systematically recording the equivalent dose rate in each room, using a portable device.

Identification of areas of interest by prospection

If the diagnosis is negative, then the operation stops there. A letter is sent to the site occupant/owner, along with the report, to inform them of the results.

If it is positive, precautionary measures may be taken following the diagnosis, if the conditions so warrant (for example, removal of radioactive objects, deployment of shielding or signposting). Radioactive objects were thus removed from one site and shielding deployed on three others.

The ASN coordinator for the site gives the occupants a verbal summary of the situation, based on the initial results. As soon as all of the results are available, they are forwarded to and explained to the occupants by the ASN coordinator. At the same time, a dosimetric evaluation is proposed to the occupants following the diagnosis: for this purpose, each current occupant of the premises diagnosed states how much time he or she spends in the various rooms on a daily basis. In the case of residential premises, lifestyles are also taken into account (presence during the week, at weekends, during holiday periods, etc.). Based on these data and the results of the diagnosis, IRSN is able to calculate the additional dose resulting from exposure to the radium present in the premises. The results of these evaluations are personalised and sent to the persons concerned by the site coordinator or an ASN physician. If necessary, personalised medical follow-up can be proposed.

Experience concerning this step shows that ASN support for the persons concerned is essential, in order to explain the results of both the diagnosis and any dosimetric evaluations. The results of the dosimetric evaluations performed to date confirm the absence of any health issues, with the most important dosimetric assessment being an annual added dose of about 2.4 mSv/year excluding radon, or appreciably the same level as natural exposure. It should be noted that in the case of commercial premises, the ASN's contact is the employer, which is itself responsible for informing the workers. The details of an ASN physician are then provided in order to answer any questions the workers concerned may have.

The transition to remediation

The remediation phase starts once all the diagnosis results are available. It is the subject of a transitional meeting involving ASN / ANDRA / occupant / owner.

This transitional meeting is an opportunity to once again explain the results and answer any questions from the owners or occupants. It also presents the next stages of the operation, assuring the transition between ASN and ANDRA.

Following this transition, a precise map and additional measurements can then be produced by ANDRA in order to optimise preparation for clean-out, define the scope and estimate the cost.

Lessons learned from the monitoring organisation put into place at regional level

The operation was launched in France at the initiative of the Prefect of the Ile-de-France region.

In order to coordinate and inform the various stakeholders, a regional operations steering committee was created. This committee is run by the regional and inter-departmental director for energy and the environment, on behalf of the Prefect of the Ile-de-France region. It comprises representatives of ASN (Paris Division, Waste Research Facilities and Fuel Cycle Facilities Department), IRSN, ANDRA, the Regional Health Agency (ARS), and finally, the various Prefect's offices of the *départements* concerned (at present Hauts-de-Seine and Val-de-Marne).

This committee meets regularly (every two to three weeks) to provide close monitoring of how the operation is running locally (launch of a site to be diagnosed, coordination of the activities of the various players, etc.). Since October 2010, this committee has met more than 35 times, representing considerable mobilisation on the part of its various members.

Experience shows that the involvement of the office of the Prefects in the relations with the local elected officials is clearly beneficial. Collaboration between ASN / IRSN / ANDRA / ARS / offices of the Prefect has proven to be fruitful in coordinating the actions of the various stakeholders and monitoring the progress being made on the sites.

Moreover, a regional "communication" unit was also set up, to coordinate communications about the operation. The operation was thus launched at a press conference by the Prefect of the region and covered by a special press briefing two months after launch. Further briefings were then given at the regional press conferences by the Paris division and when specifically requested by journalists.

To conclude, it is worth pointing out how unusual this operation was for the radiation protection inspectors of the Paris division: they were brought into direct and immediate contact with members of the general public, as most of the diagnoses concerned private homes. The experience accumulated after two years shows that the operation was well received by the public, because the vast majority of those contacted was in favour of having the diagnosis performed. The ASN coordinators demonstrated their informative approach and their professionalism in making the occupants aware of the issues and stakes involved in the operation, in answering their questions and thus enabling virtually all of the diagnoses to take place. ■

Lessons learned by an ASN inspector in charge of monitoring Operation Radium Diagnosis

Interview with Hélène Chitry, radiation protection inspector, Paris Division – Autorité de sûreté nucléaire

***Contrôle :* What does Operation Radium Diagnosis consist of and how is it run?**

Hélène Chitry: The operation is the result of the 2009 survey of sites on which radium was handled in the early 20th century. At the beginning of 2010, prior to the diagnoses, the division produced operational documents such as communication tools (brochure, poster) or template letters, for practical preparation of the operation prior to the launch in September 2010.

ASN takes the lead during the diagnosis phase. When the decision has been taken to launch the operation on a site, our role is first of all to complete the history of the site. In parallel with this documentary phase, ASN submits letters to the Prefect for forwarding to the occupants. After this, the most important and most delicate step is to make contact with the inhabitants.

The procedures involved in this contact phase vary according to the communes. In certain cases, for example in the Hauts-de-Seine *département*, the town hall asks to be involved. This contact was initially made individually, after obtaining details from the telephone directories. With hindsight, we felt that when dealing with apartment buildings, it would be preferable to identify and involve the management board or agency, to act as the go-between with the residents.

We selected a total of 84 potential sites in the Ile-de-France region, from among which we prioritized the 18 sites most likely to be polluted. At present, these 18 have been or are being diagnosed. Traces of pollution have been found on about half of them.

The diagnosis phase can be very quick, but the pollution clean-up phase very long. Everything depends on the number of positive diagnoses and the type of site. If the pollution is confirmed, the aim is to perform immediate clean-out so that the inhabitants are spared any uncertain waiting. This is why work on new sites is now taking place at a slower pace than when the operation began.

Depending on the nature and location of the pollution, total evacuation of the premises with rehousing of the family during clean-out may or may not have to be envisaged. For offices, this may be limited to a few rooms, without affecting an entire department. Pollution is usually found to be dispersed, requiring emptying of the premises to allow pollution clean-up in the best possible conditions. The work is relatively complex and can take several months, because very strict rules have to be followed. The worksite must be contained, so the preparation phase is relatively lengthy.

As at mid-2012, no site has yet been handed back, as the work is still ongoing, although the first sites are nearing completion.

How is the Paris division organised? What kinds of situations have you had to deal with?

In the Paris division, the unit responsible for the operation is run by the division's deputy regional head in charge of polluted sites and soils, in close collaboration with the regional head. A number of project managers devote most of their time to this.

The project manager follows up on his own addresses and is appointed the specific point of contact for the inhabitants. If the site proves to be polluted, ASN hands over to the ANDRA project manager, who then runs the clean-out process. ASN resumes authority for the final diagnosis, to ensure that clean-out was performed in accordance with the procedures and to confirm that the clean-out targets have been met.

One of the features of this operation is the variety of potential situations, with differing perceptions depending on whether one is dealing with a family residence or an office building. Therefore, during the contact phase, the reactions vary widely. In most cases, the reaction is one of great surprise. Some people seem to consider the whole thing a joke, others thank us and others claim not to be interested. In any case, the support of the building management agency is important, because its confirmation tends to encourage the inhabitants to pay closer attention.

Once the surprise has passed, some residents just don't believe it, or are totally unbothered, while others are very worried. Radioactivity scares people and in this case, they have to be reassured.

If pollution is actually confirmed, reactions can change, with those who were previously indifferent now taking things seriously.

The questions then vary depending on the phase. To start with, the questions are general and concern radioactivity, the hazards, radon. If the site is positive, we are asked whether their predecessors were aware. We then explain that these are very old activities, frequently on a very small scale. 19th century town buildings were never factories, but would have been used for activities taking up little space, such as a jeweller painting watch needles with radium in his apartment during the evenings.

At the time, radium was not considered to be dangerous and it was even advertised, along with the address of where to obtain it. When we show the inhabitants these advertising documents, they can more clearly appreciate the situation. Over and above these rare documents, we are also backed up by an inventory produced by IRSN at the request of ASN, which in particular identifies the quantities of radium delivered to a particular address. These data enabled us to classify the sites according to their potential risk.

If the diagnosis is declared to be negative, then everyone is reassured and relieved, preciously keeping the document confirming that their apartment is not polluted.

With regard to financing, the rehousing of individuals and the works involved in the operation are covered. However, there is no provision for any compensation in the case of a commercial activity.

Who are your main contacts at the Radium steering committee and what are their respective roles?

Our main contacts are the office of the Prefects, IRSN, ANDRA and the ARS. As I was already working on polluted sites and soils, I knew the contacts at IRSN and ANDRA. What is so fascinating about this operation is that we can follow all aspects of the entire process, with all the partners involved, including the office of the Prefects concerned and the ARS.

IRSN is involved in the initial diagnosis phase, as well as in the dosimetric evaluations regularly requested by the inhabitants when a site is positive. They are reassured, because the doses are low. However, the principle adopted by ASN, and this is the very foundation of the operation, is that no unjustified dose should be received. As radium is very long-lived, it should be removed, as there can be no justification for leaving it in place.

IRSN also measures the concentration of radon, a decay product of radium, by installing radon dosimeters, to determine whether or not it exceeds the management values. The advantage of 19th century town buildings with regard to indoor radon concentrations, is that they are poorly insulated and thus relatively well "ventilated", unlike the basements of certain private houses. Finally, IRSN intervenes after clean-out, to perform additional measurements to check that the dose rates and radon concentration levels have returned to satisfactory levels.

ANDRA is in charge of the entire clean-out phase and also manages any rehousing. During the preparatory phase, after the pollution clean-up programme has been defined, the longest step is to reach a contractual agreement with the persons concerned regarding the level of remediation following the work, the purpose of which is not complete renovation of the property.

The other contact is the Prefects, in particular the office of the Prefect of the Ile-de-France region, who is the pilot and who signs the various letters accompanying the diagnoses. The Prefects of the *départements* are contacted by the town halls, and forward their questions to us.

What lessons have you learned from this operation, two years after it was launched? What major difficulties have you faced? What changes would you like to see?

Overall, the operation runs smoothly and there are no particular stumbling blocks. The regional steering committee in particular works very well and this format should therefore be retained. At this point, during the operational phase, of the 18 priority sites, each of which comprises several residences or offices, we have received one refusal as against 17 diagnoses performed by 10 July 2012. Most people clearly understand the benefits of the approach and of receiving a free diagnosis. This explanatory phase is all the more important as for the time being there is no regulatory obligation to impose this diagnosis in the absence of any confirmed and proven hazard. This is why one must be understanding, informative and extremely available.

Even if there are no major problems, the approach is sometimes lengthy and laborious when the people we are dealing with are busy and relatively unavailable. We therefore have to adapt to their timetable. We sometimes have to deal with people who forget their appointment, who do not live permanently in Paris, are on long-term assignment elsewhere, and so on. One recurring theme is the number of lost cellar keys. I had no idea that there were so many abandoned cellars in Paris. The most laborious intervention to date was a building of 57 apartments, where the diagnoses had to be carried out on 11 different days.

In terms of the improvements to be made, a number of points have already been modified as and when it became necessary. We had originally planned to hold joint owners meetings when launching the site, but we quickly realised that this wasted a lot of time. The principle was therefore abandoned. Each party is now called individually. We take the time to explain over the telephone before coming to the site.

The long-term changes that would be desirable primarily concern the regulatory aspect, because at present it is not possible to impose either a diagnosis or the clean-out work in the absence of any health impact. ■

The involvement of the office of the Prefect of the Hauts-de-

Interview with Catherine Goussard, Director of Regulations and the Environment – office of the Prefect of the Hauts-de-Seine *département*

Hauts-de-Seine site before the work

Contrôle : **Madame Goussard, can you describe Operation Radium Diagnosis and the role of the office of the Prefect of the Hauts-de-Seine *département* and what organisational measures it took for participation in the operation?**

Catherine Goussard : This operation was launched by the Ministry for Ecology in 2010 to detect and process legacy radium pollution throughout the Ile-de-France region. It is carried out under the responsibility of the office of the Prefect of the region, which is responsible for overall coordination and communication, with ASN being in charge of operational oversight of the system. The offices of the Prefects are involved as the local go-betweens.

The various *départements* are concerned in very different ways. For the Hauts-de-Seine, eighteen sites were identified, which is a large number. Of them, three sites were considered priorities for treatment in the first phase, owing to the quantity of radium which had been handled there or delivered to them. The sites investigated also vary widely, because we had to deal with a derelict industrial site in Rueil-Malmaison, land on which residential buildings had been erected in Levallois-Perret and a housing estate in Chaville. Each situation thus requires specific case by case treatment.

At the office of the Prefect of the Hauts-de-Seine *département*, the department for regulation and the environment, more particularly the office for the environment and classified installations, is in charge of the dossier. Given the importance and sensitivity of the subject, the decision was taken to limit the number of persons involved, with operational monitoring being performed directly by the office head and myself. This represents a significant workload, with participation in all the regional steering committees, convened every fifteen days at the start of the operation and subsequently every three weeks.

Over and above our participation in these committees, we act as the interface with the elected officials and their technical services, because the Prefect decided from the outset to involve them and be completely open with to them in order to ensure their acceptance of the operation. Our role is therefore to keep them regularly informed of the progress of each of the dossiers.

What are the challenges for the office of the Prefect? How is contact made with the inhabitants? Do you have contacts with the other Prefect's offices concerned by this operation?

The challenges for the office of the Prefect are to ensure that the operation takes place in optimum relational and operational conditions. The office of the Prefect being the main point of contact for the elected officials, we have to be able to communicate, answer questions and, whenever necessary, smooth over any tensions or misunderstandings.

The Prefect decided to delegate to the mayors the task of making direct contact with the inhabitants because they are in the field and are familiar with the local context. We therefore left it up to them, together with the specialists from ASN, IRSN or ANDRA, depending on the stage concerned. When the initial contact with the inhabitants was made, the elected officials benefited from the support of ASN and IRSN when presenting the situation, explaining how the operation would be performed, answering concerns regarding the potential health impact or fears over a possible drop in the value of their property.

Coordination between the offices of the Prefects takes place within the steering committee. As we hold regular meetings, systematically reviewing the progress of each of the dossiers, the need has not yet been felt to organise coordination meetings between the office of the Prefects.

In fact, in the inner Paris region, we are the office of the Prefect most concerned by the operation.

What are your relations with ASN and with the regional radium steering committee?

The steering committee, consisting of ASN, which oversees the operation, IRSN, ANDRA, the ARS and the prefectures concerned (PRIF[1], 75, 92 and 94) is working just as we expected and is highly operational. Everyone reports on the progress of the various works and the obstacles encountered, which enables us to remain accurately informed of how the operations are going and notify the elected officials. The offices of the Prefects are involved to varying extents, for instance because the office of the Prefect of the Val-de-Marne *département* is only concerned by one site and they therefore sat less frequently. For its part, the Paris Prefect's office did not delegate a representative to the steering committee.

Outside the steering committee we hold regular discussions with ASN, which answers all questions we may have, and with ANDRA, which intervenes in implementation of pollution clean-up in the field.

Despite its particular characteristics, this operation is running smoothly, to a large part thanks to this permanent communication between all the players concerned. Good cooperation and coordination are essential in fully analysing the situations, measuring and attempting to take account of the interests of each party concerned. Regular discussions within the steering committee are a factor in success.

How would you assess this operation? What major obstacles did you encounter?

This operation is a necessary one, because we have to deal with situations inherited from the past, for which there may be health issues and which have an impact on the environment and on site redevelopment plans. This is an ambitious operation, because a large number of sites have been identified and the procedures are lengthy, because the various phases require study and analysis, because contracts sometimes have to be awarded, and so on. This operation is a delicate one, because the subject is sensitive in that when talking of radium and therefore of radioactivity, the population concerned can be worried. From this viewpoint, communication is a key factor in handling the subject.

Several types of difficulties were encountered.

First of all, we have to manage the delicate phase involving contact with the inhabitants, who must not be alarmed but must be accurately informed. This can take time. Another problem is the temporary rehousing of the occupants, with the challenge being to find solutions that are acceptable to all. Last, but not least, is that the operations take longer than had been anticipated. This is due to the fact that we are never sure of what we will find. In the treatment phase, the perimeter had to be expanded on several occasions following additional investigations.

In Chaville in particular, when treating the first property, we discovered traces at the boundary with a second one, where we thus had to intervene, and then on a third one, and then on a road.

Two years after the beginning of the operation what have you gained from this experience and what changes would you like to see?

First of all, the principle adopted by the authorities of opting for a large-scale systematic operation covering the sites, rather than dealing with them on a case by case basis over the years, as we do with other types of operations, is a good idea, because this is legacy pollution inherited from the past, so global and coordinated treatment is a means of limiting the gradual loss of records of the activities involved.

Having said that, we have seen that the operations take longer than expected, because phase 1 was to have lasted a year and we are already at twice that. The operations are proceeding satisfactorily, although there are a number of unforeseen circumstances that are dealt with more or less rapidly.

With respect to the improvements needed, we realised that certain procedures could be simplified, and this has already been done with regard to the temporary rehousing of the inhabitants. At first, the relatively cumbersome procedure in which the DRIHL[2] was involved proved not to be particularly practical. To lighten the process, following validation by the CNAR, which is required to give a ruling on all the proposals, ANDRA now looks for accommodation directly together with the occupant.

Other questions have also been modified after debate, examination by the national steering committee and the CNAR: clean-out targets, site closure doctrine, doctrine concerning recent constructions, final site inspections. The aim is to permanently improve the system by looking to reduce the time taken to carry out the treatment, while complying with the overall specifications of the "radium project". ■

1. PRIF: Prefect's office of the Ile-de-France region.
2. DRIHL: Regional and interdepartmental directorate for housing.

Operation Radium Diagnosis – pollution clean-up worksites

By Vincent Faure, head of Operation Radium Diagnosis – French National Radioactive Waste Management Agency (ANDRA)


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1. Initial condition

2. Condition after lifting of floors and removal of rubble

3. Final condition after removal of floor joists and troughs

Operation Radium Diagnosis

After months of preparation, the radium project entered the operational phase in September 2010. Among the first sites diagnosed as positive was an apartment in the third arrondissement of Paris, as well as the land and buildings of a former mechanical company in Rueil-Malmaison. Several decades ago, both had housed a laboratory or a company using radium and there were still traces of slight, but measurable pollution.

Clean-out of these sites is now complete or is nearing completion, following a campaign of works which in both cases proved to be more difficult, longer and more costly than expected.

Review of two worksites from which much was learned.

The remediation process

The remediation process for a site found to be actually polluted following the diagnosis, involves three phases:
– studies,
– clean-out,
– renovation.

The study phase

In order to precisely define the scope of the remediation work, a radiological map of the site is produced from surface measurements and physical sampling measurements. The surface map is obtained by γ radiation measurements with a collimated probe, with a mesh that is as fine as possible (generally between 0.25 and 1 m²). The analysis of the surface map makes it possible to define a pertinent surveying plan in order to identify the source term and the depth of pollution. In the case of pollution affecting premises, the surveys will be limited to collection of samples of floor coverings in order to determine the location of the pollution (for example, hardwood floor, insulation, floor joists, or even the plaster troughs) and the specific activity encountered, which is an indication of the category of the waste (VLLW – very low level waste or LLW-LL - low level, long-lived waste) that will be produced by clean-out. When dealing with polluted land (private gardens for example), the samples will be collected at different depths in order to determine the vertical profile of the pollution.

As necessary, the radiological investigations are supplemented by other types of studies such as structural studies when the remediation work is liable to endanger the integrity of the buildings, or hydrogeological studies when the radiological pollution is in the vicinity of the water table.

This knowledge acquisition phase enables ANDRA to define the programme of work and estimate its cost.

A generic doctrine, approved by the National Commission for Assistance in the Radioactive Field (CNAR), specifies the conditions (site typology, financial ceiling, etc.) in which the work can be initiated without systematically consulting the commission, along with the clean-out targets to be attained when the polluted areas are, for example, residential.

If these conditions are met, the remediation worksite can be launched with no further formalities. If not, ANDRA submits the clean-out project to the CNAR in order to obtain the corresponding financing. As necessary, it also submits the proposed clean-out targets to ASN.

Remediation worksite

When its concerns a home, the remediation work requires that the premises be vacated by their occupants and emptied of all furniture. In this case, ANDRA temporarily rehouses the occupants and transfers the furniture to a storage facility. The cost of these steps is also borne by a public subsidy.

The remediation work is performed by specialist companies employing qualified personnel. It consists of removal of the polluted materials, packaging in appropriate containers and characterisation of the waste (measuring it to check that its activity level is compatible with the chosen disposal route). Particular care is given to ensuring that there is no dispersion of the pollution. In this respect, the operations are generally carried out in a ventilated containment with numerous radiological cleanliness checks performed during the course of the programme in the areas where work is being carried out, but also in adjacent areas.

ANDRA also takes charge of the waste. The VLL waste is shipped for disposal in the low and intermediate level waste disposal facility (CSTFA). As for the LLW-LL waste, it is stored in authorised installations pending the availability of a disposal facility. The removal of the radioactive waste generated by the clean-out of sites located in a built-up area required the creation of a specific logistics organisation. Owing to the lack of space in the premises rehabilitated, it is essential for the waste to be removed as and when it is generated, to ensure that the work progresses smoothly. The radioactive waste generated on the site is packaged in small, light-weight containers (plastic drums), to facilitate the manual handling operations. The waste packages are taken away by a transport company to a transit zone at CEA Saclay. At the end of the pollution clean-up work, the waste stored in the transit zone is assembled in appropriate packaging (large flexible bulk containers (GRVS) or metal racks primarily of 1 m^3) before being taken away to the disposal facility or storage installation.

Achievement of the clean-out targets is checked by means of a final map, with three levels of inspection:
– the contractor involved performs an initial series of measurements,
– if the contractor's measurements are conclusive, ANDRA runs a cross-check using a protocol validated by ASN,
– finally, ASN asks IRSN to perform a third level series of spot checks.

When all the inspection levels confirm that the targets have been reached, and following a favourable opinion from ASN, ANDRA initiates the renovation work.

Renovation work

The renovation work consists in restoring the housing to its initial condition, replacing the materials which were removed or damaged during the remediation work.

For this phase of the work, ANDRA has recourse to architects who act as project managers, specifying and coordinating the work done by the contractors or self-employed tradesmen (mason, carpenter, plumber, painter, etc.).

Example of surface mapping of an apartment

The end of the work means that the occupants who had been temporarily rehoused, can now return to their accommodation.

Paris 3 Site (75)

The PARIS 3 site is an apartment of about 80 m² located on the first floor of a building in the 3rd arrondissement of Paris and which underwent a positive IRSN diagnosis in October 2010. The additional radiological map produced by ANDRA in December 2010 revealed the presence of significant pollution in the floors, over about ¾ of the surface area of the apartment.

The clean-out work began in March 2011 and initially consisted in removing the various floor coverings (tiles, floorboards, etc.), and old, polluted rubble between the floorboards and the building's supporting floor. After most of the contaminated materials were removed, the radiological measurements taken as the work progressed revealed polluted zones which were not detectable during the initial mapping operation. This for example concerned radiological pollution covered by a concrete screed, which acted as a barrier during the initial measurements, or bricked-up chimney flues. It was therefore necessary to extend the scope of the work to include clean-up of all the rooms in the apartment, cleaning-out down to the supporting floors by removing the old floorboard supports (floor joists and plaster troughs of up to 40 cm in height) and cleaning out the chimney flues.

The clean-out work was completed at the end of 2011 and generated more than 300 drums of radioactive waste, repackaged in about 30 GRVS of 1 m^3. The apartment is currently being renovated.

The total cost of remediation, which includes the studies, clean-out and renovation work, transportation and disposal or storage of the radioactive waste, and final status mapping, amounts to nearly € 250K.

The Paris 3 site probably corresponds to the type of site that will be frequently encountered by Operation Radium Diagnosis in the Ile-de-France region (pollution of an apartment in an old building in the heart of Paris).

It enabled ANDRA to acquire considerable experience, which is proving useful in reducing the length of future worksites. ANDRA now has a clearer understanding of the construction techniques used in the old buildings and the locations of the areas liable to be polluted, including those that are hard to detect before the work begins. This will enable ANDRA on the one hand to reinforce the measurements taken during the initial mapping of suspect areas, and on the other to make provision in the subcontracts for additional work.

Rueil-Malmaison site – Hauts-de-Seine *département* (92)

The Rueil-Malmaison site is in a district which is earmarked for redevelopment under a project supported by the Rueil-Malmaison town hall. The current owner of the site is the Hauts-de-Seine *département* public land agency (EPF) which acts as the land bank for this project. The work done by EPF-92 aims to provide the town hall with bare land on which apartment blocks are to be built, with shops on the ground floor and underground car parking.

Shortly before the work began on demolition of the site structures, ASN informed the EPF-92 of the possible presence of radium pollution generated between 1955 and 1969 by the craft activities of the "Gravure moderne" company, which used radium 226 based paint to produce radioluminescent panels. In October 2010, IRSN carried out a diagnosis which confirmed the presence of radiological pollution, thus suspending the demolition work initially envisaged by the EPF-92.

Example of en excavation site

As assistant to the owner, ANDRA intervened with the EPF-92 to define a site remediation programme. The work needed to be started quickly, because the structures on the site were in such a poor state that there was a risk of the superstructures collapsing, thus mixing the polluted and the non-polluted materials.

The radiological map made in December 2010 revealed pollution in the floor coverings of the former workshops (floorboards, wooden blocks) and the underlying earth, down to a depth of several centimetres. Outdoors, the mapping revealed an area of about 15 m² of polluted backfill down to a maximum depth of one metre. Finally, the superstructures of the buildings were virtually entirely free of pollution (apart from a few localised spots).
The radiological investigations led to the following programme of work being defined:
– phase 1: dismantling of the superstructures,
– phase 2: soil clean-out work,
– phase 3: demolition of the infrastructures.

After intervention by a specialist company, which removed the few spots of localised pollution from the walls, the phase 1 work was performed conventionally, by non-classified personnel. The demolition rubble was disposed of via conventional routes. Provision was however made for radiation protection assistance for the usual site exit inspections and rubble checks.

Protection was also laid on the ground to facilitate the rubble collection operations and avoid mixing conventional waste and radioactive waste. The phase 1 work began in March 2011 and was completed in July of the same year.

Prior to launching phase 2, ANDRA submitted a proposed clean-out target to ASN, taking account of the future use of the site and expressed in the form of maximum residual specific activity of the soil. This proposal was approved by ASN and phase 2 was thus able to start in August 2011, in other words, straight after phase 1.

The soils were then excavated until a residual activity less than or equal to the target level was attained.

Beforehand, the concrete slabs still present were demolished (during phase 1, only the building superstructures had been dismantled, not the slabs in contact with the soil).

The rubble and excavated earth, of VLLW category, were characterised and packaged mainly in GRVS, then taken away to the CSTFA.

This phase took far longer than expected. As the site progressed, it became apparent that the pollution was distributed particularly heterogeneously, and had thus been incorrectly estimated during the initial radiological mapping, which was based on spot surveys and interpolations.

Moreover, certain polluted areas had not been located because they were too deep and were masked by the old concrete slabs, themselves buried and belonging to even older buildings.

In the end, the volume of radioactive waste generated and the cost of the work were doubled. The total cost of the demolition and clean-out work on the site amounted to nearly € 1M. The work was completed in January 2012.

This pollution clean-up operation revealed all the difficulty of producing a radiological map representative of the condition of the site, when the spatial structure of the pollution is random and operation of the site goes back too far for there to be an adequate historical record. To be exhaustive and to rely on radiological measurements alone, it would have been necessary to make boreholes of between 1 to 4 m in depth and very close together (sampling pitch of about 1 m). The cost of this mapping would have been totally disproportionate by comparison with the total cost of the project. In the case of remediation of sites comparable to derelict industrial sites, ANDRA envisages incorporating geophysical reconnaissance techniques into its radiological mapping protocol. These could be valuable tools in the choice of the borehole locations, for example giving priority to areas in which the geophysical reconnaissance suspects the presence of backfill or the passage of pipes.

Conclusion

In order to meet the challenges of Operation Radium Diagnosis, which are mainly the ability to carry out several worksites simultaneously and to shorten completion times, ANDRA has set up a specific organisation which makes provision for specific contractual arrangements with subcontractors through framework agreements. This “industrial” organisation was hard to set up because the remediation worksites are not limited to radiological clean-out alone, but also entail numerous other trades that have to be coordinated. Finally, ANDRA has not forgotten the people aspects, which are a key component in the correct performance of the remediation sites it manages and which interface directly with the public. It is essential that the owners of the rehabilitated property, and sometimes their neighbours, be kept regularly informed of the progress of the work and the associated hazards, issues and challenges. ■

The National Commission for Assistance in

Viewpoint...

Marie-Claude Dupuis, Director General – French National Radioactive Waste Management Agency (ANDRA) and Chair of the CNAR

Contrôle : **Could you describe for us the role and duties of the CNAR?**

Marie-Claude Dupuis : The creation of this commission by the ANDRA board is a direct consequence of the 2006 Act on the management of radioactive waste. The Act entrusted ANDRA with new general interest duties; ANDRA thus decided to set up a commission to advise it on the one hand with regard to the collection of old radioactive objects, most of which are in the possession of private individuals, and on the other the remediation of sites polluted by radioactive substances when the owners have defaulted (the parties responsible have disappeared in most cases). The State must take the place of the defaulting party and take charge of pollution clean-up: this is one of the duties entrusted to ANDRA, which in this case relies on the CNAR. Between 4 and 5 million euros are in general allocated to ANDRA by the State to enable it to perform its duties, including for the inventory of radioactive materials and waste in France. The Commission defines the clean-out priorities and targets and in turn allocates budgets for the work.

How does the CNAR work?

The commission – and this is its major advantage – brings together everyone involved in the collection of objects and waste and the remediation of polluted sites: the administrations concerned (General Directorate for risk prevention, General Directorate for energy and climate) as well as ASN, technical experts, a representative of the public land agency, an elected official and representatives of the environmental pressure groups and associations. All parties have the same voting "weight" when it comes to the decisions taken by the commission.

The CNAR very rapidly became a benchmark body and today one can see that it works well.

Could you give us a particular example?

Of the many dossiers handled, I would mention that of the Gif-sur-Yvette site, which goes back some ten years, in other words even before the Commission was created. An eighty year old couple refused to leave their house, which was located on polluted soil, because they had already been traumatised by a compulsory purchase order several years earlier. Their other concern was to be able to leave a valuable asset to their children. The Commission went to talk to them and persuade them to accept rehousing nearby with the help of ANDRA. We managed to find a satisfactory solution both to ensure their wellbeing and enable them to leave their property to their children. The human aspect of these dossiers is often very important.

The CNAR is approached by private individuals, associations or administrations, which submit dossiers to it. Do you think that enough people are aware of its existence?

The CNAR is a relatively recent creation (2007). Although the Commission has made great strides in terms of raising its profile, it still needs to become better known. Its role of collecting old objects from private individuals (radioluminescent alarm clocks, radium fountains, clocks, etc.) is increasingly well-known and its role is more clearly identified, especially by the office of the Prefects and the administrations. I would add that the work done by the CNAR to achieve a consensus, enabling the various stakeholders to reach agreement, convinced the State of the effectiveness of its actions. The proof of this is last year's budget rise, which was originally of €1.5M. This increase in public funding is proof of the recognition of its work by the public authorities.

What difficulties does the Commission today encounter in managing polluted sites?

The CNAR frequently has no-one with whom to deal directly. The sites it is called on to handle are often closely tied into the history of radioactivity, to Marie Curie and the precursors of the discovery of radioactivity and its first applications. Several industrial sites in the Ile-de-France region are concerned. Their current owners have nothing to do with the activities linked to radioactivity. This is the case with Nogent-sur-Marne (see opposite). This is the case in the Seine-Maritime département, on the site of the former Bayard factory, which manufactured "fluorescent" alarm clocks.
This is also the case in the Marne *département*, where there was an old factory of lighter flints which used a naturally radioactive ore. Some polluted sites however are less "historical", such as the Ganagobie plant (Alpes-de-Haute-Provence *département*) (boxes p. 27 and 30) which manufactured radioactive markers for the pharmaceutical industry and which went bankrupt leaving toxic and radioactive materials and waste behind it.

The dossiers are often difficult and complex: there is little available information and the waste has to be

the Radioactive Field – CNAR

characterised, transported, disposed of…. all of which are activities that are heavily regulated in France. The absence of disposal facilities for low level, long-lived waste further complicates the management of these sites.

In your opinion, what is the future of the CNAR?

The CNAR still has a number of years of work ahead of it. There is no urgency, but the programme to rehabilitate polluted sites and collect old radioactive objects must be carried out in full. ■

Jacques Jean-Paul Martin, Mayor of Nogent-sur-Marne, Elected officials representative within the CNAR

Contrôle: **The commune of Nogent-sur-Marne is the site of the radioactive pollution clean-up work being done on the Marie Curie school, an emblematic programme in the field of polluted site management. As mayor of Nogent-sur-Marne, what is your experience of this management process?**

Jacques Jean-Paul Martin: This is a very singular experience, which obliges the Mayor to take a number of decisions. Communication and information of the local population is the first one: the worst mistake would be to attempt to hide what is happening on the site and to shy away from openness.
In dossiers such as these, we often have to deal with people (private individuals or associations) who use extremely alarmist language and create often unnecessary worries. A worksite such as this means that the mayor has to identify the considerable number of parties he has to meet in order to manage the situation: ASN, CNAR, ANDRA and the office of the Prefect – which takes the overall lead of the operation according to the terms of the 2008 circular. The second decision the mayor has to take is just as important: as accurately as possible, define the subsequent use of the site planned for after the clean-out work. This is difficult, in that the level of this reuse depends on factors that are sometimes poorly understood (the level reached in decontamination of the site, the actual activity of the site prior to clean-out and its spatial distribution, etc.): when the work begins, we do not always know what to expect. Finally, I must admit that even though there are structures designed to help, the mayor is very much on his own in managing such a situation, even though he is not the only one taking decisions in these cases!
The Marie Curie school dossier suffered from too much hesitation, changes in direction, appraisals and counter-appraisals one after the other on this site, for which the origin of the problem goes back a very long way. The challenge was therefore first of all to make the pollution clean-up project credible.

What do you feel is the best form of communication to be used with the local population?

The level of interest from the inhabitants of the commune will be different depending on whether or not they live next to the site: I believe that one should not hesitate to communicate differently to the immediate neighbours and to the rest of the inhabitants of the town, as they do not all feel the same degree of involvement. In my opinion, it is always important to communicate with a degree of perspective, in other words enable the inhabitants to compare the data and measurements they are given against standards or local values (the radon concentration in the Ile-de-France region for example) and using data that are comprehensible to a non-specialist (for instance the notions of "dose rate" or "gamma radiation"). Bare figures are meaningless to the vast majority. Finally, in a dossier of this nature, I feel that it is important not to deal only with the monitoring committee set up by the office of the Prefect - the local information and monitoring committee (CLIS) - which does not necessarily address the concerns of the local residents, but rather with other, more grass-roots bodies (environmental protection associations for example). For my part, I set up an ad hoc monitoring committee, which enabled the nearest neighbours – the local neighbourhood committee – to be in touch with the competent experts (ASN, ANDRA, etc.): this structure is more flexible and more reactive than the CLIS, and just as competent. The committee was, for example, very useful in dispelling unnecessary concerns over the building demolition phase which of course creates dust: the monitoring committee immediately reassured the local residents that this dust was not radioactive. It must be remembered that because radioactive pollution is by its very nature invisible and odourless, it gives rise to the wildest claims. The Mayor has to anticipate that this rumour will reach the entire commune and must create a climate of confidence and reach out to the population concerned. From this viewpoint, one must clearly differentiate between risk information on a general, national scale, and local information, as the two do not carry the same weight. However, the greatest risk in an operation such as this, would have been not to communicate.

Why did you agree to represent the Mayors within the CNAR?

I believe that co-opting a mayor onto the CNAR is a good thing. The CNAR is not somewhere where only the

video on asn.fr

■ **Management of sites polluted by radioactivity: numerous players** loudest voice is heard. For a mayor, the CNAR is a place for calm discussion, with no press releases published after the meeting, so there is not the same level of media pressure. I am today looking with great interest into the numerous dossiers in Paris being dealt with by the CNAR. I hope to offer pertinent experience feedback to the Commission to help it assess the difficulties and constraints that affect a municipality. My training as an engineer, my professional experience and my experience as a mayor faced with such a situation are of interest to the various mayors, who often call me for advice. I am therefore a sort of go-between for the mayors and the technical experts in charge of managing radioactive polluted sites. ■

Jacky Bonnemains, President and founder of the Robin des Bois association, member of the CNAR

Contrôle: **Pourquoi l'association Robin des Bois a accepté, aux côtés d'une autre association environnementale, de siéger à la CNAR? Quel bilan dressez-vous de cette collaboration ?**

Jacky Bonnemains: Robin des Bois took part in the CNAR in the most natural way possible. We responded to approaches from ANDRA in 1994, 1995 and 1996, with a view to identifying sites polluted with radium. Following on from this collaboration, it was therefore only natural for Robin des Bois to take part in a structure designed to organise remediation operations. The association has been a part of the CNAR for five years, and it is a good forum where the participants are not there just for show and are indeed active … provided that they are actually present. At Robin des Bois, we however often deplore the fact that not all the radioactive waste is completely removed from the sites: we feel that it is all too often left on the site, albeit with certain precautions being taken (for example, theoretical reversibility[1]).

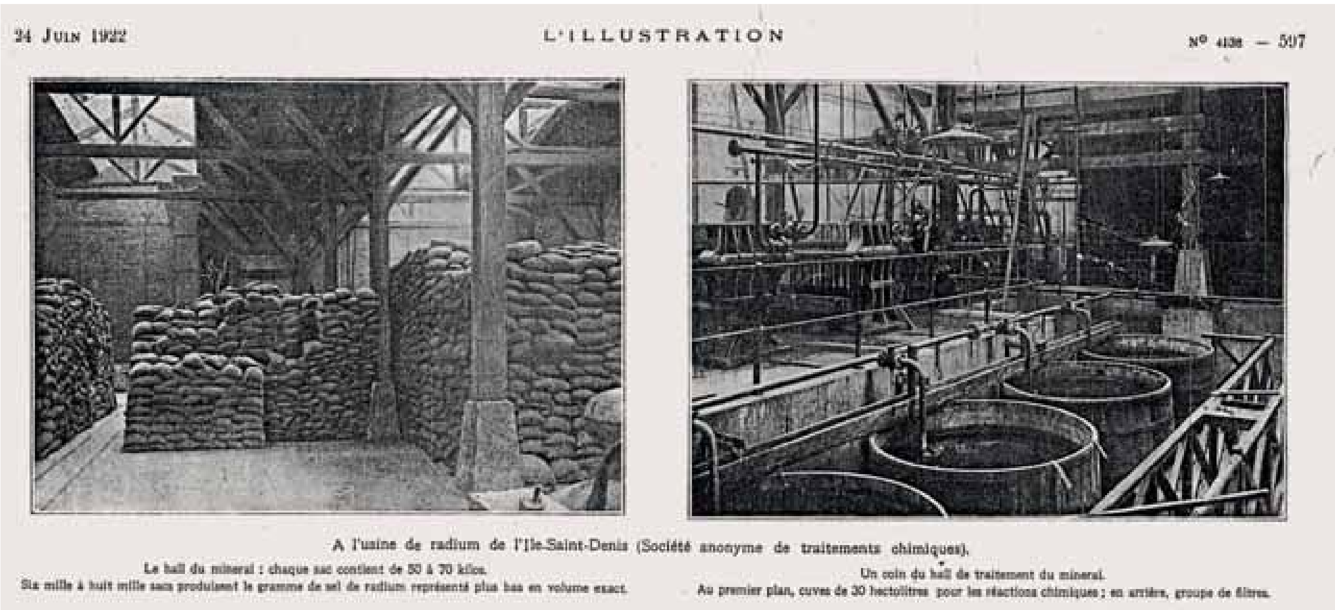
Do you think that the CNAR is useful? Do you feel that it is working satisfactorily?

Very usefull The CNAR makes it possible to clarify the situation on a very large number of sites, on most of which the pollution dates back about a hundred years. Dozens, if not hundreds of sites would still be the victims of irresponsibility, negligence or dishonesty on the part of building managers, lawyers or owners, without the intervention of the CNAR. We felt that it was strategically very important to shed light on these sites inherited from the "Curie" past, even before tackling the question of the waste produced by nuclear power plants.
The CNAR works relatively well, but the lack of diligence by certain parties to the CNAR meetings is a problem. However, the financial means are not sufficient for clean-out of the polluted sites. There is a shortage of disposal sites for legacy radium waste and we have to put together makeshift disposal solutions. The primary obstacle today to the problems posed by the CNAR is not so much money as a lack of a disposal solution for radium-bearing waste[2].
More so than a lack of financial capacity, it is this missing link which forces the authorities to leave the waste in-situ.

Why do you think this situation is still continuing?

Wherever they may be, people are highly reluctant to see waste disposal repositories created in their back yard. Legacy radioactive waste which has nothing to do with the nuclear industry is no exception, quite the contrary.

L'Illustration newspaper of June 1922


24 JUIN 1922 L'ILLUSTRATION N° 4138 — 597

A l'usine de radium de l'Ile-Saint-Denis (Société anonyme de traitements chimiques).

Le hall du minerai : chaque sac contient de 50 à 70 kilos.
Six mille à huit mille sacs produisent le gramme de sel de radium représenté plus bas en volume exact.

Un coin du hall de traitement du minerai.
Au premier plan, cuves de 30 hectolitres pour les réactions chimiques ; en arrière, groupe de filtres.

The local authority and the population are frightened. From this standpoint, local elected officials often have a very different attitude in meetings in Parliament and when faced with their election base...

Could you give us an example?

A few years ago, together with an investigator from Robin des Bois, I visited the manager of a plant which manufactured gelatine from abattoir waste, used in the production of photographic film. This plant was located on the Ile-Saint-Denis, in the Northern suburbs of Paris. We showed this manager, who was first of all sceptical and then hostile, a copy of the Illustration newspaper dating from 1922 and showing the presence of stocks of radioactive materials on the site of his plant, workshops, offices, cellars and archives. This soil was relatively heavily contaminated. The offices were relocated within a week following our visit.

What obstacles do you most commonly come up against in your polluted site management activities?

Whether dealing with the chemical or radioactive fields, the work of an association such as Robin des Bois is faced with the same difficulties: denial ("no it's not polluted") or a staggering loss of memory. Our work is similar to that of an archaeologist or a historian, identifying contaminated locations which show no visible traces, and for which there is no-one still alive to describe the past activities. In addition, associations such as Robin des Bois – unfortunately all too few in number – have, I believe, contributed to increased awareness on the part of the Authorities and the public concerning the hazards linked to chemical or radioactive polluted sites. ■

1. Reversibility means being able to remove stored packages if another waste management process were to be envisaged.
2. Low level, long-lived waste repository project

Christine Gilloire, France Nature Environnement (FNE), member of the CNAR

In 2007, the France Nature Environnement federation was approached by ANDRA to take part in the CNAR. As a volunteer worker in charge of the industrial hazards unit and treasurer at the time, I represented FNE. The clean-out actions planned and carried out as part of ANDRA's public interest duties as defined by the 28 June 2006 Act are in line with FNE's usual objectives; it could only approve of these actions to remediate situations that were degraded or potentially hazardous from a health or environmental standpoint.

Whether dealing with "small household nuclear objects", medical items (radium needles), radioactive lighting conductors, or various objects disseminated far and wide, including in antique shops (radium fountains), orphan industrial sites abandoned by their owners, or old historical sites (Marie Curie) linked to the discovery, research and utilisation of radium, we can only welcome these efforts to safeguard and/or restore a healthier environment for the inhabitants and populations concerned, both now and in the future.

It became apparent that some people were completely unaware of the environmental and health risks they were facing. The housing estates in Gif-sur-Yvette, the radium diagnosis or the old derelict industrial sites are all evidence of this.

Several lessons can be learned from these remediation operations, which are costly to the taxpayer and demand considerable human and material resources.
1 – During the 20th century, when research began into radioactivity and its applications, nobody would have thought of evoking the now famous "precautionary principle", because the scientific mind at the time was driven by the ideal of progress and the populations had nothing but confidence in and admiration for the resulting scientific discoveries at that time. Maybe the time has come to think more about the possible consequences and conditions of our research work?

2 – Retaining a record of the sites, facilities and technologies employed is important. The administrative archives (ICPE, town planning documents, such as the POS , PLU , etc.) must now aim to be exhaustive so that further errors and losses can if possible be avoided.

To conclude, the CNAR has limited financial resources; the associations recognise that the situation in the derelict industrial sites dealt with by the CNAR has significantly improved but that pollution clean-up is not total and their possible uses are limited. Owing to the lack of dedicated sites for disposal of waste according to its level of radioactive and often chemical pollution, linked to the problem of acceptability, the solutions adopted are often "the lesser evil"; partial pollution clean-up with safeguarding of the site, however effective, is only an interim solution; FNE deplores this situation and hopes that clean-out will eventually be as exhaustive as possible. ■

1. Land use plan.
2. Local urban development plan.

International approaches

Management of sites contaminated by radioactive substances – Approach by the Belgian regulator

By Stéphane Pepin, Koenrad Mannaerts, Walter Blommaert - Belgian Federal Agency for Nuclear Control (AFCN)

Introduction

In Belgium, there are a number of sites contaminated by radioactive substances, such as, for example, the land contaminated by the former radium extraction activities in Olen (Antwerp province) and a certain number of phosphate industry dumps. The Royal order of 20 July 2001 constituting the general regulations for protection of the general public, workers and the environment against the hazards of ionising radiation (RGPRI) [RGPRI, 2001] deals with the issue of contaminated sites as an intervention situation in the event of long-term exposure, on the basis of the definition in ICRP 60 [ICRP, 1991][1]: "intervention is defined as a human activity that prevents or decreases the exposure of individuals from sources which are not part of a practice or which are out of verification, by acting on sources, transmission pathways or individuals themselves".

Article 72bis of the RGPRI is a transposition of article 53 of directive 96/29/Euratom [EU, 1996]. This article provides a general framework for the problem of interventions in the event of long-term exposure, but does not address a certain number of key issues, including:
– the question of responsibility: who is responsible for the characterisation studies and for any site remediation or management measures?
– the definition of the administrative procedure and the steps in the decision-making process;
– the definition of the intervention levels.

In order to remedy these shortcomings, the Federal Agency for Nuclear Control (AFCN) submitted a bill to the relevant Minister and developed a methodological approach. As radioactive contamination is usually associated with other types of contamination (in particular heavy metals), collaborative ties were developed with the competent environmental authorities

The interventions bill

The bill proposed by the AFCN draws extensively on the existing environmental regulations concerning soil clean-out.

It defines the person who is to bear the cost of the characterisation studies necessary and the cost of any clean-out work and/or surveillance and protection measures (designated debtor).

This debtor designated by the law is, in order of priority:
– the licensee, as defined by the RGPRI, of the facility located on the land on which the contamination was generated;
– the user of this land;
– the owner of this land.

This debtor may be relieved of its obligations if it can prove that it did not itself cause the contamination and that it was unaware of the existence of said contamination. The bill also makes provision for creating an official register of information on contaminated land. Procedures concerning automatic interventions are included in the event of exemption of or defaulting by the designated debtor. The decision-making process is sequential (see below, the "methodological approach") in which each step is validated by an administrative decision.

This bill has yet to be approved at the political level.

Methodological approach

A sequential approach

The approach to contaminated sites is a sequential process in which the nature of the contamination, its impact and the means of remedying or managing it are

1. Although the ICRP 103 recommendations [ICRP, 2007] replaced the distinction between practices and interventions by a distinction between planned and existing exposure situations, we will in this article continue to use the notion of intervention, because it is used in the Belgian regulations currently in force.

investigated, step by step. These various steps can be divided into three phases: a risk assessment phase, a phase to evaluate the possible clean up or management options for the risks associated with the site, a phase implementing the option decided on by the Authorities.

Risk assessment phase

A first step is to identify the contaminated sites. This identification relies on a variety of sources: historical data about the contaminating industries, the airborne gamma-ray spectrometry measurements taken in the 1990s by the Belgian Geological Service on behalf of the national agency for radioactive waste and enriched fissile materials (ONDRAF) and the inventories of contaminated industrial sites managed by the Environmental Authorities.

The second step is an orientation study which aims to confirm the existence of contamination and establish an initial estimate of its characteristics and scale.

The third step is a descriptive study which aims to make a detailed characterisation of the contamination and assess the impact on man and the environment.

If, based on the results of the descriptive study, the radiation protection authority decides that intervention is necessary, the various possible options must then be envisaged.

Options evaluation phase

The designated debtor is required to draft a report describing the various possible intervention options; these options include the clean-up possibilities (in other words the physical measures designed to reduce exposure by acting on the sources of radiation), but also the possible risk management measures (site usage or utilisation restrictions, stipulation of a surveillance programme, etc.). Each option must be the subject of a cost/benefit analysis taking account of the radiological gains, but also of socio-economic factors.

The preferred option will be selected by means of a process of consultation between the various stakeholders. This consultation process is coordinated by the AFCN and selection of an option must take account of the overall impact associated with the implementation of this option: radiological and non-radiological impact, social acceptability and economic factors, technical feasibility, legal safety, limitation of constraints on future generations and so on. The involvement of the stakeholders in the decision-making process enables these various factors to be incorporated.

Implementation phase

Once the decision on the preferred option has been communicated to the designated debtor, the latter is required to draft a clean-up project or a risk management programme. The clean-up project (or risk management programme) must in particular give a detailed description of the planned clean-up techniques (or management procedures), the implementation schedule for these measures, a detailed cost estimate, a list of all authorisations and permits that may be required, with respect to both radiological and non-radiological aspects. These authorisations or permits may if necessary include the authorisation to create and operate a radioactive waste depot under the responsibility of ONDRAF.

Approval of the clean-up project or risk management programme is dependent on issue of the necessary authorisations and permits.

After approval of the clean-up project, the clean-up work is started, with appropriate monitoring and inspection measures, both with respect to the targets set in the clean-up project and with respect to radiation protection of the workers involved in the clean-out.

A final report is drafted on completion of the clean-up work and shall in particular demonstrate that the targets set in the clean-up project have been reached and describe any necessary monitoring and inspection measures.

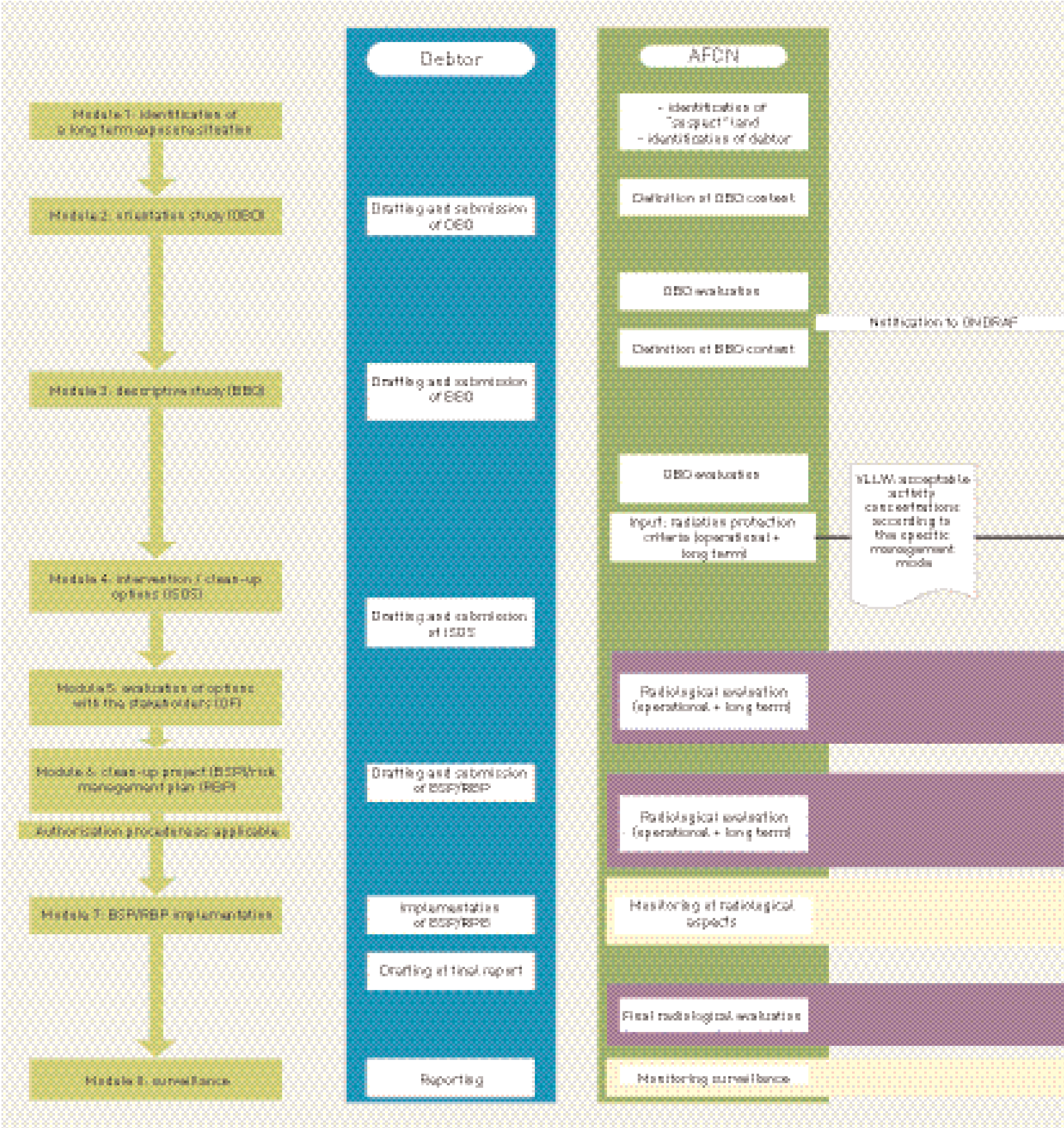
The final step in the process is the implementation of these monitoring measures: for instance surveillance of the groundwater around the site in order to check the effectiveness of the contamination containment, verification of the integrity of the covering layer, etc.

A concerted approach

The AFCN is obviously not the only player involved in the decision-making process. As already mentioned, radioactive contamination usually goes hand in hand with other forms of contamination for which the environmental authorities are competent.

Belgium – a federal state – is divided into three regions, the Flemish region, the Walloon region and the Brussels Capital region, each of which has extensive powers. Radiation protection and nuclear safety fall within the competence of the federal government, but other environmental matters are the responsibility of the regions. Each region has its own environmental regulations, more particularly for soil clean-out. This means that for each intervention, consultation is required between the AFCN (federal level) and the competent administration of the region concerned, in order to ensure that there is consistency between the approach to radioactive contamination and to the other contaminants. This consultation is necessary as of the characterisation phase, in order to jointly define the content of the characterisation studies – each administration within its own area of competence – and continues throughout the decision-making process.

TABLE 1 : THE STEPS IN THE DECISION-MAKING PROCESS AND THE ROLE OF THE MAIN PLAYERS



When the waste resulting from clean-up is to be handled as radioactive waste, ONDRAF also plays an active role in the decision-making process: it is for instance required to give explicit approval of the choice of intervention option when this entails the creation of a repository for the radioactive waste.

Alongside these players, other bodies will need to be consulted depending on the situation: local authorities, authorities in charge of land use planning, etc. This is the purpose of the consultation process described in the previous section, in order to bring the various stakeholders together around the choice of preferred intervention option.

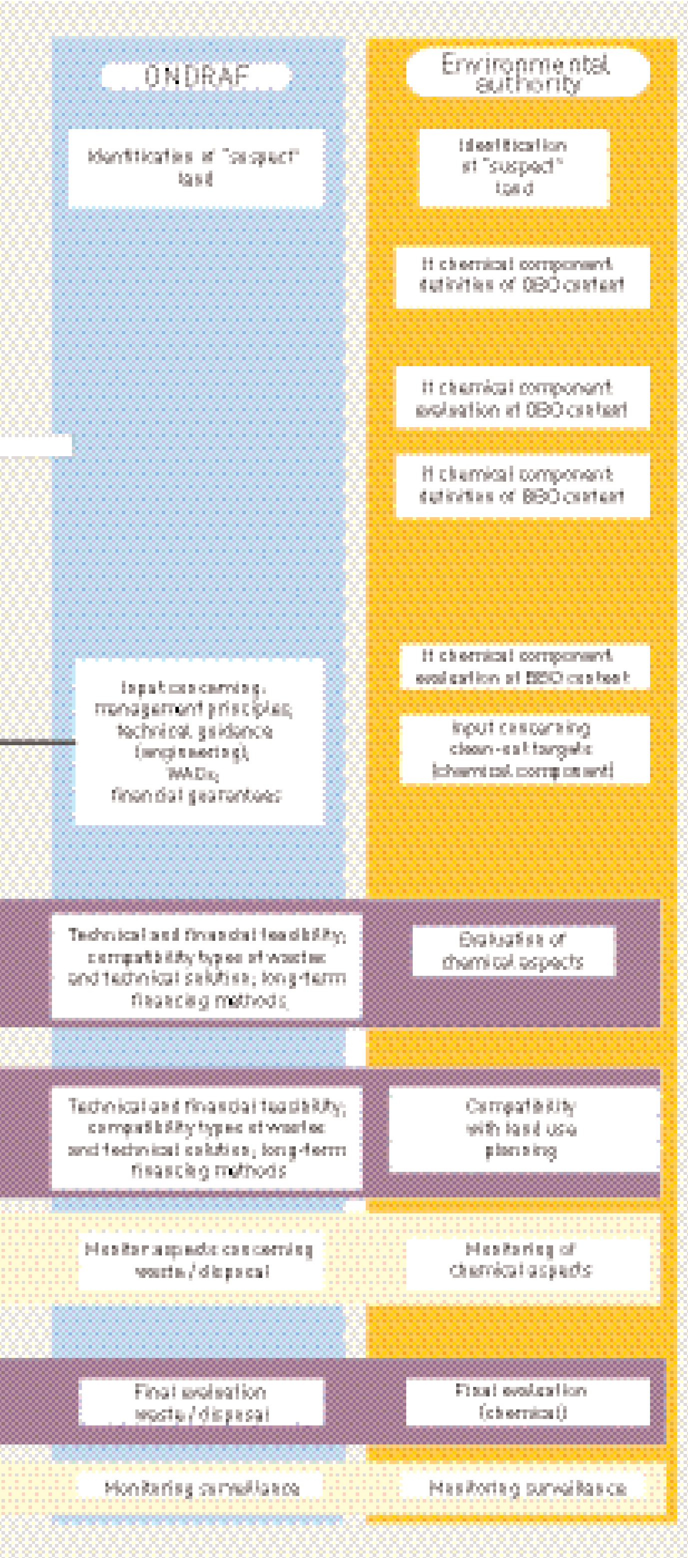


Table 1 summarises the various steps in the decision-making process and the role of the main players. A more detailed description of this methodology can be found in [Mannaerts, 2011] along with a description of how it was applied to two actual cases.

Intervention levels

Alongside the regulatory and methodological aspects, the AFCN drafted technical memoranda concerning the intervention levels and the content of the characterisation studies.

For contamination caused by natural radionuclides, the intervention levels are defined as follows:
• < 0.3 mSv/year: no intervention (unless the intervention is minor – application of the ALARA principle);
• 0.3 mSv/year < dose < 1 mSv/year: intervention rarely justified (according to the results of an in-depth evaluation taking account of socio-economic factors);
• > 1 mSv/year: intervention generally justified (depending on the results of an in-depth evaluation taking account of socio-economic factors);
• > 3 mSv/year: intervention essential. In exceptional circumstances, intervention may be justified only for a dose higher than this guideline level.

The dose evaluation takes account of the potential exposure to radon. All the doses mentioned are doses on top of the natural background level. The contamination caused by artificial radionuclides may be the subject of a more stringent approach, depending on the actual circumstances. It should be recalled that the dose criterion is only one of the components of the decision-making process.

The AFCN's technical memoranda also give information concerning the sampling strategies to be used and the choice of exposure scenarios. These are of course defined according to the specific characteristics of the site to be investigated, but must at least include:
– a scenario corresponding to the current use of the site, in order to evaluate the direct risk and any measures to be taken immediately.
– a worst-case scenario: this is a realistic scenario that is the most pessimistic in terms of dose. This is typically the residential or other sensitive scenario. The various hypotheses (for example, the diet of the critical individual, etc.) and the probability of their occurrence must be explained. The hypotheses must remain likely.
– a "probable" scenario which does not correspond to the current usage of the site but is compatible with the allocation of the site defined by the sector plans.

Examples of contaminated sites in Belgium

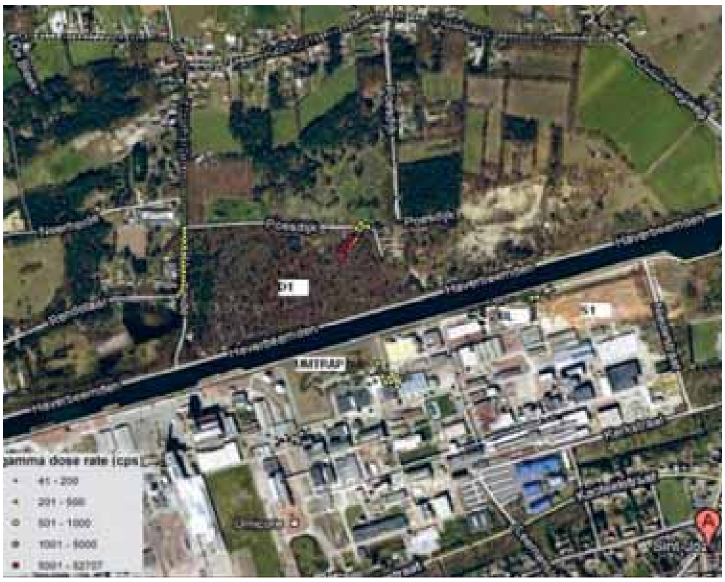
Land contaminated as a result of former radium extraction activities in Olen

The radium and uranium extraction plant operated by the former Union Minière (which became Umicore in 2001) between 1922 and 1977 and then decommissioned, led to contamination of various plots of land in the commune of Olen (province of Antwerp). Although some remediation work had already been done, in particular on the Bankloop river, where effluent had been discharged during the production period, a number of sites still require clean-up. The dump known as D1 contains about 217,000 m^3 of waste, including radium extraction residues and extraction unit decommissioning waste. The radium concentration varies widely, between the background levels in Belgian soil and 930 Bq/g. Radium contamination can also be found in other old dumps, as well as on the site of the plant itself. The following photo gives an idea of the site and the external radiation levels on the surface.

The banks of the Molse Nete

Since the 1950s, slightly radioactive effluents have been discharged into the Molse Nete river, from the nuclear facilities in the region: the nuclear energy research centre (SCK-CEN) accepted the effluents to be treated in its radioactive waste treatment facility. Despite the low activity of the effluents, these discharges led to contamination of the river sediments, which were regularly dredged and deposited on the banks.

The maximum activity concentration values (in Bq/g) in the samples taken in 1991 on the banks of the Molse Nete were 0.85 Bq/g of cobalt 60, 2.4 Bq/g of caesium 137, 1.82 Bq/g of americium 241 and 0.86 Bq/g of plutonium 239 [Sweeck, 1999]. The contamination is however extremely varied and the dose rate measured in the banks varies between the background level and 1 µSv/h.



The Olen site – visible are the authorised disposal facilities "UMTRAP" and "Bankloop" (BL) as well as the former dumping sites D1 and S1. The dots correspond to external radiation measurements in counts per second. Dumping site D1 shows the highest rises.

Contaminated sites linked to the "NORM" industry

The NORM industry, in particular the phosphate industry, is the cause of a certain amount of contamination, in particular on the sites used for dumping by these industries, for example the phosphogypsum dumps. Some of these industries are still operating: the Tessenderlo Chemie firm (located in Ham – province of Limburg) for instance produces food supplements for animals using sedimentary phosphate ore. The radium 226 activity concentration in the production residues (mainly calcium fluoride) amounts to about 10 Bq/g. Moreover, the banks and sediments of the rivers into which the company's liquid effluents were poured were also contaminated with radium.

Alongside the phosphates industry, other "NORM" industrial sectors contaminated the soil: for instance a dumping site for the slag produced by ferroniobium extraction.

The problem of "anthropogenic" radon

One particularly significant risk is that of exposure to radon in the event of construction of buildings on the sites concerned, whether places of work or, even more so, housing. This is why, in addition to the regulatory approach described in this article, the sites for which a significant radon exhalation level was observed have been classified by AFCN as anthropogenic radon risk zones. The list of the land registry plots concerned was published in the Belgian Moniteur, the official gazette of Belgium [AFCN, 2011]. This is the first step in the institutional verification process and the procedure for ensuring that a record of these sites is maintained.

A more complete round-up of the various sites in Belgium contaminated by radium can be found in [Pepin, 2011]. Each of these sites is monitored under AFCN supervision.

Conclusions

Any remediation project must meet the following general conditions:
– it must be socially acceptable and economically justified;
– it must be practically feasible;
– the resulting radiological exposure must be justified and optimised;
– the non-radiological components of the contamination must also be correctly assessed.

The AFCN has developed a regulatory and methodological approach which attempts to incorporate these principles: this is a sequential decision-making process, in which the evaluation of the radiological risk is the first phase. Intervention is a regulatory step which can take various forms: clean-up involving steps to relocate or confine the source of the contamination, or risk management measures designed to limit the exposure pathways (for example via usage restrictions) or monitor them by means of surveillance. The regulatory measures must be proportional to the radiological risks but must also take account of social and economic factors and the existing circumstances. Involving the stakeholders in the decision-making process enables these factors to be taken into account. The chosen solution must be supported by all the stakeholders.

Although the bill proposed by the AFCN has not yet been approved at the political level, its methodological aspects already make it a working basis for managing contaminated sites in Belgium. ■

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Principles and Criteria: U.S. EPA Superfund Program Policy for Decontamination and Decommissioning (D&D) at Radium, Thorium, and Uranium Contaminated Facilities

By Stuart Walker, Betsy Donovan, Melissa Taylor, David Seely – U.S. Environmental Protection Agency, United States of America

Introduction

In the United States, agencies involved in nuclear materials regulation, decontamination and decommissioning (D&D) include the Nuclear Regulatory Commission (NRC), the Department of Energy (DOE), the Environmental Protection Agency (EPA), the Department of Defense (DOD), the U.S. Department of Transportation (DOT), the Defense Nuclear Facilities Safety Board (DNFSB), and the individual states. This article will focus on EPA standards for D&D of radioactively contaminated facilities and how those standards are used at radium, thorium and uranium contaminated sites.

EPA

EPA was created in 1970 to address a growing public demand for protection of human health and natural resources: cleaner water, air, and land. EPA was given authority to improve and preserve the quality of the environment on national and global levels by implementing and enforcing environmental laws, setting environmental guidelines, monitoring pollution, performing research, and promoting pollution prevention. The Comprehensive Environmental Response, Compensation and Liability Act CERCLA, also known as Superfund, was enacted to protect citizens from the dangers posed by abandoned or uncontrolled hazardous waste sites, including radioactively contaminated sites.

A comprehensive regulation known as the National Oil and Hazardous Substances Pollution Contingency Plan or NCP contains the guidelines and procedures for implementing the Superfund program. The NCP sets forth nine criteria for selecting Superfund remedial actions. These evaluation criteria are the standards by which all remedial alternatives are assessed and are the basis of the remedy selection process. The criteria can be separated into three levels: threshold, balancing, and modifying. The first two criteria are known as “threshold” criteria. They are a reiteration of the CERCLA mandate that remedies must (1) at a minimum assure protection of human health and the environment and (2) comply with (or waive) requirements of other Federal environmental laws, more stringent State environmental laws and State facility-siting laws, which are known as Applicable or

Excavation in the neighborhood, Montclair, New Jersey, United States of America

Relevant and Appropriate Requirements (ARARs). They are the minimum requirements that each alternative must meet in order to be eligible for selection as a remedy.

Compliance with ARARs is often the determining factor in establishing cleanup levels at CERCLA sites. However, where ARARs are not available or are not sufficiently protective, EPA generally sets site-specific remediation levels for: 1) carcinogens at a level that represents an upper-bound lifetime cancer risk to an individual of between 10-4 to 10-6; and for 2) non-carcinogens such that the cumulative risks from exposure will not result in adverse effects to human populations (including sensitive sub-populations) that may be exposed during a lifetime or part of a lifetime, incorporating an adequate margin of safety. The 10-4 to 10-6 cancer risk range can be interpreted to mean that a highly exposed individual may have a one in 10,000 to one in 1,000,000 increased chance of developing cancer because of exposure to a site-related carcinogen. The specified cleanup levels account for exposures from all potential pathways, and through all media (e.g., soil, ground water, surface water, sediment, air, structures, and biota). Remedial actions for radionuclides are governed by the risk range for all carcinogens established in the NCP when ARARs are not available or are not sufficiently protective.

After the threshold criteria are applied, EPA considers a number of other evaluation criteria. Five of the criteria are known as the "balancing" criteria. The criteria balance long-term effectiveness and permanence; reduction of toxicity, mobility, or volume; short-term effectiveness; implementability; and cost. The final two criteria are called "modifying" criteria: new information or comments from the State or the community may modify the preferred remedial action alternative or cause another alternative to be considered.

EPA believes the "modifying" criteria concerning new information or comments from the local community are important. In many instances, communities are able to provide valuable information on local history, citizen involvement, and site conditions. By identifying the public's concerns, EPA is able to fashion a response that more effectively addresses the community's need.

Key ARARS for radium, thorium, and uranium

Because the diverse characteristics of Superfund sites preclude the development of prescribed ARARs, it is necessary to identify ARARs on a site-by-site basis. There are many radiation standards that are likely to be used as ARARs to establish cleanup levels or to conduct remedial actions. Some of the radiation standards most frequently used as ARARs at Superfund sites are the soil cleanup and indoor radon standards developed to address contamination at sites that are subject to the Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA). When used as an ARAR at Superfund sites, the soil cleanup level for radium 226 and radium 228 combined, or thorium 230 and thorium 232 combined, is 5 picoCuries per gram (pCi/g) [0.185 Becquerel per gram (Bq/g)] above background, while the indoor radon level is 0.02 working levels inclusive of background. For a list of "Likely Federal Radiation Applicable or Relevant and Appropriate (ARARs)", see Attachment A of EPA's guidance "Establishment of Cleanup Levels for CERCLA sites with Radioactive Contamination" at: *www.epa.gov/ superfund/ health/ contaminants/ radiation/ pdfs/radguide.pdf.*

Another set of extremely important ARARs that should be noted are Maximum Contaminant Levels (MCLs) that are established under the United States law for drinking water standards, called the Safe Drinking Water Act. EPA believes contaminated ground water should be restored to

Homes after restoration, Montclair, New Jersey

beneficial use, whenever practicable. This means that sites where the contaminated ground water is a potential or current source of drinking water should be remediated to concentrations corresponding to drinking water standards (e.g., concentrations corresponding to MCLs or more stringent State drinking water standards). The Superfund program requires MCLs be met within the aquifer, not at the tap. EPA's phased approach to addressing contaminated groundwater at CERCLA sites is discussed in "Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites, Final Guidance, which may be found at: *www.epa.gov/ superfund/ health/ conmedia/ gwdocs/ gwguide/index.htm.*

EPA's policy is to defer to State determinations of ground-water use when such determinations are based on a Comprehensive State Ground Water Protection Program (CSGWPP) that has 1) been endorsed by EPA and 2) allows such determinations to be made at specific sites. In the absence of a CSGWPP, EPA considers other state classification schemes and EPA's classification guidelines which use criteria defining ground waters of sufficient quantity and quality to supply the needs of a single family household. EPA's us of CSGWPP's at CERCLA sites is discussed in "The Role of CSGWPPs in EPA Remediation Programs" which may be found at: *www.epa.gov/ superfund/ health/ conmedia/ gwdocs/ pdfs/ role.pdf.*

The current MCLs for radionuclides are set at 4 mrem/yr [0.04 millisieverts per year (mSv/yr)] to the whole body or an organ for the sum of the doses from beta particles and photon emitters, 15 picoCuries per liter (pCi/l) [0.555 Becquerels per liter (Bq/l)] for gross alpha which includes thorium-230 and thorium-232, and 5 pCi/l [0.185 Bq/l] combined for radium-228 and radium-226, and 30 micrograms per liter of uranium.

Montclair/West Orange and Glen Ridge Radium Superfund Sites

The Montclair/West Orange and Glen Ridge Radium sites were included on the Environmental Protection Agency's (EPA) Superfund National Priorities List (NPL) in 1985. The NPL contains the United States' highest priority cleanup projects based on a risk-based scoring system. The sites are located in New Jersey and include three non-contiguous areas located in five suburban residential communities, about 12 miles west of New York City. The sites cover a total area of approximately 250 acres and include 900 residential and 24 municipal properties such as city streets, lots and parks.

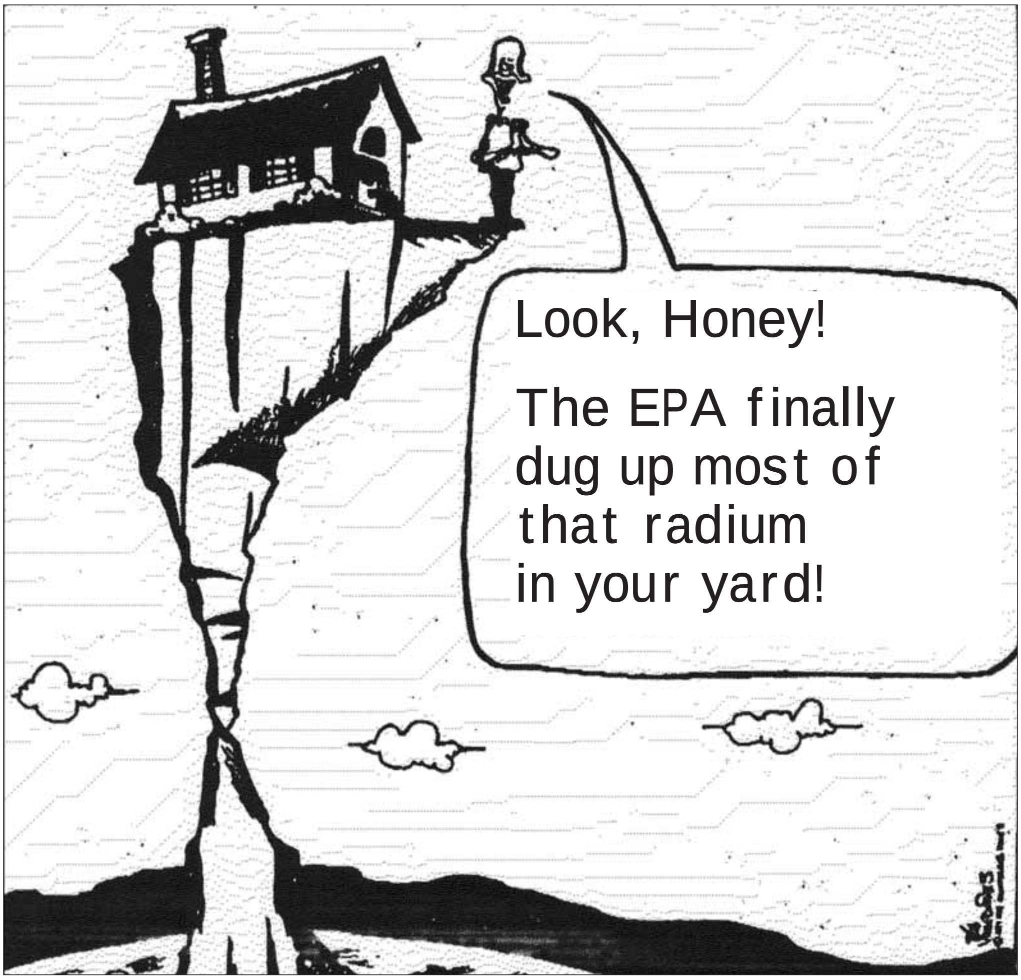
Cleanup was determined to be necessary at 355 properties. A total of about 300,000 tons of contaminated soil and debris was removed from the project boundaries and transported by rail for disposal at regulated landfills. The EPA's soil cleanup effort took approximately fourteen years to complete (1990 to 2004) and cost about $220 million. EPA pursued numerous allegations involving the source of the waste materials that were found at the Montclair/West Orange and Glen Ridge sites. No corporate or other assets were available to pursue for recovery of costs. Therefore, all of the remedial action work undertaken at the sites has been publicly funded.

The U.S. Radium Corporation, formerly known as the Radium Luminous Material Corporation, operated a facility from 1915 through 1926 in nearby Orange, NJ. The main activity at the facility involved the extraction and purification of radium from carnotite ore. At its peak, up to two tons of ore per day were processed at the plant. A large volume of process wastes, or tailings, containing residual radioactive materials was generated and dumped in undeveloped, low-lying and marshy areas. The U.S. Radium Corporation also manufactured radium-based luminous paint and employed young women to paint watch dials and other instruments. Many of the women suffered, and some died, from the harmful effects of the radium paint. Two books, entitled "Radium Girls" and "Deadly Glow: The Radium Dial Worker Tragedy" have been written on the history of the radium paint industry and its health effects. By the early 1930s, the radium industry had left the area due to the emergence of more economical sources in other countries as well as the lawsuits concerning the workers plight.

The Montclair/West Orange and Glen Ridge sites were originally identified in 1979 by the New Jersey Department of Environmental Protection (NJDEP) as part of a state program to investigate former radium processing facilities. A 1981 aerial gamma radiation survey of a 12-square-mile area surrounding a former ore processing facility identified a number of locations with elevated levels of gamma radiation. In 1983, follow-up ground investigations were conducted in the areas exhibiting elevated surface gamma radiation as identified by the aerial survey. Investigations found that the soil was contaminated primarily with radionuclides in the uranium decay chain, including isotopes of radium, thorium, uranium and lead. The main radionuclide of concern was radium-226, because its radioactive decay can cause elevated indoor concentrations of radon gas and radon decay products. Radon monitoring in the study areas found many homes with radon gas above the recommended action level. In addition, some properties exhibited elevated levels of indoor and outdoor gamma radiation.

In December 1983, the Centers for Disease Control (CDC) issued a health advisory, recommending immediate action to reduce the human health risks at the sites. EPA recognized that cleanup of the radiological contamination would take a considerable period of time to complete, given the magnitude of the problem. In response to the CDC health advisory, EPA installed temporary ventilation systems to reduce indoor radon gas concentrations in several homes where radon measurements exceeded the recommended levels. Shielding (e.g., lead) was also installed in areas with elevated gamma radiation readings to reduce potential exposures. These interim engineering measures were designed to reduce residential risks within homes until a permanent remedy could be implemented.

In 1984 a pilot study at twelve properties, conducted by NJDEP, demonstrated that excavation of the contaminated soil was a feasible cleanup approach, however problems



Local newspaper, Montclair, New Jersey, United States of America

associated with the interim storage and eventual disposal of the contaminated material were encountered. Fifteen thousand waste containers were stranded for three to four years in a residential neighborhood and rail yard, after the disposal facility revoked the disposal permit. A court battle ensued and eventually reached the United States Supreme Court. A permanent remedy consisting of excavation and off-site disposal for all contamination above the established criteria was selected by EPA in 1990, after a disposal facility that could accept a large quantity of radiological waste became available.

EPA also initiated groundwater investigations at the sites in 1984 to determine if the soil contamination had impacted the groundwater. Thirty six wells were installed and samples were collected from these wells from 1984 through 2001. The groundwater investigation for the project areas determined that no further action was necessary.

Kerr-McGee (RESIDENTIAL AREAS) Superfund Site

The Kerr-McGee Residential Areas site is one of four NPL sites in the West Chicago area contaminated with radioactive thorium wastes. The radioactive waste originated from a nearby facility known as the Rare Earths Facility (REF) which operated from 1932 until 1973. The REF produced non-radioactive elements known as rare earths and radioactive elements such as thorium, radium, and uranium along with gas lantern mantles. These elements were produced by extracting them from monazite sands, bastnasite (rare earth ore), and other ores, using an acid leaching process. Production of these elements resulted in the generation of radioactive mill tailings that contained residual levels of thorium, radium, and uranium as well as certain other insoluble metals. The facility ceased operations in 1973.

Over several decades before the health risks associated with radioactive materials were generally recognized, the mill tailings were available for use as free fill material by residents and contractors. Winds also may have spread some of the mill tailings stored on the REF to nearby properties. As a result of the windblown contamination and the use of the tailings as fill material, the soil at many properties in the West Chicago area became contaminated with radioactive materials.

The issues in the community began to surface in the late 1970s when investigations funded by the NRC began to document the existence of the radioactive materials throughout the community. Kerr-McGee Chemical Corporation, the company which then owned the REF, began conducting cleanup activities at select residential properties in the mid-1980s. The site was ultimately listed on EPA's NPL in 1990. The site ultimately encompassed includes more than 2,170 properties (approximately 1000 acres) in and around West Chicago, Illinois, 676 of which required cleanup. The cleanup involved excavating contaminated soils/materials until a cleanup level of 5 pCi/g [0.185 Becquerel per gram (Bq/g)] of total radium (i.e. Ra-226 + Ra-228) above background for disposal at a licensed facility.

The site was controversial for many reasons. There were no licensed disposal facilities until the early 1990s. EPA went to great efforts to involve the community by expanding our community outreach efforts and included block-by-block community meetings, issuing multiple factsheets and providing official public comment periods throughout each step of the development of the cleanup levels and the cleanup options that were being considered. EPA also held routine monthly meetings with local, State and Federal elected officials and interested community members providing constant updates of project status. Over time the community began to trust in EPA's approach and the controversy began to diminish.

The site included a combination of residential, commercial, recreational, business and school properties. In order to adequately characterize the extent of contamination, EPA used multiple lines of evidence and included: aerial flyovers and van mounted gamma detection equipment, walkover gamma surveys, indoor gamma survey of basement and/or crawlspaces, and indoor radon/thoron studies as well as results of investigations conducted by other parties. Once the overall boundaries of the site were established, EPA investigated every individual property within the site boundary. The only exceptions were 3 properties where access was not voluntarily granted. After evaluating the results of the radon/thoron study for 82 residential properties, EPA decided this effort would be discontinued since only one sample result was elevated and it was due to radon (i.e. a naturally occurring and not due to the site's primary contaminant which is thorium).

In all, cleanup activities generally lasted seven years but spanned over 12 years due to a few challenges relating to the property owners granting access. Approximately 110,883 loose cubic yards of contaminated materials were removed for permanent disposal at a licensed facility. All excavated areas were backfilled and restored. Although the effort involved primarily outdoor cleanups, a few required cleanup indoors. Approximately 5 properties had contaminated basement, crawlspaces, or foundations and as many as 15 properties required removing garages or excavation through garage floors. Many other challenges were faced due structures like decks, patios, driveways, sidewalks, streets and utilities which took extra effort or care. Cleanups also resulted in the development of a restoration plans with agreement of each property owner which identified specific details for how impacted areas would be restored. These specified items like the type of wood and/or footprint to be used for decks and fences, concrete specifications, and landscaping specifications. Large mature trees that had to be removed were generally limited to be replaced with immature trees or hand excavation techniques were utilized in an attempt to save these items.

Nuclear Metals, Inc. Superfund Site

Starting in 1958 and continuing until November 2011, the Nuclear Metals, Inc. Superfund site in Concord Massachusetts, has been used by various operators at various times as a specialized research and metal manufacturing facility, which was licensed to possess and process low-level radioactive substances. At various times, site operators used depleted uranium, beryllium, titanium, zirconium, copper, acids, solvents, and other substances at the Site. Manufacturing at the site consisted mainly of producing depleted uranium munitions for the U.S. Army. From 1958 to 1985, site operators disposed of manufacturing by-products, including waste solutions containing depleted uranium mixed with copper, spent acid, and lime, into an unlined holding basin located on-site. Other areas of the Site, including but not limited to a bog, a cooling water recharge pond, septic leaching fields, a sweepings pile, and a small landfill, are also believed to have been used for the disposal of manufacturing wastes. The facility was initially licensed by the NRC, however, in 1997, the Commonwealth of Massachusetts became an agreement state and subsequently the license was transferred from the NRC to the state. The Commonwealth terminated the radioactive materials license in November 2011 once the final entities had vacated the site and EPA assumed control.

From approximately the late 1980s to 2000, the current site owner/operator, Starmet Corporation (Starmet), performed certain site investigations and a partial cleanup of the Site under the oversight of the Massachusetts Department of Environmental Protection (MADEP). In 1997, Starmet, with the financial support of the United States Army, excavated approximately 8,000 cubic yards of contaminated soils from the on-site holding basin and disposed of these soils at an off-site disposal facility licensed to accept low-level radioactive wastes.

During previous investigations soils and groundwater beneath the Site were found to contain elevated levels of depleted uranium and elevated levels of beryllium. Past sampling of sediments at the Site has revealed elevated levels of depleted uranium, copper, and volatile organic compounds.

The Site was proposed for inclusion on the NPL on July 27, 2000 The Site was listed on the NPL on June 14, 2001. Based on prior sampling at the Site, EPA identified contaminants of concern that include depleted uranium, beryllium, copper, and nitrate. EPA conducted its first action in 2002 which consisted of lining the holding basin with an HDPE barrier, capping the on-site landfill with the same material, and installing a fence around the perimeter of the facility. Throughout 2006 the state Department of Environmental Protection, with Army funding, removed thousands of drums of Depleted Uranium and hundreds of tons of Depleted Uranium metal and other wastes from the facility buildings. Later, in 2008, EPA conducted a second action to address the hazardous and flammable materials inside the facility, which was prompted by a fire that occurred inside the facility in 2007 due to poor housekeeping practices. Another interim action was initiated in 2011, which will address the facility buildings and will consist of removing all interior equipment and materials and demolition of the facility buildings with off-site disposal. It is anticipated that this action will take three years to complete.

At the same time, the remedial investigation sampling program was also taking place. Field work consisted of installing over 50 groundwater monitoring well, collecting over 200 groundwater samples, 80 surface water samples, 400 sediment samples and 450 soil samples. The Remedial Investigation was completed in 2011. Currently the Human Health and Ecological Risk Assessments are in Final Draft. Once the risk assessments are complete, the Remedial Investigation Report and Feasibility Study will further evaluate the nature and extent and type of contaminants in the environment, and various alternatives to address those contaminants which pose an unacceptable risk. A final remedy for the site will then be selected in a Record of Decision currently scheduled for 2013.

Closing

The CERCLA framework for addressing hazardous sites ensures that risks from radiological contamination will be addressed in a manner consistent with risks from non-radiological contamination, except to account for technical differences posed by radionuclides, and that cleanups for all contaminants will achieve protection of human health and the environment. The goal is to provide lasting, protective site restoration while taking into account the cost and achievability of different approaches to attaining these protective goals.

For more information and copies of EPA guidance documents and tools (e.g., models, training courses, and videos) for addressing radioactively contaminated CERCLA sites, see the EPA's Superfund Radiation webpage at: *www.epa. gov/ superfund/ health/ contaminants/ radiation/ index.htm.* ■

Managing the Historic Radioactive Waste Footprint: A Canadian Perspective

By Robert Zelmer, Low-Level Radioactive Waste Management Office (LLRWMO), Atomic Energy of Canada Limited (AECL)

There are over two million cubic metres of historic low-level radioactive waste (LLRW) in Canada. This article outlines the Canadian experience, over many decades, to identify and manage this waste.

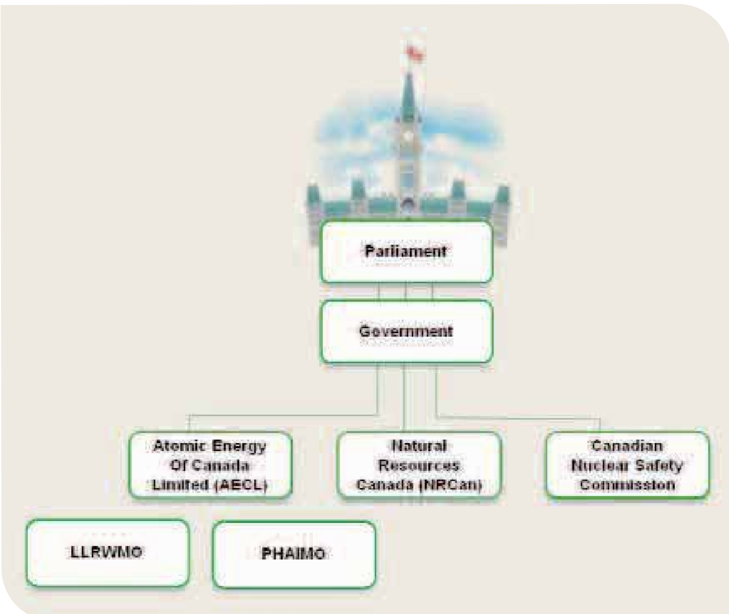
Historic radioactive waste is broadly defined as LLRW that was managed in the past in a manner that is no longer considered acceptable and for which the original owner cannot reasonably be held accountable. In many cases, the owner is not known or no longer exists. Historic Waste generally does not include mine tailings, NORM (naturally occurring radioactive material) waste or nuclear power plant operation waste. In Canada, the federal government has accepted responsibility for safely managing this historic waste.

Historic radioactive waste consists primarily of radium and uranium-contaminated soil found near the earliest mine sites, along transportation routes and near processing facilities. There is also historic waste resulting from manufacturing activities and radium contaminated artefacts, such as radio-luminescent dials, instruments and other radium contaminated artefacts. The Government of Canada has accepted responsibility for the safe cleanup and management of this waste for the long term.

The Canadian Approach to Managing Historic Radioactive Waste

To set the stage for the discussion on how the issue arose and the efforts undertaken to manage the waste, it is important to first discuss the Canadian legislative and policy framework and the key organizations involved in resolving the historic radioactive waste problem.

Institutions Involved In Managing & Regulating Historic Radioactive Waste in Canada



Canada`s federal government is responsible for nuclear energy and has enacted legislation and regulations to oversee the nuclear industry, including the management of radioactive waste. The primary legislative tool is the *Nuclear Safety and Control Act* enacted in 1997, which established the Canadian Nuclear Safety Commission (CNSC), the federal regulatory authority, and a set of regulations made pursuant to the Act. The Regulations incorporate, for instance, radiation dose limits consistent with the recommendations of the International Commission on Radiological Protection (ICRP). The Act and Regulations, taken together, apply to all aspects of nuclear energy, nuclear substances and radiation devices used in industry and medicine, and the entire nuclear fuel cycle, from uranium mining to waste management.

In 1996 the Government of Canada established the *Policy Framework for Radioactive Waste*. This policy provides the national context for radioactive waste management and a set of principles to ensure that radioactive waste management is undertaken in a safe, environmentally sound, comprehensive, cost-effective and integrated manner.

The *Policy Framework* specifies that:

– The federal government has the responsibility to develop policy, regulate and oversee radioactive waste producers and owners so that they meet their operational and funding responsibilities in accordance with approved long-term waste management plans; and

– Waste producers and owners are responsible, in accordance with the “polluter pays principle,” for the funding, organization, management and operation of long-term waste management facilities and other facilities required for their waste.

Natural Resources Canada (NRCan) is the lead federal department that has been given the responsibility of developing and implementing nuclear energy policy, including national policy respecting radioactive waste management. It is NRCan’s role to ensure that obligations under the *Policy Framework* are met.

The CNSC is the nuclear regulatory authority in Canada and is independent from government in the regulatory and licensing decisions it makes. Its role is to regulate the use of nuclear energy and materials, including radioactive waste, to protect the health, safety and security of the public; protect the environment and respect Canada’s international commitments on the peaceful use of nuclear energy. An important function of the CNSC is to consider applications for the use of nuclear material and facilities, including nuclear waste, and where appropriate, to issue licences that permit the use of nuclear materials and activities. In considering applications for licences, the CNSC considers the input received from members of the public, interest groups and other levels of government.

In 2004, the CNSC issued Regulatory Policy Document, P-290, which outlines the philosophy and principles that guide the regulation of nuclear waste in Canada. A major component of P-290 is the identification of the need for long-term management of radioactive waste. The principles in P-290 are in line with those recommended by the International Atomic Energy Agency (IAEA) in Safety Series 111-F, *The Principles of Radioactive Waste Management.*

This policy document (P-290) considers the extent to which owners of radioactive waste must address waste minimization; the radiological, chemical and biological management of the waste; the predicted impacts on the health and safety of persons and the environment; the measures needed to prevent unreasonable risk to both present and future generations; and the trans-border effects on the health and safety of persons and the environment. It is fully consistent with the *Policy Framework.*

Specifically addressing historic radioactive waste in Canada, the Low-Level Radioactive Waste Management Office (LLRWMO) was established in 1982 to carry out the responsibilities of the federal government for the management of LLRWin Canada. It was established as an agent of the Federal Government subject to its policy and regulatory oversight. The LLRWMO is structured as a division of Atomic Energy of Canada Limited (AECL), a federal Crown Corporation that is Canada`s main nuclear science and development organization. The LLRWMO receives funding and policy direction from NRCan for managing Canada`s historic LLRWfor which the federal government is responsible.

The goals of the LLRWMO historic waste program are to:
– Seek opportunities for the resolution of historic waste management issues for the long term; and
– Undertake interim remedial work and ongoing monitoring as required at contaminated sites to protect health and the environment, prior to the availability of long-term management solutions;
– Cleanup and manage for the long-term, Canada’s historic waste found along the Northern Transportation Route (NTR), in the Port Hope area and various other locations;
– Provide technical assessments and advice to NRCan for the development of federal government policies governing the management of historic waste.

The activities of the LLRWMO fall under three major programs:
– Historic waste: the LLRWMO carries out cleanup and long-term management of historic waste on behalf of the federal government. The responsibilities of the LLRWMO are set out in a Memorandum of Understanding (MOU) entered into between NRCan and AECL.
– Ongoing waste: producers and owners are responsible for the management of their radioactive waste. The LLRWMO provides support to NRCan in the development and implementation of national policies and strategies for this waste. The LLRWMO also assists NRCan in ensuring that Canada meets its international obligations regarding nuclear energy.
– Information: the LLRWMO provides public information on historic waste and low-level radioactive waste.

Historic LLRW sites in Canada

The Origins of Historic Radioactive Waste

The accumulation of historic waste in Canada dates to the early 1930s with the discovery of radium and uranium ore at Great Bear Lake in the Northwest Territories, and subsequent refining of the ore in Port Hope, Ontario. The historic waste is also a result of industrial and medical practices using radium, e.g.; in watch and instrument dials and cancer treatment, but principally from the placement of radioactive waste in locations that were once acceptable, but are now deemed to potentially pose health, safety and environmental concerns.

Other contaminated sites exist along a 2,200 km route of waterways and portages known as the Northern Transportation Route (NTR). This route is where ore was shipped from the original sources (Port Radium Mine) in the Northwest Territories to Fort McMurray, Alberta, the major transfer point. At this point the ore was then transferred to rail for shipment to Port Hope, Ontario, a further 3,000 km distance to the south east.

Historic radioactive waste accumulations were discovered elsewhere in southern Ontario and in Surrey, British

Columbia. The Surrey waste, however, was not related to the mining or production legacy associated with the waste found in other parts of the country. The map below identifies the major discoveries of historic LLRWin Canada.

There is an estimated 2.33 million cubic metres of LLRWin Canada, the vast majority of which is historic waste concentrated in the Port Hope area

Remediation of Historic Contaminated Sites in Canada

Northern Transportation Route

During the period from the 1930s to the 1960s, ore from the Port Radium Mine was shipped by barge from the eastern shore of Great Bear Lake through a system of lakes and rivers to what is now Fort McMurray, Alberta. The transfer work was largely manual labour undertaken by residents of local communities. In the early years, the ore was transported in burlap sacks that were prone to breaking and the sacks themselves did not prevent fine ore particles from escaping. Transfer sites along the route were required in order to bypass areas where river barges could not navigate so the ore was handled frequently. Spillage of ore occurred at these transfer points.

The LLRWMO investigated locations for possible radioactive contamination in this northern area. A transport barge was found to have contamination and the loading dock and surrounding area were found to have isolated point sources of elevated gamma radiation due the spillage of uranium ore.

The discovery of elevated radioactivity levels on a barge and around a loading dock prompted the LLRWMO to conduct a review of the entire historic uranium ore transport network along the NTR. Through radiological studies, discussions, open houses and meetings with community groups and local individuals the LLRWMO gained valuable insight into how the contamination occurred and began to compile a list of potential locations for further investigation.

The LLRWMO initiated a program of gamma radiation surveys at ore transfer points. At the same time, contaminated soil that had been earlier identified in populated communities at Tulita, Fort Smith, Hay River and Fort McMurray was removed and/or consolidated and placed in interim storage.

In each community where radioactive contamination was anticipated or found, the LLRWMO applied the same approach. Planning and implementation of full remediation and long-term management was based on results from initial fact finding and consultation, environmental surveys and waste delineation.

In Tulita (NT), the waste was initially placed into interim storage and in 2009 was safely removed and transported to the United States to a licensed, long term management facility. Work continues to identify and implement long-term solutions for all the remaining historic waste along the NTR.

Toronto Area

The LLRWMO carries out radiological inspections and assessments on public and private properties, and provides the owners with information, guidance and support if remediation of their properties is required.

The LLRWMO also provides technical guidance and may take possession of contaminated materials on a site-specific basis. Contamination of these sites often resulted from past radium recovery and radioluminescent dial painting activities. If warranted, the costs of such waste recovery projects are shared between the LLRWMO and the property owner. Regular inspections of these sites by the CNSC, attended by the LLRWMO, ensure that they are being safely managed and that the property owners continue to be aware of the regulatory role.

Past remedial operations by the LLRWMO have resulted in the development of two historic waste consolidation mounds in the Toronto area: the Passmore Avenue Temporary Storage Site, an LLRWMO-engineered storage mound that contains the marginally contaminated soil from the Malvern Remedial Project, and the Lakeshore Road Consolidation Mound, a facility under the direction of the Toronto and Region Conservation Authority.

A number of properties in the Greater Toronto Area are currently under licensing exemption by the CNSC. Contact with the owners of these properties and provision of information on their obligations are regularly provided by the CNSC, in accordance with the Nuclear Safety and Control Act. The property owners have agreed to contact the CNSC and the LLRWMO in the event that they wish to renovate, excavate, or construct in the areas that have been identified to them as contaminated.

One of the larger projects completed by the LLRWMO in the Toronto area is the Malvern Remedial Project. The historic waste in Scarborough (Malvern), Toronto, contained the naturally radioactive element radium and arose from radium-recovery operations and other activities that took place on a farm in the mid-1940s. The McClure Crescent area was developed at this location in the mid-1970s without knowledge of the history of the site. In 1980, radium contamination was discovered on McClure Crescent. Additional contamination was discovered at nearby McLevin Avenue in April 1990.

Hundreds of properties were investigated and assessed. In 1990, the LLRWMO removed contaminated soil from properties in the urban community of Malvern and in 1995-1996 the LLRWMO completed a full-scale survey and remediation of approximately 60 properties in the area containing radium-contaminated soil and artefacts. The Malvern Remedial Project, a joint Canada-Ontario project, was established to complete the cleanup in the Malvern area. With the assistance of the community, a proposal was developed to excavate the soil and sort the soil and place storage. The mildly contaminated soil (about 9,000 cubic metres) resulting from the soil-sorting process was placed in an engineered storage mound (Passmore) landscaped to blend in with the surrounding land. The licensable portion of the LLRW excavated was transferred to a storage building at Chalk River, Ontario, operated for the LLRWMO by AECL (about 300 km away).

The Malvern Remedial Project resulted in the removal of radium-contaminated soil from the front and/or rear yards of residential and commercial properties in the community of Malvern, and completed the solution to a long-standing problem. Until cleanup of the contaminated properties at Malvern, land transfers and development was impeded.

An environmental monitoring and site maintenance program is in effect until a long-term management solution is available to the LLRWMO. Results of the environmental monitoring program are posted at the interim storage mound, and annual monitoring reports are available at the Malvern Public Library in Scarborough. The results show that the storage site is not adversely affecting the local environment.

Fort McMurray

Remediation work in Fort McMurray began in 1992. Over a period of four years, the LLRWMO excavated and removed contaminated soil from nine properties where the transfer of uranium ore had left a legacy of contamination. The project was completed in 2002 with the finalization of a long-term management facility that contains approximately 42,500 cubic metres of contaminated material. The remediated land is now being used for recreational and commercial purposes. The storage facility continues to be inspected and monitored regularly to ensure safe operation as designed.

Port Hope Area

The Port Hope area contains the vast majority of the historic LLRW in Canada, over 1.6 million cubic metres, and efforts are underway to complete the remediation and the safe long term management of the waste material. Waste was found throughout the community, in the 1970s when the initial community wide remediation was undertaken in homes and yards and elsewhere. Majority of the waste is located at two radioactive waste sites, Welcome Waste Management Facility (in Port Hope, Ontario) and Port Granby Waste Management Facility (in Clarington, Ontario).

In addition to implementing the long-term solution, there are continuing activities in Port Hope to address issues that arise currently day-by-day. The LLRWMO operates an Interim Waste Management Program comprised of a Construction Monitoring Program, a Property Compliance Program and an Environmental Monitoring Program to ensure safe co-existence with the contamination while implementation of the long term solution is developed.

Beginning in 2008 the Port Hope Area Initiative Management Office (PHAI MO) was charged with completing the final remediation of all the historic wastes in the community and the construction of two local repositories.

This major undertaking, known as the Port Hope Area Initiative (PHAI) is composed of two major projects, the Port Hope Project and the Port Granby Project. Each project involves the cleanup and restoration of contaminated sites, construction of a new, highly engineered long-term waste management facility and supporting infrastructure to receive the wastes from the remediated sites, and enable the monitoring and maintenance of the facilities for the long term.

After advancing the PHAI environmental assessment and planning activities in Port Hope, the federal government on January 13, 2012, announced that it is investing $1.28 billion over 10 years to finalize the cleanup of LLRW in the Port Hope area. The PHAI is being undertaken as a joint initiative of NRCan, AECL through the PHAI MO, and Public Works and Government Services Canada.

Artefact Recovery

The LLRWMO provides technical advice on the identification and management of radium and other radioactive artefacts found on public and private properties throughout Canada. Where necessary, the artefacts are characterized, removed and stored at sites licensed by the CNSC.

In 2009-2010, the LLRWMO assisted in the removal of radioactive devices from eight different locations across Canada, including locations in Ontario, Quebec and New Brunswick. As part of the artefact recovery program, the LLRWMO received a request from the Department of National Defence for support in their radium dial recovery operations from locations across the country.

Compendium of resources on Radium Remediation

The environmental impact of radium remains even today. The legacy of radioluminescent paints, radium therapy needles, mining and processing and associated contamination has long been pursued in France, Belgium, Canada, the USA and other countries. The management of these tasks provides a rich and fascinating history as well as successes and lessons learned in environmental remediation.

The LLRWMO prepared a worldwide overview of the historic radium footprint, remediation success stories and links to many informative resources. This compendium is available on DVD *(or on the LLRWMO website: www.llrwmo.org)*

Summary

The Government of Canada has put in place a comprehensive structure of legislation, policies and organizations to govern the management of historic radioactive waste in Canada.

The *Nuclear Safety and Control Act* and regulations made pursuant to the Act, along with the *Policy Framework for Radioactive Waste* provide the national context for radioactive waste management to ensure that it is carried out in a manner that protects public safety and the environment. Waste owners are responsible for their waste except in the case of historic radioactive waste where the federal government has accepted responsibility.

The LLRWMO has implemented a cooperative approach to resolving historic LLRW problems in Canada since 1982. Working with local, provincial and federal organizations as well as engaging in extensive communication and consultation activities in communities where historic waste is located, the LLRWMO has remediated sites across Canada and has safely recovered and managed varied historic artefacts. However, much work remains and the federal government has expressed strong support to ensure that all historic radioactive waste issues are addressed.

Through the efforts of the LLRWMO, there have been many successes to date including:
• In the Port Hope area, interim remediation of residential and industrial sites and placement of contaminated soil into safe storage facilities until the launch of the PHAI final cleanup. Once completed by the PHAI MO, this will address over 95% of Canada's known historic waste.
– Small scale cleanup activities along the NTR, including cleanup of about 44,000 cubic metres of historic waste in Fort McMurray and safe removal to a disposal facility of some 900 cubic metres of historic waste in Tulita.
– In the Greater Toronto Area, sites containing approximately 16,600 cubic metres of historic waste have been remediated and a number of smaller of contaminated sites identified and remediated.
– In Surrey, British Columbia, sites containing about 5,000 cubic metres of historic waste have been remediated.
– Radium artefacts continue to be collected from across Canada and safely managed.

Overall, the number of new occurrences of historic waste in Canada has been reduced significantly and sites identified to date have either been remediated or are in the process of being addressed. There are mechanisms in place to deal with any new areas of contamination that may be found. ■

Links
Atomic Energy of Canada Limited - *www.aecl.ca*
Canadian Nuclear Safety Commission - *nuclearsafety.gc.ca/*
• www.nuclearsafety.gc.ca/eng/mediacentre/updates/2012/February-28-2012-could-your-collectible-be-radioactive.cfm
Government of Canada - *www.canada.gc.ca/*
Low-Level Radioactive Waste Management Office (LLRWMO) - *www.llrwmo.org*
• Compendium on Radium Remediation - *www.llrwmo.org/Radium%20Compendium%20DVD/Radium_Remediation_Compendium.pdf*
Natural Resources Canada - *www.nrcan.gc.ca/*
Port Hope Area Initiative - *www.phai.ca/*

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http://nuclearsafety.gc.ca/pubs_catalogue/uploads/P290_e.pdf
www.nuclearsafety.gc.ca/eng/mediacentre/updates/2012/February-28-2012-could-your-collectible-be-radioactive.cfm
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Government of Canada
October 2011

G.G. Case, R. L. Zelmer
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Radioactive polluted sites in the Arctic

By Jacky Bonnemains, President and founder of the Robin des Bois association

The scientific community is concerned by the loss of the polar icecap and the thawing of the permafrost, a prospect that is all the more worrying as the soils and subsoils of the Arctic have long been considered as the final resting place for mining, military and hydrocarbon waste.

At the end of 2009, Robin des Bois published an inventory of polluted sites in the Arctic. 2,750 sites were identified. Only chemical, metallic and organic pollution was considered and Russia did not provide any precise information on this subject. A similar report is under way concerning the terrestrial sites and water masses contaminated by the radioactivity emitted by industrial or military activities beyond the Arctic polar circle. At present, the Robin des Bois investigators have little data on the volume and management methods for the technologically-enhanced naturally occurring radioactive materials produced as by-products by the 4,000 oil and gas wells in Arctic Alaska. Norway has just opened a site dedicated to metal parts activated by radium and removed from its offshore platforms. This disposal facility is located below the Arctic polar circle but will also take waste from the platforms operated in the polar ocean. In the Spitzberg archipelago, the coal mines opened in 1906 contaminated the environment with potassium 40, uranium 238 and thorium 232.

Canada operated uranium mines around the aptly named Port Radium in its Far North. A good part of the mining waste was sunk in Great Bear Lake. Both the local residents and the federal action plan are demanding that the site be made safe. As of 1942, Canadian uranium was used by the Manhattan military project in the United States.

Twenty years later, the United States set up two nuclear reactors in the sub-Arctic region and in the Arctic. The first, at Fort Greely in Alaska, supplied a military base with electricity. The decommissioning conditions are somewhat unclear. Transuranic elements are being detected in the environment and it is possible that the winds, surface and groundwater may have entrained residual contaminants into the Arctic. The second American nuclear reactor was installed close to the Thule air base in Greenland. At least 200 tonnes of liquid waste have apparently been left in-situ.

American military activities had other radioactive consequences for Greenland, when a bomber carrying nuclear weapons crashed onto the ice pack in 1968. At least one kilo of plutonium is unevenly distributed over a 17 km radius around the site of the accident. Radioactivity in the marine sediments is well above the regional background level, as well as in more remote terrestrial soils.

Royal Air Force of Canada Detection Team, Operation Morning Light[2]

Another large Arctic area is contaminated by military radioactivity, this time Russian, and that is the island of Nova Zemlya and its vicinity, where 138 airborne, underground and underwater nuclear tests took place from 1954 to 1990. If we add the terrestrial sites, the underwater sites in the Barents sea or the Kara sea where entire atomic submarines, containers and drums of waste, ships loaded with radioactive materials have been sunk, it becomes clear that the Arctic continent and the Arctic ocean, which provide 20 to 30% of the world's marine food resources, must be the subject of a reinforced programme to screen for radioactivity and remediate the contaminated sites.

International efforts are underway in Murmansk and in Gremikha Bay. They are inadequate and suffer as much from a lack of transparency and detailed knowledge on the part of all historical stakeholders as from a lack of funding. The inventory of radioactive polluted sites in the Arctic will be published by Robin des Bois by the end of the year. ■

1. Directive 2008/68/EC of the European Parliament and of the Council of 24 November 2008 concerning the inland transport of dangerous goods.
2. Technologically Enhanced Naturally Occurring Radioactive Materials, nuclear power plants, sunken waste, the Arctic is concerned by radioactivity of human origin, not forgetting the 24 January 1978 crash by a nuclear-powered Russian satellite. 124,000 km2 were affected by debris scattered across the Canadian Far North. Only 0.1% of the 31.1 kilos of U235 from the core of the reactor have been recovered.

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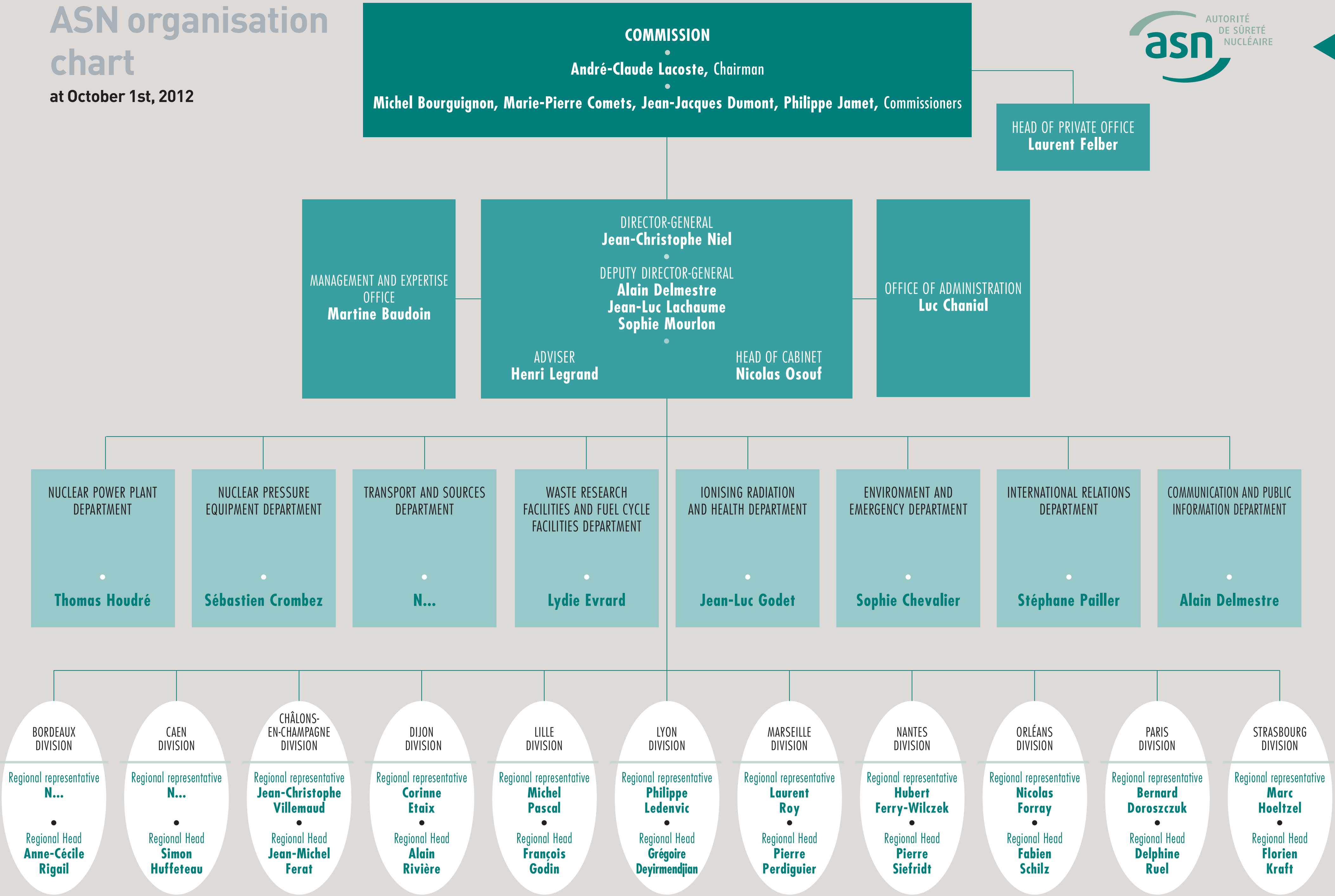

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