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Swedish national plan for the management of all radioactive waste

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Background

The Swedish Radiation Safety Authority has been assigned by the government to develop a national plan for the management of all radioactive waste. This report was presented to the government 30 June 2009.

The report has been developed in coordination with representatives from other authorities, trade and industry organizations, operators and other parties interested, forming a joint action group. The views of the joint action group and the Swedish Radiation Safety Authority on existing problems with the management of radioactive waste have formed the basis for the prioritized areas in the report.

For each area, the Swedish Radiation Safety Authority proposes measures which the Authority considers must be implemented in order to overcome the deficiencies in the waste-management system. These measures form the foundation and a direction for society's continued work with the management of all radioactive waste.

Contents

Summary

Background

In 2008, the Swedish Government assigned to the then Swedish Radiation Protection Authority to develop a national plan for the management of all radioactive waste by 30 June 2009 [1]. The assignment was taken over by the Swedish Radiation Safety Authority, which was established on 1 July 2008 through a consolidation of the Swedish Radiation Protection Authority and the Swedish Nuclear Power Inspectorate [2]. The work was carried out, in project form, at the Swedish Radiation Safety Authority during autumn 2008 and spring 2009. The project had an external joint action group with representatives from the authorities, trade associations and operators among others.

The proposal for the development of a national plan for all radioactive waste derives from the 2007 evaluation of the environmental quality objective a Safe Radiation Environment [3]. The Swedish Radiation Protection Authority, at the time, considered that the management and disposal of all radioactive waste should be given the highest priority in the continued work for a Safe Radiation Environment, with regard to radiation from radioactive materials. With a national waste plan, an overall strategy for the disposal of all types of radioactive waste is obtained, which facilitates the planning of the disposal of particular waste streams. These waste streams bring together radioactive waste from different sectors, including radioactive waste with non-radioactive waste.

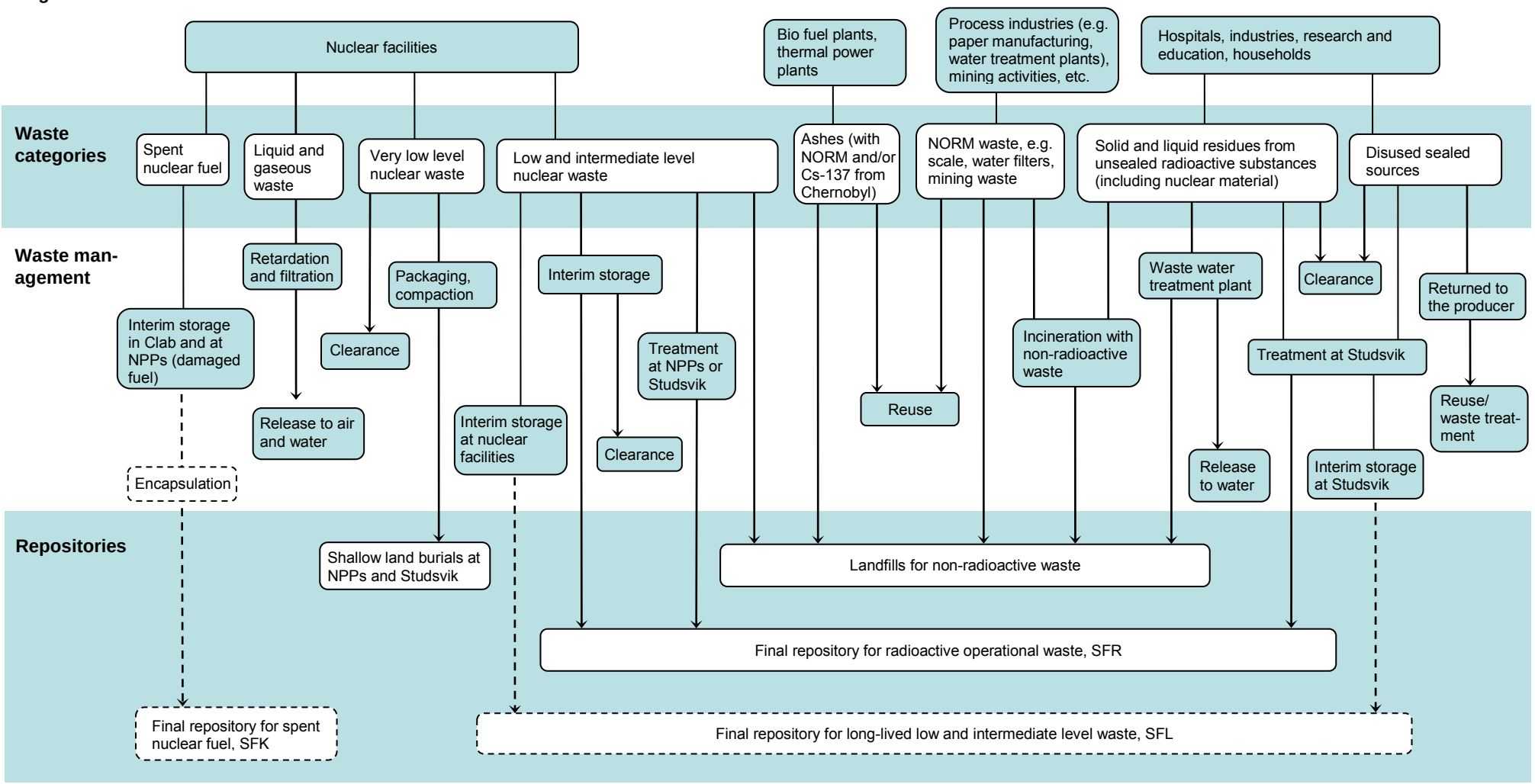
Focus on radioactive waste from non-nuclear activities

As far as the national waste plan is concerned, the Swedish Radiation Safety Authority believes that all waste management included in the nuclear field (and the division of responsibilities and financing) is covered by the Act on Nuclear Activities [4], the Financing Act [5] and the Studsvik Act [6]. The management of other radioactive waste is based on the Act on Radiation Protection [7], but this is not as clear, even if the introduction of two producer responsibility ordinances [8, 9], with the support of the Environmental Code [10], have created better conditions for the disposal of non-nuclear radioactive waste.

The action proposals in this report are focused on bringing waste management *outside* the nuclear field, where requirements are essentially regulated by the Act on Radiation Protection, to a level comparable with the management of nuclear waste (including the management of spent nuclear fuel).

The Swedish Radiation Safety Authority believes that the objective of the national waste plan is that Sweden, by 2020, will have a comprehensive waste-management system whereby all types of radioactive waste will be disposed of in a safe manner. The plan will make it easier to ensure that waste sub-systems for nuclear and non-nuclear waste – which could otherwise easily be regarded as being separated from each other – do not need to be distinguished to any great extent. This is illustrated by the figure on the next page, which provides a general view of the waste streams from nuclear and non-nuclear activities and which shows that there are common management and repository solutions.

Activities from which radioactive waste originates



To ensure continuity in the work in the future, with regard to the follow-up of plans for all radioactive waste, the Swedish Radiation Safety Authority propose that the national waste plan is updated every three years. The plan can then function as the strategy document or the action plan it is intended to be, ensuring that the focus remains on the various problems associated with waste management at different times, so that the set objective can be reached by 2020.

Content of the report

A survey was carried out to identify the problems and shortcomings that were found in the waste-management system and what measures are required to resolve them within the near future. The joint action group has contributed by describing various problems as well as by offering points of view on the action proposals which the Swedish Radiation Safety Authority has developed. The following four prioritised areas are discussed in the report: the need for safe interim storage and disposal of non-nuclear radioactive waste, shortcomings in the monitoring of radioactive materials in society, the need for a clarification of responsibilities in legislation and the need for a long-term preservation of information regarding repositories of radioactive waste.

The action proposals that have been developed for each area are summarised in the next section. Several of the proposals are addressed to the Government, and the Swedish Radiation Safety Authority intends to highlight others for the ongoing Legislative Inquiry on a coordinated regulation of the nuclear safety and radiation protection field [11] (the legislative inquiry). Some proposals can be carried out by the Swedish Radiation Safety Authority within the framework of their ordinary operations or following a decision by the Government.

The report presents an overview regarding what happens with radioactive waste streams from nuclear activities (nuclear power plants and other nuclear facilities) and from non-nuclear activities (hospitals, research, education and industry), i.e. where the different categories of radioactive waste arise in society and how they are managed, including disposal. Together with this report, there is a description of the actors involved in the waste streams in one way or other, along with the division of responsibilities among them.

Impact analysis

In most cases, the action proposals point towards a solution without being too specific. A socio-economic impact analysis has been made of the proposals, see Appendix 1 (Appendix 1 has not been translated into English and is not included in this report). The consequences are difficult to quantify, but the analysis provides the basis for further studies by structuring benefit and cost items and by providing indicators regarding what further knowledge is required in order to develop financial estimates in those cases it has not been done. The total benefit of implementing the action proposals falls primarily on the general public, as the proposals contribute to the environmental work and, by 2020, there will be an all-embracing waste-management system whereby all types of radioactive waste will be managed and disposed of safely. The Swedish Radiation Safety Authority expects that more detailed analyses will be carried out when each action proposal is implemented; the precise nature of the proposals can then be determined and it will be easier to provide a more exact estimate of the effects of the proposals.

Action proposals

Area 1: Interim storage and disposal of radioactive waste from non-nuclear activities

No.	Proposal	
1	**Periodic updating of the national waste plan** Every third year, the Swedish Radiation Safety Authority should update the national waste plan so that it acts as a support for the long-term work for a safe radiation environment.	
	Is directed at	**Implementation by**
	The Government	A Government decision The Swedish Radiation Safety Authority

No.	Proposal	
2	**Extended waste plan requirements** The Swedish Radiation Safety Authority will elucidate the requirements for the establishment of waste plans and expand the application of such plans to additional activities involving radiation.	
	Is directed at	**Implementation by**
	The Legislative Inquiry	Amendment to the law if required The Swedish Radiation Safety Authority

No.	Proposal	
3	**Dialogue on waste where solution for management and disposal is lacking** The Swedish Radiation Safety Authority will continue to identify and engage with those who have waste where management and disposal methods are lacking, and involve in dialogues with the parties concerned in order to find solutions.	
	Is directed at	**Implementation by**
	The Swedish Radiation Safety Authority	The Swedish Radiation Safety Authority

No.	Proposal	
4	**The state will guarantee safe interim storage and disposal in special cases** Sufficient resources will be guaranteed so that the Swedish Radiation Safety Authority can finance interim storage and disposal of radioactive waste in special cases when the owner cannot fulfil their responsibility.	
	Is directed at	**Implementation by**
	The Government	Post 2 in the Swedish Environmental Protection Agency's appropriation 1:4 is to be expanded The Swedish Radiation Safety Authority

No.	Proposal	
5	**Investigation of a final repository for NORM waste** The Swedish Radiation Safety Authority will investigate the need for a separate final repository for NORM waste in connection with the authority drafting regulations concerning the handling of such waste.	
	Is directed at	**Implementation by**
	The Legislative Inquiry	An amendment to the law, if required The Swedish Radiation Safety Authority

Area 2: Radioactive material which unintentionally ends up adrift without regulatory control

No.	Proposal	
6	**The state implements collection campaigns** Sufficient resources are guaranteed so that the Swedish Radiation Safety Authority is able to implement specific collection campaigns for radioactive waste.	
	Is directed at	**Implementation by**
	The Government	Post 2 in the Swedish Environmental Protection Agency's appropriation 1:4 is to be expanded The Swedish Radiation Safety Authority

No.	Proposal	
7	**Routine border control of radioactive substances from a third country is to be established** The government provides the Swedish Customs with the assignment of introducing routine border controls of radioactive substances from 3rd countries.	
	Is directed at	**Implementation by**
	The Government	A Government decision

Area 3: Legal responsibility

No.	Proposal	
8	**Waste responsibility is clarified in legislation** The question of responsibility for radioactive waste will be clarified in the regulatory framework so that no ambiguities exist regarding who has prime responsibility and when responsibilities have been fulfilled in accordance with the law. At the same time, provisions regarding a time approach to waste management, decommissioning and decontamination should be introduced.	
	Is directed at	**Implementation by**
	The Legislative Inquiry	An amendment to the law, if required

No.	Proposal	
9	**A review is implemented regarding the responsibility for products with radioactive materials** The government provides the Swedish Radiation Safety Authority with a mandate to review producer liability for products which contain radioactive substances. The preview is to be carried out together with stakeholders.	
	Is directed at	**Implementation by**
	The Government	A Government decision The Swedish Radiation Safety Authority

Area 4: Information preservation for the long-term monitoring of waste disposal facilities

No.	Proposal	
10	**State register to be established** The government nominates an authority which is given the assignment of establishing a register to facilitate the long-term preservation of information regarding waste disposal facilities for long-lived radioactive waste.	
	Is directed at	**Implementation by**
	The Government The Legislative Inquiry	A Government decision An amendment to the law, if required

Introduction

The assignment

When the environmental quality objective A Safe Radiation Environment[1] was evaluated in 2007, the then Swedish Radiation Protection Authority concluded that, when regarding radiation from radioactive substances, the management and disposal of all radioactive waste should be given the highest priority in the continued work towards the objective [3]. The Swedish Radiation Protection Authority suggested the wording of a new interim objective to be: 'By 2020 there will be solutions for the safe management and disposal of all radioactive waste.' To comply with this interim objective, the authority suggested that a national plan for the management of all radioactive waste should be established.

The Swedish Government responded by giving the Swedish Radiation Protection Authority the assignment of establishing a national plan for all radioactive waste, in the letter of regulation (2008) [1]:

The Swedish Radiation Protection Authority shall present a national plan for the management of all radioactive waste to the Government (The Ministry of the Environment) no later than 30 June 2009. The work should be done in cooperation with other relevant authorities and stakeholders. The plan should include a strategy with objectives for the management and disposal of all radioactive waste. The plan should describe how the waste comes into existence, is handled and disposed of. The plan should also shed light on any problems relating to the present way of managing radioactive waste and indicate areas where further action is needed. From the plan and the strategy, the various actors' roles and responsibilities should be described.

The assignment was taken over by the Swedish Radiation Safety Authority, which was established on 1 July 2008 through a consolidation of the Swedish Radiation Protection Authority and the Swedish Nuclear Power Inspectorate [2].

Purpose

With a national waste plan, an overall strategy for the disposal of all types of radioactive waste is achieved, in a similar way to what has been done for all non-radioactive waste [12]. A national plan for the management of all radioactive waste creates a foundation and a direction for society's continued work with the management of all radioactive waste. As a result, the plan will facilitate the management of specific waste streams. These waste streams bring together radioactive waste from different sectors, including radioactive waste with non-radioactive waste.

Focus

Previously, a national system for the management and disposal of radioactive waste from non-nuclear activities was requested, which resulted in the Government report *Radioactive waste in safe hands* 2003 [13].

[1] The Environmental quality objective A Safe Radiation Environment reads: 'Man's health and the biodiversity must be protected from the harmful effects of radiation in the external environment'.

Regarding nuclear activities, there are requirements for waste plans in the regulations SSMFS 2008:1 [14] and SSMFS 2008:22 [15]. Moreover, requirements are regulated regarding plans for waste management relating to nuclear power plants through the Act on Nuclear Activities [4], which states that the nuclear industry must present a plan every three years which provides details of research, development and demonstration (the RD&D programme) relating to waste management. There is also a system to provide sufficient financial resources for waste management through the Financing Act [5] and the Studsvik Act [6].

As far as the national waste plan is concerned, the Swedish Radiation Safety Authority believes that all nuclear waste management, and the division of responsibilities and financing, is covered by the Act on Nuclear Activities, the Financing Act and the Studsvik Act. However, the management of other radioactive waste based on the Act on Radiation Protection [7] is not as clear, even if the introduction of two producer responsibility ordinances [8, 9], with the support of the Environmental Code [10], has created better conditions for the management and disposal of radioactive waste from non-nuclear activities.

The action proposals in this report focus on bringing waste management *outside* the nuclear field, where requirements are essentially regulated by the Act on Radiation Protection to a level comparable to the management of nuclear waste (including spent nuclear fuel).

Radioactive waste refers, in this context, to

- Waste from the nuclear fuel cycle: uranium mining, operation and the decommissioning of nuclear plants, the reprocessing of nuclear fuel and spent nuclear fuel, i.e. such materials that in the Act on Nuclear Activities are defined as nuclear waste and/or nuclear material.
- Waste that arises through non-nuclear activities, for example hospitals, industries and research institutions, following the use of radioactive substances. The waste consists of discarded products which contain radioactive substances and other materials contaminated with radioactive substances, from, for example, laboratory activities.
- Waste which contains elevated concentrations of naturally occurring radioactive material and which are created as a side effect of non-nuclear activities where large amounts of natural materials are handled, for example in process industries and water purification plant. In this report, this type of waste is referred to as NORM waste.
- Waste, in the form of ash, which contains caesium-137, spread into the environment following the accident that took place in Chernobyl. The ash comes from the burning of peat or wood fuel in biofuel plants and thermal power plants.

Objective

The overall objective for the entire environmental action is that we will be able to hand over a society to the next generation in which the major environmental problems have been resolved. For a safe radiation environment, new interim objectives have been proposed for this purpose [3]:

"By 2020 there will be solutions for the safe management and disposal of all radioactive waste".
This is an objective which, if it is to be achieved, should permeate all aspects of waste management. It is also an obvious target for the national plan for the management of all radioactive waste: By 2020, Sweden will have an all-embracing waste-management system where all types of radioactive waste are safely dealt with.

The national waste plan will make it easier to ensure that waste management systems for nuclear and non-nuclear waste – which could otherwise easily be regarded as separated from each other – do not need to be distinguished to any great extent. There are, among other things, joint management and repository solutions. In a memorandum, the Swedish Radiation Safety Authority, prior to the preparatory work regarding the ongoing review of legislation within the area of radiation safety, stated that there is no reason to differentiate between the concepts of 'nuclear waste' and 'radioactive waste' [16]. This brings forth the importance of a coordinated approach to the management and disposal of all radioactive waste.

In order to provide continuity to the work that will be carried out in the future – dealing with all radioactive waste and also to follow up on the action proposals – the Swedish Radiation Safety Authority suggests that the national waste plan is updated every three years, see Part 1. The plan can then function as the strategy document, the action plan it is intended to be, ensuring that the focus remains on the various problems associated with waste management at different times, so that the objective that has been set can be reached by 2020.

Waste plans – an international perspective

Sweden has ratified the Convention on the Safety of Spent Fuel Management and the Safety of Radioactive Waste Management, the Joint Convention [17]. This convention imposes a number of obligations on the contracting parties with regard to the safety of the handling and disposal of spent nuclear fuel and other radioactive waste, including waste from non-nuclear activities. The Joint Convention also points to the importance of every country developing strategies for the safe management of all radioactive waste.

The EU Council states, in its conclusions from a meeting held on 7 January 2009 regarding nuclear safety and the safe management of spent nuclear waste and radioactive waste, that each member state in the EU should be encouraged to establish a long-term national plan of action for the management of all types of radioactive waste, including spent nuclear fuel [18]. The plan should be revised on a continuous basis and include an inventory of the country's radioactive waste, examine existing solutions or developing new solutions and defining responsibilities.

Reading instructions

While developing the national plan for the management of all radioactive waste, the Swedish Radiation Safety Authority has based its work on the specific requirements in the government assignment regarding what should be included.

Part 1 presents the **proposals for action**, which the Swedish Radiation Safety Authority considers must be implemented in order to overcome the deficiencies in the waste-management system which have been identified in this report. During the preparation of the plan, four prioritised areas emerged, each with different problems. Each area is described, together with a description of what the problems are and what the objective is, i.e. what the continued work on dealing with the problems related to waste management should strive towards. After that, the action proposals are presented followed by a short description of the consequences the proposals have, according to the Swedish Radiation Safety Authority. As a basis for the evaluation of the consequences, the Swedish Radiation Safety Authority has used the impact analysis in Appendix 1 (not translated into English).

Part 2 provides a general **background description** with facts regarding the radioactive waste streams, i.e. where radioactive waste arises in society and how it is then dealt with, including disposal. In addition, the actors which in some way are involved in the waste streams, and also the division of responsibilities among the parties concerned, are described.

Appendix 1 contains the socio-economic **impact analysis** which has been carried out in the action proposals. The appendix has not been translated into English and is therefore not included in this version of the report.

Appendix 2 reports on who has participated in the **joint action group** during the development of the national waste plan. The group has consisted of approximately 50 representatives, from government authorities, trade and industry associations, operators, environmental organisations, etc.

Appendix 3 reproduces the joint action group's **points of view regarding the proposed measures** and the Swedish Radiation Safety Authority's comments on these points of view. The appendix has not been translated into English and is therefore not included in this version of the report.

Appendix 4 explains the **abbreviations** that appear in the report.

Part 1.

Action proposals

Area 1: Interim storage and disposal of radioactive waste from non-nuclear activities

The radioactive waste generated from non-nuclear activities, for example hospitals, industry, research and education, is described in more detail in Part 2, together with how the waste is managed and disposed of. Some of the waste can be deposited in SFR, the repository for operational waste from nuclear power stations owned by SKB (the Swedish Nuclear Fuel and Waste Management Company). Waste which cannot be deposited in SFR is in interim storage until eventually deposited in SFL, SKB's planned final repository for long-lived low- and intermediate-level waste, to be in operation by 2045.

Lack of treatment methods and disposal solutions

Some categories of the radioactive waste derived from non-nuclear activities have an uncertain future, i.e., there are no developed methods of treatment and/or final repository solutions (waste in interim storage at Studsvik in anticipation of the planned repository SFL is not included). For example, the deposition of liquid or gaseous waste is not allowed in SFR. Consequently, Studsvik Nuclear AB does not accept this type of waste for treatment [19]. In many cases, industry, research and health-care services that produce liquid or gaseous waste which primarily contain tritium, carbon-14 or krypton-85, store the waste pending a solution. Other gaseous radiation sources which at present are stored at different places throughout the country are exit signs containing tritium from aeroplanes etc. and smoke detectors which contain krypton-85.

There are several examples of radioactive waste which lack treatment methods and/or a solution for their final repository and which are stored by the owner pending a solution. The waste types and amounts which are stored vary greatly, however they are usually low-level waste. For example, a school is currently storing a few grams of uranium in a chemical form which cannot easily be treated, while at Swedish steelworks, a total of 5 tonnes of powder and 25 tonnes of slag contaminated with americium-245 are stored, following unintentional melting of radiation sources. The steel and scrap metal industry have become involuntary receivers of radioactive materials for which they cannot always determine the original owner of the waste (this is dealt with in more detail in the next chapter). Today, at least 20 tonnes of NORM waste is stored in the form of tanks and pipes which have scale containing radium-226. The steel and scrap metal industry also receive other radioactive materials which contain radium-226, cobalt-60, caesium-137 or americium-241. A lot of the waste probably can be managed, but certain types of waste may require treatment methods which have not yet been developed. How these materials should be managed is still being investigated.

It is highly probable that there is more material stored in different areas throughout the country. Nevertheless, the indication is that there is a limited

amount of waste categories which today lack a treatment method and/or final repository; even if, in some instances, large quantities may be involved. Nonetheless, it poses a problem for those that have waste which they cannot get rid of.

In cases where no disposal is available today, it is important to ensure that the waste is placed in interim storage and that it is safely stored until a solution is found. Interim storage can take place in a safe manner for a long period of time, but there are also circumstances whereby intermediate storage cannot take place in a safe manner and where there is a lack of economic incentives for another actor to provide interim storage for the waste. As long as safe interim storage or safe disposal cannot be guaranteed for all categories of waste, the Swedish Radiation Safety Authority see an increased risk of waste ending up out of regulatory control.

Disposal of NORM waste

NORM waste has its own problems, because of the lack of regulatory framework for the management and disposal of this type of waste and the fact that no final repository for the waste been identified. Often, the large amounts mean that – for instance because of the excessive costs – disposal in SFR (or the planned repository SFL) is probably not an optimal solution. So far, NORM waste has mostly been placed in repositories that are available for non-radioactive waste. This is a procedure that the Swedish Radiation Safety Authority believes could be applied in the future for large amounts of this kind of waste, in cases where this kind of disposal provides sufficient protection. Nevertheless, it cannot be excluded that some NORM waste may contain too high levels of long-lived nuclides, preventing it from being disposed of in a repository for non-radioactive waste.

Objective

For all categories of radioactive waste there must be designated repositories, and, if necessary, interim storage.

Action proposals

1. Periodic updating of the national waste plan
Every third year, the Swedish Radiation Safety Authority should update the national waste plan so that it acts as a support for the long-term work for a safe radiation environment.

The proposals for action presented in this report have focused on ensuring that there are routes to take for the management and disposal of all radioactive waste, as described in the opening section. At this stage it means, first and foremost, to bring the system for the management and disposal of non-nuclear waste to the same level as that for nuclear waste. A successive development of the plan is desirable so that improvement proposals within the nuclear sector can also be highlighted and so that focus can also be given to general issues, such as waste minimisation, recycling (material and energy) and reuse, while at the same time maintaining or increasing ambitions with regard to radiation safe-

ty. The plan can then function as the strategy document, the action plan it is intended to be, ensuring the focus remains on the various problems associated with waste management at different times, in order to achieve a long-term safe radiation environment.

The government should take the proposal into consideration and, if necessary and appropriate, make the necessary decisions for its implementation.

2. Extended waste plan requirements

The Swedish Radiation Safety Authority will elucidate the requirements for the establishment of waste plans and expand the application of such plans to additional activities involving radiation.

To avoid future categories of waste which management and disposal cannot be resolved, the Swedish Radiation Safety Authority intends to review the requirements regarding the granting of licences and request that waste plans are established to a greater extent than what is currently carried out. Today, the Swedish Radiation Safety Authority regulates on waste plans for high-activity sealed radioactive sources.[2] The authority should expand the procedure so that it also includes activities that use radiation sources with lower activities. Even in those cases where NORM waste is produced, demands should be made that operators have plans regarding how the waste will be disposed of.

The Swedish Radiation Safety Authority intends to draw the attention of the legislative inquiry to the proposal so that, if necessary, and also if appropriate, legislative support can be adapted for the implementation of the measure.

3. Dialogue on waste where solution for management and disposal is lacking

The Swedish Radiation Safety Authority will continue to identify and engage with those who have waste where management and disposal methods are lacking, and involve in dialogues with the parties concerned in order to find solutions.

The responsibility for management and disposal of waste lies with he/she who generates the waste. The current waste posts where a solution for management and disposal is lacking are being held by a small and heterogeneous group of operators. The chances are poor for them to finance the development of a treatment method and/or a disposal on their own. In 2009, the Swedish Radiation Safety Authority will examine how other countries manage their discarded sealed gaseous radiation sources, which contain tritium and krypton-85, in order to develop guidelines for a Swedish solution. The Swedish Radiation Safety Authority should also engage in a dialogue with parties concerned to find out what sort of solutions for the management and disposal can be developed for each specific waste category.

[2] The waste plan shall show how the radiation source will be safely disposed of when it is discarded, which can be done by returning it to the manufacturer or to the supplier, or by transferring it to another licensee or by sending it to an approved waste facility, in accordance with the regulations SSMFS 2008:9 [17].

Updated versions of the national waste plan (see Action Proposal 1 on periodic updating of the national waste plan) should list the relevant identified waste categories and activities involving radiation, and also describe how the plans for management and disposal have developed.

4. The state will guarantee safe interim storage and disposal in special cases

Sufficient resources will be guaranteed so that the Swedish Radiation Safety Authority can finance interim storage and disposal of radioactive waste in special cases when the owner cannot fulfil their responsibility.

In those instances where the holder of the waste does not have the opportunity to store their waste or transfer the waste to somebody else, then the state should step in and guarantee safe interim storage of the waste. This should mainly concern private individuals, but other owners of waste may also be considered. Safe interim storage can be obtained by the Swedish Radiation Safety Authority establishing an agreement with a waste contractor that can store the waste.

Since 2006, the Swedish Radiation Safety Authority has had, at its disposal, a share of the Swedish Environmental Protection Agency's appropriation 1:4 (previously 20:34) for the decontamination and restoration of contaminated areas. The Swedish Radiation Safety Authority's share is used to ensure the safe management and disposal of some historic radioactive waste from non-nuclear activities. Thus, The Swedish Radiation Safety Authority already finances the management and disposal of such radioactive waste when there is no owner, or when the owner has been judged as not having to pay for the disposal of the waste.

Financing, in order to guarantee safe interim storage of the above-mentioned radioactive waste, should take place through the Swedish Radiation Safety Authority being given the possibility of having access to an increased share of the Swedish Environmental Protection Agency's appropriation 1:4. At the same time, the government should review the terms and conditions of the allocation post so that it agrees with the expanded use of the funds.

5. Investigation of a final repository for NORM waste

The Swedish Radiation Safety Authority will investigate the need for a separate final repository for NORM waste in connection with the authority drafting regulations concerning the handling of such waste.

An important question is how NORM waste should be managed and disposed of. Today, this type of waste, which sometimes consists of significant amounts, is stored by different operators pending a solution.

At present, the Swedish Radiation Safety Authority is developing regulations for the clearance, disposal and management of NORM waste. In connection with this, the Swedish Radiation Safety Authority should investigate whether the existing non-radioactive waste repositories can receive all types of NORM waste, or whether a separate final repository for NORM waste is required and

how this could be realised. A final repository of this kind could also be used for other radioactive waste streams.

Pending the development of the guidelines for management and final disposal, the waste must still be placed in interim storage in a safe manner. Therefore it may also be reasons for the Swedish Radiation Safety Authority to develop guidelines for this.

The Swedish Radiation Safety Authority intends to draw the attention of the legislative inquiry to the proposal so that, if necessary, and also if appropriate, legislative support can be adapted for the implementation of the action.

Consequences of the action proposals

1. Periodic update of the national waste plan

The Swedish Radiation Safety Authority has not analysed the proposal. On the other hand, an impact analysis was carried out in connection with the evaluation of A Safe Radiation Environment 2007 [3], in which the proposal for the development of a national plan for the management of all radioactive waste was presented. At that time, the Swedish Radiation Safety Authority considered that the authority's work of developing the plan could also be accommodated in the authority's regular activities, which has been the case. It is also the Swedish Radiation Safety Authority's opinion that there is room within the authority's regular activities for the proposal to update the plan every three years. Based on the work that has been carried out on the development of this report, the Swedish Radiation Safety Authority believes that a future update of the plan requires approximately one person for a period of one year. In the event of an update, the participation of other parties interested is important. It is difficult to assess the scope of their work efforts, but, according to the Swedish Radiation Safety Authority, it should be relatively limited.

2. Extended waste plan requirements

The Swedish Radiation Safety Authority intends to review the requirements regarding the granting of licences and request that waste plans are established to a greater extent than at present. Exactly how the requirements will look has not yet been decided. As a result of the revision of the regulations governing the handling of open radioactive sources from non-nuclear activities [21] the Swedish Radiation Safety Authority intends to introduce requirements on the development of plans for waste management and disposal. The future requirements for establishing waste-management plans for other radioactive waste should be in-line with those, also with regard to the exemption levels.

The Swedish Radiation Safety Authority believes that the more stringent requirements for establishment of waste-management plans, in most cases, will not affect the licence holders to any great extent. It is customary that the licence holders either establish an agreement with the supplier or Studsvik Nuclear AB regarding the handling of a discarded radiation source. The procedures should, in most cases, be sufficient to comply with the Swedish Radiation Safety Authority's requirements. The operators that need to establish completely new plans for radioactive waste are those that generate radioactive waste as a side effect, i.e. NORM waste. Even in this instance, the Swedish Radiation Safety

Authority believes that it should not need to lead to an excessive administrative burden.

3. Dialogue on waste where solution for management and disposal is lacking

The Swedish Radiation Safety Authority believes that the proposal regarding dialogues involving the authority and the actors concerned will not lead to the actors incurring any significant costs. On the other hand, the discussions may lead to measures in the form of, for example, investigations. At present, it is impossible to say what costs this would lead to. It is the responsibility of the owner of the waste to pay for the safe management and disposal of the waste, which, in most cases, should also include the above-mentioned investigations. The Swedish Radiation Safety Authority sees its own role, in this context, primarily as the initiator of and to maintain the dialogues. At the same time, the authority has decided that, during late 2009, it will be examining how other countries manage their discarded sealed gaseous radiation sources which contain tritium and krypton-85, in order to develop guidelines for a Swedish solution.

4. The state will guarantee safe interim storage and disposal in special cases

The proposal will obviously incur a cost for the state. The scenario in Appendix 1 (not translated into English) is that the Swedish Radiation Safety Authority will establish an agreement with Studsvik Nuclear AB regarding interim storage. The Swedish Radiation Safety Authority believes that there should be more actors capable of providing interim storage for radioactive waste, even though they may not be able to treat the waste. There are many uncertainties that must be examined in order to provide cost data. At present, the Swedish Radiation Safety Authority cannot say anything more about this other than what is described in Appendix 1.

5. Investigation of a final repository for NORM waste

The Swedish Radiation Safety Authority has not carried out an impact analysis of the proposal as it suggests an investigation.

Area 2: Radioactive material which unintentionally ends up adrift without regulatory control

Orphan sources

Sometimes, orphan sources, i.e. radiation sources whose ownership cannot be established, are found in society. They can, for example, derive from licenced activities involving radiation sources where the regulatory control has failed and the radiation sources have gone astray. Abroad, orphan high-activity sealed sources have been found by the general public, in some instances resulting in serious injuries and deaths. In Sweden, radiation sources with lower activities have gone astray on a few occasions, but they have not had the same serious consequences. For example, radiation sources have been melted down together with scrap in smelting plants. The incidents that have occurred in Sweden have not posed a substantial risk to any individual's health or to the environment, but they have resulted in economic consequences for those involved.

Now and again, private individuals or institutions discover that they, involuntarily or through ignorance, have radioactive material in their possession. Private individuals have often taken over or 'inherited' historic objects from relatives. In general, these materials do not have a high concentration of radioactive materials. Nonetheless, they do cause concern for those who discover them; not only for their own health, but also with regard to how the material should be taken care of, as the individual often lacks the technical and financial prerequisites to deal with this.

The scrap recycling industry regularly finds radioactive materials of different sorts in the scrap metal it takes in for processing. Other recycling companies and municipal recycling stations also receive radioactive materials. Most of the materials found can be traced back to an owner who can assume responsibility for the waste, but the incorrect handling may lead to the risk of personal injury and an environmental impact, as well as an increase in the cost of its disposal. Owners cannot be found for a small fraction of the radioactive materials found at recycling companies, and the waste therefore remains orphan sources. The steel and scrap metal recycling industry, which receives most of the radioactive materials, has carried out an inventory of the materials accumulated over several years. It is most likely that the majority of the waste can be managed straight away, but certain types of waste may require treatment methods which have not yet been developed.

There are prerequisites to manage the costs of the safe management and disposal of orphan sources and other radioactive material which can be similarly designated as orphan sources, through the funds which the Swedish Radiation Safety Authority has access to via the Swedish Environmental Protection Agency's appropriation 1:4. Unfortunately, information regarding the availability of these funds has not reached out to all interested parties in society, which means that the cleaning up of historic radioactive waste is a very slow process. The radio-

active material is in many instances not of any great significance from a risk point of view, for either human beings or for the environment, but it should nevertheless be taken care of.

Import of radioactively contaminated products

Global trade with steel products and steel scrap has over the years become extensive. Now and again, both radioactively contaminated scrap metal and radioactively contaminated products appear on the international market. During autumn 2008 it was discovered that several countries, including Sweden, had imported radioactively contaminated products, such as flanges and buttons used in lifts, which contained cobalt-60. Sweden has no routine border controls monitoring radioactive substances (note, however, that through the steel and scrap recycling industry's routines, most of the *scrap metal* that is imported is checked). If the Swedish authorities had not been contacted by the Swedish importer, which in turn had been contacted by Rotterdam, where parts of the products got stuck in a routine control, the presence of radioactively contaminated products on the Swedish market would not have come to light.

In this instance, the contaminated products did not result in any tangible health risks, neither in Sweden nor in any other country, but the associated costs were high for society, for instance, for the tracing and analysing of products and the examination of and spreading of information to people who had been in contact with the products. The incident raises questions about the unintentional import of radioactively contaminated products and whether this has occurred before, but, most of all; the focus is on how it can be avoided in the future.

Objective

The risk of radiation sources and radioactive materials ending up in undesirable places in society must be minimised.

Action proposals

6. The state implements collection campaigns

Sufficient resources are guaranteed so that the Swedish Radiation Safety Authority is able to implement specific collection campaigns for radioactive waste

Sweden can take advantage of experiences from for example UK, USA and Spain where they have introduced major collection campaigns in order to collect discarded radiation sources, and other historical waste, in order to remove it from society. Via the share in the Swedish Environmental Protection Agency's appropriation 1:4 (for the decontamination and restoration of polluted areas), which the Swedish Radiation Safety Authority has had recourse to since 2006, historic waste can be disposed of in Sweden too, but the Swedish Radiation Safety Authority believes that collection campaigns would accelerate the process. The HASS Directive [22] calls on EU member states to conduct collection campaigns, directed at high-activity sealed sources. The Swedish Radiation

Safety Authority believes that Sweden should go one step further, by extending the collection campaigns to include, for example, small consumer products and school radiation sources that might otherwise end up out of control in society.

The results of the collection campaigns carried out abroad show that it is important to allow a longer period of time for planning, inventory and information before the campaigns are started. In addition to the information released in connection with the collection campaigns, the Swedish Radiation Safety Authority should also conduct information campaigns directed towards activities where radioactive materials and radiation sources may exist without employees being aware of what they are dealing with (for example, within the dismantling and demolition industry).

The Swedish Radiation Safety Authority believes that the framework for its utilisation of the allocation post 2, in the Swedish Environmental Protection Agency's appropriation 1:4, should be raised to finance the collection campaigns. At the same time, the measures require an increase in personnel resources at the Swedish Radiation Safety Authority, which the authority intends to return to in the budget discussions.

7. Routine border control of radioactive substances from a third country is to be established

The government provides the Swedish Customs with the assignment of introducing routine border controls of radioactive substances from countries outside the EU.

The amount of radioactively contaminated steel products and radioactively contaminated scrap metal, which exists on the international market, shows no sign of decreasing. For this reason, the Swedish Radiation Safety Authority believes that it is very important that some form of state control is established to avoid imported radioactive products entering the Swedish market. The Swedish Radiation Safety Authority is also of the opinion that an important first step is to establish routine border controls of radioactive substances from countries outside the EU.

Consequences of the action proposals

6. The state implements collection campaigns

Before the collection campaigns are implemented, the campaigns that have already been carried out in other countries should be studied closely in order to gain the best possible benefit from the experiences that have already been made. At the moment, it is impossible to guess what the associated costs would be regarding collection campaigns in Sweden. This will transpire at a later stage, prior to the actual campaigns, when more in-depth knowledge is available of the waste that needs to be managed and disposed of.

7. Routine border control of radioactive substances from a third country is to be established

In order to implement the action, an investigation is required regarding the level of ambition of the border controls required to search for radioactive substances and how border controls should be organised. Possible issues to discuss include: Where the border controls should be established and how extensive the controls should be. Should the import of scrap metal also be included? Should the export of products (and scrap metal) be checked? One distinction has already been made due to the fact that the proposal includes border control that only applies to countries outside the EU. The scenario in the impact analysis is based on 20–25 harbours and 10–15 airports equipped with portal monitors. The Swedish Radiation Safety Authority lacks the knowledge to determine whether this is reasonable, but, despite the level of ambition, this is most likely to be the most expensive action proposal in the report.

Area 3: Legal responsibility

Responsibility for waste management and decontamination

Section 13 of the Act on Radiation Protection [7] includes provisions regarding the obligation to manage and dispose of radioactive waste. In 2006, a change was made to this paragraph, with the purpose to clarify that this obligation also includes those who carry out such activities which were not initially considered as activities involving radiation, for example industrial processes where naturally occurring radioactive substances are concentrated and form radioactive waste as an undesirable side effect. The previous formulation of section 13 stated that the operator is responsible for 'radioactive waste which *results from* the activities'; this has been replaced with 'radioactive waste which *exists in* the activities'. The change that was carried out can, however, lead to some ambiguity regarding who has the primary responsibility for the radioactive waste. For example, anyone who deals with or stores waste for somebody else may be singled out as responsible for the waste, because the waste exists as a part of the storage operator's business activities. In the long run, this may lead to unwillingness among the waste managers to take in waste for treatment and can therefore create problems for the management of waste streams.

Another ambiguity with section 13 of the Act on Radiation Protection is that it does not clearly state that anyone who carries out activities involving radiation is obliged not only to take care of the resulting waste, but also to decontaminate premises, buildings and land which have been polluted as a result of the activities. The Swedish Radiation Safety Authority is currently considering to clarify this aspect in the revised regulations regarding the discharging of goods and oil from controlled areas in nuclear facilities [23]. The Swedish Radiation Safety Authority is, however, of the opinion that it should also be clarified directly in the law.

Time approach to waste management, decommissioning and decontamination

The legislation lacks clear requirements stating that the waste must be disposed of within a certain (reasonable) amount of time after it came into existence and that equipment, premises, buildings and land must be decommissioned and decontaminated within a reasonable amount of time after an activity has ended. Unnecessarily prolonged storage of waste can produce potential problems with the actual storage and difficulties in properly treating the waste in the future, either because the waste's composition changes with time and/or knowledge is lost about the waste. Similarly, the postponement of decommissioning measures may lead to potential problems related to the dispersion of residual radioactive materials and difficulties in the event of future decommissioning, because of changes in the composition of the radioactive contaminant over time and/or because the knowledge of the previous activity is lost.

Requirements that waste must be managed and disposed of within a certain amount of time is necessary in order to ensure that the operator assumes their responsibilities, and also, as far as possible, in order to avoid the above-

mentioned problems. The issue also has an ethical dimension with regard to the avoidance of waste problems being transferred to future generations.

Termination of licences following completion of obligations

Section 14 of the Act on Nuclear Activities [4] states that obligations, in accordance with the Act, remain until *completion* or *exemption from them* has been granted. Exemption is granted by the government or an authority determined by the government. In section 27 of the Ordinance on Nuclear Activities [24], the Swedish Radiation Safety Authority has been given the mandate to deal with issues regarding exemption in those instances where the authority has provided a licence for the activities. For other operations, the government decides whether exemption is granted. With regard to whether the responsibilities described in the Act on Nuclear Activities have been fulfilled, how and who should review the situation is not described in the Act. The Swedish Radiation Safety Authority believes that it would be appropriate to require that the licence holder, after having complied with all obligations, is responsible for declaring the situation to the authority and that this is followed by a decision from the authority where it states that all obligations have been fulfilled and that the licence holder is released from his/her obligations. The same should apply following compliance of responsibilities in accordance with the Act on Radiation Protection.

The ambiguity in the law means that there is no clear final reconciliation that all of the obligations that the licence holder must comply with have been fulfilled. At the termination of an activity, there are often remaining obligations with regard to the disposal of waste, the decontamination of premises and the restoration of polluted areas of land, etc. These are measures that may be carried out over a long period of time, and not all measures are necessarily associated with individual decisions made by the Swedish Radiation Safety Authority (for example, the clearance of material or the disposal of waste may take place at the licence holder's own responsibility, in accordance with regulations or conditions issued by the Swedish Radiation Safety Authority). So that there will be no doubt regarding whether the obligations have been fulfilled, a final reconciliation should be carried out with the authority. The legislator should, however, also specify that the designated authority may require further action if, following the final check, it is discovered that all obligations have not actually been complied with. The procedures should be compared with how the issue regarding remaining liability for the decontamination of polluted areas is regulated in accordance with the Environmental Code.

Responsibility for products that contain radioactive materials

Producer responsibility for electrical and electronic products was introduced in 2005 [8]. The idea behind producer responsibility for electrical products is that it should motivate manufacturers to develop products which have a focus on saving energy, are easier to recycle and do not contain environmentally hazardous substances. Some electrical products contain a radiation source, for example certain types of smoke detectors. These products are therefore covered by the producer responsibility, i.e. the producer has a responsibility for the product

even after it has become a waste product. If the product contains radioactive material or other environmentally hazardous substances, these must be disposed of separately before the rest of the electrical product can be recycled. A radiation source found in a piece of equipment must be disposed of in accordance with the Act on Radiation Protection and must then either be disposed of or stored until the radiation has decayed.

To have a system with producer liability which covers *all* products that use radioactive materials, an additional ordinance was introduced in 2007 which imposes a responsibility on the producer for products which are not electrical products but which contain radiation sources, including orphan sources [9]. As a result of the ordinance, the part of the HASS Directive which requires financial guarantees for high-activity sealed sources is implemented. The ordinance is issued with the support of the Environmental Code [10]. The Swedish Radiation Safety Authority does not have supervisory responsibilities according to the ordinance, which the authority believes is cause for concern and would like to see this matter addressed. Producer responsibility for electrical products has been in existence for four years and producer responsibility for products with radioactive materials for two years; the Swedish Radiation Safety Authority believes that it would be a good idea to evaluate the experiences from the introduction of the two ordinances. The EU Directive [25], which the ordinance for producer responsibility for electrical products is based on is at present the subject of a review, as it has been noticed that in some cases it does not work properly.

According to section 13 of the Act on Radiation Protection, anyone who has used a radiation source in their activities is obliged to make sure that it is properly managed and disposed of when it is discarded. This can either take place through the owners taking care of the management and disposal themselves or – for products covered by producer liability – by handing over the discarded radiation source to a responsible producer. Already before the producer responsibility was added to the Act on Radiation Protection, it was customary that suppliers of radiation sources offered their customers a return service for discarded radiation sources at a cost and often in exchange for a new radiation source.

In the continued work of developing legislation, the most simple and user-friendly approach is sought. It can be regarded as unnecessarily complicated that producer liability for products containing radioactive materials is regulated in addition to the Act on Radiation Protection, through two parallel ordinances.

Objective

The regulatory framework regarding the responsibility for radioactive waste and what the responsibility means must be clear and simple, well adapted to its purpose, and easy to understand.

Action proposals

8. Waste responsibility is clarified in legislation

The question of responsibility for radioactive waste will be clarified in the regulatory framework so that no ambiguities exist regarding who has prime responsibility and when responsibilities have been fulfilled in accordance with the law. At the same time, provisions regarding a time approach to waste management, decommissioning and decontamination should be introduced.

Specifically, these clarifications should cover the following issues and needs:

- Section 13 of the Act on Radiation Protection should be clarified so that there are no longer any ambiguities regarding who has primary responsibility for the management and disposal of radioactive waste.
- Both the Act on Nuclear Activities and the Act on Radiation Protection should clearly state how the obligations in each act have been fulfilled and who is responsible for examining the issue.
- Provisions should be introduced to the legislation regarding the management and disposal of waste, along with decommissioning and decontamination, and that they should take place as quickly as reasonably possible after the waste has come into existence or the activity has ceased.

The Swedish Radiation Safety Authority intends to draw the attention of the legislative inquiry to the proposal so that, if necessary, and also if appropriate, legislative support can be adapted for the implementation of the action.

It may be noted that the implementation of these measures also facilitate the establishment of relevant and comprehensive waste plans, see action proposal 2.

9. A review is implemented regarding the responsibility for products with radioactive materials

The government provides the Swedish Radiation Safety Authority with a mandate to review producer liability for products which contain radioactive substances. The preview is to be carried out together with stakeholders.

The government provides the Swedish Radiation Safety Authority with a mandate to review producer liability for products which contain radioactive substances. The preview is to be carried out together with stakeholders.

The Swedish Radiation Safety Authority should conduct an evaluation of experiences from the introduction of the two producer responsibility ordinances. How are the two ordinances interpreted by those concerned? Does having two parallel ordinances for producer liability for radioactive products work, or should there be just one? Can we see that producer liability for radioactive products will lead to more environmentally friendly solutions? Should producer liability for products with radioactive materials, as is the case today, also include all short-lived radioactive material and low activities down to the exemp-

tion levels? Is it appropriate to have producer liability for products that contain radioactive materials, or should we consider returning to a system of pure owner responsibility?

Consequences of the action proposals

8. Waste responsibility is clarified in legislation

The proposal focus on three areas where the Swedish Radiation Safety Authority believes the legislation should be clarified regarding responsibility for radioactive waste. The second area was revised after the impact analysis had been performed and there was no time to analyse the revised version. The Swedish Radiation Safety Authority believes that the consequences that arise from the revised proposal should, more or less, agree with the original proposal. (The impact analysis has not been translated into English.)

9. A review is implemented regarding the responsibility for products with radioactive materials

Because the proposal here is to initiate a review, the Swedish Radiation Safety Authority has not carried out an impact analysis of the proposal.

Area 4: Information preservation for the long-term monitoring of waste disposal facilities

Lack of information preservation

The long-term monitoring of geological repositories for radioactive waste cannot be guaranteed. The same applies to near-surface repositories that contain radioactive waste. If no information is available on where a repository is located and of its content of hazardous substances there is a risk that for example near-surface repositories will be subject to intrusion, which can lead to its long-term protective function deteriorating. This, in turn, can lead to the risk of harmful exposure to radioactive materials for humans and the environment.

Similarly, if the monitoring of the ground above an area where radioactive waste is stored is neglected, there is an increased risk of intrusion, which can lead to damage to the technical barriers, with a subsequent exposure of the radioactive materials.

The lack of societal and institutional control, together with lack of information preservation, can therefore pose a risk for radiation protection problems for future generations who, as a result of ignorance regarding closed repositories for radioactive waste, carry out accidental intrusion.

Objective

The state will keep a register which facilitates long-term preservation of information regarding location, design and content of near-surface repositories and geological repositories for radioactive waste.

Action proposal

10. State register to be established

The government nominates an authority which is given the assignment of establishing a register to facilitate the long-term preservation of information regarding waste disposal facilities for long-lived radioactive waste.

To maintain information on a long-term basis regarding waste disposal facilities for long-lived radioactive waste, and thereby uphold long-term control of the disposal facilities, the Swedish Radiation Safety Authority believes that a state register must be established. The register should be able to receive information on near-surface and geological repositories, and it should clearly define land-use restrictions which may need to be applied for the short- and long-term use of the areas in question.

Instead of using up resources for the establishment and development of a completely new register, existing records could be further developed. One proposal is to use the already existing property registers administered by The Swedish Mapping, Cadastral and Land Registration Authority.

The Swedish Radiation Safety Authority intends to draw the legislative inquiry's attention to the above proposal so that, if necessary and also if appropriate, legislative support can be adapted for the implementation of the action.

Consequences of the action proposal

10. State register to be established

The task of establishing a register, in accordance with the proposal, could theoretically be given to several different authorities, for example the Swedish Radiation Safety Authority. However, the Swedish Radiation Safety Authority believes that it would be an advantage to make use of a register that already exists and that the property register would the most suitable register for this purpose. The scenario in the impact analysis (which has not been translated into English) has therefore been based on the property register being used. The Swedish Mapping, Cadastral and Land Registration Authority, which already reports on other types of land-regulating plans and ordinances today, has been forthcoming with information. According to the analysis, the costs of carrying out this action would be quite moderate, even though all cost items have not been fully analysed.

Part 2.

Radioactive waste streams

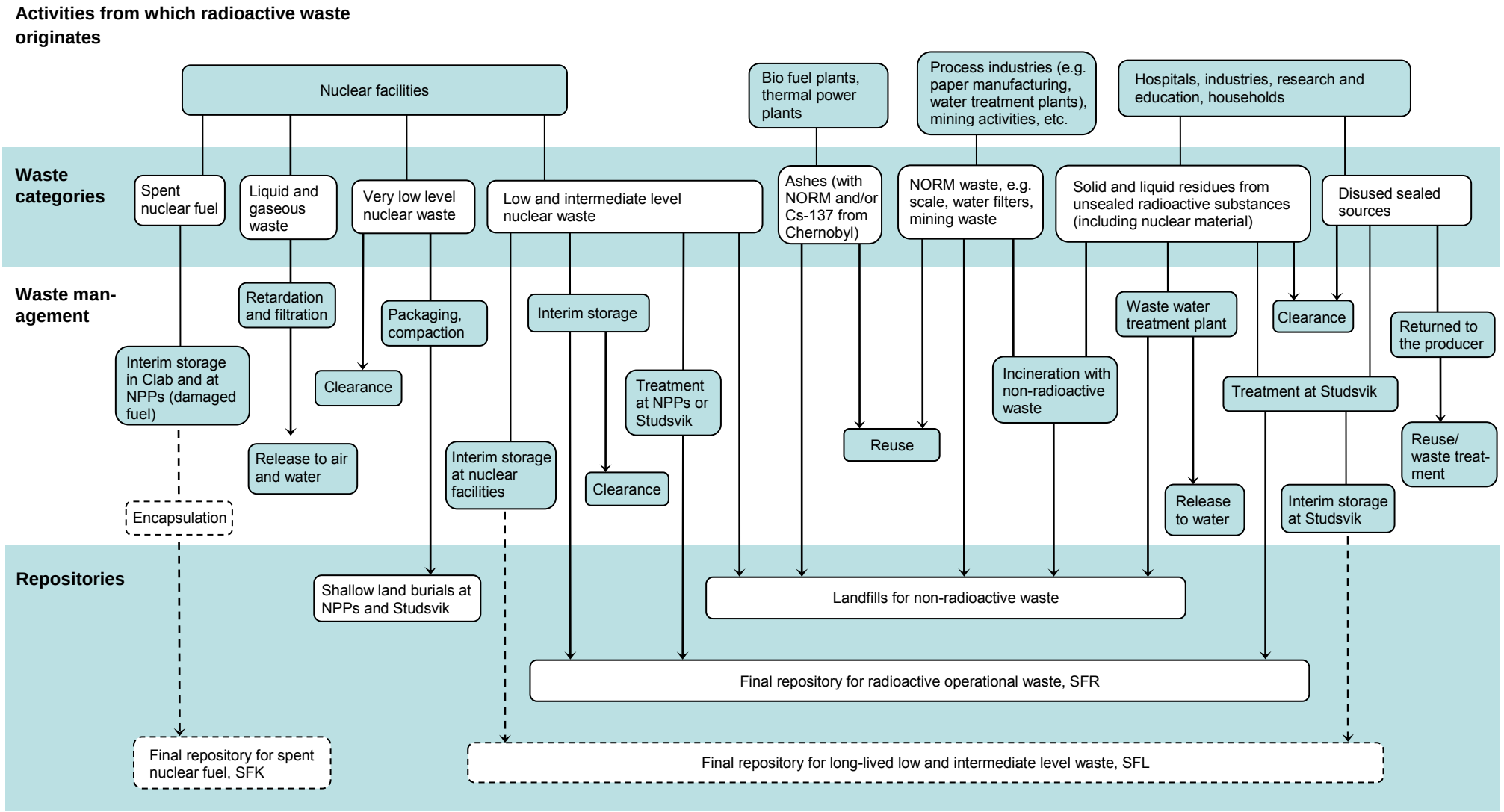
Radioactive waste in Sweden

Figure 1 provides an overview of the flows of radioactive waste that exist in Sweden today and presents the activities within which the waste arises along with the categories the waste is divided into.

The way in which waste will be managed depends on the type of waste, for example whether it contains short or long-lived nuclides. The figure shows, among other things, that despite the fact that radioactive waste arises in completely different activities, in several cases individual waste streams can share common management and repository solutions.

In the following two chapters, a more detailed description is made of waste streams, divided into nuclear and non-nuclear activities. A more detailed picture can be obtained in the third national report under the waste convention [26], which was recently reviewed internationally.

Figure 1 does not show where in the system there is an absence of solutions as to how certain categories of waste should be disposed of. This is described in more detail in Part 1. It should also be pointed out that even in those cases where final disposal exists or is planned, there might be room for improvement in the waste management, which is partly dealt with in the action proposals described in Part 1.


Activities from which radioactive waste originates
Nuclear facilities
Bio fuel plants, thermal power plants
Process industries (e.g. paper manufacturing, water treatment plants), mining activities, etc.
Hospitals, industries, research and education, households
Waste categories
Spent nuclear fuel
Liquid and gaseous waste
Very low level nuclear waste
Low and intermediate level nuclear waste
Ashes (with NORM and/or Cs-137 from Chernobyl)
NORM waste, e.g. scale, water filters, mining waste
Solid and liquid residues from unsealed radioactive substances (including nuclear material)
Disused sealed sources
Waste management
Retardation and filtration
Packaging, compaction
Interim storage
Waste water treatment plant
Clearance
Returned to the producer
Interim storage in Clab and at NPPs (damaged fuel)
Clearance
Treatment at NPPs or Studsvik
Incineration with non-radioactive waste
Treatment at Studsvik
Release to air and water
Reuse
Reuse/ waste treatment
Interim storage at nuclear facilities
Clearance
Release to water
Interim storage at Studsvik
Encapsulation
Repositories
Shallow land burials at NPPs and Studsvik
Landfills for non-radioactive waste
Final repository for radioactive operational waste, SFR
Final repository for spent nuclear fuel, SFK
Final repository for long-lived low and intermediate level waste, SFL

Radioactive waste from nuclear activities

Radioactive waste which arises from nuclear power plants and other nuclear facilities is designated nuclear waste. It consists of material contaminated with radioactive substances and residual products from the fabrication of nuclear fuel. Spent nuclear fuel from nuclear reactors is another residual product with a very high level of radioactivity which also needs to be disposed of as radioactive waste and which, according to legislation, is regarded as waste after it has been placed in storage. Nuclear waste from the operation of nuclear power plants or other nuclear facilities qualifies as low- or intermediate-level waste.

Table 1 shows the various sources of nuclear waste in the nuclear fuel cycle: uranium mining (Ranstadsverket), fuel production (Westinghouse Electric Sweden AB, WSE), nuclear power plants (KKV) and interim storage for spent nuclear fuel (Clab) and the facilities in Studsvik. The latter have two licence holders: AB SVAFO, responsible for historic waste with related historic facilities and Studsvik Nuclear AB, which runs commercial management of nuclear material and nuclear waste, including the decommissioning of its own facilities, among them the research reactors R2 and R2-0.

Waste management

At nuclear power plants and other nuclear facilities, different types of treatment of radioactive operational waste takes place so that it can be disposed of directly or put into interim storage pending disposal. Very low-level nuclear waste is stored in local shallow land burials at Studsvik and at the Forsmark, Oskarshamn and Ringhals plants. Low- and intermediate-level nuclear waste is placed in the repository for radioactive operational waste, SFR, next to the Forsmark plant. Very low-level waste may also be released for unrestricted use according to the Act on Radiation Protection [7] and the Act on Nuclear Activities [4], and may then be used freely, incinerated or disposed of on a municipal landfill site. Long-lived low- and intermediate-level waste (for example scrap metal from maintenance and the exchange of internal parts from reactors) is in interim storage until further notice at the nuclear power plants, Studsvik or Clab. Spent nuclear fuel and high-level waste, in the form of scrap metal from maintenance and the exchange of internal parts for reactors will be in interim storage for a few years at the nuclear power plants and is later transported to Clab. In the event of the decommissioning of nuclear facilities, large amounts of radioactive materials are generated, which need to be disposed of in more or less the same way as low- and intermediate-level operational waste.

Since the 1980's, well-established systems and methods which are under the supervision of the Swedish Radiation Safety Authority have been applied to the management and disposal of spent nuclear fuel and most of the nuclear waste. The nuclear power industry is, according to the law, obliged to carry out research and develop these systems. The research and development programme is previewed every three years by the authorities (see next section). The arrangements for financing these activities and the costs involved relating to the decommissioning of nuclear facilities are determined by law [5].

The nuclear power industry's programme for research, development and demonstration

Every third year, SKB submits its programme for research, development and demonstration (the Fud programme) regarding the management and disposal of nuclear waste and the decommissioning of nuclear facilities to the Swedish Radiation Safety Authority.

The latest Fud programme was presented in 2007 and was the eighth ordinary programme of the series, which started with the R&D programme in 1986. The reporting takes place in accordance with section 12 of the Nuclear Activities Act [4]. Since 2003, the Fud programme also deals with social research. Part of the programme includes an overview of all planned measures for the management and disposal of waste and for the decommissioning of finally shut down facilities. The programme also provides a report of the measures which the SKB and the nuclear power companies intend to carry out over the following six years.

The Swedish Radiation Safety Authority submits the programme to other authorities, universities, non-profit-making organisations that receive funding from the Nuclear Waste Fund, candidate site municipalities, etc., for their consideration. The Swedish Radiation Safety Authority analyses and evaluates the programme and submits it together with its opinions to the government. In its statement the Swedish Radiation Safety Authority proposes conditions for the programme and the further research and development activities. The government then makes a decision regarding the programme. The government can specify conditions for the continued work and also request that the programme is further developed. Further development has been requested three times since 1986.

Since the Fud programme 2004 SKB includes some of the authority's viewpoints from the examination of the previous Fud in its reporting. This makes it easy to follow up regarding whether the SKB and the nuclear power companies have taken the authority's points of view into consideration.

Table 1. Radioactive waste from nuclear activities.

Origin of waste	Waste category	Radionuclides	Activity concentration	Annual quantity, current value	Total amount	Handling and interim storage	Disposal	Trend	Comments
Ranstad	Decommissioning waste	Natural and enriched uranium	LLW-LL, < 10 MBq α/kg	–	Approx. 20 tonnes	Packaged, solidificated, will be stored in AM	SFL	–	Including some existing waste. Small amount of enriched uranium
		Natural and enriched uranium	VLLW-LL, < 100 kBq α/kg	–	400 tonnes	Decontaminated, handled in bulk	Landfill	–	Small amount of enriched uranium
	Historic process waste, leaching residues	Natural uranium	VLLW-LL, < 30 kBq α/kg	–	1.7 million tonnes	Handled in bulk	Leaching residues repository	–	Terminated activity
WSE, incl. RMA	Operational waste	Enriched uranium	LILW-LL, VLLW-LL, < 3 MBq α/kg	45 tonnes	–	Recycled, packaged, incinerated; stored at WSE and RMA	SFL, SFR or landfill	May increase	At present, 255 tonnes at RMA. Some streams to be re-planned
	Decommissioning waste	Enriched uranium	LILW-LL, < 3 MBq α/kg	–	180 m^3	Decontaminated, packaged	SFR, SFL	–	
		Enriched uranium	VLLW-LL, < 100kBq α/kg	–	1040 m^3	Decontaminated, packaged, handled in bulk	Landfill	–	
	Process waste	Enriched uranium with daughters	VLLW-LL, < 10 kBq α/kg	< 700 tonnes	–	Handled in bulk, stored WSE	Landfill	May increase	Proportional to production
	Service waste	FP	LILW-SL, VLLW-SL	1.5 tonnes	–	Packaged, incinerated	SFR	-	
NNP + Clab	Operational waste	FP, IA	LILW-SL, < 5 GBq/kg	< 1,500 m^3	51,000 m^3	Solidificated, packaged	SFR	May increase	After 50 years of reactor operation
		FP	VLLW-SL, < 160 kBq/kg	Approx. 1,000 m^3		Packaged	Ground-level storage	Increasing	Total amount depends on operating time
		IA, FP	LILW-LL, < 100 GBq/kg	Intermittent	2,800 m^3	Packaged, stored in BFA	SFL	Increasing	Storage in BFA not started, except for OKG. Approx. 1,000 m^3 is stored at present at NPP
	Spent nuclear fuel	FP, An, IA	–	Approx 210 tonnes	12,000 tonnes	Stored in Clab, encapsulated	SFK	May increase	
	Decommissioning waste	FP, IA	LILW-SL, < 5 GBq/kg	–	150,000 m^3	Packaged, solidificated	SFR	–	
		IA, FP	LILW-LL, < 100 GBq/kg	–	6,900 m^3	Packaged, stored in BFA	SFL		
Studsvik	Historic	FP, IA	LILW-SL	–	–	Packaged, stored in Studsvik		–	No longer separated from LILW-LL
		An, FP, IA	LILW-LL/SL	–	5,200 m^3	Packaged, stored in Studsvik	SFL	–	1,800 m^3, according to SKB [27], reasons described above
	Operational waste	FP, IA	LILW-SL,	Varies, approx. 40 m^3/year	5,400 m^3	Packaged, solidificated, stored in Studsvik	SFR		Total amount to 2030
		FP	VLLW-SL, < 300 kBq/kg	Varies, approx. 200 kg/year	–		Ground-level storage	–	Permit for 1,540 m^3 to 2010, not separated from historical waste
		IA, An, FP	LILW-LL	Small amounts of fuel residues (kg), in total approx. 36 m^3/year			SFL		Total amount included in the historic waste above

Table 1, continued. Radioactive waste from nuclear activities.

Origin of waste	Waste category	Radioactive nuclides	Activity concentration	Annual quantity, current value	Total amount	Handling and interim storage	Disposal	Trend	Comments
Studsvik, continued		Nuclear material (as waste)	Thorium	–	2.5 tonnes	Packaged	SFL or sold	–	
			Corroded R1 fuel	–	82 kg	Method not determined	SFK	–	
			Uranium, recycled (REPU)	–	9 tonnes	Packaged	SFL	–	From Ågesta
			Plutonium	–	3.3 kg	Method not determined		–	
	Demolition waste	Short-lived	LILW-SL	–	5,000 m^3	Packaged, solidificated	SFR	–	
		Long-lived	LILW-LL	–	500 m^3	Packaged	SFL		

Comments and explanations to the table

Origin

Operation and decommissioning waste from old nuclear facilities (e.g. Ågesta district-heating nuclear plant and research reactor R1) has not been reported separately. The decommissioning of Ågesta is not included in SKB's plans, but is entirely managed, until further notice, by Vattenfall AB. The amount of waste from Ågesta can, however, be regarded as covered by the figures for the nuclear power plants and Clab. At Ågesta there are, at present, approximately 15 tonnes of waste in the form of control units, drain plugs and other core components, with approximately 1 TBq beta/gamma. Also, 22 tonnes of spent fuel from Ågesta were taken to Clab from Studsvik during the 1980s.

Radioactive nuclides

FP = fission products, such as strontium-90 and caesium-137
An = actinide isotopes, such as uranium-238, plutonium-239 and americium-241
IA = induced activity (from neutron activation), such as cobalt-60 and nickel-63

Activity concentration

LILW=low- and intermediate-level waste (ILW, requires radiation shielding when being handled)
LLW=low-level waste (does not require radiation shielding when being handled)
VLLW=very low-level waste (can be disposed of at a landfill or in a shallow land-burial, often without being packaged)
SL=short-lived, half-life period for the dominating nuclides is up to approx. 100 years
LL=long-lived, half-life period for the dominating nuclides is greater than approx. 100 years

The values specified for the activity concentration are either estimated maximum values for specific packages, average values for the entire waste stream or are based on what is permissible to deposit. The values are approximate and are only provided to give an estimate regarding the main difference between various streams. For the monitoring and control of the handling of waste, more exact details are available for specific waste posts and deposition occasions.

Annual quantity

The estimated annual production is indicated here as an amount or volume per year. In some cases, there is no purpose in specifying any values because the waste is generated irregularly or the stream relates to waste not yet been produced, for example from decommissioning.

Total amount

The total amount of operational waste depends on how long each facility is expected to be in operation. Variations in this data between different sources depend, therefore, on when the estimation was carried out and in what context. The values specified here provide a good picture of the scope of how much is dealt with and agrees, more or less, with the industry's planning documentation for disposal. Inactive waste and waste which can be cleared/recycled is not included. (The amount of waste from conventional demolition of buildings at NNPs amounts to approximately 3 million tons).

Handling and interim storage

Specified here is how the waste is handled and stored. Handling in bulk means that it is not packaged but is taken directly to a repository. Solidification of certain types of waste is carried out in cement or bitumen (asphalt). Storage can be carried out at the producer's premises, in Clab (for spent fuel), in OKG's warehouse for waste (BFA) or at Studsvik. All of these storage areas are located in underground cavities.

Disposal

Final storage of short-lived low- and intermediate-level waste from operations and demolition takes place (or will take place) in SFR. Long-lived waste of this type is planned for disposal in SFL, a deep geological repository which is planned to become operational in 2045.

Waste can be disposed of in shallow land burials, which are facilities with licences according to the Act on Nuclear Activities, or in different types of repositories for industrial non-radioactive waste. For this kind of disposal, the waste must first have been exempt/released from the Act on Nuclear Activities and the regulations in the Act on Radiation Protection.

Trend

This section deals with whether the waste stream is expected to increase or decrease.

Radioactive waste from non-nuclear activities

The non-nuclear activities that use radiation in accordance with the Act on Radiation Protection can more or less be divided into health care, research and education and industrial activities. The radioactive waste resulting from these activities consists of various types of nuclides, activities and quantities. There are also a number of consumer articles that contain radioactive materials, for example fire alarms. Radioactive waste can also arise as a side effect within an activity which (initially) cannot be related to the concept *activity with radiation*, for example in process industries where large amounts of water flow through tube systems and as a result naturally occurring radioactive substances in the water are deposited in the pipes. This type of waste is called NORM waste.

Information regarding radioactive waste streams from non-nuclear activities has previously been compiled in different contexts by the then Swedish Radiation Protection Authority. In connection with the present report being drawn up, the information has been summarised [28]. Here follows an outline regarding waste streams from non-nuclear activities which describes where the waste arises and how it is managed and finally disposed of. Tables 2 and 3 illustrate the different categories of radioactive waste from non-nuclear activities in more detail. They cover most types of waste but the tables are not comprehensive. Because the various types differ so much from each other, there are limitations to the comparative figures that can be used. Sometimes, it is the activity which is a characteristic comparative figure; in other cases it may be more relevant to specify the amount by weight or volume.

Table 2 refers to various products, such as radiation sources and other types of industrial products, as well as consumer articles. Table 3 refers to waste types which have a common denominator, that they contain raised levels of naturally occurring radioactive materials, so-called NORM waste. This group also includes what we call the Chernobyl-related waste, i.e. radioactive waste which contains caesium-137[3].

Waste from open radiation sources

Open radiation sources are used primarily in the form of solutions, but also as gases or powders in nuclear medicine, research operations and tracer-element studies in the process industry or field research. In most cases the radioactive nuclides have a short half-life period, for example teknetium-99m and iodine-131, which is favourable from a waste point of view. The waste is placed in interim storage by the licensee until its activity has dropped below the nuclide-specific level permitted by regulations. The waste can then be sent for incineration as non-radioactive waste. In the pharmaceu-

[3] Caesium-137 has a half-life of about 30 years. Release of the material across parts of the country has occurred as a result of human activities: atmospheric nuclear weapons testing up to 1963 and the release into the air following the Chernobyl accident in 1986. In those areas where caesium-137 still occurs in nature, it is sometimes appropriate to deal with the substance together with the naturally occurring radioactive materials within the group NORM.

tical industry, radioactive waste with carbon-14 and tritium exists which is in excess of the prescribed limitations.

Disused sealed sources

Sealed radiation sources are used in many different areas of application, in research, health care and industry. The health-care services use sealed high-activity radioactive sources for radiation treatment and in blood irradiation equipment. Common nuclides include cobalt-60, iridium-192 and caesium-137. In research and industrial operations, sealed radiation sources are used in many applications and with many different radioactive nuclides. In research, irradiation equipment is used with strong radiation sources, primarily with caesium-137 and cobalt-60 sources, for biological, technical and physical research. In addition, a number of odd radiation sources are used for diverse applications in research. In the process industry, many types of permanently installed equipment with radiation sources for analysis and monitoring are used, such as: level monitors, weight-per-unit-area gauges and density gauges. In industry, many small radiation sources are used in portable equipment, for example to separate valuable metal in the scrap yards or to analyse a substance's chemical composition. Smaller radiation sources are also used for calibration and other metrological activities.

Certain consumer articles also include sealed radiation sources, for example ionising smoke detectors, compasses with tritium illumination, bearing compasses, bearing binoculars and night reticles. Sealed radiation sources are used for the calibration of instruments and for exercise and development purposes by the military. There are also a large number of products which contain tritium as a night aid, for example glow-in-the-dark luminous signs and luminous instrument panels.

NORM waste and Chernobyl-related waste

Waste with naturally occurring radioactive materials, so-called NORM waste, arises in activities which, in general, are not considered activities with radiation. A few examples of NORM waste include water filters with uranium, pipes with deposits of uranium and radium, drill cuttings from uranium exploration and demolition waste which contains blue concrete.

Caesium-137, from the fallout from Chernobyl, is not a naturally occurring radioactive material; it should, instead, be regarded as an *occurring substance in nature* after the accident. However, the handling of, for example, caesium-containing wood fuel ash should be dealt with based on similar principles as NORM waste.

Uranium exploration and uranium mining

Uranium exploration leads to small amounts of drill cuttings which may contain uranium in concentrations exceeding exemption levels. The Swedish Radiation Safety Authority therefore requires that there is a licence for activities of this kind.

The mining of uranium is considered a nuclear activity and requires a permit from the government and consent from the municipality concerned. There are no such applications submitted to the Swedish Radiation Safety Authority today. An application for this type of extraction/mining, and the report in the consultations required in connection with the EIA (Environmental Impact Assessment), must include types and quantities of waste, and other environmental consequences this type of extraction would lead to. Uranium mining is also considered an activity with radiation, and any licence for the activity would come with radiation protection conditions.

Waste management

Waste from open radiation sources which lies under the specified activity levels in SSMFS 2008:50 [21] may be released into municipal drainage systems or disposed of on a landfill for non-radioactive waste. Much of the waste that is produced may be dealt with in this manner, but a small amount of waste from open radiation sources must be disposed of as radioactive waste. This is sent to Studsvik Nuclear AB to be incinerated together with other forms of waste contaminated with radioactive substances, from laboratory activities, before it is disposed of in SFR. Another category of waste from open radiation sources which must be disposed of as radioactive waste includes the residues from nuclear materials, for example uranium compounds in powder or soluble form. The waste is placed in interim storage at Studsvik until it can be sent to the planned repository SFL.

For disused sealed sources, the radioactive nuclides' half-life in general are so long and the activities so high that it must be dealt with as radioactive waste. A limited number of calibrated radioactive sources used in laboratories, and which are under 50 kBq, may be sent to municipal landfills.

Most of the radioactive waste which comes from health care, research and education and non-nuclear industrial activities, and which is to be disposed of in Sweden, is dealt with by Studsvik Nuclear AB. Studsvik treats, sorts and packages the waste prior to the final storage. Studsvik states that they receive around 200 sealed radiation sources every year, excluding fire alarm warning devices [19], a figure which fluctuates somewhat from one year to the next, but which is relatively stable. Most sealed radiation sources with relatively short half-lives are generally returned to the supplier. Disused sealed sources are, more or less, always sent back to their country of origin.

When the waste is transferred to Studsvik, Studsvik resumes the ownership of the material and thus becomes responsible for its management and disposal. Since 1983, Studsvik have had an agreement with SKB regarding the deposition of low- and intermediate-level waste in SFR. Within the framework of the agreement, radioactive waste from non-nuclear activities is also deposited there. Waste which cannot be deposited in SFR is generally long-lived and is placed in interim storage at Studsvik pending a new agreement with the SKB regarding future deposition in the planned SFL repository.

To clarify the management and disposal of the radioactive waste from non-nuclear activities at Studsvik, the authority has requested that Studsvik, no later than 31 December 2010, reports on its plans regarding how the radioactive waste will be managed and disposed of [30]. For waste which must be deposited in SFL, Studsvik is assuming that a new agreement will be reached

with the SKB. In this context, it may be mentioned that, in the agreement regarding the deposition in SFR, SKB has agreed to 'plan and dimension its other waste facilities so that waste of another type other than that covered by this agreement (high-level waste and decommissioning waste) from Studsvik can be disposed of there' [29)].

It might be possible that the majority of the radioactive waste from non-nuclear activities can be disposed of in facilities which are run or planned by the SKB. Today, some of the waste is placed in SFR whereas other parts of the waste may be deposited in SFL, when this repository is eventually put into operation. The waste must be placed in interim storage in the meantime, which leads to a degree of uncertainty regarding how long the waste must be stored, whether it is appropriate to deposit it in SFL and how the waste must be conditioned to fit the unknown requirements for SFL.

The regulation of NORM waste and Chernobyl-related waste is, at present, being investigated by the Swedish Radiation Safety Authority. Caesium-containing wood fuel ash is today regulated in the regulations SSMFS 2008:16 [31]. New regulations which will regulate peat ash that may contain naturally occurring radioactive materials, including caesium, are being drawn up.

Guidelines for uranium exploration have been published. The licences which the Swedish Radiation Safety Authority issues for uranium exploration include conditions for the management of waste, which means that drill cuttings may be deposited in the bore hole or at landfills for non-radioactive waste. There are also guidelines for the handling of blue lightweight concrete as demolition material. General regulations are being drafted regarding the release of NORM waste, which includes clearance for a specific purpose for such materials that can be disposed of in landfills for non-radioactive waste or which can be recycled. It is worth noting that regulations of this kind are based on radiation protection principles and does not take into consideration any other environmental requirements.

Table 2. Radioactive waste from non-nuclear activities, consisting of radiation sources, industrial products and consumer articles. The table is a reworked version of the summary in table form that has been developed in [28].

Product and origin	Radionuclides	Activity	Annual quantity, current value	Total amount	Handling and interim storage	Disposal	Trend	Comments
Sealed radiation sources mainly from health care and research	Ra-226	Very high	Sporadic radiation sources	A larger amount of sporadic radiation sources	Stored at Studsvik	Will eventually be deposited in SFL	Decreasing, historic activity	High-level radiation sources which require radiation shielding when handled
Products and remains from industry, research, health care and consumer articles	Ra-226	Varying	Sporadic articles	Large amount	Stored at Studsvik	Will eventually be deposited in SFL	Decreasing, historic activity	Radium is used, among other things, in luminous paint in older instrument panels/dashboards and watches/clocks
Overvoltage arrestors	Pm-147	50–100 kBq/kg	–	Tens of thousands	Collected and stored at Studsvik		Do not arise any longer, historic activity	Pm-147 has a short half-life period (2.5 years), which means that it no longer needs to be regarded as radioactive waste
Orphan sources from the health-care sector, industry and research	Co-60, Cs-137, Am-241, etc.	Varying	Sporadic radiation sources	–	Stored at Studsvik	Most taken to SFR	Unchanged	Mainly sealed radiation sources
Urine and excrement (open radiation sources) from the health-care sector	I-131, etc.	Significant	Considerable activity to water supply and sewage disposal	–	–	Goes directly to water supply and sewage disposal	Unchanged	Half-life for I-131 is eight days. Decays quickly. Even if the waste reaches municipal waste facilities, it does not constitute a long-term waste problem.
Products and remains from open radiation sources in the form of hypodermic syringes, remains of paper etc.	Short-lived	Significant	Considerable activity in primary waste	–	Stored in order to decay	Municipal waste treatment	Unchanged	Release may be available for waste which contains low levels of long-lived nuclides
Products and remains from open radiation sources	Long-lived	Moderate	A few tonnes	Moderate volumes	Collected, sorted and stored pending deposition	Municipal waste treatment or SFR	Unchanged	
Orphan sources from the health-care sector, industry and research	Co-60, Cs-137, Am-241, etc.	Very high	≈ 200 sources	Large amount	Stored at owner or Studsvik, or returned to supplier	Most taken to SFR, some will eventually be deposited in SFL	Unchanged	Producer responsibility applies
Gaseous sealed radiation sources from industry	H-3, C-14 and Kr-85	Varying	≈ 10 sources	Large amount	Stored at owner or Studsvik	Being investigated	Unchanged	
Consumer articles with luminous paint	H-3, Ra-226 etc.	Normally less than exemption levels per unit	Hundreds of articles	Large amount	No uniform handling and storage	No uniform deposition	No important changes are expected	Individual units may have activity levels that exceed the exemption levels. The odd tin with luminous paint remains which contain significant activity may occur.
Fire-alarm devices	Am-241	Up to 40 kBq per unit	Approx. 60,000 units	Approx. 7 million	Collected by supplier and sent to Studsvik for treatment and interim storage	Will eventually be deposited in SFL	Constant over the next 10 years	The Swedish Radiation Safety Authority's estimation of the number of units to be disposed of. Approx. 14 million units have been sold over the years, an indeterminate number have been thrown away in repositories for non-radioactive waste in accordance with regulations which are no longer in force. New sales have reduced heavily

Table 2, continued. Radioactive waste from non-nuclear activities, consisting of radiation sources, industrial products and consumer articles. The table is a further-processed version of the summary in table form that has been developed in [28].

Product and origin	Radionuclides	Activity	Annual quantity, current value	Total amount	Handling and interim storage	Disposal	Trend	Comments
Smoke detectors	Am-241	Up to 200 kBq per unit	Approx. 5,000 units	Almost 2 million	May be returned to the supplier, the radiation sources are sent to Studsvik for interim storage	Will eventually be deposited in SFL	Constant over the next 10 years	New sales have reduced heavily. The Swedish Radiation Safety Authority is planning to forbid smoke detectors that are of the ionising type
Depleted uranium	Uranium	≈ 10^4 kBq/kg	Hundreds of kilos	Moderate	Collected for transport to Studsvik for interim storage	Will eventually be deposited in SFL	No important changes are expected	Large variations can be expected each year, as there are only a few units which vary in volume
Glazings containing uranium	Uranium	Low	Moderate	Moderate	Sent to Studsvik for interim storage	Will eventually be deposited in SFL	No important changes are expected	It is unlikely that sporadic glazed objects will be sent to Studsvik
Products containing thorium: welding electrodes, aircraft parts, incandescent mantles	Thorium	Normally less than the exemption levels per unit	Moderate	Moderate	No uniform handling and storage	No uniform deposition	No important changes are expected	

Table 3. NORM waste and Chernobyl-related waste. The table is a further-processed version of the summary in table form that has been developed in [28].

Product and origin	Radionuclides	Activity concentration kBq/kg	Annual amount	Total amount	Handling and interim storage	Disposal	Trend	Comments
Burnt alum shale	Uranium + daughter nuclides	2.5–5, could be higher	–	Millions of tonnes		Deposited in special repositories	Terminated activity	Residue after the use of alum shale. Comprises historic repositories
Phosphogypsum	Uranium + daughter nuclides	0.6–2.5	–	Millions of tonnes		Deposited in special repositories	Terminated activity	The largest repository is in Landskrona
Inorganic fertiliser production	Uranium + daughter nuclides		–				Terminated activity	There is no information about activity levels in residual products from the production of inorganic fertiliser
Old waste rock	Uranium + daughter nuclides	Locally, more than a few dozen	–			Deposited in special repositories	No longer produced	The information relates to old waste rock piles with boulders where uranium mineralisation occurs
Old iron ore slag	Uranium + daughter nuclides	2–10	–		Taken directly to local repository	Deposited in special repositories	No longer produced	Old iron ore slag has also been used as filling and as a building material
Blue lightweight concrete in demolition materials	Uranium + daughter nuclides	0.5–3.5	Thousands m^3	Millions of tonnes		Being investigated	Unchanged over a long period of time	Recycled at present, usually for construction purposes where settlements are not planned
Building gypsum	Uranium + daughter nuclides					Deposited as demolition waste	Constant	No information available regarding activity levels in gypsum that is used
Coal ash	Uranium and thorium + daughter nuclides	No measurements available	Significant (1 million tonne)	Millions of tonnes		Deposited	Constant	Global mean value etc. available via statistics
Peat ash	Uranium and thorium + daughter nuclides (Cs-137)	< 10 (< 2)	30,000 tonnes	< 1 million tonnes	Used, among other things, for construction as filling material		Constant	Peat ash also contains ^{137}Cs from fallout
Wood fuel ash	Cs-137	< dozens	100,000 tonnes	Millions of tonnes	Used as filling material, for example	< 10% deposited	Constant	Regulated by the Swedish Radiation Safety Authority. Ash with specific activity > 10 kBq/kg is placed in a repository
Water purification filter	Uranium + daughter nuclides			Low		Filter from wells sent to repository for non-radioactive waste	Increase expected	Investigation underway regarding disposal of filters from a number of municipalities' groundwater plants
Coatings on pipes from process industry etc.	Uranium + daughter nuclides		Moderate	Low	Interim storage, in some cases at owner	Being investigated	Constant	Better monitoring of scrap yards over the past decade has brought to light the waste stream
New waste rock	Uranium + daughter nuclides	< 1	Millions m^3	Millions of tonnes	Taken directly to local repository	Deposited in special repositories	Constant	The mining does not relate to uranium, which is not mined today
New iron ore slag	Uranium + daughter nuclides	< 1	Very large				Constant	Does not normally have to be regulated for radiation protection purposes
Zircon sand	Uranium and thorium + daughter nuclides		480 tonnes	Low			Constant	

Actors and division of responsibilities

A clear division of responsibilities between the actors concerned is important in trying to achieve a purposeful waste-management system. Described in this chapter is the legal framework that forms the basis for the responsibility for radioactive waste together with an account of the actors that play important roles in the waste management.

The responsibility for radioactive waste – legal conditions

For the most part, the requirements in the Act on Nuclear Activities [4], the Act on Radiation Protection [7] and the Environmental Code [10] represent the legal framework regarding the handling of radioactive waste. At present, an inquiry is being carried out regarding a coordinated regulation of the nuclear safety and radiation protection fields [11]. In particular, the inquiry will loom into the possibilities of bringing together the provisions in the Act on Nuclear Activities and the Act on Radiation Protection to form a single law. The inquiry also touch upon the relationship to the Environmental Code and will report its findings no later than 30 April 2010 (a progress report regarding, among other things, the generation change for Swedish nuclear power installations shall be presented on 7 September 2009). The legal conditions can therefore change in the future. However, the actual provisions regarding, for example, responsibility for the waste, will not be affected.

According to the Swedish law, radioactive waste is to be divided into waste which arises from nuclear activities and waste which arises from non-nuclear activities. For both categories of waste, there is an explicit responsibility for 'the polluter to pay' for any environmental disorder generated by activities such as the management and disposal of the waste in a safe manner. This Polluter Pays Principal (PPP) is also expressed in the Environmental Code and in several international agreements.

The Act on Nuclear Activities only covers nuclear radioactive waste (i.e. nuclear materials and spent nuclear fuel). The Act on Radiation Protection applies to both nuclear radioactive waste and other radioactive waste. In parallel with these acts, the Environmental Code also applies, irrespective of whether it relates to nuclear waste or other radioactive waste.

The Act on Nuclear Activities

The Act on Nuclear Activities contains basic provisions regarding safety in connection with nuclear activities. The act also contains far-reaching demands on the licence holder to ensure that all produced nuclear waste and spent nuclear fuel is handled. The responsibility means that the licence holder must take all measures needed to ensure that the waste will be managed and disposed of in a safe manner and also that plants in which nuclear activi-

ties are no longer to be carried out are decommissioned and dismantled appropriately.

The Financing Act

In the Financing Act [5] is defined the responsibilities for costs assumed by the holders of a licence to operate nuclear facilities, with regard to the management and disposal of spent nuclear fuel and nuclear radioactive waste. The Act also includes regulations on nuclear waste fees, which the licensees must pay to the state to ensure that the costs associated with waste management are met.

The Studsvik Act

The Studsvik Act [6] includes special financing arrangements for the management of nuclear waste from older experimental facilities, which are linked to the development of the Swedish nuclear power programme. This Act expires at the end of 2011.

The Act on Radiation Protection

According to the Act on Radiation Protection [7], the owner of radioactive waste always has the primary responsibility for the safe management of the waste. For waste from certain radioactive products, the owner of the waste may hand over the responsibility to a producer when there is one that is obliged to dispose of the waste according to the regulations on producer liability. This is described in more detail in the following section.

A degree of uncertainty prevailed whether NORM waste was covered by the Act's requirements for waste management. This led to section 13 of the same Act being changed in 2006. According to the Act, the owner of radioactive waste must manage, and if need be dispose of, the waste irrespective of whether or not the waste arose in an activity whereby the purpose was to make use of the ionizing radiation from a radiation source of any kind.

The Producer Liability Ordinances

With the support of Chapter 15, section 6 of the Environmental Code [10], the government has decided on two producer responsibility ordinances which are of immediate interest for radioactive waste; the Ordinance (2005:209) on Producer's Responsibility for Electrical and Electronic Equipment [8] and the Ordinance (2007:193) on Producer's Responsibility for Certain Radioactive Products and Orphan Sources [9]. The producer liability for product waste with radioactive materials means partly an obligation for the producer to be responsible for the collection, management and disposal of the radioactive waste and partly an obligation to provide financial guarantees for the waste's management and disposal. The basis of the argument is that the system of producer liability will cover all products that make use of radioactive materials, from high-activity sealed radioactive sources to fire alarm warning devices and other consumer products. The producer lia-

bility also includes historic waste. The producer, who is also carrying out activities involving radiation, is obliged to take care of the waste and comply with the regulations described in section 6 of the Environmental Code, including the regulations on the handling of waste contained in chapter 15 of the same code.

Some discarded products that contain radioactive materials are subject to ordinance 2005:209 [8], i.e. electrical or electronic products which contain radiation sources (for example, medical equipment and monitoring and control equipment). For other radioactive product waste, ordinance 2007:193 [9] applies.

The Environmental Code

The Environmental Code [10] also includes activities involving radiation. In parallel with the regulations in the Act on Radiation Protection and the Act on Nuclear Activities, the provisions in the Environmental Code also apply. According to these, everyone who has pursued an activity that causes damage or is detrimental to the environment shall be responsible for restoring it to the extent deemed reasonable (Chapter 2, section 8 of the Environmental Code). This applies irrespective of whether the activity is no longer operating or has been transferred. The obligation applies until the damage has been rectified. The scope of the responsibility is described in more detail in Chapter 10 of the Environmental Code.

Actors within the nuclear field

According to the Act on Nuclear Activities, a holder of a licence to operate a nuclear facility must take the necessary actions in order to manage and dispose of spent nuclear fuel and nuclear waste (nuclear waste management) in a safe manner. A licence holder can on approval by the Swedish Radiation Safety Authority instruct a third party to implement specific measures for nuclear waste management. Nevertheless, the licence holder still remains responsible for the spent nuclear fuel and nuclear waste and has to ensure its management and disposal. This fundamental responsibility cannot be transferred to anybody else.

Table 4. The licence holders of nuclear facilities in Sweden.

Licence holder	Facility
Barsebäck Kraft AB	Barsebäck nuclear power plant (finally shut down in 2005).
Forsmarks Kraftgrupp AB	Forsmark nuclear power plant, with associated shallow land burial and interim storage for core components.
OKG AB	Oskarshamn nuclear power plant, with associated shallow land burial and interim storage for core components.
Ringhals AB	Ringhals nuclear power plant, with associated shallow land burial
Vattenfall AB	Ågesta district-heating nuclear plant (finally shut down in 1974).
Westinghouse Electric Sweden AB	Nuclear fuel factory in Västerås.
Ranstad Mineral AB	Uranium recovery facility in Ranstad.
Studsvik Nuclear AB	Facilities for fuel and materials testing and waste management. Research reactors R2 and R2-0 at Studsvik (finally shut down in 2005)
AB SVAFO	Facilities for management and storage of waste at Studsvik.
SKB AB	Clab (Central interim storage for spent fuel) in Oskarshamn. SFR (Final repository for operational radioactive waste from nuclear power plants) in Forsmark.

According to the Financing Act [5], the licence holder must pay a nuclear waste fee which will cover future costs for the waste management. For the owners of the nuclear power reactors, it is also necessary that they carry out extensive research and development activities in consultation with each other. Those who carry out nuclear activities at a smaller scale or at a university or a similar institution do not need to pay a nuclear waste fee.

Interim storage, transport and final storage

The Swedish nuclear power companies have chosen to establish the SKB together. SKB was given the assignment to dispose of radioactive waste from the nuclear power plants. The SKB is responsible for two facilities: SFR, repository for operational radioactive waste from the nuclear power plants and Clab, central interim storage for spent nuclear fuel. SKB is also responsible for the radioactive waste being transported in a safe manner from the nuclear power plants to the storage facilities. Transportation often takes place by sea on the vessel Sigyn. SKB's assignment also includes the development of a solution regarding how the spent nuclear fuel will be disposed of and for the management of other long-lived waste and low- and intermediate-level decommissioning waste.

Studsvik Nuclear AB, AB SVAFO and Westinghouse Electric Sweden AB have reached an agreement with SKB regarding interim storage and disposal of nuclear waste in SKB's facilities. The nuclear power installations in Ringhals, Oskarshamn and Forsmark, and Studsvik Nuclear AB, have shallow land burials where very low-level radioactive waste can be disposed of.

Actors within the non-nuclear field

The number of activities that may give rise to radioactive waste in the non-nuclear field is a significantly larger and more heterogeneous group compared with the nuclear activities. Radioactive materials are used in many different areas of application in research, health care and industry. There are also consumer articles that contain radioactive materials. In some industries, naturally occurring radioactive materials, but also caesium-137 which is found in nature due to human activity, may concentrate and cause radioactive waste.

Operators of activities including radiation

According to the Act on Radiation Protection, everyone who conducts or has conducted activities which involve radiation is responsible for the radioactive waste that arises; that it is safely managed and in case it is needed disposed of. In certain cases the operator can, according to the Act, choose to hand over the waste to a producer of certain radioactive products, who is obliged to take care of the waste.

The operator is considered to have fulfilled his/her responsibility when the waste has been transferred to a producer or an approved waste management facility who can then assume responsibility for the waste.

Producers

Through two Ordinances, producer liability has been introduced for radioactive products. Ordinance 2005:209 [8] applies to electrical and electronic products, where many radiation sources can be found. Ordinance 2007:193 [9] applies to certain radioactive products and orphan sources. This means that the importer or retailer of a product are also responsible for collecting and dealing with the waste if the owner chooses to hand over the waste to the producer.

Transports

The transportation of radioactive waste is carried out by several transport companies, but it is the dispatcher, i.e. the owner of the waste, that has a licence for the transport according to the Act on Radiation Protection, and who is responsible for the waste being packaged and marked correctly. The transportation of such waste by road in Sweden is covered by the regulations from the Swedish Civil Contingencies Agency [32]; in some cases special licences may be required in accordance with these regulations.

Interim and final storage

Today, Studsvik Nuclear AB is the only approved Swedish facility that accepts radioactive waste for disposal. Studsvik will assume responsibility for the waste. Studsvik Nuclear AB has an agreement with the SKB to make use of the space in SFR, where waste is taken that passes the repository's criteria

and which mainly involves short-lived low- and intermediate-level radioactive waste. Studsvik retains its responsibility for the waste even after it has been placed in SFR. Long-lived low- and intermediate-level waste is placed in interim storage in Studsvik pending final storage, which is assumed to be a repository for long-lived radioactive waste which the SKB is planning to make operational by 2045.

Today, some operators receive low-level radioactive waste which has been exempted or released from regulatory control. This waste is often disposed of through deposition in landfills. Sometimes, waste is dealt with without it being known that it is classified as radioactive, for example demolition waste which includes blue lightweight concrete or water filters with raised levels of naturally occurring radioactive materials (NORM waste). Municipal actors are responsible for a significant part of the incineration of radioactive waste, in particular from hospitals, which has been released from regulatory control, and the removal of waste through deposition in landfills.

Authorities

Several authorities play an important role in the regulation and handling of radioactive waste.

The Swedish Radiation Safety Authority

The Swedish Radiation Safety Authority is an administrative authority for radiation protection and nuclear safety and works towards protecting people and the environment from the harmful effects of radiation, now and in the future. The Swedish Radiation Safety Authority conducts supervision of activities that give rise to radioactive waste at nuclear installations, hospitals, industries and research facilities. The authority examines the handling of all radioactive waste and produces regulations which describe what the limits are and the requirements that apply to different types of radioactive waste.

The Environmental Court

The Environmental Court consists of five individual courts which deal with the environment and water issues which are regulated in the Environmental Code. The Environmental Court reviews permits for environmentally hazardous activities and other environmental protection issues for nuclear facilities as well as facilities for the treatment of high-level radioactive waste and storage of radioactive waste. The Environmental Court also reviews facilities which handle, process, or provide interim or final storage for spent nuclear fuel, nuclear waste or other radioactive waste in accordance with the Act on Nuclear Activities or the Act on Radiation Protection.

The County Administrative Boards

At the County Administrative Boards, there are environmental assessment delegations that decide on permits for environmentally hazardous activities. The County Administrative Boards also participate in EIA processes in ac-

cordance with the Environmental Code and the Act on Nuclear Activities and, in certain cases, the Act on Radiation Protection. The County Administrative Boards also has supervisory responsibility in accordance with the Environmental Code for several operative functions where radioactive waste is handled. The County Administrative Boards' responsibilities include the coordination of the regional waste plans. The County Administrative Boards also works with the restitution and after-treatment of polluted areas where radioactive contaminants may be found.

The Municipalities

The municipalities act as an authority through environmental committees and municipal environmental administrations that supervise and review smaller environmentally hazardous areas of operation in accordance with the Environmental Code. The environmental administrations often inform the general public and companies about issues which concern waste management and they work with the after-treatment of contaminated areas and deal with issues that concern radon.

The municipalities are responsible for collecting and dealing with household waste, which includes planning for the disposal of radioactive waste from households. The municipalities are also responsible for establishing municipal sanitation systems and waste plans. In some cases, the municipalities operate their own waste management facilities; these may come in contact with and manage radioactive waste.

The Swedish Environmental Protection Agency

The Swedish Environmental Protection Agency has developed a national waste plan and strategy for sustainable waste management for all types of waste except for radioactive waste [12]. The authority has the guiding responsibility for planning and implementing after-treatment projects of contaminated areas. A certain proportion of their allocated funds may be used by the Swedish Radiation Safety Authority to deal with orphan radiation sources and radioactive materials which could otherwise produce harmful effects in society.

The Swedish Civil Contingencies Agency

The Swedish Civil Contingencies Agency is a new authority which is responsible for all work related to public safety, emergency management and civil defence. The authority issues regulations for the inland transport of dangerous goods, including radioactive materials, supported by the Transport of Dangerous Goods Act [33]. The Swedish Civil Contingencies Agency is also responsible for coordinating supervisory operations for road and rail transportation of dangerous goods.

The Swedish Transport Agency

The Swedish Transport Agency strives to achieve good accessibility, high-quality, safe and environmentally adapted transportation on the railways, in the air, on the seas and on the roads. The Swedish Transport Agency has the overall responsibility of developing regulations in this area and ensuring that they are followed. The Authority issues regulations for the sea and air transport of dangerous goods, including radioactive materials supported by the Transport of Dangerous Goods Act [33]. The Swedish Transport Agency is also a supervisory authority for the sea, air and railway transportation of hazardous goods.

The Swedish Customs and the Swedish Coastguard

The mission of both the Swedish Customs and the Swedish Coastguard is border protection. In principle, it is possible for them to temporarily take care of orphan sources in cooperation with the Swedish Radiation Safety Authority, the police, etc. The Swedish Customs have operational and supervisory responsibilities for the dumping and incineration of all types of waste, as regulated in chapter 15, section 31–33 of the Environmental Code. The authorities use vehicles with surveying equipment when they are searching for radioactive goods. The Swedish Coastguard exercises control and supervisory operations at sea and collaborates in international efforts to develop, among other things, border controls and environmental protection at sea.

The Swedish Coastguard is a supervisory authority for the transport of hazardous goods in harbours and surrounding areas and, at the request of the Swedish Transport Agency, at sea.

All other interested parties

Radioactive waste, irrespective of where it arises, affects and involves many people, even those outside the circle of bodies that have an explicit role and responsibility for the management of waste. In addition to individuals (for example, the general public, politicians and journalists), radioactive waste is an issue which is followed by several trade organisations, environmental organisations and non-profit-making associations.

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Appendices

Appendix 1. Socio-economic impact analysis

The analysis has not been translated into English. The text (in Swedish) can be found in SSM Report 2009:29, *Nationell plan för allt radioaktivt avfall*.

Appendix 2. Members of the joint action group

AB Jernbruksförnödenheter, JBFAB	Miljöorganisationernas kärnavfallsgranskning, MKG
AB SVAFO	Miljörörelsens kärnavfallssekretariat, Milkas
AstraZeneca AB	Miljövänner för kärnkraft
Avfall Sverige	Naturvårdsverket
Brandvarnargruppen	Nejtilluranbrytning
Barsebäck Kraft AB, BKAB	OKG AB
Chalmers Tekniska Högskola, CTH	Oskarshamns kommun
Forsmark Kraftgrupp AB	Ranstad Industricentrum AB
Försvarets materielverk, FMV	Ranstad Mineral AB
Gröna Kvinnor	Ringhals AB
ISS Industri/Kärnkraft	Sahlgrenska universitetssjukhuset/ Göteborgs universitet
Karolinska institutet, KI	Statens Energimyndighet
Krokoms kommun	Statens geologiska undersökning, SGU
Kustbevakningen	Stena Recycling AB
Kävlinge kommun	Studsvik Nuclear AB
Livsmedelsverket	Svensk Kärnbränslehantering AB, SKB
Lokala säkerhetsnämnden vid Oskarshamns kärnkraftverk	Svenska Energiaskor AB
Lokala säkerhetsnämnden vid Ringhals kärnkraftverk	Svenskt Vatten
Lokala säkerhetsnämnden vid Studsvik	Sveriges kommuner och landsting, SKL
Lunds universitet	Sveriges lantbruksuniversitet, SLU
Läkemedelsindustriföreningens Service AB, LiF	Uppsala universitet
Läkemedelsverket	Vattenfall AB
Länsstyrelsen i Kalmar län	Vattenfall AB Värme Uppsala
Länsstyrelsen i Uppsala län	Östhammars kommun
Länsstyrelsen i Västra Götalands län	

Appendix 3. Compilation of the joint action group's comments regarding the action proposals

The compilation has not been translated into English. The text (in Swedish) can be found in SSM Report 2009:29, *Nationell plan för allt radioaktivt avfall*.

Appendix 4. Abbreviations

BFA	Rock cavern for waste at OKG
Clab	Central interim storage for spent fuel
Fud	SKB's programme for research, development and demonstration (the Fud programme)
HASS	High-activity sealed radioactive sources
NNP	Nuclear Power Plants
NORM	Naturally occurring radioactive material
OKG	Oskarshamn nuclear power plant
RMA	Ranstad Mineral AB
SFK	Final repository for spent nuclear fuel
SFL	Final repository for long-lived low- and intermediate-level waste
SFR	Final repository for short-lived low- and intermediate-level waste
SKB	Swedish Nuclear Fuel and Waste Management Company
SKI	Swedish Nuclear Power Inspectorate
SSI	Swedish Radiation Protection Authority
SSM	Swedish Radiation Safety Authority
WSE	Westinghouse Electric Sweden AB

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The Swedish Radiation Safety Authority has a comprehensive responsibility to ensure that society is safe from the effects of radiation. The Authority works to achieve radiation safety in a number of areas: nuclear power, medical care as well as commercial products and services. The Authority also works to achieve protection from natural radiation and to increase the level of radiation safety internationally.

The Swedish Radiation Safety Authority works proactively and preventively to protect people and the environment from the harmful effects of radiation, now and in the future. The Authority issues regulations and supervises compliance, while also supporting research, providing training and information, and issuing advice. Often, activities involving radiation require licences issued by the Authority. The Swedish Radiation Safety Authority maintains emergency preparedness around the clock with the aim of limiting the aftermath of radiation accidents and the unintentional spreading of radioactive substances. The Authority participates in international co-operation in order to promote radiation safety and finances projects aiming to raise the level of radiation safety in certain Eastern European countries.

The Authority reports to the Ministry of the Environment and has around 270 employees with competencies in the fields of engineering, natural and behavioural sciences, law, economics and communications. We have received quality, environmental and working environment certification.

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