An International Peer Review of the Programme for Evaluating Sites for Near Surface Disposal of Radioactive Waste in Lithuania

Report of the IAEA International Review Team

IAEA
International Atomic Energy Agency

AN INTERNATIONAL PEER REVIEW OF THE PROGRAMME FOR EVALUATING SITES FOR NEAR SURFACE DISPOSAL OF RADIOACTIVE WASTE IN LITHUANIA

REPORT OF THE IAEA INTERNATIONAL REVIEW TEAM

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INTERNATIONAL ATOMIC ENERGY AGENCY
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FOREWORD

Lithuania's national Radioactive Waste Management Agency (RATA) is mandated by national legislation to find a disposal solution for radioactive waste arising mainly from the operation and decommissioning of the Ignalina nuclear power plant. A key step in the process of obtaining a disposal solution is to identify potential sites for detailed consideration. The RATA has completed this first step and is now directing a programme for detailed investigation of these sites.

In this context, the RATA requested that the IAEA, on the basis of its statutory mandate to establish safety standards and provide for their application, conduct a peer review of the safety of the proposed disposal concept. The objective of the peer review, carried out in December 2005, was to provide an independent assessment of the safety related aspects of the sites under consideration on the basis of international safety standards and applicable national standards. The review also considered the feasibility of the proposed reference design and its suitability for the local conditions. The peer review provides an independent opinion as to whether the RATA's siting and site characterization programme is consistent with international standards and agrees with good practice in other national disposal programmes.

Peer reviews are increasingly being acknowledged as an important component in building broader stakeholder confidence in the safety of facilities. For this reason, an increase in their number and frequency is anticipated. The coming into force of the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management has also focused attention on the demonstration of the safety of waste management facilities. This report presents the consensus view of the international group of experts convened by the IAEA to carry out the review.

This publication will be of interest to organizations responsible for the development and operation of facilities for the disposal of radioactive waste, regulatory bodies responsible for regulating their safety, technical support organizations and the broader range of stakeholders interested in or affected by the development of such facilities.

EDITORIAL NOTE

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SUMMARY

S01. Lithuania's national Radioactive Waste Management Agency (RATA) is mandated to find a disposal solution for the short lived low and intermediate level waste (LILW-SL) arising from the operation and decommissioning of the Ignalina nuclear power plant. As part of its obligations under the European Union Accession Treaty, Lithuania is required to shut down Units 1 and 2 of the Ignalina plant and to decommission them as soon as possible. Unit 1 was shut down on 31 December 2004, and Unit 2 is to be shut down by 2010. In 2002, the Government of Lithuania approved the adoption of the immediate dismantling strategy for decommissioning both units. A key component of this strategy is the disposal of operating and decommissioning waste in a near surface repository (NSR) that is to become operational by 2011. This NSR should have the capacity to hold approximately 100 000 m^3 of LILW-SL.

S02. The RATA is currently directing a site investigation programme in order to propose to the Government a preferred site for construction of the NSR. With support from the Swedish Government, the RATA developed a reference design for the NSR and finalized a site screening process that identified three candidate sites in the vicinity of the Ignalina nuclear power plant. Recently, the RATA concluded detailed investigations at the three sites. The next step in the programme is for the RATA to issue an environmental impact assessment (EIA) to the Lithuanian Ministry of Environment to provide information for the Government's decision concerning the preferred site. The EIA will also include information on repository design and safety assessment.

S03. In the light of the decision to be made, the RATA requested that the IAEA organize an international peer review to render an independent opinion on the RATA's siting and site characterization programme. The present report documents the findings and recommendations of the IAEA's international peer review. The objective of this review was to provide, on the basis of international and national safety standards, an independent assessment of the safety of the three potential sites currently being considered by the RATA. The objective included an evaluation of the technical feasibility of the reference design and its suitability for local conditions. The review provides the RATA with an independent opinion as to whether its programme is consistent with international standards and with good practice in other national disposal programmes.

S04. The review was carried out in December 2005 by an international review team appointed by the IAEA and technical specialists and professionals with a broad range of expertise in the field of radioactive waste disposal. To prepare

for the peer review, some six weeks prior to the review meeting the Review Team received translations of key technical reports detailing the RATA's programme of site investigation. The review meeting was held in Vilnius from 12 to 16 December 2005. The Review Team attended a number of technical presentations by the RATA and its support organizations that complemented and elaborated upon the material covered in the technical reports. The review meeting included a visit to each of the three sites under investigation. Three observers from Belarus and two from Latvia also attended the presentations and participated in the site visits.

S05. The findings and recommendations of the Review Team were grouped under six topics considered to be of fundamental importance for this stage of the RATA's programme:

- — Legal and regulatory framework for waste management;
- — Quality management system;
- — Inventory and waste characterization;
- — Site characterization and quality of characterization data;
- — Repository design;
- — Safety assessment.

S06. Each topic is reviewed in terms of international good practice and the observations and conclusions of the Review Team. The conclusions comment on meeting international good practice, identify areas where improvements are needed to meet the requirements for safety and provide additional suggestions for improvement.

S07. The Review Team concluded that the process of site characterization is being conducted according to international good practice and that the three sites being considered offer good prospects for meeting internationally recognized safety objectives and criteria. However, further work is necessary to improve and finalize site selection with a view to subsequent confirmation of safety. In particular, investigations using direct investigation methods should aim at determining those characteristics that are the most significant for estimating contaminant migration rates and those that could influence the repository design and construction.

S08. The recommendations made by the Review Team, grouped under the six topics, are reproduced below. A detailed account of the findings and recommendations can be found in the main body of this report.

LEGAL AND REGULATORY FRAMEWORK FOR WASTE MANAGEMENT

S09. The Review Team recommends that a process be established to identify key regulatory issues in the licensing of the disposal facility and to track their resolution; for example, the State Nuclear Power Safety Inspectorate (Valstybine Atomines Energetikos Saugos Inspekcija (VATESI)) should provide guidance to the operator on developing and presenting safety assessments (content and scope) and other required safety related information, such as the time period required for post-closure safety assessments (para. 224).

S10. The Review Team recommends that the VATESI develop a guidance document specifically for the licensing of facilities for the disposal of radioactive waste (para. 224).

S11. It is recommended that the Ministry of Economy take steps to ensure improved communication between the RATA and the Ignalina nuclear power plant. Communication should cover issues such as expected waste inventory, waste characteristics and strategic planning (para. 226).

S12. The development of the NSR is a long term multidisciplinary process that requires systematic planning of both managerial and technical activities. This planning includes supporting activities (e.g. public information, research, staff training) as well as technical activities (e.g. field work, engineering studies), preferably expressed in sequence diagrams, specified staffing needs, a comprehensive schedule and cost estimates. It is strongly recommended that such plans be developed, updated at regular intervals and implemented through yearly plans. Approval of long and medium term plans at the governmental level provides a higher level of confidence in such plans and enhances their implementation. These plans should be consistent with the national strategy for radioactive waste management (para. 227).

S13. According to IAEA safety standards for near surface disposal [1], “Situations in which exposure could arise as a result of the occurrence of unlikely events that affect the repository, i.e. events with low associated probabilities, shall also be considered.” It is recommended that the Lithuanian authorities provide guidance for the RATA to assess such situations (para. 228).

QUALITY MANAGEMENT SYSTEM

S14. The RATA should implement a quality management system (QMS) that should be applied to all aspects of the organization's work and be extended to suppliers, contractors and the waste producers who might have their waste packaging arrangements audited by the RATA. It is recommended that the RATA seek accreditation indicating that its QMS conforms to an appropriate international standard (para. 322).

S15. The Review Team recommends that the RATA ensure that all exploratory data in the siting process can be traced to their origin and that associated uncertainties are adequately described and explained. The uncertainties and the basis for estimated values used in the siting and assessment processes should be clearly justified and documented so that they will be recognized during the design process (para. 324).

S16. It is recommended that the RATA trace changes in the design of the facility, the reasons for these changes and how recommendations from reviews are taken into account (para. 325).

S17. The RATA is a relatively new organization, and although the staffing levels are increasing, there is still need for more staff. The Review Team recommends that the RATA be provided with the necessary human and financial resources to perform, in a timely manner, the planned activities concerning siting, design, construction, commissioning and operation of the near surface disposal facility (para. 326).

S18. While the responsibilities for the current phase of the repository development programme are clearly and logically addressed, uncertainty exists with regard to managing the subsequent phases. To ensure that the programme runs smoothly and that there is continuity from one programme phase to the next, it is recommended that key long term responsibilities be defined so that the necessary staff can be trained for subsequent phases of the programme. The competent authorities are also encouraged to take a similar approach (para. 327).

INVENTORY AND WASTE CHARACTERIZATION

S19. The Review Team recommends that the inventories be presented with a justified uncertainty range and that an appropriate level of contingency be included in the capacity of the repository reference design (para. 423).

S20. The Review Team recommends that a decision on the final disposal route of the bituminized waste be made without delay, as such waste is a potentially significant component of the total inventory of the NSR (para. 424).

S21. The Review Team recommends that the RATA establish a comprehensive reference inventory for all radionuclides to be disposed of in the NSR (para. 425).

S22. The Review Team recommends that current practice for characterization of relevant waste streams prior to treatment and conditioning be continued to ensure that the resultant waste form is compatible with the waste acceptance criteria (para. 426).

S23. The Review Team recommends improving the dialogue among the Ignalina nuclear power plant, the RATA and the VATESI in implementing the waste acceptance criteria and package specifications (conditioning and packaging options) that satisfy the requirements for storage and disposal (para. 427).

S24. With regard to the characterization of the chemical and physical composition of the waste, the Review Team recommends that the categories (see Table 2 in Section 2 of this report) be aligned with the waste acceptance criteria (i.e. to a disposal endpoint), and that they be periodically reviewed (para. 428).

SITE CHARACTERIZATION AND QUALITY OF CHARACTERIZATION DATA

S25. To facilitate the evaluation of the siting process by the competent authorities, and to make the process more transparent, it is recommended that the siting criteria (see Table A–1 in the Annex to this report) and the manner in which they have been applied be made publicly available and that they be well documented in the EIA (para. 507).

S26. The Review Team recommends that the RATA develop a data acquisition plan for finalization of the site characterization stage and that it organize all data from various data sources and subcontracting organizations into a structured database designed to meet quality assurance requirements (para. 537).

S27. The Review Team recommends that the final decision on site selection be based on three concepts outlined in paras 409, 414 and 413 of Ref. [2], respectively:

- “Preference should be given to sites with a uniform and predictable geology which can be readily characterized through geological investigative techniques”;
- “Preference should be given to sites with a simple geological setting that could make characterizing or modelling of the hydrogeological system easy”;
- “The hydrogeological setting of the site should include low groundwater flow and long flow paths in order to restrict the transport of radionuclides” (para. 538).

S28. Further site investigation could be an integral part of pre-operational monitoring. Such monitoring would provide input data needed for site characterization, including characterization of migration pathways for further safety assessment. The Review Team recommends that the pre-operational monitoring plan be developed prior to the start of detailed investigations (para. 539).

S29. To confirm the geological, hydrogeological and geochemical characteristics of the disposal zone and its immediate surroundings at each candidate site, it is recommended that more use be made of direct investigation methods (e.g. boreholes, including cores for laboratory examination) (para. 540).

S30. It is recommended that further investigations at the candidate sites be aimed at determining those characteristics that are the most significant for the description of the movement of contaminants that may be released from the repository and those that could influence the design of the repository (e.g. groundwater level fluctuations, natural drainage and natural barrier permeability, migration parameters) (para. 541).

S31. The conceptual hydrogeological models for candidate sites should be validated by further field observations and experiments, including studies of groundwater level fluctuation in response to precipitation for individual hydrostratigraphic units. It is recommended that the importance of a potential shallow migration pathway, including groundwater–surface water interactions, be validated by field studies (para. 544).

S32. It is recommended that internationally accepted and up to date methodologies be used to assess the vibratory ground motion (VGM) and the stability of human made and natural slopes, potential liquefaction and differential settlement — especially at the detailed design stage (para. 547).

S33. Because flooding represents an important exclusion criterion, it is recommended that an analysis of the potential for flooding at the three sites be performed. The analysis must take into account not only meteorological and hydrological data, but also potential damming of the valley floor due to natural and human made phenomena (e.g. landslides, destruction of human made structures) (para. 548).

REPOSITORY DESIGN

S34. In the detailed design stage, it is recommended that the safety functions allocated to the different components of the disposal system and the performance required from these components be specified (para. 620).

S35. For the proposed reference design, it is recommended that the RATA study how to meet the requirements of Article 53.2 of VATESI Regulation P-2002-2 [3], namely, that the monitoring programme of the disposal facility include "measurements of repository parameters demonstrating that the barriers have the features as expected". If the basis layer that is engineered below the vaults is to be used as a collection system to monitor infiltrated water, its settlement under the burden of the vaults should be taken into account (para. 621).

S36. On-site investigations should include the measurement of those parameters that are important for assessing the feasibility of construction of the disposal vaults. In the detailed design stage, it is recommended that appropriate methodologies (e.g. numerical calculations using the finite element method) be applied to assess geotechnical conditions, and that special attention be paid to the possible occurrence of very shallow groundwater (para. 622).

S37. The RATA plans to demonstrate the feasibility of the construction of the clay based engineered isolation layer in a pilot in situ demonstration. It is recommended that the in situ demonstration be planned and carried out so that it serves for developing a quality assurance and quality control programme for the construction of the capping system and confirms that the capping system will perform as expected (para. 623).

S38. The Review Team recommends that, in future stages of planning and assessment, special attention be given to the possible accumulation of precipitation water in the open disposal cells of the vaults to be constructed during the operational phase of the repository (para. 624).

S39. It is recommended that a criterion be developed for the minimum surface area required for the facility, including auxiliary buildings (e.g. ancillary structures such as administration buildings, temporary storage, laboratories), protected zones and the capping footprint (para. 625).

S40. In approving package specifications, it is recommended that the RATA include the impact of conditioning processes on the volume and properties of the final waste form for disposal, as this aspect could have an effect on the total surface area required for the disposal facility (para. 626).

SAFETY ASSESSMENT

S41. The RATA has used a simplified approach to operational and post-closure safety assessment in the Joint Report [4], relying appreciably on qualitative reasoning. The Review Team recommends that, for the next iteration of the assessment, additional site specific and design related scenarios be considered, screened and documented (para. 722).

S42. It is recommended that the assessment context be formulated carefully for future safety assessment iterations to allow the assessment to focus on site specific features and to build confidence in the process. It is important to establish the assessment philosophy (e.g. conservative, best estimate), especially when significant uncertainties exist with regard to disposal facility design, waste inventory, site description and parameter values (para. 723).

S43. It is recommended that a schematic description of each disposal system be included in the corresponding part of the safety assessment to make the assessment more logical and transparent (para. 724).

S44. The Review Team recommends that all types of waste package now in use or planned for use in the operational period of the disposal facility be considered in future safety assessments. Currently, only one type of waste package is considered, which may not be the most critical waste package from the point of view of radiological consequences in emergency situations (para. 725).

S45. The Review Team recommends that a structured approach be taken to performing the assessment of operational safety, such as an approach similar to the ISAM methodology. The use of a structured approach brings more transparency and is helpful for building confidence in the results obtained (para. 726).

S46. Intrusion and emergency scenarios can differ from site to site and may have different consequences depending on site specific conditions such as the distance to the nearest open water sources, wind speeds and directions, and proximity to protected areas (such as national parks and boundary reserves) and national borders. Therefore, it is recommended that arguments be justified to explain why operational safety assessment is performed without taking site specificities into account (para. 727).

S47. The Review Team recommends that the RATA place emphasis on demonstrating that the models and data used in the safety assessment are both traceable and justified (para. 741).

S48. Complex modelling tools were applied for the safety assessment of only one of the sites; it is recommended that the same modelling tools be used for all sites being compared (para. 742).

S49. The Review Team recommends that uncertainty and sensitivity analysis be used to identify and rank the key site specific parameters to be investigated. This could save time and resources during the safety assessments at the site confirmation stage (para. 743).

1. INTRODUCTION

BACKGROUND

101. Lithuania's national Radioactive Waste Management Agency (RATA) was established on 20 July 2001. The RATA developed a national strategy for radioactive waste management that was approved by the Government of Lithuania in February 2002. As part of its programme of activities, and consistent with the national radioactive waste management strategy [5], the RATA was mandated to prepare a plan for the construction of a new facility for the disposal of LILW-SL. Consistent with practice in other European countries and with international practice, the RATA has chosen to develop a near surface concept for LILW-SL disposal.

102. A large fraction of the radioactive waste arisings for the new disposal facility will be derived from the decommissioning of the Ignalina nuclear power plant. The Ignalina plant, located near the town of Visaginas in eastern Lithuania, close to the borders with Belarus and Latvia, has two 1500 MW RBMK type reactors that were commissioned in 1983 and 1987. As part of the terms of the European Union Accession Treaty, the Government of Lithuania agreed to shut down Units 1 and 2 of the Ignalina plant by 2005 and 2010, respectively, and to decommission them as soon as possible. The decommissioning of these units will generate a large volume of LILW-SL.

103. The LILW-SL that has been generated by the operation of the Ignalina nuclear power plant has been stored in vaults and tanks on the site. Only a fraction of the radioactive waste generated by the operation of the Ignalina plant has been processed. The operation of a new solid waste treatment, conditioning and storage facility expected by 2009 should accelerate the production of radioactive waste packages suitable for disposal. At the end of 2005, the cumulative volume of radioactive waste (excluding spent fuel) generated by plant operations was 35 400 m^3, including 11 700 m^3 of bituminized waste and some 3600 m^3 of liquid waste concentrates [6].

PREPARATORY WORK FOR SITING

104. The RATA is in the siting and design phase of the project to build an NSR. The NSR is designed for disposal of LILW-SL generated by the operation and decommissioning of the Ignalina nuclear power plant, and perhaps small

volumes of waste generated by research, industrial and medical institutions in Lithuania. On the basis of waste forecasts, the NSR is designed for a waste volume of 100 000 m^3.

105. In late 2002, the RATA established a national project for the siting of an NSR with technical and financial support from Sweden. In 2003, a team of Lithuanian experts, funded by the RATA and supported by Swedish experts, identified three potential sites for the NSR. A draft report that documented this siting work was reviewed by an international team at the beginning of 2004. The final report that was prepared recommended two of these potential sites in the vicinity of the Ignalina nuclear power plant: Apvardai and Galilauke. The RATA issued a draft EIA for these two sites in early 2005 [7]. The siting investigations should have been finalized by early 2005; however, due to unanticipated difficulties associated with negotiations at the municipal level, a third site had to be investigated.

106. The RATA is currently completing its siting programme and will update the EIA to take into account additional information gathered since the end of 2004, information on the third site (Stabatiske) and the findings of the present international peer review. The revised EIA will be submitted to the Lithuanian Ministry of Environment to provide information for the Government's decision regarding the selected site. The locations of the three potential sites, all in the vicinity of the Ignalina nuclear power plant, are shown in Fig. 1.

107. In the context of the revised EIA and the important siting decision ahead, the RATA requested that the IAEA organize a peer review of the siting and site characterization aspects of its programme for the construction of an NSR for disposal of LILW-SL.

REFERENCE DESIGN OF THE NEAR SURFACE DISPOSAL FACILITY

108. As far back as 1995, thus predating the establishment of the RATA, there was a proposal to establish a national repository for low and intermediate level waste in Lithuania. As Lithuania had no national waste management organization at that time, the proposal did not advance. In 2000, Sweden agreed to finance a project on the development of a reference design for an NSR for disposal of LILW-SL in Lithuania. The design work was done by a Swedish team (SKB, SWECO and Westinghouse Atom) with support from Lithuanian

FIG. 1. Locations of three sites proposed by the RATA for a near surface disposal facility.

experts (e.g. from the Lithuanian Energy Institute). The report [8] documenting the reference design was presented to the RATA in 2002. This report was reviewed by an international group of specialists, and the comments received were considered in the further development of the project [9]. The NSR design developed within the bilateral project is the basis for the present reference design.

109. Figure 2 is a cutaway drawing of the reference design for the NSR showing the series of barriers that will surround the waste as well as how the NSR will appear after closure. Figure 3 presents a cross-sectional view of the facility showing the engineered barriers in more detail.

TERMS OF REFERENCE

110. The objective of the peer review was to provide, on the basis of international safety standards and applicable national standards, an independent assessment of the safety of the three sites under consideration and of the

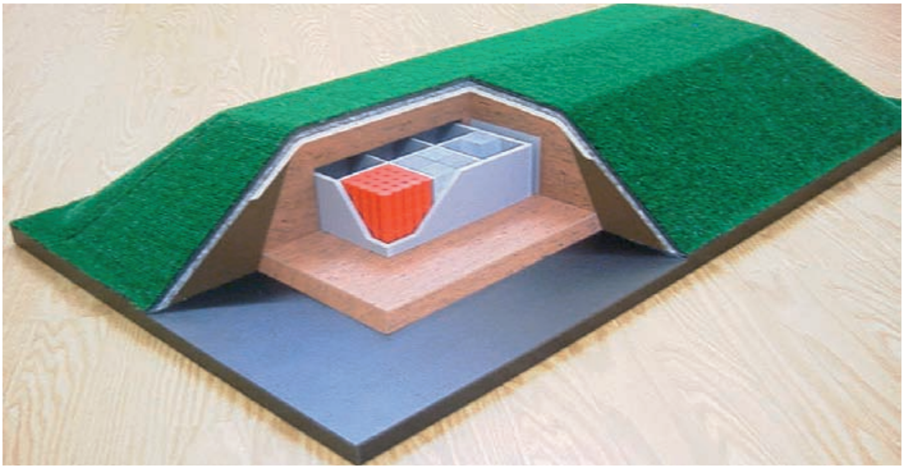

FIG. 2. Depiction of the RATA's reference design for a near surface disposal facility.

feasibility of the proposed reference design and its suitability for local conditions. This peer review provides an independent opinion as to whether the RATA's siting and site characterization programme is consistent with international standards and with good practice in other national disposal programmes. The review was based primarily on Ref. [4], which describes the general and

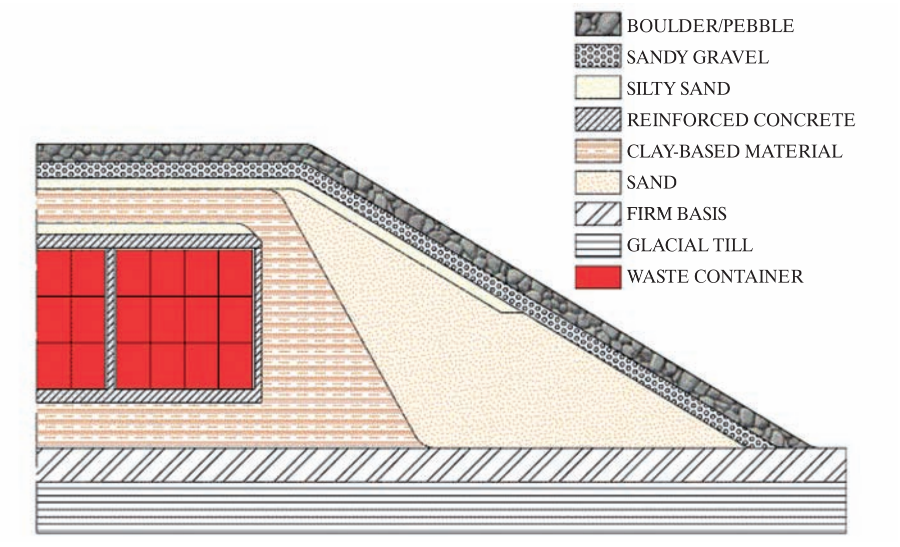

FIG. 3. Cross-section of the RATA's reference design for a near surface disposal facility [8].

safety relevant environmental conditions at the investigated sites and provides an overview of the information on the waste to be disposed of. The reference design for the RATA's near surface disposal facility is detailed in Ref. [8].

111. In conducting the review, the IAEA Review Team considered:

— The stage of disposal facility development;
— The relevance and completeness of the site characterization studies;
— The siting process and safety approach;
— The relevance of site characterization work for future safety assessments;
— The adequacy of the methods used;
— The clarity and completeness of the primary documents under review;
— The nature and characteristics of the radioactive waste to be disposed of;
— The reference design for the disposal facility;
— Good scientific and systems engineering practice.

112. By requesting this review, the RATA obtained an opinion as to the adequacy of the overall safety approach they have taken to date. The detailed findings and recommendations of the Review Team are intended to strengthen the safety basis for future steps in the RATA's programme, such as the development of technical specifications for the facility, the development of the detailed facility design and the preparation of licensing documents.

CONDUCT OF THE REVIEW

113. The review was conducted by a nine member international team of experts, selected from IAEA Member States, with knowledge of IAEA safety standards and experience in near surface disposal of radioactive waste, particularly those aspects of facility development that pertain to site characterization, facility design and long term safety assessment. The members and chairperson of the Review Team were selected by the IAEA Secretariat and accepted by the RATA, and the peer review was carried out according to the terms of reference described above.

114. Most of the peer review activities were carried out over a seven week period. The main documents for review were sent to the Review Team during the first week of November 2005. Ten days prior to the start of the review meeting, the IAEA Secretariat sent to the RATA a list of preliminary questions and issues for discussion during the meeting. At the review meeting, which took place in Vilnius from 12 to 16 December 2005, the RATA and their

support organizations made presentations and responded to questions from the Review Team. Over the course of the meeting, the Review Team met individually with the Lithuanian safety experts to discuss issues and findings. The review meeting also included a visit to each of the three proposed sites on 13 December 2005.

115. Four observers — two from Latvia and two from Belarus — were officially invited to participate in the review meeting; in addition, a representative from the Embassy of Belarus in Lithuania participated in most of the peer review activities. The observers attended the presentations, participated in the visits to the proposed sites and addressed questions to the involved parties during the different sessions of the peer review meeting.

116. The main findings of the review were presented orally to the involved parties on 16 December 2005. They were also provided to the RATA in written form just prior to the oral presentation. Following the review meeting, the Review Team compiled and drafted their findings to create the present report. A draft of this report was submitted to the RATA at the beginning of March 2006 *for fact checking only*. The Review Team reviewed the comments received by the RATA and, as appropriate, incorporated them into the final version of the report.

STRUCTURE OF THE REPORT

117. The organization of this report is as follows. The report begins with a summary that presents a concise statement of the recommendations. Section 1 provides a description of the siting and design work that has been carried out; it discusses the objectives and scope of the review and describes how the review was carried out. The six sections that follow this introduction detail the observations, findings and recommendations pertaining to the:

- Waste management framework in Lithuania;
- Quality management system;
- Inventory and waste characterization;
- Site characterization and quality of characterization work;
- Reference design of the NSR;
- Safety assessment.

118. Each section is divided into three parts: international good practice, observations and conclusions. The conclusions report on national good practice and provide the recommendations of the Review Team. A short biographical note on each member of the Review Team is provided at the end of this report.

2. LEGAL AND REGULATORY FRAMEWORK FOR WASTE MANAGEMENT

INTERNATIONAL GOOD PRACTICE

201. The concept of a global safety regime has emerged in recent years in nuclear, radiation and radioactive waste safety. The regime is made up of binding international conventions and international safety standards that support national legal and regulatory infrastructures. With regard to radioactive waste management, the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (the Joint Convention) [10] is the applicable international convention. The IAEA waste safety standards (IAEA safety standards) make up the applicable international standards, and a number of supporting activities and documents provide for their use and application.

202. The IAEA safety standards and the Joint Convention require the establishment and maintenance of a legislative and regulatory framework to govern the safety of spent fuel and radioactive waste management. This framework must provide for:

— The establishment of applicable national safety requirements and regulations;
— The establishment of radiological safety criteria for the post-closure phase;
— A system of licensing and regulatory control;
— Appropriate institutional control;
— A clear allocation of responsibilities for the bodies involved in the different steps of radioactive waste management.

In addition, a regulatory body with sufficient independence must be entrusted with the implementation of the legislative and regulatory framework, and be provided with adequate authority, competence, and financial and human resources to fulfil its assigned responsibilities. The prime responsibility for safety rests with the holder of the relevant licence.

203. A number of international safety standards are relevant to the objective of the review mission. Of prime consideration are:

— Near Surface Disposal of Radioactive Waste [1];

— Siting of Near Surface Disposal Facilities [2];
— The Principles of Radioactive Waste Management [11];
— Safety Assessment for Near Surface Disposal of Radioactive Waste [12];
— International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources [13];
— Legal and Governmental Infrastructure for Nuclear, Radiation, Radioactive Waste and Transport Safety [14];
— The Management System for Facilities and Activities [15].

These various standards, recommendations and related projects cover radiation protection objectives and criteria, siting, design and operational aspects of facilities, licensing, and demonstration of safety and management systems. Also of relevance are the recommendations of the International Commission on Radiological Protection (ICRP) on disposal of solid radioactive waste [16].

204. In recent years, there have been a number of international collaborative projects on the safety of near surface disposal of radioactive waste whose outcomes point to an emerging consensus on international good practice in this area [17, 18]. Recent international developments have also seen consensus emerging in a number of other areas of particular interest to the near surface disposal of radioactive waste in Lithuania. These concern the structure and content of safety cases for near surface disposal facilities, the systematic structuring and presentation of supporting safety assessments, and the step by step approach to facility development. Collectively, the Review Team has used all these elements as measures of international good practice.

OBSERVATIONS

205. Lithuania is a Contracting Party to the Joint Convention, which it ratified on 18 December 2003, and has met its primary obligations under the convention by compiling a national report that explains how it is complying with the articles of the convention and submitting this report for review by the Contracting Parties to the convention. The basic provisions in Lithuania's legislation concerning the management of radioactive waste are given in the Law on the Management of Radioactive Waste [19], which defines the principles of radioactive waste management, competence of the authorities, duties and responsibilities of the waste producer, functions of the RATA and provisions for licensing. The Law on Radiation Protection [20] regulates activities that involve sources of ionizing radiation and the management of radioactive waste.

206. In Lithuania, the licensing process for activities related to the management of radioactive waste is not strictly centralized. According to Ref. [19], the main regulatory body for the management of radioactive waste in Lithuania is the State Nuclear Power Safety Inspectorate (VATESI). The VATESI is responsible for issuing licences for the design, construction, modification, operation and maintenance of nuclear facilities, and for the storage and disposal of radioactive waste. The Radiation Protection Centre (RPC), under the Ministry of Health, is responsible for issuing licences for the transport of radioactive waste and the management of institutional waste, excluding disposal. The RPC is also responsible for issuing licences to collect and sort radioactive waste, to undertake its pre-treatment, treatment and conditioning, and to store, recover and decontaminate this waste. The RPC also issues one-time permits for the transport of radioactive waste. The waste management strategy approved by the Government of Lithuania [5] details specific tasks for modernizing waste management practices at the Ignalina nuclear power plant; these are detailed in Table 1.

207. The RATA is in charge of designing, constructing and operating radioactive waste repositories [21]. Figure 4 provides an overview of the RATA's programme for the development of an NSR. The RATA has issued a near surface disposal facility project implementation plan, which is described in Ref. [22]. The RATA performs its activities based on the annual plan approved, together with the relevant budget, by the Ministry of Economy at the end of the preceding year. The RATA has not developed long and medium term implementation plans (medium term would typically be the duration of a single phase of repository development, and long term would typically be ten years).

208. The RATA must comply with the regulations and safety criteria issued by the relevant regulatory bodies. The VATESI issued the regulation on Pre-disposal Management of Radioactive Waste at Nuclear Power Plants [23], which describes the requirements for the storage and processing of waste generated by the operation or decommissioning of nuclear power plants, as well as of waste that could be transferred to a nuclear power plant. In particular, this regulation provides principles for the segregation of waste according to the waste classification system shown in Table 2.

209. According to Ref. [3], criteria for acceptance of radioactive waste packages for storage should be developed. The acceptance criteria for the storage facility should reflect both the requirements for storage and the known or likely (interim) acceptance criteria for waste disposal. Before it can operate a waste conditioning facility, the Ignalina nuclear power plant must present for

TABLE 1. STRATEGY FOR THE MANAGEMENT OF SOLID RADIOACTIVE WASTE AT THE IGNALINA NUCLEAR POWER PLANT

The Ignalina nuclear power plant has a programme under way to modernize the management and storage of solid short lived and long lived radioactive waste at the plant; the programme started in 2002 and is expected to be completed by 2009. The aims of this modernization programme are to:

- Reduce both the total activity and the volume of radioactive waste by implementing the best available technologies.
- Implement the new classification system for radioactive waste.
- Arrange for a licensed landfill for disposal of very low level waste.
- Retrieve, characterize and, as necessary, condition existing LILW-SL and return the waste to storage until a disposal facility is available.
- Retrieve, characterize and provide interim conditioning and storage for long lived low and intermediate level waste accumulated in existing storage facilities. This waste is to be returned to interim storage facilities until final management methods for this waste stream are decided on.
- Create and implement a record keeping system for the inventory of radioactive waste at the Ignalina plant.
- Implement a programme for clearance of radioactive waste that strives to maximize the amount of waste that can be cleared.
- Investigate methodologies for the calculation of conditional clearance levels and identify best management methods for materials with contamination exceeding unconditional clearance levels.

The programme called for the performance of necessary investigations and for drawing up recommendations on the development and construction of an NSR for LILW-SL by the end of 2005.

the RATA's approval a waste package specification for each type of conditioned solid and immobilized LILW-SL intended for near surface disposal.

210. The Review Team judged that communication between the RATA and the Ignalina nuclear power plant, which is the main producer of radioactive waste, could be improved. The options that the Ignalina plant selects to condition waste in order to store it on the site may have significant impacts on disposal. For example, the choice of a conditioning option for the storage of waste may affect the volume of waste to be disposed of and the containment properties of the waste form. Better communication between the Ignalina plant and the RATA would allow more efficient transfer of relevant information for an optimal disposal solution.

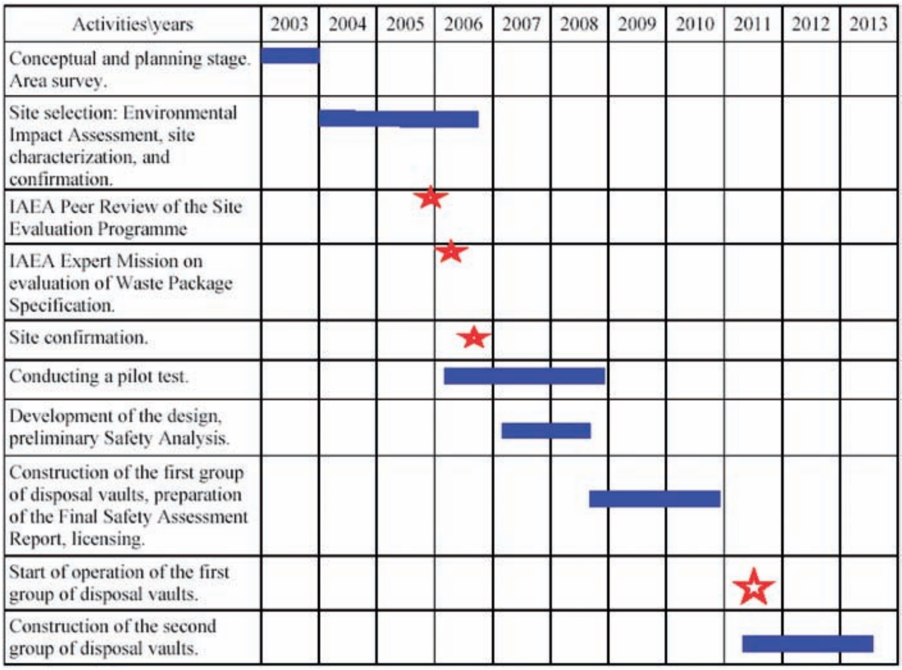

FIG. 4. The RATA's comprehensive programme for the development of an NSR [22].

211. The VATESI issued a regulation on the disposal of LILW-SL [3] describing the process to be followed for licensing at the different phases of the disposal facility: siting, design and construction, operation, closure and post-closure. An EIA must be performed prior to construction.

212. The EIA is structured according to a detailed guide [24] issued by the Ministry of Environment. The applicant is required to consult with the Ministry of Environment and other competent State and municipal institutions at an early stage of the process to ensure that all relevant issues are covered. The public must be informed about the assessment and its results.

213. The Review Team noted that the draft EIA issued by the RATA [7] mainly considered the impact of the repository on activities undertaken within Lithuania. However, calculations of the radiological impact of the projected repository were also made for Belarus and Latvia. During the presentations, the Review Team was informed that, considering the location of the potential sites near the borders of Belarus and Latvia, some additional relevant

TABLE 2. RADIOACTIVE WASTE CLASSIFICATION SYSTEM IN USE IN LITHUANIA SINCE 2001 [3]

Waste class	Definition	Abbreviation	Surface dose rate (mSv/h)	Conditioning	Disposal method
			Short lived low and intermediate level waste[a]		
A	Very low level waste	VLLW	≤0.5	Not required	Very low level waste repository
B	Low level waste	LLW-SL	0.5–2	Required	Near surface repository
C	Intermediate level waste	ILW-SL	>2	Required	Near surface repository
			Long lived low and intermediate level waste[b]		
D	Low level waste	LLW-LL	≤10	Required	Near surface repository (cavities at intermediate depth)
E	Intermediate level waste	LW-LL	>10	Required	Deep geological repository
			Spent sealed sources		
F	Disused sealed sources	DSS		Required	Near surface or deep geological repository[c]

[a] Containing beta and/or gamma emitting radionuclides with half-lives of less than 30 years, including ^{137}Cs, and/or long lived alpha emitting radionuclides with measured and/or calculated (using approved methods) activity concentrations of less than 4000 Bq/g in individual waste packages, with the condition that the overall average activity concentration of long lived alpha emitting radionuclides is less than 400 Bq/g per waste package.

[b] Containing beta and/or gamma emitting radionuclides with half-lives of over 30 years, not including ^{137}Cs, and/or long lived alpha emitting radionuclides with measured and/or calculated (using approved methods) activity concentrations of more than 4000 Bq/g in individual waste packages with the condition that the overall average activity concentration of long lived alpha emitting radionuclides exceeds 400 Bq/g per waste package.

[c] Depending on acceptance criteria applied to sealed sources.

information about these neighbouring countries would be added to the report. This point is still under discussion in the framework of transboundary consultations: in 2005, two meetings were held involving Lithuanian and Latvian officials, and three meetings were held with Belarusian officials. In connection with the development of the repository, the participation in the peer review of representatives of neighbouring countries indicates a desire for transparency on the part of the Lithuanian authorities.

214. The regulation concerning disposal of LILW-SL [3] refers to Lithuanian safety criteria [25] for the operational and closure phases of the disposal facility (Table 3). In addition, a dose constraint for members of the public (i.e. the critical group) of 0.2 mSv/a resulting from the operation and decommissioning of nuclear facilities is specified in Ref. [26].

215. Radiological safety criteria that are specific to the post-closure phase of nuclear installations have not yet been established by the regulatory authority. They could be in the form of dose criteria, risk criteria or both. Additional safety indicators such as those provided in Ref. [1] may be considered appropriate by the national regulatory body. For those modes of evolution of the repository that are judged to be likely during the post-closure phase, the repository should be designed so that projections of doses or risks to members of the public do not exceed an appropriate fraction of the dose limit, 1 mSv/a, or its risk equivalent. The regulatory body should determine the appropriate fraction to be designated as the dose or risk constraint.

TABLE 3. DOSE LIMITS FOR PLANT WORKERS AND MEMBERS OF THE PUBLIC ACCORDING TO REF. [25]

	Dose limit	
	Plant worker	Member of the public
Effective dose	50 mSv/a, with no more than 100 mSv within a period of five consecutive years	1 mSv/a; under special circumstances 5 mSv/a, provided that the exposure does not exceed 5 mSv within a period of five consecutive years
Lens of eye	150 mSv/a	15 mSv/a
Skin, hands, forearms and feet	500 mSv/a	50 mSv/a

216. In this connection, the Review Team noted that the dose constraint used by the RATA for assessing water pathways in the post-closure phase is 0.2 mSv/a (see appendix J1 of Ref. [4]). The same dose constraint was used to derive acceptance criteria for waste packages in the repository within the framework of a long term intrusion scenario; this is a cautious and conservative approach, as a higher impact may be admitted in accordance with the long term, low probability scenarios discussed in Ref. [16].

CONCLUSIONS

Good practice

217. The fact that Lithuania is a Contracting Party to the Joint Convention was considered by the Review Team to be an indicator of international good practice. The flexibility inherent in the regulatory regime for taking account of international good practice is considered to be particularly useful.

218. The Review Team welcomed the discussions with Lithuania's neighbouring countries as part of the site selection/EIA process. Such discussions are essential to establishing transparency and trust in the decision making process.

219. Lithuania has established an appropriate legislative and regulatory framework to govern radioactive waste management safety. According to Ref. [6], all legal acts concerning radioactive waste management are prepared according to IAEA safety standards and take into account national and international good practice. The acts cover all areas of radioactive waste predisposal management, disposal of very low level waste and disposal of low and intermediate level waste. It should be noted that, before adoption of the Law on Nuclear Energy in 1996, Lithuania's laws and regulations covering the management of radioactive waste lacked coherence and completeness.

220. The fact that Lithuania has called for an international peer review of the siting process for a near surface disposal facility is also deemed to be consistent with international good practice with regard to building confidence in the safety of waste disposal facilities.

221. The regulatory body has issued generic waste acceptability criteria for disposal in NSRs [27]. These generic requirements identify the items that the RATA should develop in the acceptability requirements for the disposal of radioactive waste in any repository. The RATA has issued preliminary activity

limits for LILW-SL solidified in cement. This conforms to the intent of para. 5.2 of Ref. [28].

222. The operators of radioactive waste management facilities are responsible for the safety of these facilities. The operators of the Ignalina nuclear power plant are responsible for the safe management of radioactive waste arising from the operation and decommissioning of their facilities until this waste is transferred for disposal. The RATA is responsible for the management and disposal of all radioactive waste transferred to it (i.e. the RATA is responsible for the storage facilities and repositories assigned to it).

223. Principle 8 of Ref. [11] states that "interdependencies among all steps in radioactive waste generation and management shall be appropriately taken into account". In Ref. [27], the VATESI set out the requirement that, before operating a waste conditioning facility, the nuclear power plant must present for the RATA's approval a waste package specification for each type of conditioned solid and immobilized LILW-SL that is intended for near surface disposal. The presentations made to the Review Team at the Ignalina nuclear power plant show that the RATA is actively involved in the definition of new types of package.

Recommendations

224. The Review Team recommends that a process be established to identify key regulatory issues in the licensing of the disposal facility and to track their resolution; for example, the VATESI should provide guidance to the operator on developing and presenting safety assessments (content and scope) and other required safety related information, such as the time period required for post-closure safety assessments. The Review Team recommends that the VATESI develop a guidance document specifically for the licensing of facilities for the disposal of radioactive waste.

225. Although the peer review focuses on the RATA's work, it was judged appropriate to comment on a few issues that concern the regulatory body, as these issues may strongly influence the RATA's programme. The VATESI should develop and approve those regulations needed to ensure that:

— Conditions for the acceptance of waste for disposal in the NSR are specified by the RATA on the basis of either generic studies or site specific safety assessments, with account taken of appropriate radiological criteria, the conditions of operation, the planned duration of active institutional controls, and the characteristics of natural and engineered systems. Waste acceptance requirements developed by the RATA should be reviewed and approved by the VATESI. The established requirements should be made binding on the waste generators or consignors of waste to the repository.

- Compliance with quality management requirements, particularly those that relate to waste acceptance requirements, is verified. The RATA, as the operator of the waste disposal facility, should, wherever practicable, conduct a periodic review of the procedures of the waste generators. The VATESI should verify that these procedures are effective in ensuring compliance with the requirements.
- The waste packages are verified by the waste generator as being characterized and in compliance with the requirements specified by the VATESI and the operator of the NSR.
- The waste generator provides all of the information needed by the RATA for site selection and design of the NSR; this information should be duly documented and provided according to a schedule that supports the goals and decision points of the project.
- Decisions relating to any one of the steps of radioactive waste management are taken with due consideration of the impacts and/or needs at the other steps linked with safe disposal. This requires coordination of activities, including exchange of information, among the waste generators, the RATA and the VATESI, and should be established in accordance with national regulations. This applies, in particular, to the exchange and review of documents such as those concerning criteria established by the VATESI and specifications established by the RATA, as well as technical documents provided by the waste generator. Past experience and new developments in the field of waste management and disposal should be taken into account in regulations and ongoing practices.
- The VATESI develops guidance on the format of the documentation required for each particular step of the licensing process.

226. It is recommended that the Ministry of Economy take steps to ensure improved communication between the RATA and the Ignalina nuclear power plant. Communication should cover issues such as expected waste inventory, waste characteristics and strategic planning.

227. The development of the NSR is a long term multidisciplinary process that requires systematic planning of both managerial and technical activities. This planning includes supporting activities (e.g. public information, research, staff

training) as well as technical activities (e.g. field work, engineering studies), preferably expressed in sequence diagrams, specified staffing needs, a comprehensive schedule and cost estimates. It is strongly recommended that such plans be developed, updated at regular intervals and implemented through the yearly plans. Approval of long and medium term plans at the governmental level provides a higher level of confidence in such plans and enhances their implementation. These plans should be consistent with the national strategy for radioactive waste management.

228. Reference [25] states, inter alia, that “the annual dose constraint for members of the public (critical group) due to the operation and decommissioning of the nuclear facility is 0.2 mSv”. Reference [25] also states that the effective dose limit for the public is 1 mSv/a, and in special circumstances up to 5 mSv in a single year, provided that the average dose over five consecutive years does not exceed 1 mSv/a. According to Ref. [3], for a near surface disposal facility, “situations shall also be considered in which a potential exposure could arise in excess of the dose limit, even those of a low probability”. This is consistent with Ref. [1], which states that: “Situations in which exposure could arise as a result of the occurrence of unlikely events that affect the repository, i.e. events with low associated probabilities, shall also be considered.” It is recommended that the Lithuanian authorities provide guidance for the RATA to assess such situations. This could, for example, be accomplished by using the ICRP recommendation set forth in Ref. [16].

3. QUALITY MANAGEMENT SYSTEM

INTERNATIONAL GOOD PRACTICE

301. The objective of radioactive waste management is "to deal with radioactive waste in a manner that protects human health and the environment now and in the future without imposing undue burdens on future generations" [1]. Management systems play an important role in realizing this objective, and should be implemented for all stages of waste management, from waste generation to disposal. According to para. 1.4 of Ref. [15], the term management system:

> "reflects and includes the initial concept of 'quality control' (controlling the quality of products) and its evolution through quality assurance (the system to ensure the quality of products) and 'quality management' (the system to manage quality). The management system is the set of interrelated or interacting elements that establishes policies and objectives and which enables those objectives to be achieved in a safe, efficient and effective manner."

302. The management systems applied during the siting, design, construction, operation, closure and post-closure phases of waste disposal facilities all contribute to compliance with the principles in Ref. [11]. This includes the safety assessments that are conducted to evaluate all aspects of a facility that are relevant to safety and environmental protection, and the structure and presentation of safety arguments and supporting evidence in the safety case for the disposal facility. Quality management systems (QMSs)[1] are applicable to any organization. In the context of radioactive waste management, they apply directly to the licence holder or would-be licence holder (i.e. the applicant). Formal recognition of an organization's commitment to quality management is usually achieved by gaining accreditation indicating compliance with ISO 9001:2000 (or its national equivalent). Although accreditation is valuable, it is not essential to quality management, nor does it automatically lead to compliance with the relevant quality standards for radioactive waste disposal.

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[1] In this report the terms 'management system' and 'quality management system' are used synonymously.

303. The QMS should apply to all of the work of an organization and extend to suppliers and contractors, who should also be expected to work to agreed procedures. In this context, nationally and internationally recognized codes, regulations and standards provide practical, widely understood benchmarks and should be used whenever possible. In the case of an applicant, the QMS should extend to the waste producers who might have their waste packaging arrangements audited by the applicant. The regulatory body may wish to see accreditation of the applicant's QMS by an independent third party.

304. The operating organization that manages waste may itself carry out internal inspections (audits) in the course of controlling and improving its processes. Other bodies (regulatory bodies or independent organizations or experts) may independently carry out external inspections to maintain confidence that the operating organization is conducting its operations in an acceptable manner.

305. All data used should always be traceable to their origin and should be developed into a coherent, well documented description of site characteristics. It should be recognized that some information (e.g. estimated values, extrapolated values and existing information from local studies that were conducted for other purposes) may not readily satisfy the required level of confidence. Lack of confidence in the quality of the data — that is, in their accuracy, applicability, completeness or quantity — may preclude their use. In such cases, a pragmatic approach based on expert judgement should be used. The use of such data should be declared, justified, authorized and recorded. The format of information and data should, as far as practicable, be consistent, should facilitate an easy comparison of results between disposal sites and should allow for prompt identification of gaps in information.

306. The design process always requires effective input and output controls and records. In addition, the design process for a disposal facility should be part of a larger iterative process that also involves site characterization and the development of the safety case for the facility. Site knowledge, facility design, and safety and environmental protection arguments should be refined iteratively to establish a robust safety case and well founded technical specifications.

307. A documented process should be developed to acquire, review, track, quantify and qualify all design data, and to demonstrate their suitability before they are used as information that will be entered into any system, computer program or computer model. This includes data generated as a result of literature searches, laboratory tests, field tests and observations, seismic

analyses, monitoring and measuring, and test results from other relevant sources.

308. Data related to natural geological systems may incorporate uncertainties or be based on estimated values deduced from similar situations. The uncertainties and the basis for estimated values should be clearly documented so that they will be recognized during the design process.

309. Computer software programs and models will be used during all phases of waste disposal activities, particularly during the design phase. Appropriate measures should be provided for verifying and validating such applications.

310. Information about the design parameters that were considered important for the safety, health, environmental, quality, security and economic aspects of the facility should be retained and controlled for as long as any concern about the facility persists.

311. Where assessments are performed of work processes used in a waste disposal facility, the following aspects should be confirmed:

- During the siting phase, all exploratory data must be traceable to their origin, and associated uncertainties must be adequately described and explained.
- During the design phase, the understanding of the natural geological setting, the facility design and the safety assessment of the facility should be developed concurrently, and the final descriptions should be adequate and mutually consistent.

312. The precepts of the Joint Convention [10] should be considered in developing a QMS for waste disposal activities, in order to give due recognition to the international aspects of the disposal activities.

OBSERVATIONS

313. The Review Team was informed that the RATA does not currently have a well established QMS. Nevertheless, this activity is of extreme importance for the RATA, and their management has decided to prioritize the development and establishment of such a system.

314. The documentation presented to the Review Team contains no discussion of how changes to the siting process and preliminary design of the disposal facility have been and will be managed. The RATA will have to trace to their origin the preliminary data that have been used for site characterization. The RATA will also have to describe how it has managed the associated uncertainties.

315. The Review Team was informed that different independent external reviews have been or will be made over the course of the project, including:

- An assessment of the reference design of the NSR undertaken in September 2002 by Serco Assurance, a Swedish consortium, the Lithuanian Institute of Physics and the Kaunas University of Technology [9];
- A review meeting on the design of the NSR, held in June 2004 [29];
- The present peer review, carried out in December 2005;
- An IAEA expert mission on waste package specifications in January 2006 [22].

316. There is no available documentation to track how the observations or the recommendations made during these reviews were taken into account. Such documentation could be very useful for keeping track of decisions made and their justification.

317. The Review Team was convinced that the RATA has established effective communication with the different regulatory authorities in the country and was impressed by the general information provided to support the mission. However, the RATA should ensure that it has appropriate control over the information and that adequate stages of checking and approval are implemented prior to release of information for independent review. Such measures are necessary to build confidence in the decision making process.

318. An important effort involving subcontractors was deployed to develop the NSR project, and the professionalism of the RATA's effort was appreciated by the Review Team. However, internal resources are required within the RATA to implement a QMS to enable efficient management of subcontractors.

319. The siting process in Lithuania has been clearly defined, including responsibilities for its implementation (site selection up to the EIA process); the allocation of responsibilities for the subsequent phases of the development of the repository (construction) has yet to be determined.

CONCLUSIONS

Good practice

320. The Review Team was informed that the establishment of a QMS is of extreme importance to the RATA, and its development has high priority at present. It will be designed to comply with ISO 9001:2000 and with the IAEA safety standards, instilling confidence that the activities covered by the QMS will be fit for the purpose of siting and designing a disposal facility.

321. The Review Team noted that the RATA commonly uses design control and independent external review appraisals at different project development stages. The Review Team also noted that the RATA has established effective communication and working relationships with the regulatory authorities in the country.

Recommendations

322. The RATA should implement a QMS that should be applied to all aspects of the organization's work and be extended to suppliers, contractors and the waste producers who might have their waste packaging arrangements audited by the RATA. It is recommended that the RATA seek accreditation indicating that its QMS conforms to an appropriate international standard.

323. The RATA should consider the relevant IAEA safety standards [15] in developing and implementing the waste management system for all phases of the NSR.

324. The Review Team recommends that the RATA ensure that all exploratory data in the siting process can be traced to their origin and that associated uncertainties are adequately described and explained. The uncertainties and the basis for estimated values used in the siting and assessment processes should be clearly justified and documented so that they will be recognized during the design process.

325. It is recommended that the RATA trace changes in the design of the facility, the reasons for these changes and how recommendations from reviews are taken into account. In this framework, the Review Team considers it beneficial to demonstrate the impact of the generic safety assessment results on the elaboration and improvement of the conceptual design of the facility for

the preliminary safety assessment. Similar work should be done for subsequent steps of facility development.

326. The RATA is a relatively new organization, and although the staffing levels are increasing, there is still need for more staff. The Review Team recommends that the RATA be provided with the necessary human and financial resources to perform, in a timely manner, the planned activities concerning siting, design, construction, commissioning and operation of the near surface disposal facility. The Review Team also advises the RATA to establish and implement a personnel training programme on those issues that need to be developed to successfully complete the site selection and design stages of the near surface disposal facility project.

327. While the responsibilities for the current phase of the repository development programme are clearly and logically addressed, uncertainty exists with regard to managing the subsequent phases. To ensure that the programme runs smoothly and that there is continuity from one programme phase to the next, it is recommended that key long term responsibilities be defined so that the necessary staff can be trained for subsequent phases of the programme. The competent authorities are also encouraged to take a similar approach.

4. INVENTORY AND WASTE CHARACTERIZATION

INTERNATIONAL GOOD PRACTICE

401. At the start of the conceptual and planning stage, the types of waste to be disposed of, including the projected waste volumes and their radionuclide content, should be defined and characterized [2]. On the basis of this information, generic facility design concepts and preliminary safety assessments may be developed. The inventory may also be used to formulate appropriate strategies for radioactive waste management. The IAEA has issued technical documents concerning the development of an NSR for LILW-SL that discuss the topic of waste inventory [30–32].

402. The waste inventory should include arisings predicted for several decades into the future in order to develop optimal waste management solutions. The inventory must include all existing waste; thus old waste that has been stored in inactive facilities will also need to be included.

403. The usefulness of a waste inventory depends on the reliability and completeness of the information assembled. The waste characteristics and information in the inventory should include:

- Identification of the producer or owner (company name and name of the manager);
- Where the waste was generated;
- Type of waste (e.g. solid, liquid, compactable, non-compactable, combustible);
- Volume;
- Radionuclides present;
- Activity per nuclide;
- Chemical and physical properties;
- Current form of waste (e.g. untreated or conditioned, including properties of the conditioning material);
- Type and characteristics of container and of overpack, if any (e.g. material, dimensions, weight and handling items);
- Current storage conditions.

404. Knowledge of the characteristics of the waste is of fundamental importance for waste conditioning, packaging, disposal option selection and repository design. The parameters to be characterized and the required

equipment and procedures for waste characterization should be identified and taken into account.

405. The waste to be disposed of must be solid waste. Such waste can be very heterogeneous, for example, sludge from chemical co-precipitation. Heterogeneous waste is more difficult to characterize than homogeneous waste and requires both explicit identification as such in the inventory records and a more conservative approach in safety assessment and repository design.

406. Different types of conditioning materials are used to immobilize waste, with cement being the most common. Bitumen and polymers have also been used for conditioning different types of waste. Cement, bitumen and polymers can all contribute to the confinement of the radionuclides within the waste package. The main objectives of waste conditioning are to limit the potential for dispersion of the waste and to reduce the voids within the container, thus providing integrity and stability to the package.

407. Waste packages are in themselves containment barriers, contributing to the isolation of radionuclides from the environment. They are designed and fabricated to have sufficient mechanical strength to bear loads after repository closure, to be capable of withstanding accidents during the operational phase and to comply with requirements for waste handling, transport and storage. Accordingly, consideration must be given to waste package design and fabrication, addressing in particular the following:

— Performance of waste packages during handling, transport, storage and receipt at a disposal facility, with particular attention paid to the implications for radiation protection;
— Compatibility of mechanical properties with the features of the disposal structures;
— Ability to prevent or reduce the potential release of radionuclides to the environment during the post-closure period.

408. The long term behaviour of waste packages in repository conditions is subject to greater levels of uncertainty than their behaviour during storage. This uncertainty should be considered in the safety assessments of the repository.

OBSERVATIONS

409. Reference [4] states that the waste to be disposed of in an NSR for LILW-SL in Lithuania will include:

— Radioactive waste from the dismantling and decommissioning of Units 1 and 2 of the Ignalina nuclear power plant;
— Radioactive waste from the operation of the Ignalina plant (both past and future arisings);
— Research, medical and industrial waste consigned to the Ignalina plant.

410. The overall volume of waste packages to be disposed of is shown in Table 4.

411. The Review Team noted that the radionuclide inventory for the NSR was declared to a high degree of precision, which does not reflect the uncertainties mentioned above.

412. The Review Team noted that different waste forms have been identified for disposal in the repository. These include conditioned spent resins, perlite and sediments, conditioned combustible waste (ashes) and conditioned non-combustible waste. Reference [4] provides characterization information only for the conditioned spent resins, which the RATA considers to be the reference waste type, although the justification for this choice was not clear.

413. The Review Team noted that a final decision has not been made concerning the disposal route of the bituminized waste [6]. If it is decided that this waste stream will be disposed of in the NSR, it will be a significant component of the total inventory (11 771 m^3 as of 1 January 2005 [6]).

TABLE 4. VOLUME OF WASTE PACKAGES TO BE DISPOSED OF IN THE NEAR SURFACE REPOSITORY [4]

Waste type	Volume of containers to be disposed of (m^3)
Conditioned spent resins, perlite and sediments	56 717
Conditioned combustible waste (ashes)	534
Conditioned non-combustible waste	36 676
Total	93 927

414. It was also acknowledged that there is little international experience in the dismantling of RBMK type reactors, which will lead to additional uncertainties associated with predictions of waste arisings (in terms of both the radiological and the chemical inventory).

415. Information was not published in the Joint Report [4] for all relevant radionuclides. Table 5 illustrates how Ref. [4] presents data and the analysis for different radionuclides in different areas.

TABLE 5. RADIONUCLIDES ASSESSED IN THE JOINT REPORT [4][a]

Radionuclide	Assumed NSR activity (inferred by scaling)	External doses (normal operations)	Assessed radionuclides (pathway analysis)	Emergency situations (operations and post-closure)
^{3}H			√	√
^{14}C	√		√	√
^{36}Cl				√
^{54}Mn		√		
^{59}Ni	√		√	√
^{60}Co		√		
^{63}Ni	√		√	√
^{90}Sr	√		√	√
^{94}Nb	√		√	√
^{99}Tc	√		√	√
^{129}I	√		√	√
^{134}Cs		√		
^{137}Cs	√	√	√	√
^{226}Ra				√
^{237}Np			√	√
^{234}U			√	√
^{235}U			√	√
^{238}U			√	√
^{238}Pu	√		√	√
^{239}Pu	√		√	√
^{240}Pu	√		√	√
^{241}Pu	√		√	√
^{241}Am	√		√	√

[a] Column headings indicate the purpose of the assessment; a tick indicates that the radionuclide was assessed for that purpose.

416. The Review Team acknowledges that a risk based approach can be appropriate for considering different radionuclides for different pathways, depending on the purpose of the assessment (e.g. a screening assessment versus a detailed safety assessment). However, it would be beneficial to establish a comprehensive reference inventory for all relevant radionuclides to be disposed of in the NSR.

417. The Review Team noted that, since 2001, the characterization of solid radioactive waste has included an inventory of radionuclides. Information on radioactive waste generated before 2001 is of poor quality. Therefore, the higher uncertainties associated with this historical waste need to be considered with regard to the overall inventory identified for disposal in the NSR. The Review Team was made aware that there will be future campaigns to further characterize different waste streams prior to treatment and conditioning. With these campaigns in mind, establishment of scaling factors to assess the activities of radionuclides that are difficult to measure could be a part of the quality assurance monitoring of processes related to the waste according to Article 37 of Ref. [27].

418. The Review Team noted that the radioactive content of the conditioned combustible waste (ashes) is considerably higher than similar waste streams in other Member States and may present specific radiological issues both from potential emergency situations during the operational phase and from human intrusion scenarios after withdrawal of institutional control (e.g. as a result of resuspension of the ash and inhalation of radionuclides).

419. The Joint Report contains information on the physical and chemical composition of both the operational and the decommissioning waste to be disposed of (Ref. [4], table 2.1). However, the categories are arbitrary and do not appear to relate to any specific waste acceptance criteria.

420. The Review Team noted that the VATESI has issued regulations that describe generic waste acceptance criteria [27], although it was not clear what relation these had to the inventory and characterization of existing waste.

421. The Review Team noted that an IAEA expert mission on evaluation of waste package specification and predisposal waste management was to be undertaken in January 2006. The use of independent review of any stage of the siting process is good practice, as it builds confidence in the process.

CONCLUSIONS

Good practice

422. The Review Team noted that the RATA has requested a review of waste package specifications in 2006. Expert review is an effective way of building confidence in the programme.

Recommendations

423. The Review Team recommends that the inventories be presented with a justified uncertainty range and that an appropriate level of contingency be included in the capacity of the repository reference design.

424. The Review Team recommends that a decision on the final disposal route of the bituminized waste be made without delay, as such waste is a potentially significant component of the total inventory of the NSR.

425. The Review Team recommends that the RATA establish a comprehensive reference inventory for all radionuclides to be disposed of in the NSR.

426. The Review Team recommends that current practice for characterization of relevant waste streams prior to treatment and conditioning be continued to ensure that the resultant waste form is compatible with the waste acceptance criteria.

427. The Review Team recommends improving the dialogue among the Ignalina nuclear power plant, the RATA and the VATESI in implementing the waste acceptance criteria and package specifications (conditioning and packaging options) that satisfy the requirements for storage and disposal.

428. With regard to the characterization of the chemical and physical composition of the waste, the Review Team recommends that the categories (see Table 2) be aligned with the waste acceptance criteria (i.e. to a disposal endpoint), and that they be periodically reviewed.

5. SITE CHARACTERIZATION AND QUALITY OF CHARACTERIZATION DATA

MANAGEMENT OF THE SITING PROCESS

International good practice

501. Reference [2] suggests that the site selection process be carried out in four stages, namely:

— A *conceptual and planning stage* aimed at the development of an overall plan for site selection (responsibilities, timing, sequence of activities, costs); mobilization of human, technical and financial resources; establishment of siting principles and identification of desirable site features and site screening/selection criteria; initiation of public involvement in the process; and performance of 'table' studies not requiring field activities (waste inventory, generic design, safety assessment methodology);
— An *area survey stage* to be finalized by selecting candidate sites through regional mapping and subsequent screening of potential areas;
— A *site characterization stage* focused on demonstrating that candidate sites meet safety and environmental requirements;
— A *site confirmation stage*, during which detailed site investigation is conducted.

502. The siting process requires a multidisciplinary approach that integrates managerial and technical activities (both in the field and at the laboratory) such as engineering studies, computer modelling and communication with stakeholders. The process should be conducted according to the national legislative requirements and implemented through the established waste management infrastructure.

Observations

503. Pursuant to Article 17 of Part 1 of the Law on the Management of Radioactive Waste [19], siting is governed by the Law on Territory Planning (land use planning) and the Law on the Environmental Impact Assessment of the Planned Economic Activity. In this particular case, the process consists in the development by the RATA of an EIA for each site for assessment by the Ministry of Environment and other competent authorities; the public can also

amend the report. The format of the report is clearly defined [24] and the Ministry's decision is binding: only the selected site can be further considered for construction of the disposal facility. The final site, to be selected on the basis of the EIA screening results, will then be proposed to the Ministry of Economy, which will submit the proposal to the Government for final approval. The development of a disposal facility will continue after the VATESI and other competent authorities have issued a construction licence; the content and extent of the documentation required to apply for this licence will be clearly defined by the regulatory bodies.

504. The RATA has been following the step by step approach to siting. In accordance with this internationally approved approach, identification of potential areas in Lithuania started in the pre-selected region within a 10 km radius of the Ignalina nuclear power plant. It consisted in considering geological data, but also in assessing geographical, ecological, infrastructural and other such constraints. The aim was to identify and exclude from further consideration those territories where construction of an NSR is precluded for some reason. The following areas typically were excluded: State protected territories (reservations, military facilities) and their buffer zones, ecologically significant regions (regions that qualify as 'bio-centres' or 'bio-corridors'), territories with surface and underground water resources, sanitary protection zones, tectonically affected areas, areas containing mineral deposits, forested land and land containing regional infrastructure (roads, railways, pipelines, municipalities).

505. The narrowing of the number of sites continued on the basis of technical and safety criteria such as topographical features, geotechnical stability, hydraulic conductivity, impact from natural phenomena, and hydrological, tectonic and transport risks. In connection with the siting of a disposal facility, Ref. [2] suggests that the selection criteria be proposed prior to the start of site investigations and consultations with local communities, and that, optimally, if the regulatory body has not issued the selection criteria, that it as a minimum confirm them. Such an approach ensures that the site selection procedure is transparent.

Conclusions

Good practice

506. The RATA and its subcontractors have followed the phased approach to the development of the repository, an approach that also complies with

national legislation and is well accepted internationally. In the current programme stage, the sites under consideration have been characterized, the conceptual design and initial safety assessment have been developed and the EIA reports are being completed; the goal is to confirm the final site in 2006. The Review Team considers the development programme to be comprehensive and appropriate in terms of the technical investigations performed. As noted previously, the RATA communicates with the public and performs information campaigns beyond national borders.

Recommendation

507. To facilitate the evaluation of the siting process by the competent authorities, and to make the process more transparent, it is recommended that the siting criteria (see Table A–1 in the Annex to this report) and the manner in which they have been applied be made publicly available and that they be well documented in the EIA.

SITE CHARACTERIZATION

International good practice

508. According to Ref. [2], during the conceptual and planning stage, potentially important factors are identified, potential host rocks and possible siting areas are identified, and investigation objectives and identification programmes are defined. In the area survey stage, a broad region is examined to identify one or more candidate sites for further investigation. These sites are studied during the site characterization stage to select the preferred site for confirmation. Finally, during the site confirmation stage, the preferred site should be characterized through detailed subsurface studies to determine its acceptability from the safety point of view.

509. The site characterization stage requires site specific information to establish the characteristics and the range of parameters with regard to the location of the intended disposal facility. This will require site reconnaissance and investigations to obtain evidence on actual geological, hydrological and environmental conditions at the site. This involves on-site surface and subsurface geological investigations supplemented by laboratory work.

510. Reference [2] provides guidelines on the data expected to be necessary to characterize the site from the point of view of geology, hydrogeology,

geochemistry, tectonics and seismicity, as well as surface processes and meteorology. Paragraph 6.2 of Ref. [1] states, inter alia, that “The site characteristics shall be taken into account in the safety assessment and the repository design. In determining the site characteristics that are important to the assessment of the design and safety, the following shall be considered as a minimum: geology, hydrogeology, geochemistry, tectonics and seismicity, surface processes, meteorology, climate and the impact of human activities.”

511. Regarding tectonics, seismicity and surface processes, Refs [1, 2] provide safety requirements and safety guidance with regard to site characterization for disposal facilities. It is also possible to infer additional guidance from other IAEA safety publications [33–35]. In particular, according to Ref. [2], the site should be located in an area of low tectonic and seismic activity so that the isolation capability of the disposal system will not be endangered. Therefore, areas of low tectonic and seismic activity should be selected in the regional analysis, and preference should be given to areas or sites where the potential for adverse tectonic or seismic events is sufficiently low that it will not affect the ability of the disposal system to meet safety requirements. As a consequence, the distance of sites from areas with high seismicity or from known or suspected capable faults may be used as a screening factor at the area survey stage for the selection of candidate sites.

512. Surface processes such as flooding of the disposal site, landslides or erosion should not occur with such frequency or intensity that they could affect the ability of the disposal system to meet safety requirements. The disposal site should be generally well drained and free of areas of flooding or frequent ponding. Accumulation of water in upstream drainage areas due to precipitation, snowmelt, failure of water control structures, channel obstruction or landslides should be evaluated and minimized so as to decrease the amount of runoff that could erode or inundate the facility. Preference should be given to areas or sites with topographical and hydrological features that preclude the potential for flooding. In the area survey stage, areas and sites subject to flooding should be evaluated. In the site characterization and confirmation stages, information should be collected, such as the location of existing and planned surface water bodies, the identification of potentially unstable slopes (i.e. the potential for landslides), identification of materials of low bearing strength or high liquefaction potential and data on the flood history of the region.

Observations

513. The Joint Report [4] is clearly written and presented, and represents a significant milestone in the repository development project. With respect to the process of site characterization, the Review Team acknowledged that careful and detailed work has been carried out for both the area survey and site characterization. However, some problems were noted with the data acquisition and data management programme.

Hydrogeology

514. The site characterization data provided in Ref. [4] and in the supporting documents are not entirely adequate for finalization of the site selection stage. The three candidate sites (Galilauke, Apvardai and Stabatiske) were surveyed on the basis of different levels of knowledge. In particular, less information is available for the Stabatiške site. To make relevant comparisons between sites, the data required for the safety assessments should have equivalent levels of completeness, quality and reliability. The investigation process performed on the candidate sites nevertheless complies with the step by step approach that is now considered to be international good practice.

515. The hydrographic situation and specific hydrological characteristics of the candidate sites are described in Ref. [4] in a detailed manner. All candidate sites belong to the Lake Druksiai basin, which is a part of the Daugava (Dysna) basin. The hydrographic network and runoff conditions of the Lake Druksiai basin underwent significant changes in the twentieth century. Comprehensive drainage amelioration was carried out and different kinds of waterworks were built in the environs of the candidate sites.

516. The sluice in the town of Druksiai in Belarus (Facility 500) and the blind earth dam on the Drisviata River have changed the surface water regime and the flow direction of some natural streams. The operation of Facility 500 is governed by an agreement between Lithuania and Belarus. Both installations are important in terms of potential inundation of candidate sites and potential aquatic pathways for contaminant transport in the border area between Lithuania and Belarus. Thus cooperation and the exchange of information would be an important condition for safe operation of a radioactive waste disposal facility at the candidate sites.

517. For the site characterization stage, para. 416 of Ref. [2] states that:

“the following information should be considered:

— location, extent and interrelationship of the important hydrogeological units in the region
— average flow rates and prevailing directions of the groundwater flow
— information on recharge and discharge of the major hydrogeological units
— information on regional and local water tables and their seasonal fluctuations.”

The regional hydrogeological setting has been adequately addressed; in contrast, the local site specific conditions should be more fully investigated. The candidate sites differ in the complexity of their hydrogeological conditions.

518. The organizations involved in the site characterization process are highly professional and have extensive experience with the local geological and hydrogeological settings. Their hydrogeological conceptual models of the sites seem to be well founded on a qualitative level (see Fig. 5), whereas quantitative characteristics will require more extensive field and laboratory investigations. There are some uncertainties in the evaluation of the importance of shallow groundwater circulation in sandy interlayers and the fissured upper part of tills, which leads to groundwater drainage to ditches and surface streams.

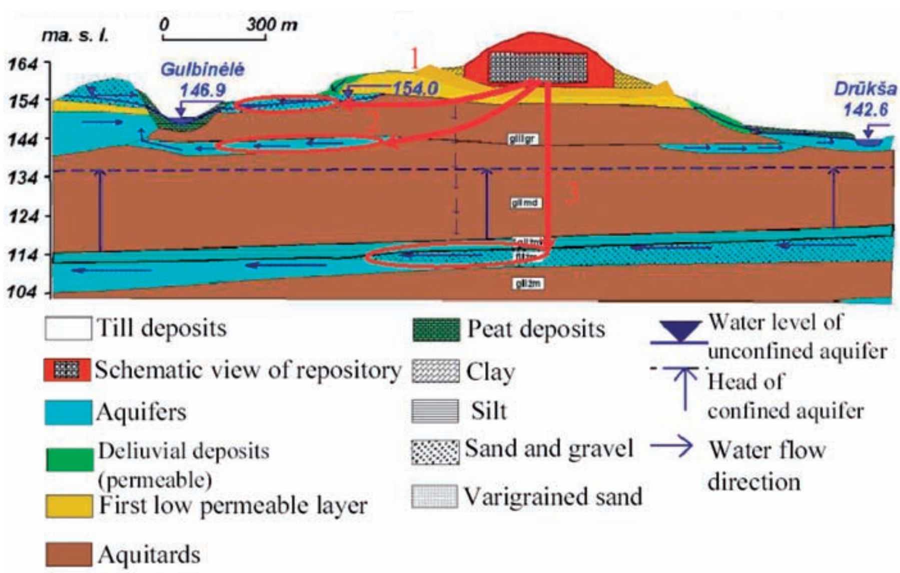

FIG. 5. *Conceptual hydrogeological model for the Galilauke site.*

519. Field and laboratory investigations were conducted to assess the hydraulic properties of the sediment environment on a field scale and on small and medium laboratory scales. Due to disturbance of the sediment environment by fissures, the field scale permeability is greater than the laboratory scale values. Within the safety assessments, however, the laboratory scale values were taken to be representative, which is an approach that is unlikely to be sufficiently conservative.

520. The effective porosity factor was not determined for the natural and engineered barriers. The groundwater flow rate was assessed only on the basis of Darcy velocity; however, Darcy velocity does not directly describe the movement of the advective front of a potential contaminant plume.

521. Paragraph 420 of Ref. [2] states, inter alia, that:

"In the consideration of the likely chemical interactions within the disposal system, the following processes should be evaluated:

— corrosivity of groundwater towards the engineered barriers
— processes or conditions influencing the solubility and the sorption of radionuclides
— Eh and pH of the groundwater
— processes or conditions involving the presence of natural colloids and organic materials
— potential gas generation by the disposal system."

The hydrochemical investigations of the candidate sites did not cover all of the parameters, as only one sampling campaign aimed at determining the basic chemical composition of groundwater was performed. The same is true for parameters that describe the transport of radionuclides in groundwater.

522. The hydrological regime and description of the hydrographic situation and specific hydrological characteristics of the candidate sites were provided in a very detailed manner. The possibility of flooding was assessed and excluded. The water budgets of the candidate sites were calculated on the basis of comprehensive studies; however, large uncertainties remain for the Stabatiske site owing to the short period of observation.

523. Meteorological and climatological data, based on long term observations, are adequately addressed in Ref. [4].

Tectonics and seismicity

524. Regarding the regional setting, the Ignalina region is part of the European stable platform. The stratigraphy consists of a sequence of Quaternary moraine deposits that reach a maximum thickness of 300 m. This sequence overlies a Devonian, mainly sandstone, formation. Its maximum thickness is in the range of 400 m, and it covers the Precambrian crystalline basement.

525. The Quaternary moraine shows horizontal and vertical facies variations. No faults were found in these sediments during the geological mapping of the entire Ignalina region at a scale of 1:50 000.

526. Morphologically, the entire area presents low, very gentle slopes. The difference in elevation between the valley floors and the tops of the hills is typically in the range of 10–20 m.

527. The following investigations have been carried out at the different sites:

- Apvardai:
  - Three boreholes, 15–20 m deep.
  - Two geophysical profiles (electric tomography) for a total length of about 500 m.
  - One static cone penetration test.
  - One dynamic cone penetration test.
- Galilauke:
  - Ten boreholes, one reaching a depth of more than 200 m and the others in the same range of depth as the boreholes at the Apvardai site. The deep borehole was drilled for the regional geological survey at a scale of 1:50 000.
  - Seven geophysical profiles (electric tomography).
  - Five static cone penetration tests.
  - Two dynamic cone penetration tests.
- Stabatiske:
  - Ten boreholes, three 30 m deep and seven up to 20 m deep.

528. On the basis of the above results, the following potential hazards should be considered at this stage:

- VGM;
- Settlement;
- Liquefaction.

The three sites can be considered to be identical in terms of potential VGM (intensity 7 on the MSK scale resulting from an earthquake of magnitude 4.5).

529. Although the bearing capacity (settlement, liquefaction) is different for each of the three sites, on the basis of the data given and the site visits, all three are considered to be adequate for the construction of a repository. However, a reanalysis could be performed taking into account the potential VGM level to confirm this conclusion.

Surface processes

530. On the basis of the geological, seismological, hydrological, hydrogeological, metereological and morphological characteristics of the Ignalina region and the three candidate sites, the following potential hazards should be considered at this stage:

— Slope stability;
— Flooding;
— Erosion.

531. On the basis of the present analysis, slope stability was not recognized as a significant potential hazard for the three sites. However, it is recommended that potential VGM be taken into account in the studies that remain to be performed. On the basis of the data provided, the presentations and the site visit, flooding still needs further assessment for the three sites, particularly to check the impact of events that may affect water levels. Erosion has been adequately taken into account and is not considered to be a hazard for the three sites.

Conclusions

532. Additional site specific information is needed to improve judgements about the behaviour of the repository (i.e. long term safety) within the natural environment.

533. As previously stated, and in accordance with para. 316 of Ref. [2], a quality assurance programme for all activities during the site characterization stage should be established to ensure compliance with relevant standards and guidelines. In particular, it should provide for the production of documentary evidence to demonstrate that the required data quality has been achieved.

Good practice

534. The Review Team concluded that the process of site characterization was being conducted according to international good practice and that the candidate sites show good prospects of meeting internationally endorsed safety objectives and criteria. However, further work is necessary to demonstrate safety. It would be desirable to improve the siting process by better defining an overall plan for the process of site selection by establishing siting principles and identifying desirable site features, in accordance with para. 210 of Ref. [2].

535. The operator should plan the data acquisition programme carefully to ensure that objectives are achieved in a cost effective manner, in accordance with para. 3.7 of Ref. [12].

536. The conclusions regarding the sites that have been investigated are appropriate for the level of the technical investigations performed to date and have been enhanced by the overall understanding of the region, which has developed over years of study.

Recommendations

537. The Review Team recommends that the RATA develop a data acquisition plan for finalization of the site characterization stage and that it organize all data from various data sources and subcontracting organizations into a structured database designed to meet quality assurance requirements.

Hydrogeology

538. The Review Team recommends that the final decision on site selection be based on three concepts outlined in paras 409, 414 and 413 of Ref. [2], respectively:

- “Preference should be given to sites with a uniform and predictable geology which can be readily characterized through geological investigative techniques”;
- “Preference should be given to sites with a simple geological setting that could make characterizing or modelling of the hydrogeological system easy”;
- “The hydrogeological setting of the site should include low groundwater flow and long flow paths in order to restrict the transport of radionuclides”.

539. Further site investigation could be an integral part of pre-operational monitoring, as described in section 4 of Ref. [36]. Pre-operational monitoring would provide input data needed for site characterization, including characterization of migration pathways for further safety assessment. The frequency of field observations must be sufficient to allow for seasonal variations in site parameters to be adequately addressed and for spatial heterogeneities in hydrological and hydrogeological characteristics to be determined on a scale commensurate with the modelling requirements for the safety assessment. The duration of pre-operational monitoring should be longer than a single hydrologic year — preferably several years — to reliably describe the hydrodynamic and hydrochemical regime of hydrostratigraphic units. The Review Team recommends that the pre-operational monitoring plan be developed prior to the start of detailed investigations.

540. To confirm the geological, hydrogeological and geochemical characteristics of the disposal zone and its immediate surroundings at each candidate site, it is recommended that more use be made of direct investigation methods (e.g. boreholes, including cores for laboratory examination).

541. It is recommended that further investigations at the candidate sites be aimed at determining those characteristics that are the most significant for the description of the movement of contaminants that may be released from the repository and those that could influence the design of the repository (e.g. groundwater level fluctuations, natural drainage and natural barrier permeability, migration parameters). Effective porosities of natural and engineered barriers should be determined to calculate average groundwater flow rates (i.e. tracer velocity).

542. Additional studies are required to determine the hydrochemical parameters in accordance with para. 420 of Ref. [2]; observation of the hydrochemical regime (i.e. variations over time) is also necessary.

543. In accordance with paras 421 and 422 of Ref. [2], information needed to estimate the potential for migration of radionuclides to the biosphere should be collected, including:

- “mineralogical and petrographical composition of the groundwater flow system and its geochemical properties
- “groundwater chemistry.” (para. 421)
- “This information is not likely to be available at the area survey stage for the selection of candidate sites. However, it should be collected as part of

the investigation programme carried out during the site characterization and confirmation stages.” (para. 422)

544. The conceptual hydrogeological models for candidate sites should be validated by further field observations and experiments, including studies of groundwater level fluctuation in response to precipitation for individual hydrostratigraphic units. The professionals involved in site characterization should consider the option to perform hydrodynamic testing (i.e. a recharge test in the boreholes) and/or tracer tests. It is recommended that the importance of a potential shallow migration pathway, including groundwater–surface water interactions, be validated by field studies.

545. A comprehensive study of the hydrological water budget of the candidate sites should continue on the basis of hydrological, hydrogeological and meteorological monitoring. The frequencies chosen for this purpose need to reflect daily and seasonal variations (for meteorological data). Vadose zone monitoring does not seem to be important owing to the limited thickness of the aeration zone.

Tectonics and seismicity

546. In the calculation of the VGM at the site and its consequences regarding assessment of the stability of the site and the repository, an earthquake with a magnitude of between 4.5 and 5 should be taken into account. On the basis of present knowledge, the occurrence of an earthquake of this size in the Ignalina seismotectonic environment cannot be excluded. This earthquake should be put at a hypocentral check distance of between 5 and 10 km from the location of the repository. The VGM should take into account source mechanism, travel path and site characteristics. This implies:

— A reanalysis (dynamic) of the slope stability (natural and human made);
— An analysis of potential liquefaction at the site, taking into account the characteristics of the aquifers;
— An analysis of potential differential settlement.

547. It is recommended that internationally accepted and up to date methodologies be used to assess the VGM and the stability of human made and natural slopes, potential liquefaction and differential settlement — especially at the detailed design stage. In particular, for slope stability, a safety factor above 1.3 should be demonstrated.

548. Because flooding represents an important exclusion criterion, it is recommended that an analysis of the potential for flooding at the three sites be performed. The analysis must take into account not only meteorological and hydrological data, but also potential damming of the valley floor due to natural and human made phenomena (e.g. landslides, destruction of human made structures).

6. REPOSITORY DESIGN

INTERNATIONAL GOOD PRACTICE

601. The IAEA Safety Requirements for an NSR [1] state, inter alia, that:

> "the repository shall be designed to provide adequate isolation of disposed waste for the required period of time, with account taken of the waste characteristics, the characteristics of the site and the safety requirements applicable to the repository. (para. 7.1)
> "The design of the repository shall minimize the need for active maintenance after site closure and complement the natural characteristics of the site to reduce any environmental impact. The design shall take into account operational requirements, the closure plan…and other factors contributing to waste isolation and stability of the repository, such as protection of the waste from external events. (para. 7.2)
> "Near surface disposal facilities may include engineered barriers which, together with the emplacement medium and its surroundings, isolate the waste from humans and the environment. The engineered barriers include the waste package and other human made features such as vaults, covers, linings, grouts and backfills, which are intended to prevent or delay radionuclide migration from the repository to the surroundings. (para. 7.3)
> "Although disposal is usually defined as the emplacement of waste in an approved location without the intention of retrieval, some jurisdictions may nevertheless require that retrievability be designed into a repository. If the ability to retrieve waste is a design requirement, it shall be considered in the design process in such a way as not to compromise long term performance capabilities. (para. 7.4)
> "The design of a near surface repository shall allow for implementation of a monitoring programme to verify the containment capability of the disposal system during operation and, as necessary, after closure of the repository. Arrangements for monitoring shall not compromise the long term performance of the disposal system." (para. 7.5)

602. Technical aspects of the design of engineered barriers are described in Ref. [30]. Generally, the following engineered barriers are considered in the design of an NSR:

- The waste package, comprising the waste matrix, package, overpackage and coatings;
- The disposal unit, comprising the engineered structures/isolation layers and lining and backfilling materials;
- The human made cover, comprising a series of alternate low and high permeability layers.

603. It is pointed out in Ref. [30] that the important features to be considered in the selection of barrier structures and materials are their long term durability, their compatibility with site characteristics, associated media and other materials, and their availability. For an NSR, durations of a few hundred years are considered, during which the barrier serves to maintain the safety functions of the disposal facility.

604. When selecting the barrier materials, the designer therefore evaluates their potential for long term integrity. This evaluation can address processes that are relevant to the specific site environment (e.g. chemical attack, leaching effects, corrosion and erosion stability, mechanical strains, freeze–thaw effects).

605. According to Ref. [31],

> "The engineered barriers can be designed to:
>
> - minimise the release of radionuclides from the waste packages or from the engineered barrier itself;
> - restrict infiltration of precipitation water or groundwater;
> - control infiltrating groundwater to provide beneficial aqueous conditions;
> - minimise the probability of potential human intrusion;
> - provide a mechanism for the restriction and dispersal of gases, if any, generated within the facility, in particular the waste package;
> - provide long term structural stability;
> - protect waste package integrity from degradation through ingress of degrading materials;
> - assist in the monitoring designs to collect and direct infiltrating water for monitoring and/or conditioning;
> - control erosion of the disposal facility (top surface/soil); and
> - provide physical and chemical conditions in the near field to minimise radionuclide release rates."

Furthermore, Ref. [31] points out that:

> "The detailed design of the engineered barriers is very important to the overall design of the disposal facility. Therefore, the expected properties and functional efficiencies of these barriers are often defined within the context of general requirements so that some quantitative guidance can be given to the safety assessment at an early stage. Feedback from safety assessment is important in defining areas where improved performance is required. Alternatively, it is possible that the engineered barriers may have been over specified and the specifications can be revised."

OBSERVATIONS

606. The reference design presented in Ref. [8] (see also Figs 2 and 3) clearly refers to IAEA standards, in particular to Ref. [1]. The design is supported by a review of near surface disposal facilities that have been designed and completed in different countries, including the Centre de l'Aube disposal facility in France, Spain's El Cabril facility, the Drigg disposal facility in the United Kingdom, the Rokkasho disposal facility in Japan and the SFR repository in Sweden.

607. The generic design of the repository considers the following elements of the multibarrier system:

— Multilayer capping that includes a 30 cm thick clay isolation layer (50 cm and 1 m layers are also considered);
— Reinforced concrete disposal vaults designed to allow for migration of gases;
— Packages containing radioactive waste (at least two types, namely, steel drums and multidrum concrete boxes);
— Solid or solidified radioactive waste of different forms (concrete, bitumen, compressed ash, dry ion exchange resins and perlite).

608. The reference design was assessed in 2002 by an international review team made up of experts from an international consortium, the Lithuanian Institute of Physics and the Kaunas University of Technology [9]. The assessment was an efficient way to improve the concept. However, the way the conclusions of this assessment were addressed in subsequent studies for the NSR in Lithuania was not discussed.

609. The conceptual design is not explained by a comprehensive description of the safety functions allocated to the different components of the disposal system, even though some properties or functions are provided in Ref. [8]. This approach, which is emphasized in Ref. [30], is important for identification of key components for the safety of the repository.

610. At this stage of the design, the way the engineered barrier system will be monitored has not yet been finalized. The Review Team observed that there was no underground gallery to collect any leachate that might be generated in the vaults. Some designs have a collection system beneath the repository (below the clay) for this purpose. The Review Team noted that the monitoring issue is still under discussion, as alternative options were presented during the meetings.

611. It is important that characterization measures on the site include measurements that enable verification of the feasibility of construction and that calculations be done to assess geotechnical conditions.

612. If a drainage system were to be included in the design, it would be important to distinguish between leachate and ‘parasite’ effluents that might enter the drainage system, particularly for sites with shallow groundwater. In empty vaults, prior to emplacement of waste, attention should be given to drainage of rainwater, as freeze–thaw cycles can damage the vaults.

613. The reference design requires that the permeability of the clay layer be higher below the vaults than above and around them. This requirement is made so that a ‘bathtub’ scenario will be avoided. The feasibility of monitoring contrasts of permeability on a large scale must be carefully assessed.

614. The RATA plans to demonstrate the feasibility of the construction of the clay based engineered isolation layer in a pilot in situ demonstration. This is a highly recommended approach, provided the pilot system has a well designed monitoring and evaluation programme. These plans should include the development of quality control and quality assurance systems for constructing barrier layers. On the basis of this pilot programme, changes to the design of the capping system might be considered, including, for instance, the use of an additional isolation barrier, such as a synthetic geomembrane. Generally, the use of multiple isolation layers is considered a better way to ensure long term functioning of the barrier system.

615. As soil settling processes may appear several years after the construction of the repository's capping system, studies of this effect could be incorporated into the programme of the pilot in situ demonstration.

616. The vaults will have a square horizontal base 18 m long and 6 m high. The different layers of the capping system above the vaults will be about 3 m thick. The disposal facility will include not only disposal vaults but also some auxiliary buildings (possibly including an interim storage structure, an administration building or a laboratory) (Fig. 6). At the present stage of the project, the compatibility of the available surface at the different sites has only been checked for the vaults area and the capping system (Fig. 7) and with a reference inventory of 100 000 m^3 of waste packages. A preliminary estimate for the site area is about 40 ha, with 10 ha for the disposal zone. The flexibility of the sites may differ if the inventory of the waste changes.

CONCLUSIONS

Good practice

617. The reference design refers to IAEA standards and to the international experience gained in the design and construction of near surface disposal facilities. The preliminary reference design includes a robust, multibarrier system that can be summarized as follows:

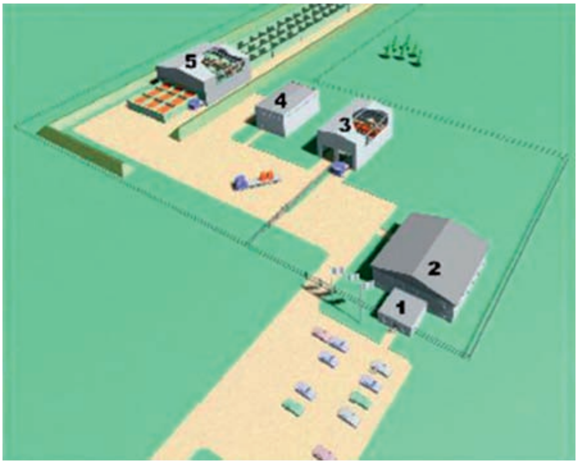

FIG. 6. Schematic layout of the disposal facility.

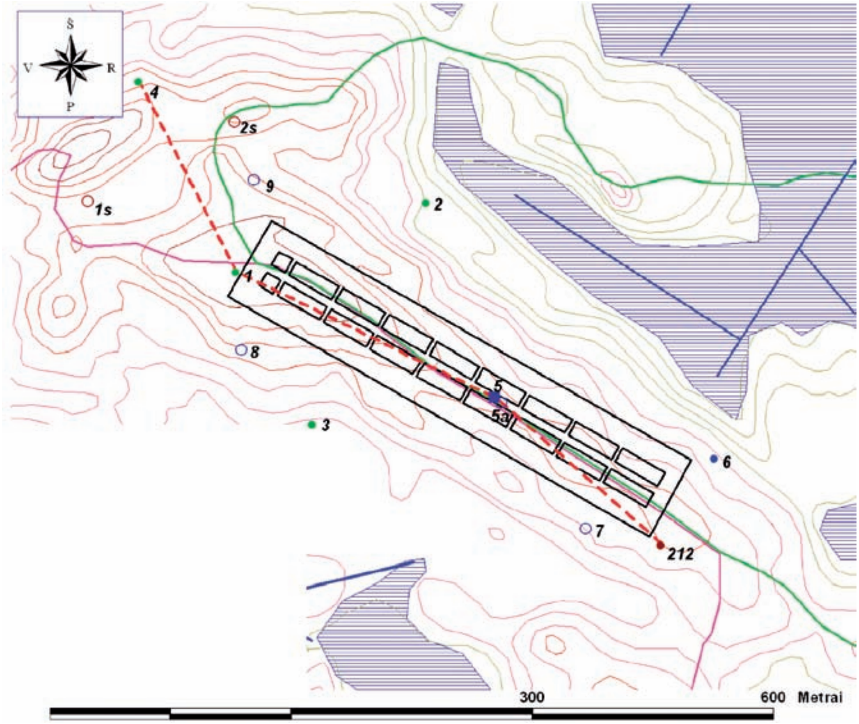

FIG. 7. Projected layout of the vaults area at the Galilauke site.

— The conditioned waste is encapsulated in waste packages.
— The waste packages are encapsulated in vaults.
— The vaults are encapsulated in a clay barrier.
— The repository is constructed above the water table.

618. The RATA has been using experts from abroad to assess the repository design. The planned introduction of an NSR by the RATA includes the performance of a pilot test. The demonstration of the feasibility of the construction and performance of the barrier under actual site conditions and on a field scale was considered a responsible approach and should be fully encouraged.

619. The RATA has studied the basic processes of the long term performance of the engineered barrier system. These studies are adequate for the current phase of the development of the repository, but they will have to be intensified and extended before the full safety assessment of the repository is carried out in support of the documentation necessary for the construction permit.

Recommendations

620. In the detailed design stage, it is recommended that the safety functions allocated to the different components of the disposal system and the performance required from these components be specified.

621. For the proposed reference design, it is recommended that the RATA study how to meet the requirements of Article 53.2 of VATESI Regulation P-2002-2 [3], namely, that the monitoring programme of the disposal facility include "measurements of repository parameters demonstrating that the barriers have the features as expected". If the basis layer that is engineered below the vaults is to be used as a collection system to monitor infiltrated water, its settlement under the burden of the vaults should be taken into account.

622. On-site investigations should include the measurement of those parameters that are important for assessing the feasibility of construction of the disposal vaults. In the detailed design stage, it is recommended that appropriate methodologies (e.g. numerical calculations using the finite element method) be applied to assess geotechnical conditions, and that special attention be paid to the possible occurrence of very shallow groundwater.

623. The pilot test should aim at demonstrating that the required properties of the engineered clay layer proposed in the vault design can be achieved. It is recommended that the in situ demonstration be planned and carried out so that it serves for developing a quality assurance and quality control programme for the construction of the capping system and confirms that the capping system will perform as expected. For this reason, the in situ demonstration should last long enough to enable the assessment of potential degradation processes in the engineered layer. Based on the observations made during the pilot demonstration, the design of the capping system should be reassessed to ensure its safe long term function.

624. The Review Team recommends that, in future stages of planning and assessment, special attention be given to the possible accumulation of precipitation water in the open disposal cells of the vaults to be constructed during the operational phase of the repository. If these cells are not properly drained, the freezing of accumulated water could damage the engineered barrier system.

625. It is recommended that a criterion be developed for the minimum surface area required for the facility, including auxiliary buildings (e.g. ancillary

structures such as administration buildings, temporary storage, laboratories), protected zones and the capping footprint.

626. In approving package specifications, it is recommended that the RATA include the impact of conditioning processes on the volume and properties of the final waste form for disposal, as this aspect could have an effect on the total surface area required for the disposal facility.

7. SAFETY ASSESSMENT

METHODOLOGICAL ASPECTS OF THE SAFETY ASSESSMENT

International good practice

701. Regarding the conceptual and planning stage of the siting process, para. 214 of Ref. [2] states, inter alia, that:

> "Available methodologies for safety analysis should be reviewed and basic methods and models selected. Subsequently, a generic safety assessment should be performed according to the national regulatory requirements or international recommendations. This generic safety assessment would give confidence that the proposed facility is capable, basically, of meeting the regulatory requirements for the anticipated waste."

702. The next stage of the siting process, site characterization, involves the investigation of one or more candidate sites to demonstrate that they meet safety and environmental requirements. To demonstrate the acceptability of the sites, "A preliminary safety assessment should be performed for each candidate site to determine that each one is potentially suitable for accommodating a disposal facility" (Ref. [2], para. 224).

703. Paragraph 228 of Ref. [2] further states that: "The site confirmation stage consists of detailed laboratory studies and field investigation of the preferred site(s) and its (their) surroundings prior to the start of construction". Paragraph 229 of Ref. [2] states that: "Safety analysis data and models should be updated for the specific site(s), and a detailed safety and environmental impact analysis should be performed using all the detailed information available". Paragraph 230 of Ref. [2] states that:

> "A final safety and environmental impact assessment based on all the investigations and evaluations should be prepared, summarizing all the relevant data, evaluations and conclusions derived from all site characterization and confirmation activities. Careful comparisons with criteria should be made to ensure that the site(s) will perform as required. Upon confirmation of the suitability of the site(s), the regulatory body should be provided with sufficient information to permit decisions to be made on

authorization for construction and operation, taking into account closure and post-closure considerations."

704. Bearing these aspects in mind, the quantity of data required and the complexity and sophistication of the safety assessment should increase as the overall siting process progresses towards its goal of confirming a site.

705. As stated in para. 1.3 of Ref. [12]:

> "Safety assessment is a procedure for evaluating the performance of a disposal system and, as a major objective, its potential radiological impact on human health and the environment. The safety assessment of near surface repositories should involve consideration of the impacts both during operation and in the post-closure phase. Potential radiological impacts following closure of the repository may arise from gradual processes, such as degradation of barriers, and from discrete events that may affect the isolation of the waste. The potential for inadvertent human intrusion can be assumed to be negligible while active institutional controls are considered fully effective, but may increase afterwards. The technical acceptability of a repository will greatly depend on the waste inventory, the engineered features of the repository and the suitability of the site. It should be judged on the basis of the results of the safety assessments, which should provide a reasonable assurance that the repository will meet the design objectives, performance standards and regulatory criteria. These are specified in the Safety Requirements…."

706. Formal methodologies for evaluating the long term safety of near surface disposal facilities have been developed over the years, but intercomparisons of these methodologies carried out by the IAEA have revealed inconsistencies in their application. As a result of these findings, the IAEA initiated a coordinated research project to improve and harmonize the approach to such safety assessments, which resulted in development of the ISAM methodology [18].

707. Taking into consideration the more recent approaches to safety assessment for near surface disposal facilities, the ISAM project identified the need to address the following key components:

— Specification of the assessment context;
— Description of the waste disposal system;
— Development and justification of scenarios;

— Formulation and implementation of models;
— Analysis of results and building of confidence.

708. For this purpose, in addition to the most likely scenarios considered in the framework of the safety assessment, it can be helpful to evaluate alternative scenarios for the evolution of the disposal system ('what if' calculations). These alternative scenarios and 'what if' calculations address regulatory and stakeholder concerns (e.g. concerns of local populations or neighbouring countries). They can serve to build confidence in and provide more transparency to the decision making process. While such an approach is relevant at an advanced stage of the facility development, it can be started at the preliminary safety assessment stage.

Observations

709. A generic safety assessment initially performed by SKB (Sweden) when the reference design of the disposal facility was developed is presented as appendix 3 in Ref. [8]. The results obtained during the generic design and safety studies did not lead to any significant changes to the conceptual design. However, further site specific data and detailed inventory will need to be taken into account and may require changes to the conceptual design.

710. The safety assessments for the candidate sites were performed by the RATA and contracting organizations — the Lithuanian Energy Institute and the Institute of Geology and Geography. The results of this work are presented in the Joint Report [4] and were evaluated by the Review Team for the assessment of the safety of the sites considered and the feasibility of the proposed reference design and its appropriateness for the local conditions.

711. Both operational and post-closure safety assessments were performed and are presented in Ref. [4]. The safety assessment for the operational period is presented as an estimation of external doses using the existing dose constraint values for Lithuania as the safety criteria [25, 26]. Exposure of the personnel and the public during normal operation of the repository was assessed. Emergency situations for the operational period were also considered and are presented separately. Incidents considered in the report included:

— An accident during the transfer of a radioactive waste package within the site;
— Suspension of a radioactive waste package;
— Drop and rupture of a radioactive waste package;

— Possible incidents during the transport of a radioactive waste package to the repository;
— A fire within the area controlled by the repository.

712. The above situations are described in appendix K (emergency situations) of Ref. [4], which is a summary of Ref. [7]. However, no explanation or justification is given for the selection of these scenarios. For instance, no calculation was made for a fire scenario, based on the reasoning that the fire hazard potential was very low, without a quantitative evaluation for this hazard. The main potential sources of fire, such as electrical problems and vehicles, are recognized, but no attention is paid to the fact that the Stabatiske site is located in a forested area and that a fire from an external source could threaten a repository at that site.

713. With regard to the post-closure period, the main focus of attention was the site specific water pathway for exposure of members of the public. Such an approach is reasonable; however, it should be taken into account that intrusion and emergency scenarios can differ from site to site and in some cases could result in rather different impacts, depending on site specific conditions.

714. The overall approach used for post-closure safety assessment in Ref. [4] follows the ISAM methodology, which is now widely used in many countries. All three candidate sites are assessed, and in all cases the calculated doses are below the dose constraints that are now applied in Lithuania. According to the assessment results, all sites are potentially suitable for accommodating a disposal facility from a radiation protection point of view.

715. The safety assessments performed did not bring to light significant additional arguments for or against any of the considered sites in support of the decision making process. The time period for the assessment and the behaviour of the disposal system over time are not described clearly. Moreover, the nature of the parameters chosen (e.g. conservative, best estimate) was not explained.

716. An institutional period of 300 years, including 100 years of active institutional control, is in agreement with current practice. It would be informative to include intrusion scenarios and other ‘what if’ calculations to cover the institutional control period. ‘What if’ scenarios are a useful way to build confidence and may be helpful for the decision making process.

717. For safety assessment calculations, a simplified performance scenario was used that assumed that the concrete materials of the vaults degraded in three stages, namely:

— Full function without any deterioration for the first 100 years after disposal;
— Natural degradation in the interval from 100 to 300 years;
— Full degradation beyond 300 years.

The system description covers all available information and is presented in separate chapters and appendices of Ref. [4]. It is not clear from the report which data from these chapters were actually used for the safety assessment calculations.

718. As the safety assessments will be used for comparative assessment of the three sites considered, this rather simple approach is considered to be adequate (the source term is not affected by site specific characteristics). However, for the safety assessment to be developed in support of the application for a construction licence, the engineered barriers should be described in more detail. The time dependent performance of the different forms of waste and packages considered for disposal needs to be taken into account along with the anticipated loss of function of the isolation barriers. In addition, the mutual influence of particular barrier elements should be considered. The results should be interpreted as a time dependent flow of contaminants from the repository system into the aquifer and biosphere.

719. The generic design considers the creation of gases (due to processes of corrosion and decay of organic materials) in the disposal system and addresses their controlled release in the design solutions for the vaults and the construction of the capping system. Although this is a recommended approach, in the future, considerations of transport of some radionuclides (e.g. radiocarbon, tritium) through atmospheric pathways could be assessed in some specific scenarios to demonstrate that all safety requirements are met.

720. Only one exposure scenario that was considered as pessimistic was used for the post-closure safety assessment, namely, a borehole drilled in the vicinity of the repository (appendix J of Ref. [4]); two cases of degradation of the engineered barrier system were studied. More scenarios would need to be generated, considered and screened, depending on the assessment context.

Conclusions

721. Any key site parameters identified in the generic safety assessment should be examined in subsequent stages of the site selection process; that is, the sensitivity of these parameters should be examined in subsequent iterations of the safety assessment.

Recommendations

722. The RATA has used a simplified approach to operational and post-closure safety assessment in the Joint Report [4], relying appreciably on qualitative reasoning. The Review Team recommends that, for the next iteration of the assessment, additional site specific and design related scenarios be considered, screened and documented.

723. It is recommended that the assessment context be formulated carefully for future safety assessment iterations to allow the assessment to focus on site specific features and to build confidence in the process. It is important to establish the assessment philosophy (e.g. conservative, best estimate), especially when significant uncertainties exist with regard to disposal facility design, waste inventory, site description and parameter values.

724. It is recommended that a schematic description of each disposal system be included in the corresponding part of the safety assessment to make the assessment more logical and transparent.

725. The Review Team recommends that all types of waste package now in use or planned for use in the operational period of the disposal facility be considered in future safety assessments. Currently, only one type of waste package is considered, which may not be the most critical waste package from the point of view of radiological consequences in emergency situations. Waste packages containing compacted ashes, for example, may give rise to significant exposure in the event of a crash or fire.

726. The Review Team recommends that a structured approach be taken to performing the assessment of operational safety, such as an approach similar to the ISAM methodology. The use of a structured approach brings more transparency and is helpful for building confidence in the results obtained.

727. Intrusion and emergency scenarios can differ from site to site and may have different consequences depending on site specific conditions such as the

distance to the nearest open water sources, wind speeds and directions, and proximity to protected areas (such as national parks and boundary reserves) and national borders. Therefore, it is recommended that arguments be justified to explain why operational safety assessment is performed without taking site specificities into account. It could be important to analyse external factors that could affect the safety of a disposal facility, such as the presence of explosive materials, oil pipelines, and roads and routes for the transport of flammable materials in the vicinity of the site.

MODEL FORMULATION, IMPLEMENTATION AND TREATMENT OF UNCERTAINTIES

International good practice

728. The ISAM report [18] notes that:

> "Throughout this process, data are used to help develop the conceptual and mathematical models and provide input into the computer tools. The performance of safety assessment usually requires a significant amount of information and data related to the disposal system. The data are used throughout the safety assessment process, particularly in scenario development and justification, model formulation and implementation, and in the interpretation of the results."

729. In the safety assessment, particular attention should be given to [18]:

> "(i) The sources of uncertainty in parameter values and methods for dealing with them in the safety assessment;
> (ii) The use of generic data in the absence of site specific data and the trade-off between the use of generic data and the requirement for the collection of further site data; and
> (iii) The choice of methods used to select appropriate ranges for input parameters."

730. Reference [12] states, inter alia, that:

> "Reasonable conservatism that can withstand scientific scrutiny should be built into the safety assessment modelling from the beginning. A simple modelling approach is likely to be more efficient, easily understandable and justified. Assumptions should be formulated on the basis of

available data and knowledge of the system or similar systems, and selected so that they are not likely to underestimate the release and transport of radionuclides or, if required, the exposure of an inadvertent intruder. Since acceptance of the results can be the most difficult aspect of an assessment, any approach to make that acceptance easier will be a long term benefit. An approach which balances simplicity, conservatism and realism is likely to be the best starting point for assessments. (para. 3.30)

"The chosen model should be consistent with the assessment objective, easy to use (considering the complexity of the system), and the one for which the data can be obtained. The model should be appropriate for the application, the accuracy of the algorithms should be demonstrable, the assumptions should be reasonable and the input data should be representative." (para. 3.31)

731. Reference [2] states, inter alia, that:

"Using appropriate guidelines and analysis techniques, a reasonable comparative evaluation may be made among sites on the basis of their ability to meet safety requirements and of their suitability for construction of the disposal facility. Economic, social and political considerations should be taken into account at this stage." (para. 225)

732. Reference [2] also provides recommendations for the site confirmation stage:

"A final safety and environmental impact assessment based on all the investigations and evaluations should be prepared, summarizing all the relevant data, evaluations and conclusions derived from all site characterization and confirmation activities. Careful comparisons with criteria should be made to ensure that the site(s) will perform as required." (para. 230)

Observations

733. The Review Team could not make a full scientific review of the construction and justification of the model. However, some observations were made.

734. A sophisticated modelling approach was used for the estimation of doses relating to the aquatic pathway. The process follows the ISAM methodology [18],

although some steps (e.g. the description of the system of radioactive waste disposal) are at a very preliminary stage. The data characterizing radioactive migration in the geosphere and biosphere should be justified on the basis of field investigations.

735. In most cases, transport parameters used in calculations were not site specific. In some cases, literature values have been used in modelling, which is acceptable at this stage. For site specific parameters (e.g. hydraulic conductivities), significant variations were observed between values derived from laboratory measurements and values derived from field investigations. In Section 5 of this report, recommendations are proposed to justify the parameters by field investigations.

736. The calculations performed did not cover the observed range of parameters. The modelling studies were based on the judgements of the professionals involved in the studies. A very conservative approach would be to apply worst case scenarios based on the least favourable parameter values.

737. Some application problems arose from the implementation of the complex modelling approach (e.g. the FEFLOW code). The boundary conditions were not fully justified and probably would need revision in future assessments. The three dimensional modelling approach was appropriate in such a complex geological environment (see Fig. 8).

738. No formal treatment of parameter uncertainty or sensitivity is presented in the Joint Report [4]. Uncertainties are not bounded by the selection of parameters in a deterministic calculation.

Conclusions

739. As elaborated in the discussion of Methodological Aspects of the Safety Assessment at the beginning of this section, a clear and consistent strategy should be applied to the selection of the level of conservatism used in the safety assessments. This strategy should be derived from the assessment philosophy established in the assessment context. The strategy may or may not include formal uncertainty and sensitivity analysis methods; however, it is good practice to use such methods to determine areas where further development of design or site characterization data is needed.

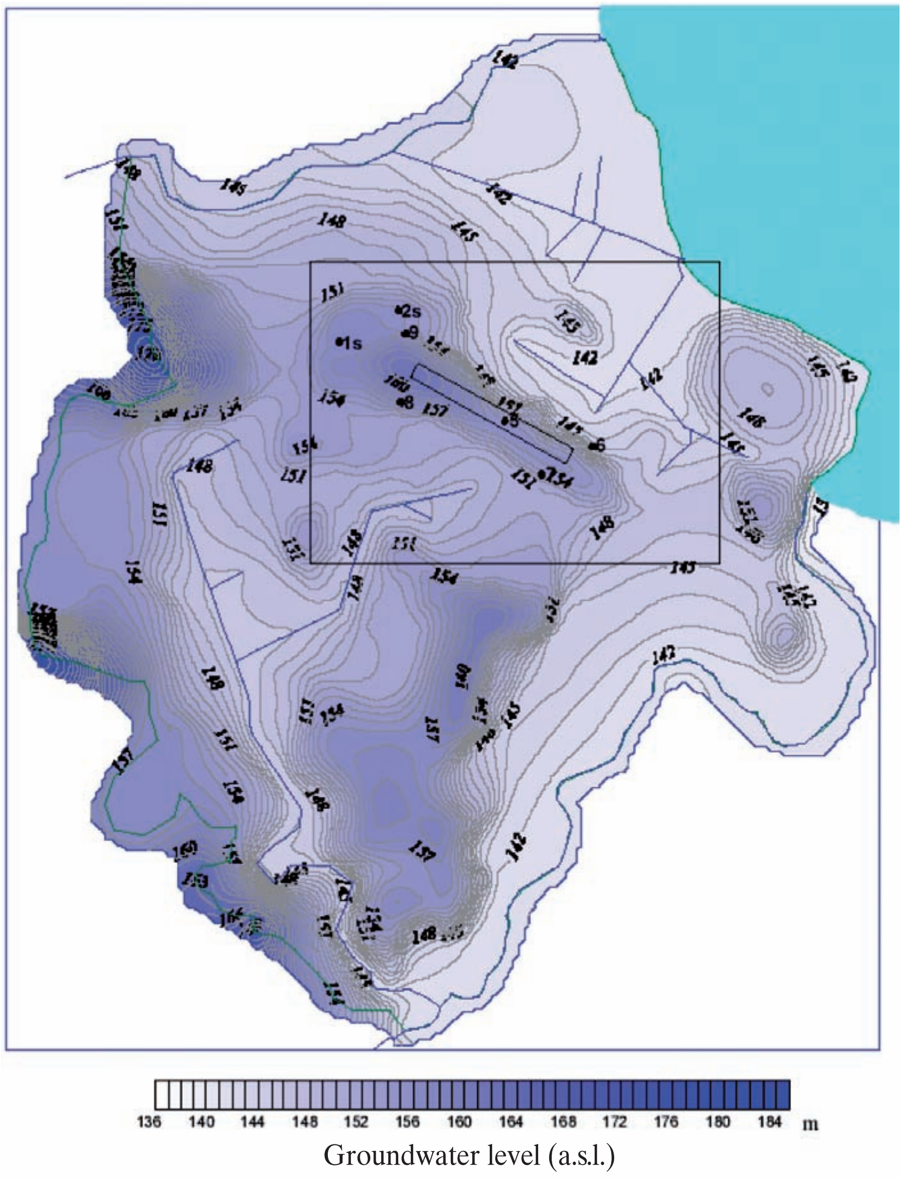

FIG. 8. Groundwater modelling for the Galilauke site, with the aid of the FEFLOW code.

740. Changes that will be made in the conceptual design of the disposal facility should be traced, and their consistency with the model used for safety assessment should be checked.

Recommendations

741. The Review Team recommends that the RATA place emphasis on demonstrating that the models and data used in the safety assessment are both traceable and justified. All parameters need to be justified.

742. Complex modelling tools were applied for the safety assessment of only one of the sites; it is recommended that the same modelling tools be used for all sites being compared.

743. To perform the safety assessment at the site confirmation stage, data and models should be updated for the specific site(s), and a detailed safety and environmental impact analysis should be performed using all information available and the recommendations highlighted above. Extensive laboratory studies and in situ testing should be conducted. In situ tests, together with results of laboratory studies, should provide site specific data for radionuclide transport modelling. The Review Team recommends that uncertainty and sensitivity analysis be used to identify and rank the key site specific parameters to be investigated. This could save time and resources during the safety assessments at the site confirmation stage.

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Annex

TABLE A–1. SITE SELECTION CRITERIA PROPOSED BY THE RATA[a]

Main requirements for site	Site exclusion criteria	Desirable site features
Topographical features	Possibility of flooding of foundation	Surface inclination is sufficient and water can drain away into a surface water body. Preference should be given to a big hill.
	High erodability	High resistance to erosion — relatively smooth site, shallow water flow speed v is below the critical speed $v_{cr.}$
Geotechnical stability	Unstable slopes (safety factor $\mathbf{F}_{\tan\varphi}$ is less than 1.3)	Slope stability of friction material; safety factor $\mathbf{F}_{\tan\varphi}$.> = 1.5.*
Geotechnical stability	High compressibility of bottom bed (high volume compression coefficient β)	Compressibility, compression strength, shear strength, internal friction angle and stiffness (E-modulus) of bottom bed shall comply with requirements for massive constructions*.
	High liquefaction	— 1. Low pore water pressure. — 2. The maximum seismic intensity on the MSK scale < = 6.
	Bad constructability	Feasibility of excavation.
	Variety of ground features	Homogeneous ground.
Hydraulic conductivity	High hydraulic conductivity (filtration coefficient **k** is bigger than 10^{-5} m/s)	Low hydraulic conductivity. It is desirable that filtration coefficient **k** is less than 10^{-7} m/s or even 10^{-9} m/s*.
Impact from natural phenomena	— 1. Unfavourable climate — 2. Unfavourable hydrological conditions	— 1. Low and steady groundwater level. It is desirable that groundwater level is at least 3 m below bottom barrier*. — 2. No risk of being flooded.
Transport risks	— Long distance to Ignalina plant, transport of waste through big settlements and protected or recreational territories.	— 1. Vicinity to Ignalina plant. — 2. Favourable infrastructure and logistics.

* These features will be further verified.

[a] Table reproduced in unedited form as it appears in: SWEDISH INTERNATIONAL PROJECT ON NUCLEAR SAFETY, et al., Identification of Candidate Sites for a Near Surface Repository for Radioactive Waste, RATA, Vilnius (2004).

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Lucien Cécille is a chemical engineer who joined the European Commission (EC) in 1974. He has been working in the field of radioactive waste for over 30 years, first as a scientist at the Joint Research Centre at Ispra in Italy and then as a manager of EC funded projects at the EC Headquarters in Brussels. Through the EC, he has been involved in a number of projects dealing with the safety assessment of near surface and underground disposal facilities in different parts of Europe including the Russian Federation, Lithuania, Bulgaria, Romania, Poland and the Czech Republic.

Michel Dutzer (France, ANDRA) – Chairperson

Michel Dutzer is a civil engineer with 28 years of experience in the French nuclear industry. He was in charge of the construction and startup of the Centre de l'Aube disposal facility and currently is Deputy Head of the Industry Department at the Agence nationale pour la gestion des déchets radioactifs (ANDRA), France's national radioactive waste management agency. The Industry Department is responsible for the repositories for very low, low and intermediate level waste, and for waste collection from small producers and the cleanup of contaminated sites. Mr. Dutzer is a member of the French national standing committee in charge of appraising the safety assessments of nuclear laboratories and facilities.

Andrey Guskov (Russian Federation, MosSIA 'Radon')

Andrey Guskov, an engineer with a degree in applied mathematics, has 23 years of experience in the modelling of contaminant migration in groundwater systems. The first half of his career was focused on optimization of uranium leaching systems and assessment of the environmental impact of uranium production. For the past 12 years, Mr. Guskov has carried out safety assessments for Russia's near surface 'Radon' facilities. Currently, he is Head of the Ground Monitoring Laboratory at the Moscow Scientific and Industrial Association 'Radon' and is responsible for safety assessment activities carried out for the Moscow 'Radon' facilities. Mr. Guskov has lectured many times at IAEA workshops and training courses, and has served the IAEA as a specialist on radioactive waste management on expert missions to Belarus, Armenia and the Islamic Republic of Iran.

Luis Jova Sed (IAEA)

Luis Jova Sed is a waste safety specialist working in the Waste Safety Section of the Division of Radiation, Transport and Waste Safety of the IAEA. He has over 25 years of experience in the fields of radiation protection and radioactive waste management. From 1990 until 2002, he was General Director of the Centre for Radiation Protection and Hygiene in Cuba, which provides all of Cuba's radiation protection services, including radioactive waste management, and related research and development. From 1999 to 2001, Mr. Jova Sed served as a member of the IAEA's Radiation Safety Standards Committee (RASSC). He has participated in more than 70 technical missions in different countries, including more than 40 IAEA missions (for RaSSIA, IRRS and WATRP) related to the development of radiation protection infrastructure and regulations, radiological emergency response, the decommissioning of radiation sources and radioactive waste management. He holds an MSc (1978) and a PhD (1982) in radiochemistry from Lomonosov Moscow State University.

Lumir Nachmilner (IAEA)

Lumir Nachmilner graduated with a degree in radiochemistry from the Institute of Chemical Technology in Prague and has been working in the field of radioactive waste management since 1976. He has experience in the areas of conditioning technologies; waste acceptance criteria, a field in which he earned a PhD; and development of near surface repositories. For ten years he managed the national project for the development of a geological repository in the Czech Republic. He has served in senior managerial posts at the Nuclear Research Institute Řež, including as Division Director and a member of the Board of Directors. Since 1986, he has been involved in IAEA activities including consultancies, expert missions, course lectures and short term contracts. From 1997 to 2004, he headed the Geological Repository Department of the Czech Republic's Radioactive Waste Repository Authority (RAWRA). Since 2004, he has been a member of the IAEA's Waste Technology Section in the Division of Nuclear Fuel Cycle and Waste Technology, where his area of responsibility is near surface disposal.

Nada Rapantova (Czech Republic, Technical University of Ostrava)

Nada Rapantova graduated with a degree in mining engineering from the Faculty of Mining and Geology of the VSB–Technical University of Ostrava, where she is currently an associate professor of hydrogeology. She holds a PhD in geology of deposits and applied geophysics, and for the past 15 years has been engaged in research in hydrogeology, modelling of groundwater flow and contaminant transport, and mining hydrogeology. Her research focus has been the development of hydrogeological and contaminant transport models, and environmental impact assessments for radioactive waste disposal and uranium mining sites. Most recently, her research focus has been on non-traditional utilization of uranium deposits after completion of underground mining. She has lectured widely on hydrogeology, groundwater hydraulics and mathematical modelling of groundwater flow and contaminant transport, and has served as an expert on various assignments with the European Commission. Ms. Rapantova has published many peer reviewed papers in journals and conference proceedings. At present, she is President of the Czech National Committee of the International Association of Hydrogeologists (IAH).

John Rowat (IAEA)

John Rowat holds a BSc in engineering chemistry and a PhD in chemistry, both from Queen's University in Kingston, Ontario. His PhD work centred on chemical physics and was carried out in cooperation with researchers at the Max Planck Institute for Medical Research in Heidelberg. In 1988, he joined Atomic Energy of Canada Limited (AECL) to work in the Division for Radioactive Waste Management of the Chalk River Laboratories. His work at Chalk River covered a number of topics, including safety assessment of disposal facilities for low and intermediate level waste, selection of optimal waste processing and conditioning technologies, safety assessment and formulation of alternatives for cleanup of historical waste sites, characterization of radioactive waste and decommissioning planning for historic waste sites. In 2002, Mr. Rowat joined the Waste Safety Section of the IAEA's Division of Radiation, Transport and Waste Safety. His work at the IAEA has focused on development of safety standards for storage and disposal of radioactive waste, and on studies to examine the safety implications of long term storage of spent fuel and radioactive waste. He is also very much engaged in the suite of activities for the application of the IAEA safety standards.

Leonello Serva (Italy, APAT)

Leonello Serva holds a PhD in geological sciences from the University of Rome and has 28 years of experience in the geological and seismological aspects of nuclear science and engineering, and in environmental protection. He is currently Director of the Department of Land Resources and Soil Protection (the Italian Geological Survey) in the Agency for the Protection of the Environment and Technical Services (APAT). He is also a contract professor at the University of Insubria at Como, where he lectures on the earth sciences aspects of the siting of high risk plants/infrastructures. Mr. Serva is a specialist in geoseismological assessment for the siting of nuclear power plants and waste disposal facilities, and has consulted for the IAEA on numerous occasions. He was a member of the working groups that drafted IAEA Safety Series 50-SG-S1 (Rev. 1) and the IAEA Safety Guide on Evaluation of Seismic Hazards for Nuclear Power Plants. He has taken part in more than 70 international review missions and has worked with the European Commission in the evaluation of research projects dealing with environmental sciences (natural and technological risks).

Ian Streatfield (United Kingdom, Environment Agency)

Ian Streatfield joined the UK's Environment Agency in 1998 after nine years of working in radioactive waste management in the nuclear industry. He is currently responsible for the regulation of the UK national low level radioactive waste repository at Drigg in Cumbria. He has been a member of the Environment Agency's Review Team assessing the post-closure safety case for the Drigg facility and is now managing a review of the existing authorizations for the site to determine how it should be regulated in the future. Mr. Streatfield is a chartered engineer who holds a BA (honours) in chemical engineering and an MA in environmental law.

Elmer Wilhite (USA, Department of Energy)

Elmer Wilhite is a senior advisory scientist at the Savannah River National Laboratory with 36 years of experience in the nuclear sciences. He holds a BSc and MSc in chemistry. His assignments include environmental research, research on high and low level waste, and supervision of environmental monitoring and analytical chemistry groups. He served as a consultant to the US Department of Energy (DOE) headquarters on low level waste management for 18 years, and was chairman of the DOE's panel for peer review of low level waste performance assessments. He was also the technical lead for radiological assessment in the DOE's response to Recommendation 94-2 from the Defense Nuclear Facilities Safety Board. He has authored many technical reports on subjects such as human bioassay, trace element speciation in the environment, management of low and high level waste, and performance assessment. Mr. Wilhite was awarded the Don Orth Award for technical excellence in 2003.

Lithuania's national Radioactive Waste Management Agency (RATA) requested the IAEA to conduct a peer review of the safety of its proposed disposal solutions for radioactive waste arising mainly from the operation and decommissioning of the Ignalina nuclear power plant. The objective of the peer review, carried out in December 2005, was to provide an independent assessment of the safety related aspects of the design and sites under consideration on the basis of international safety standards and applicable national standards. This report presents the consensus view of the international group of experts convened by the IAEA to carry out the review.

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