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Regulatory control of naturally occurring radioactive material (NORM) in the Nordic countries

Report from working group Nordic NAT

The Radiation Safety Authorities in Denmark, Finland, Iceland, Norway and Sweden

Regulatory control of naturally occurring radioactive material (NORM) in the Nordic countries

Nordic Radiation and Nuclear Safety Series, Number 03:2023
Report, Nordic Working Group on Natural Ionizing Radiation (Nordic-Nat)

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Summary

Radiological risks associated with naturally occurring radioactive materials (NORM) have been fully recognized in recent decades, and hence, resulted in the integration of NORM radiation protection requirements within the EU Directive 2013/59 and IAEA BSS (2014). Still, it has been internationally emphasized that NORM-related knowledge gaps and uncertainties might present issues in coping with the existing regulatory requirements during their transposition and implementation into national legislations and regulatory frameworks. Therefore, NORM is one of the main subjects in the recently formed Nordic working group on natural ionizing radiation (WG Nordic-Nat). NORM regulatory approaches for radiation protection control, possibilities for collaboration, scientific projects and joint research, monitoring programmes, communication issues, etc. are considered within the group, based on the defined mandate.

The current report is a result of the first joint WG Nordic-Nat activity related to NORM, and it provides an overview of national legislations, regulatory approaches and practices concerning NORM across Nordic countries i.e., Denmark, Finland, Iceland, Norway and Sweden.

Denmark, Finland and Sweden are member states of the European Union (EU), and hence, the Council Directive 2013/59/Euratom (EU BSS) containing NORM specific requirements has been adopted and implemented in the legislation of these countries. Although Norway and Iceland are not member states of the EU, and thus not bound by the EU BSS, legislation and regulatory approaches for NORM have also been developed in these countries according to the international standards and specific country circumstances.

Both differences and similarities related to the legislation, adopted regulatory control approaches for handling of NORM in the industries, NORM waste management and disposal as well as for environmental discharge control have been seen across Nordic countries, and are presented in this report. Furthermore, a provided description of the approahes in regulatory control of NORM-processing industries, NORM waste and pollution in the Nordic countries allows an identification of the common interest for NORM specific issues.

The potential topics for future WG Nordic-Nat collaboration have been identified as (a) use of dose criteria for exemption and clearance of NORM and NORM industries from notification and authorization; (b) safety and environmental assessments for radioactive NORM waste disposal and discharge; (c) regulatory control of multi-contaminants in NORM waste; (d) environmental monitoring in NORM processing industries and disposal sites; (e) inspections in facilities involving NORM; (f) NORM legacy sites and remediation; (g) stakeholder engagement and risk communication in NORM; (h) transboundary movement of NORM waste for disposal and NORM contaminated materials for processing, and finally, (i) potential update of Nordic flag book - publication "Naturally Occurring Radiation in the Nordic Countries (Recommendations, 2000).

Content

1. Introduction

1.1 Background

A decision to establish a Nordic working group on natural ionizing radiation (radon, NORM, building materials), Nordic-Nat, was made at the Nordic Chiefs Meeting in 2018. The first meeting of the group was organized 30-31 January 2019 in Oslo, Norway. Main activities within the group's mandate were considered and identified as follows:

- to identify common topics of interest for further work at the Nordic level and develop relevant projects, documents and statements;
- to harmonize and promote Nordic views and positions internationally, when appropriate;
- to provide a forum for exchanging experience in order to facilitate the future implementation and maintenance of more efficient regulatory framework, as well as information to the public; and
- to facilitate the sharing of expensive and high maintenance laboratory infrastructure, such as reference instruments and atmospheres, as well as sharing observations on new measurement techniques and instruments.

Naturally occurring radioactive materials (NORM) is one of the main subjects of the work of this group, within the given mandate, with respect to regulatory approaches for radiation protection control, but also regarding possibilities for scientific projects, joint research, monitoring, sharing facilities, communication issues, etc.

The status of the regulatory work concerning NORM has been presented by each of the Nordic countries during the first WG meeting (Oslo, 2019). Denmark, Finland and Sweden are member states of the European Union (EU), and the Council Directive 2013/59/Euratom (EU BSS) has been adopted and implemented in the legislation of these countries. However, Norway and Iceland are not member states of the EU, and hence not strictly bound by the EU BSS Directive. Differences in legislation and adopted regulatory approaches have been seen across the Nordic countries. Therefore, sharing challenging issues, good practice, harmonization of regulatory practice where possible, and identification of the topics for potential joint projects or collaborations in the field of NORM was set out as a long-term objective of the Nordic-Nat Working group.

1.2 Preparation and purpose of the report

It was decided, as a first group task, to make an overview report of the regulation of NORM in the Nordic countries. The purpose of the report was to provide compiled, detailed information on different developed regulatory approaches and to identify possible NORM related topics for further joint work and exchange of experience, e.g., concerning both good practices and challenges.

The present report provides, therefore, an overview of the existing regulatory control of NORM in the Nordic countries, including information on:

- Legislation and regulatory framework in each country;
- Identified NORM industrial activities of radiological concern; and
- NORM waste streams and disposal options.

The following sections summarize the national inputs related to the abovementioned topics. Section 5 sets out concluding remarks. NORM related topics, identified as possible subjects of future joint consideration and activities, are listed in Section 6. Finally, each country links to relevant legislation, guidance and/or other valuable national material related to NORM-processing industry regulation are provided in the Annex.

As aforementioned, the purpose of this document is to present the Nordic regulatory frameworks for NORM, and given sections are not an official translation of the national regulations. This document is based on the information available as of September 2021, with minor amendments made during 2022 and 2023 prior to publication. However, it may be periodically updated to reflect any changes in countries national legislations and practices affecting NORM.

2 Legislation and regulatory framework concerning NORM in the Nordic countries

2.1 Denmark

2.1.1 Legislation

The EU BSS is implemented in the Danish regulatory system by passing of the Radiation Protection Act (Act no. 23 of 15 January 2018), which entered into force on 6th of February 2018 together with a number of orders. The central orders relevant for NORM are:

- Executive Order no. 669 of 1 July 2019 on Ionising Radiation and Radiation Protection (Executive Order no. 669/2019),
- Executive Order no. 670 of 1 July 2019 on Use of Radioactive Substances (Executive Order no. 670/2019).

In Denmark, NORM is regulated as any other radioactive material; hence, NORM is not explicitly mentioned in the legislation.

The principles of justification, optimisation and dose limitation are fundamental to the Radiation Protection Act, hence also to the use of NORM. The use of NORM and exposure related to NORM may only take place if:

- The health, financial, societal or other benefits of the use or exposure overweigh any detriment,
- The likelihood and magnitude of exposure, including the number of individuals exposed are as low as reasonably achievable taking into account the current state of technical knowledge and economic and societal factors,
- The sum of doses to an individual shall not exceed the dose limits set by the Danish Health Authority.

2.1.2 Licensing, notification and assessment of safety

Any user of radioactive materials, including use involving NORM, subject to licensing under the provisions of the Radiation Protection Act, must compile a safety assessment commensurate with the nature, scale and complexity of the practice.

The safety assessment should amongst other things demonstrate compliance with a dose constraint of 0.1 mSv/year to the member of the public and dose limits for occupational and public exposure for the practice cf. the table below (Table 1). The Danish Health Authority may authorise an effective dose of up to 50 mSv/year for an exposed worker aged 18 years or over, provided that the average annual dose over any five consecutive years does not exceed 20 mSv/year. In contrast, the dose constraint of other workers within the undertaking should not exceed 0.3 mSv/year.

Table 1. Dose limits for occupational and public exposure from the use of radiation sources and exposure by undertakings (Executive Order no. 669/2019, Annex 1).

Category of individual	Effective dose limit (mSv/a)	Equivalent dose limit (mSv/a)		
		Lens of the eye	Skin[1)]	Extremities[2)]
Exposed worker, aged 18 years or over	20	20	500	500
Individual aged between 16-18 years, pursuing a programme of vocational education of at least two years' duration which is governed by or pursuant to legislation and in which the use of radiation sources or exposure are necessary components of that programme	6	15	150	150
Member of the public	1	15	50	-

1)The dose limit for the skin applies to any surface of $1cm^2$
2) Extremities means hands, forearms, feet and ankles.

§ 5 in Executive Order no. 670/2019 describes the framework for licensing, notification and exemption, and § 9 states that a licence must be obtained, or a notification submitted to the Danish Health Authority before the use of NORM commences (use is defined as manufacture, processing, holding, import, export, transfer, handling, application, control, third-party inspection, storage, disposal, recycling, reuse, discharge and transport of radioactive substances, hence also NORM).

Central to the level of regulatory control is the Annex 1 of Executive Order no. 670/2019. In combination with values for exemption of limited quantities of any type of material in Executive Order no. 670/2019, Annex 3 and values for exemption and clearance of any quantity of material in Annex 4, constitute the basis for setting the level of regulatory control.

In relation to any holding, use and, storage, etc. of one or more radionuclides, the sum of nuclide specific activity or the activity concentration divided by the corresponding exemption value expressed as index values of activity (IA) or activity concentration (IAC) shall be used in order to determine the regulatory control level in accordance with the Table 2.

The regulatory control level for any use, safe discharge, of unsealed sources, including that of NORM, is shown in the tables given in Annex 1 of Executive Order no. 670/2019, also presented below in Table 2.

Table 2. Regulatory control level for unsealed sources (Executive Order no. 670/2019, Annex 1)

Regulatory control level for unsealed sources		Activity index (I_A)		
		IA, Annex 3 ≤ 1	1 < *IA*, Annex 3 ≤10	10 < *IA*, Annex 3
Activity concentration index (I_{AC})	1,000 < *IAC*, Annex 3	Licensing	Licensing	Licensing
	1< *IAC*, Annex 3, ≤ 1,000	Notification	Licensing	Licensing
	IAC, Annex 3 ≤ 1< *IAC*, Annex 4	Exempt from the licensing and notification requirement*	Notification	Licensing

*However, if the total activity per month corresponds to an activity index greater than 10, notification is required.

For discharge, the total discharge per month of unsealed sources, including NORM, is subject to a regulatory control level contingent on the activity concentration (AC) and the activity (A).

In the case of discharge of one or more radionuclides, the sum of nuclide specific activity or the activity concentration divided by the corresponding exemption values shall be used, expressed as index values of activity (IA) or activity concentration (IAC) in order to determine the regulatory control level in accordance with the table below.

The regulatory control level for discharge of radioactive material is shown in the Table 3 below, also from Executive Order no. 670/2019, Annex 1:

Table 3. Regulatory control level for discharge of radioactive material (Executive Order no. 670/2019, Annex 1)

Regulatory control level for discharge of Radioactive materials		Activity index (I_A)		
		IA, Annex 3 ≤ 1	1 < *IA*, Annex 3 ≤10	10 < *IA*, Annex 3
Activity concentration index (I_{AC})	100 < *IAC*, Annex 3	Licensing	Licensing	Licensing
	1< *IAC*, Annex 3, ≤ 100	Notification	Licensing	Licensing
	IAC, Annex 3 ≤ 1< *IAC*, Annex 4	Exempt from the licensing and notification requirements	Notification	Licensing

Index values are defined by the following formulas:

$$I_{\text{A,Annex 3}} = \sum_{c} \frac{A_c}{A_{E,c}} \qquad \text{and} \qquad I_{\text{AC,Annex 3}} = \sum_{c} \frac{AC_c}{AC_{E,c}}$$

$$I_{\text{AC,Annex 4}} = \sum_{c} \frac{AC_c}{AC_{E,c}}$$

were A_c and AC_c are, respectively the activity and the activity concentration of radionuclide c, and $A_{E,c}$ and $AC_{E,c}$ are the associated exemption values in the tables found in Annex 3 and 4 in Executive Order no. 670/2019.

2.1.3 Exemption and clearance

The values given in Annex 3 and 4 of Executive Order no. 670/2019, respectively reflects Table B and Table A of Annex VII in the EU BSS. However, Annex 4 is further developed with exemption and clearance values for naturally occurring radionuclides for both parent radionuclides and their progeny, but also for subparts of the decay chain of U-238, U-235 and Th-232 and individual radionuclides belonging to these decay chains cf. the Table 4.

Table 4. Naturally occurring radionuclides – activity concentration values for exemption or clearance (Executive Order no. 670/2019, Annex 4).

Radionuclide	Activity concentration ($AC_{E,C}$) (Bq/g)
U-238 sec (1)	1
U-238 + (1)	5
U-234	5
Th-230	10

Ra-226+ (1)	1
Pb-210+ (1)	5
Po-210	5
U-235 sec (1)	1
U-235 + (1)	5
Pa-231	5
Ac-227+ (1)	1
Th-232 sec (1)	1
Th-232	5
Ra-228+ (1)	1
Th-228+ (1)	1
K-40	10

1) Parent radionuclide and their progeny, if the dose contributons of those progeny are taken into account in the dose calculation thus requiring only the activity concentration value of the parent radionuclide to be considered, are listed in the table above.

Radioactive material including NORM in solid form is exempted for requirements for notification or licensing or may be granted clearance if the activity concentration is less than or equal to the tabulated values for naturally occurring radionuclides in Executive Order no. 670/2019, Annex 4 (Table 4 of this document). NORM with activity contents less than the values given in Executive Order no. 670/2019, Annex 3, may be exempted or cleared from regulatory control if activity concentrations are below the corresponding values in Executive Order no. 670/2019, Annex 3.

Clearance or exemption may also be granted, with prior approval of the Danish Health Authority, in accordance with the general criteria for exemption form licensing or notification requirements and for clearance as given in Annex 2 of Executive Order no. 670/2019. The general criteria reflect the framework given in section 3 of Annex VII in the EU BSS and state amongst other, that the effective dose to any member of the public due to cleared radioactive material must be of the order of 10 µSv or less in a year for artificial radionuclides or of the order of 1 mSv or less in a year for naturally occurring radionuclides. Material containing naturally occurring radionuclides, where their processing for their radioactive, fissile or fertile properties is licensed, is subject to the dose criterion for artificial radionuclides.

In addition, there are requirements to be fulfilled in order to release buildings, facilities, equipment and sites form regulatory control. In general, buildings, facilities, equipment can be released from regulatory control on the basis of surface or mass-specific clearance criteria as specified in Executive Order no. 670/2019, Annexes 4 and 5. The clearance of land is subject to a dose constraint on the effective dose of 10 µSv/year to members of the public.

The dose to members of the public due to incorporation of NORM into building materials must not exceed 1 mSv/year.

2.2 Finland

2.2.1 Regulatory framework

The Finnish Radiation Act (859/2018) implementing the EU BSS came into force 15th December 2018. At the same time, a Governmental decree on ionizing radiation (1034/2018) and a Ministerial decree on ionizing radiation (1044/2018) were implemented. There are also multiple Radiation and Nuclear Safety Authority (STUK) Regulations, with Regulation STUK S/6/2022 on "Practices that cause exposure to natural radiation" being the most relevant for NORM. The framework of regulations related to NORM in each level of legislation are shown in the following Table 5.

Table 5. Framework of NORM-regulations in the Finnish legislation.

Legislation level	Types of regulation related to NORM
Radiation Act (859/2018)	• Principles of radiation protection • General requirements for notification, exposure assessment, mitigation, and licensing of NORM-related activities • Requirement for approval by STUK for waste recycling and disposal when above clearance levels
Governmental decree on ionizing radiation (1034/2018)	• Industrial list from EU-BSS Annex VI with some national additions; exposure assessment required from at least these industries • NORM-waste classification (=not radioactive waste)
Ministerial decree on ionizing radiation (1044/2018)	• Reference levels for workers (1 mSv/a) and public (0.1 mSv/a) for NORM (excluding radon and background) • Separate reference levels for building materials and for indoor radon at workplaces
Regulation STUK S/6/2022 on Practices that cause exposure to natural radiation	• Details on notification and exposure assessment • Criteria on exemption from exposure assessment, including the specific cases of use of ash and building materials • For licensed operations: minor discharge limits, baseline survey and monitoring
Regulation STUK SY/1/2018 on Exemption and Clearance levels	• General clearance levels for U238-series, Th232-series and K40 in solid materials, taken from EU-BSS Annex VII Table A Part 2 (not applicable to building materials)
Regulation STUK S/6/2019 on Radiation practices subject to a safety license	• Dose constraints for workers and public • Details on safety assessment

In Finnish national legislation the term 'NORM', or its direct equivalent, is not used. In Finland NORM-related industry is one of the existing exposure situations that are referred to as 'activities causing exposure to natural radiation'. These activities include indoor radon at workplaces, drinking water, building materials, aviation, and the use of natural materials such as rocks, soil, and their derivatives (which includes NORM).

2.2.2 Exemption and clearance

The general requirement is that any activity that could cause larger exposure to natural radiation than the reference levels, is required to investigate the exposure. Specific industries are named in the industrial list, but there is also a generic requirement for NORM, meaning that for the handling, use, storage or utilization of materials where U-238, Th-232 or their decay products exceed 1 Bq/g the exposure needs to be investigated irrespective of the type of industry.

The level of 1 Bq/g in solid materials for U-238 series and Th-232 series and 10 Bq/g for K-40 is used as the main criterion for all named industries to decide whether the exposure assessment (i.e. estimation of doses) is required or not (Regulation STUK S/6/2022). This level is thus used as a kind of an exemption level for exposure assessment, but Notification-level information is still required for these cases. An added requirement is that the discharge from the industry must not cause exposure of the public at a level higher than the reference level, even when solid materials have < 1 Bq/g of U-238, Th-232 or their progeny. In order to use the exemption from exposure assessment, the activity concentrations of materials and discharge need to be demonstrated to STUK.

For natural materials containing fallout Cs-137 (e.g. peat, wood or ash thereof) there are levels set for specific exemption from exposure assessment. The occupational exposure need not be assessed if the activity concentration of Cs-137 does not exceed 5 Bq/g. The public exposure need not be assessed if it has been demonstrated that the activity concentration of Cs-137 does not exceed 1 Bq/g.

Additionally, the public exposure arising from ash resulting from the combustion of peat, coal and wood materials need not be assessed if the ash is used for construction and its activity concentrations meet the conditions for building materials, or the ash is used as forest fertilizer up to a maximum of 10 tonnes per hectare over a period of 20 years and the activity concentration of the ash meets the condition:

$$C_{Th\text{-}x}/4 + {}_{CU\text{-}x}/5 + C_K/100 + C_{Cs}/8 \leq 1;$$

where $C_{Th\text{-}x}$ is the highest activity concentration of the radionuclides thorium-232, radium-228 and thorium-228, $C_{U\text{-}x}$ is the highest activity concentration of the radionuclides uranium-238, radium-226 and lead-210, and C_K and C_{Cs} are the activity concentrations of potassium-40 and caesium-137; all activity concentrations are in units of becquerel per gram.

For building materials, including the possible use of NORM in mixed building materials for houses, roads or landscaping, there are separate levels for the exemption from assessment of exposure to the public:

- $C_{Th232}/200 + C_{Ra226}/300 + C_{K40}/3000 \leq 1$ in materials for houses;
- $C_{Th232}/500 + C_{Ra226}/700 + C_{K40}/8000 + C_{Cs137}/2000 \leq 1$ in materials for roads, streets and yards;
- $C_{Th232}/1500 + C_{Ra226}/2000 + C_{K40}/20000 + C_{Cs137}/5000 \leq 1$ in materials for other earth works;

all units in Bq/kg.

Clearance levels for the utilization, re-use, recycling and disposal of waste and other materials are set with Regulation STUK SY/1/2018. If the activity concentrations are higher than clearance levels approval from STUK is required in addition to the requirements from the Waste Act, if lower, the Waste Act is followed without considerations of radiation. The clearance levels for natural radionuclides in solid materials are:

- 1 Bq/g for radionuclides in the U-238 decay series,
- 1 Bq/g for radionuclides in the Th-232 decay series,
- 10 Bq/g for K-40.

There are no specific clearance levels for parts of the decay chains, or activity concentration-based clearance levels for aqueous discharge. For aqueous discharge, the reference level of the public of 0.1 mSv/a is used. For licensed operations there are additional limits on minor discharge (see Licensing).

2.2.3 Notification and exposure assessment

Notification to STUK is required from:

- Mining, as specified in the Mining Act,
- Any handling, use, storage and utilization of materials and waste where U-238, Th-232 or their decay product has activity concentration higher than 1 Bq/g.

The contents of the notification are listed in Regulation STUK S/6/2022. These include information about the responsible party, description of processes, and the amounts, types and activity concentrations of materials, wastes and discharge. One of the purposes of Notification is to decide whether a baseline survey is required before the activity starts (e.g. whether important discharge is likely, see Licensing). As a complication to the application of Notification, there are no clear requirements with regard the timing of the Notification, for example compared to the Environmental Impact Assessment required from many industrial activities.

Exposure assessment is required, if exemption from assessment is not demonstrated, for:

- Industries that are listed in Notification,
- Activities exploiting soil, rock or other materials occurring in nature or materials brought about by the utilization, if the reference levels for exposure can be exceeded. Such industries are listed as being at least the ones from the EU-BSS Annex VI industrial list, with the addition of oil refinery,peat combustion and enrichment of ores other than uranium ore.

Additionally, exposure assessment is required from:

- Any activity, if the reference levels for exposure can be exceeded (authority is given to STUK to demand exposure assessment, if risk of exposure is evident),
- Previously exempted activities, if changes in the process or materials are causing a risk of exceeding the reference levels.

In the exposure assessment, internal and external exposure for natural radiation is assessed for workers and public by the responsible party, and the exposure is compared to the reference levels (Regulation STUK S/6/2022). The reference levels for exposure resulting from natural radiation other than indoor radon, cosmic radiation or background are the effective doses of 1 mSv per year for workers and 0.1 mSv per year for the public. If reference levels are exceeded the responsible party is required to apply measures to limit exposure. Limiting measures can be for example limiting exposure time, using protective equipment, limiting exposure distance, changing the industrial process, and/or limiting discharge. If, despite measures taken to limit exposure, exposure (including potential exposure) exceeds the reference levels, the activity is regarded as a radiation practice, which is subject to a safety license.

2.2.4 Licensing

A safety license issued by STUK is required for NORM-related industries if the exposure or potential exposure to natural radiation to the workers or public can exceed the reference levels despite measures to limit exposure. A safety license may be issued if:

- the radiation practice follows the principles of justification, optimization and limitation;
- a safety assessment has been made for the radiation practice;
- the practice can be carried out safely; and
- the operator is licensed to engage in a trade in Finland.

In order to be granted a safety license, the applicant must prepare a safety assessment and prepare a plan for radiation safety incidents. The safety assessment is a document that is periodically updated and contains exposure estimates and dose constraints, the classifications of radiation exposure and descriptions of measures to ensure radiation safety and optimize radiation protection. In addition, the applicant must demonstrate that its radiation protection officer, radiation protection expert, management system and quality assurance system comply with the requirements.

If a safety license is required due to discharge that may cause exposure of the public, the operator must prepare a report on the baseline of environmental radioactivity before starting the operation. The baseline report is an account of the state of radioactivity in the environment before the operation, making it possible to measure how much of the natural radiation exposure is due to the discharge during the operation. In addition, discharge and public exposure levels must be monitored during the operation.

If the industry is subject to a safety license, the operator must limit the discharges of natural radionuclides to the environment and the sewage system to a minimum. Discharge levels must be lower than the level for minor discharge, and all releases must be recorded. The minor discharge limit for natural radionuclides in aqueous discharge is 0.1 mSv per year for the public. The corresponding limit for the discharge of natural radionuclides into outdoor air outside the operating site is 0.01 mSv per year, except for radon. The minor discharge limit for the annual average radon concentration caused by radon that is released into outdoor air outside the operating site is 10 Bq/m^3. In exceptional cases, STUK may issue a permit to exceed the limit for minor discharge based on a plan of releases and exposure assessment.

The dose constraint for workers in exposure class 3 (most likely class for licensed NORM-related operations) is 0.3 mSv/a. The dose constraint for the public for licensed operations is 0.1 mSv/a. The maximum dose constraint for the exposure of the public from discharge/emissions and waste is 0.1 mSv/a.

2.2.5 Waste management

NORM-waste is not classified as radioactive waste in the Finnish Radiation Act. Radiation protection aspects for workers and public concerning radioactive waste are also applied to waste, which is not classified as radioactive waste, but requires radiations safety considerations. This "waste other than radioactive waste" includes waste from activities causing exposure to natural radiation (equivalent to "NORM-waste") and waste from protective measures after accidents, in both cases when the activity concentrations are higher than clearance levels.

If the activity concentrations of the radionuclides in the waste are higher than the clearance levels, an approval from STUK is required for waste reuse, recycling, utilization or disposal in addition to following the Waste Act. If the activity concentrations of natural radionuclides in solid materials are lower than clearance levels, the waste may be reused, recycled, utilized and disposed in accordance with the Waste Act.

The conditions for the approval of reusing, recycling, utilization or disposal of NORM-waste are:

- Exposure and potential exposure are so small, that there is no harm to health (for natural radiation this is defined to mean exposure below the reference levels for natural radiation),
- Activity is justified (meaning the radiation protection principle of justification),
- Activity is inherently safe (there are no radiation workers, and the effective dose from natural radiation in addition to the background to an individual of the public is at a maximum of the order of 1 mSv/a).

The legislation makes NORM-waste dilution by mixing possible (with approval from STUK required), because only the radiation protection aspects of radioactive waste are applied to NORM-waste, and compliance is compared to the reference levels of exposure. The dilution of radioactive waste is forbidden for the purposes of avoiding regulation.

2.2.6 Protection of workers and the public

The regulation of natural radiation is centered on the reference levels. If the exposure is shown to be below reference levels, no additional regulation is needed because it is considered an adequate demonstration of protection. If the exposure can be higher than reference levels, measures for limitation of exposure are required. If the exposure is above reference levels even after limiting measures, the industrial activity needs to be licensed and monitored. The optimization principle should always be followed, but it is not actively pursued by the regulator in unlicensed activities.

Separate reference levels are given for indoor radon at dwellings and workplaces, radioactivity in drinking water and building materials, cosmic radiation (aviation) and "other exposures to natural radiation". NORM-related industries belong to these "other exposures", and the reference levels are given for workers at 1 mSv/a, and the public at 0.1 mSv/a (effective dose in addition to the effective dose from the background, excluding indoor radon and cosmic radiation).

2.2.7 Natural radionuclides and the Nuclear Energy Act

Mineral and metal processing and other material uses are in certain cases considered as "use of nuclear energy" in the Finnish Nuclear Energy Act, and this can cause some overlap with the NORM-regulation according to the Radiation Act. In accordance with the Nuclear Energy Act, official authorization is required if the practices result in the creation of products or waste with a combined uranium and thorium concentration of more than 0.5 kg per ton (500 ppm by weight), as this is considered nuclear material. Nuclear materials are formed in the mineral and metal processing industries even when the raw materials have small uranium concentrations, resulting in uranium being concentrated in a product, intermediate product or waste. If the purpose of the mining practice is to produce uranium or thorium, authorization as referred to in the Nuclear Energy Act is always required. Applications for licenses for producing uranium or thorium, as well as concentrates with uranium or thorium content that exceeds the nuclear material limit, can be submitted to STUK or the Government depending on the extent of the operations. STUK may issue a license for producing a maximum of 10.000 kg of uranium and thorium per year. More extensive operations need to be authorized by the Government. There is one Government license in force for the production of yellow cake at a mine site, but production has not started yet.

2.3 Iceland

2.3.1 Regulatory framework

The Icelandic Act on Radiation Protection (Lög um geislavarnir 44/2002) was revised in 2014 with regard to the new EU BSS. Iceland is not part of the EU and is therefore not obligated to implement the EU BSS. At the time of the revision, NORM had not been found in Iceland and due to the low radioactivity of the Icelandic bedrock, no specific articles were dedicated to NORM in the revised Act.

2.3.2 Exemption and clearance, regulatory approach

The exemption levels and clearance levels from IAEA (GSR part 3), EU BSS, have been published in guidelines from Geislavarnir ríkisins (e. The Icelandic Radiation Safety Authority). The radioactive waste limits are 1 Bq/g for alfa and 10 Bq/g for gamma and beta.

Geislavarnir ríkisins is the regulatory authority regarding all sources of ionizing radiation. That includes the licensing of the use, importation, exportation, storage and disposal of radioactive sources. Geislavarnir ríkisins

has made use of the European BSS and international guideline when setting requirements in the licence for NORM. The regulation on the radiation protection of unsealed sources is scheduled to be revised and specific requirements for NORM will be address in that regulation.

2.4 Norway

2.4.1 Radiation protection and pollution legislation

Norwegian Radiation and Nuclear Safety Authority (DSA) is the main regulatory authority for radiation protection from all sources of ionizing radiation, including regulatory control of NORM processing industries and other NORM involving activities.

In regulatory control of ionizing radiation, including naturally occurring radioactive sources and NORM-processing industries, the following acts and regulations are used:

- Pollution Control Act,
- Regulations on the Application of the Pollution Control Act to radioactive pollution and radioactive waste,
- Act on Radiation Protection and Use of Radiation,
- Regulations on Radiation Protection and Use of Radiation,
- Regulations on Recycling of Waste,
- Nature Diversity Act.

The Norwegian Pollution Control Act (1981), main Norwegian legislative act concerning overall environmental protection, was amended and came into force on radioactive waste and radioactive pollution (releases, discharges and contaminated areas) from 2011. With these updated regulations - *Regulations on the Application of the Pollution Control Act to radioactive pollution and radioactive waste (2010)* - an ecosystem-based approach for the protection of human health and environment from radioactivity, was integrated in the regulatory practice in Norway.

2.4.2 Authorized NORM limit values for definition of radioactive waste and control of radioactive discharge

Legislation and developed regulatory practice in Norway consider any NORM processing and/or handling that may produce both radioactive waste and radioactive pollution. The necessary authorization is issued by the DSA.

Terms of exemption and clearance are not provided in the Norwegian legislation as given in the EU BSS and IAEA BSSD. However, same numerical values of 1 Bq/g for Th-232 and U-238 and 10 Bq/g for K-40 are defined in legislation. More detailed, Annex I (a) of Regulations on the Application of the Pollution Control Act to radioactive pollution and radioactive waste (2010) sets limits of NOR (among other radionuclides) for what is radioactive waste. Annex I (b) of regulations sets out NOR values for identification which radioactive waste is subject to a special disposal requirement. Furthermore, screening values for total activity (Bq) per year, or specific activity (Bq/g) for activity that lead or may lead to the release of radioactive substances are given the Annex II. Any such activity (that is greater than or equal to the values in Annex II) always requires a permit. Values given in Annexes I and II in the regulations were defined by considerations of exemption and clearance levels previously provided by EC RP 122, part 2 (2001) and IAEA RS-G-1.7 (2004).

As mentioned, NOR limit values for Th-232, U-238 and K-40 are set in regulations equally to the clearance and exemption levels provided by the current EU-BSS and IAEA standards. However, additional radionuclides (both NOR and artificial), which are not included in the EU-BSS, are given in the Norwegian regulations. Example of screening values for certain NOR radionuclides are presented in Table 6 (for complete list of radionuclides please see Annexes of the mentioned Norwegian regulations).

Table 6. Screening values for NORM radioactive waste

Radionuclide	Specific activity concentration (Bq/g)
Th-nat (incl. Th-232)[a]	1
U-nat (incl. U-238)[a]	1
Ra-226	1
Ra-228[a]	1
Th-228[a]	1
Th-234[a]	10
Po-210	1
Pb-210[a]	1
U-235[a]	1
K-40	10

[a] Radionuclides in equilibrium with daughter products. The activity limits in the table refer to the mother nuclide alone, but the radiation contribution from the daughter products is taken into account in determining the activity limit for the mother nuclide.

The summation rule must be applied whenever radioactive equilibrium in the decay chain is disturbed. In such situations, if the weighted sum of activity concentrations divided by the corresponding legislative screening values of radionuclides specific activities is ≥ 1 material is to be considered as radioactive waste:

$$\sum_k \frac{C_k}{C_{e,k}} \geq 1$$

where:

- C_k *is specific activity concentration for radionuclide k,*

- $C_{e,k}$ *is limit value for specific activity of radionuclide k from the table.*

2.4.3 Regulatory control approach

An overview of developed approach for regulatory control of practices that include NORM processing industries, activities and related waste handling and management, is given in Table 7 below.

Table 7. Developed regulatory control approach

Waste producer	Waste management	Waste repository

	Screen and measure raw material, waste and pollution		
Information	Send information to DSA		
3a. Radioactive waste	Generic requirements	License from DSA	License from DSA
	Waste and pollution legislation Radiation protection legislation	Graded approach in requirements depending on activity	Graded approach in requirements depending on activity
	Waste managed in a justifiable manner		
	Send to waste management at least once a year		Waste which is classified as both hazardous and radioactive waste, and with low activity concentrations, may be accepted with only a license for hazardous waste
	Declared in same manner as hazardous waste		
3b. Radioactive pollution	Licence from DSA	Licence from DSA	Licence from DSA

In process of granting a permit to the NORM industries and practices, DSA always considers principles of justification, optimization and dose constraints. Undertakings should commonly provide detailed description of their NORM involving activities of potential radiological concern, estimation of waste and possible pollution, risk assessment concerning both workers, public and environmental exposure. Furthermore, requirements such as use of the best available technique (BAT), safe handling, responsible storage and regular delivering of radioactive waste, developed plan for emergency measures and competence, environmental monitoring are included in the given permits.

The inspection procedures are developed for the NORM involving industries in accordance with national inspection rules, and commonly there are 2 inspections/year for each different NORM involving industry type (i.e. separately for oil and gas, mineral processing, metal mining and processing, etc).

2.4.4 Regulatory control of NORM waste and environmental discharge

According to Regulations on recycling of waste (Waste regulations, 2004), all companies that generate radioactive waste (including NORM processing industries) have duty to properly handle, temporarily store and deliver waste at least once per year in order to avoid pollution of the environment and unwanted effects for human health and the environment. Waste must be declared in a common written document (scheme), that contains the information in European waste list, but also the Norwegian waste category number that provides more detailed information if waste of concern is radioactive, hazardous or both. The online declaration form (e-declaration) has been in use from 2015.

In addition to radioactive waste, environmental discharge of NORM is regulated in Norway according to screening values given in in Regulations on the Application of the Pollution Control Act to radioactive pollution and radioactive waste (2010) (Annex II), as mentioned above.

Environmental impact and public risk assessment is a common requirement in the process of issuing the permits for radioactive waste handling and/or disposal and for radioactive discharge to the environment. The possibility for granting exemption or clearance of NORM-activity of radiological concern is given in regulations, in specific

conditions that must be proved. The decision in these special cases must be made by responsible Ministry or whomever the ministry authorises (commonly DSA).

Principles of justification, optimization and dose constraints are included in The Act on Radiation Protection and Use of Radiation (2000), which constitutes the legal basis for regulating the use of ionizing and non-ionizing radiation and radiation protection requirements, both in the medical and non-medical fields as well as in contingency planning. The Act also applies to human activity giving increased levels of naturally ionising radiation from the environment. These kinds of activities shall be justifiable. In the assessment of the justification, importance shall inter alia be given to whether the benefits of the activity outweigh the risks associated with the radiation, and to whether the activity is arranged in such a way as to avoid acute injury to health and to minimise the risk of late injury as far as is reasonably possible. According to Regulations on Radiation Protection and Use of Radiation, the effective dose to the public and non-occupationally exposed workers shall not exceed 1 mSv/year for all ionising radiation. Equivalent dose to the lens of the eye shall not exceed 15 mSv/year. Equivalent dose to the skin shall not exceed 50 mSv/year, measured or calculated over any skin area of 1 cm^2. The undertaking shall plan the use of radiation (including different aspects of NORM use and/or processing) and protective measures to ensure that exposure of the non-occupationally exposed workers and the public, shall not be exposed to an effective dose exceeding 0.25 mSv/year.

2.4.5 Responsible authorities concerning control of ionizing radiation including NORM

The Norwegian Radiation and Nuclear Safety Authority (DSA) is the responsible authority for control of radioactive waste and pollution, while other authorities such as Norwegian Environment Agency, Norwegian Directorate of Mining and County Governors have the responsibility for control of other environmental hazards, depending on case and situation. Collaboration has been established between these authorities as well as responsible ministries (e.g., Ministries of Petroleum and Energy, Climate and Environment, Health and Care Services, Trade and Industry) for achieving the holistic, integrated and ecosystem based regulatory control of the relevant industries in the country.

Furthermore, recommendations and agreements of the international conventions (e.g., OSPAR, London, IAEA Joint convention) are implemented in regulations. In addition, the DSA has developed guidance documents for the different areas of radioactive waste management, radioactive discharge and application of radioactive sources.

2.5 Sweden

2.5.1 Regulatory framework

The regulation of NORM processing industries in Sweden is based on Council Directive 2013/59/Euratom. The directive is implemented in the Radiation Protection Act (2018:396), the Radiation Protection Ordinance (2018:506), and regulations issued by the Swedish Radiation Safety Authority (SSM). These regulations are SSMFS 2018:4, concerning NORM and building materials, and SSMFS 2012:3 concerning contaminated ash. NORM processing industries may also be subject to the Act on Environmental Protection (1998:808).

NORM is generally exempt from the Act on Nuclear Activities (1984:3), unless the material is subject to Euratom safeguards according to Commission Regulation (Euratom) No 302/2005.

- The Radiation Protection Act

  The Radiation Protection Act contains general regulations on protection against ionizing and non-ionizing radiation: protection of workers, and protection of the general public and the environment. The Radiation Protection Act also regulates permits and registration.

- The Radiation Protection Ordinance

  The Radiation Protection Ordinance states that SSM is the competent authority regarding radiation protection, and that SSM shall carry out the identification of practices involving NORM according to art 23 in the directive.

- Regulation issued by the Swedish Radiation Safety Authority (SSMFS 2018:4) concerning NORM and building materials

  The regulation issued by SSM (SSMFS 2018:4) concerning NORM and building materials contains more detailed regulation on exemption and clearance of NORM, handling of NORM and NORM waste, and building materials.

- Regulation issued by the Swedish Radiation Safety Authority (SSMFS 2012:3) concerning contaminated ash

The regulation issued by SSM (SSMFS 2012:3) concerning contaminated ash contains detailed provisions on handling ash from burnt peat and wood. The provisions mainly regulate ash contaminated with Cs-137, but also naturally occurring radionuclides. This regulation applies to energy production sites that produce more than 100 tonnes of ash annually. The regulation contains requirements on performing measurements and governing reuse of this ash, depositing it in landfills, and spreading of the ash.

NORM is defined as:

"Materials with naturally occurring radioactive substances which are in their natural state or only processed or enriched for purposes other than for the extraction of these substances and which are also not intended to be processed for use of the radioactive, fissile or fertile properties of the material." [Section 2 of SSMFS 2018:4].

This definition entails that certain products containing naturally occurring radioactive substances are not considered to be NORM. This is the case if the materials were processed for the purpose of extracting these substances, even if the purpose was not to make use of their radioactive properties. For example, products containing thorium, for its heat resisting properties, are not considered to be NORM. We sometimes find that these products fall outside of our legislation.

2.5.2 Exemption and clearance

All NORM is exempt from the Act on Nuclear Activities (1984:3), unless the material is subject to Euratom safeguards according to Commission Regulation (Euratom) No 302/2005 [Section 3 of SSMFS 2018:4].

Exemption and clearance levels for NORM (dry substance):

- 1 kBq/kg for nuclides in the uranium and thorium series,
- 10 kBq/kg for K-40.

NORM with activity concentration below the exemption level is exempt from the Radiation Protection Act. These exemption levels do not apply to building materials, which are regulated separately based on an activity index [Section 4 of SSMFS 2018:4]. No dose criteria for exemption or clearance are explicitly stated in the regulation of NORM. However, 1 mSv/year is mentioned in the preparatory work for this regulation.

The owner of the material may carry out clearance of NORM if the activity concentration is below the clearance levels (with the exception of building materials) [Section 9 of SSMFS 2018:4]. It is prohibited to dilute or mix NORM with other materials for the purpose of clearance [Section 10 of SSMFS 2018:4].

Conditional clearance is also possible for NORM originating from Sweden and having activity concentrations below 10 kBq/kg as regards nuclides in the uranium and thorium series, and below 100 kBq/kg as regards K-40 if

the material is placed in a landfill [Sections 9 and 11 of SSMFS 2018:4]. This is an important waste stream for NORM.

Certain types of activities involving NORM are exempt from parts of the regulation contained in the Radiation Protection Act (e.g., registration, regulation of transfer and handover, monitoring discharges, and certain obligations for employers) [Section 6 of SSMFS 2018:4]:

- Handling of concrete containing alum shale,
- Handling of soil and rock,
- Handling of burnt alum shale and phosphogypsum,
- Handling of geological samples,
- Handling of ceramic objects such as kitchenware and ornaments,
- Handling of water filters from individual households.

2.5.3 Registration

Registration is required for any activity involving NORM with an activity concentration above the exemption levels, unless the activity or material is exempt from registration according to the list shown above [Sections 7 and 8 of SSMFS 2018:4]. This registration is valid for five years, and a new registration is required after this period. There is no "positive list" of industry sectors or activities for regulation of NORM.

The Swedish system for regulation of NORM does not have targeted provisions for registered NORM activities, in terms of protection of workers etc.; only the general regulation contained in the Radiation Protection Act applies.

3 Overview of NORM processing industries – existing and/or potential radioactive waste producers and sources of pollution

3.1 Denmark

In Denmark, NORM may be associated with the following industries:

Oil and gas production

- There are two oil and gas operators in the Danish part of the North Sea. Each company has a license to handle and store NORM waste and NORM contaminated parts offshore.

- On shore, the two above-mentioned companies have their own licensed NORM waste storage facility. The NORM waste originates from the offshore production of oil and gas and from decontamination of NORM contaminated part and decommissioning of offshore production units.

Distribution infrastructure for oil and gas

- There are two operators of the distribution infrastructure for gas (pipelines) on shore that hold licences to handle and store NORM waste resulting from pigging of the pipelines.
- These companies also hold licenses to handle and store NORM waste at their own NORM storage facilities.

Geothermal energy production

- There are tree geothermal energy production plants in Denmark. NORM only occurs at one site, which is licensed to handle and store NORM waste. The waste arises from the decontamination of piping and with time, NORM waste may be expected from the decommissioning of the plant.
- The owner of the abovementioned geothermal plant also holds a license for a NORM waste storage facility.

Decommissioning and decontamination facilities handling equipment for the above-listed industries

- Currently, there are two licensed company that provides NORM decontamination services both on shore and offshore.
- However, several other companies have shown the interest in this field.

Borehole cores, geological sample materials, ore and tailings

- Several universities and companies have storages containing borehole cores and geological sample materials (rocks and minerals).
- 4.800 tons of ore and ore-tailings are stored in ore heaps and tailing pools by the national waste management operator, Danish Decommissioning.
- NORM contaminated metallic waste from the production of phosphoric acid is stored by Danish Decommissioning.

Recycling industry

- Occasionally, scrap metal and other materials contaminated with NORM or containing NORM, are detected in the recycling industry. Such radioactive materials are transferred to, managed and stored by the national waste management operator, Danish Decommissioning.
- Minor amounts of metallic parts (turbine components) containing Th are also stored at one of the storage facilities for radioactive waste at Danish Decommissioning.

Waste processing facilities

- Treatment of waste containing radioactive materials may lead to accumulation of NORM in ashes, slag and filters at waste processing facilities.

Other industries where NORM may occasionally or potentially be encountered:

- Industries that use mineralogical raw materials e.g., TiO_2, corundum (Al_2O_3)
- Coal-fired power plants
- Heat and power production plants using biofuel such as e.g., straw primarily due to K-40 (not listed on the positive list in the EU BSS)

- Ground water filtration facilities. The Danish drinking water supply stems from groundwater sources. The radionuclide contents of the drinking water are well documented and low. However, the potential for long term accumulation of radionuclides in filtration units at waterworks has not yet been investigated.

3.2 Finland

The identification of NORM-related industrial sites has been mainly completed. The NORM-regulations have been introduced to the NORM-related industry during 2019 and enforcing the regulations started 2020 by a graded approach. The emphasis was first on the sites with higher concentrations and higher level of radiation exposure anticipated. The NORM-related activities and potential NORM activities identified in Finland so far:

Mining and milling

- 9 active metal mines and several projects applying for environmental permissions, 12 active mines for carbonate-minerals and 14 active mines for other industrial minerals (2022)
- Ni-Cu-Zn-Co mine has large amounts of leachate solutions with 25-35 mg/l and seepage waters with 20 mg/l uranium, and forms NORM waste with 1.3 Bq/g U-238. Exposure is below reference levels due to limiting measures. The same facility has a uranium yellow cake production license according to the Nuclear Energy Act, but production has not started yet,
- Gold-ore enrichment facility produces an intermediate gravity concentrate with 15-20 µSv/h (nuclear material), and a flotation concentrate with 50-250 ppm uranium; exposure is below reference levels due to limiting measures,
- Several mines have no NORM due to low <1 Bq/g concentrations, but all mines have not demonstrated this yet for all relevant materials. There are multiple projects where NORM will form if mining starts.

Mineral exploration, borehole cores, geological sample materials

- The geological survey of Finland, universities, museums, and exploration companies have storages containing borehole cores or geological sample materials (rocks and minerals),
- In one case an exploration company was required to restrict public access to large sample boulders due to elevated dose rates and potential exposure of the public above reference level (the public was reported to spend time sitting on the boulders when access was open),
- Two exploration companies have made exposure assessments due to handling and storage of cores with elevated uranium or thorium contents, exposure is below reference levels.

Metal processing – hydrometallurgy and smelters, including laboratories (Ni, Cu, Zn, Co, Fe)

- Two licenses according to the Nuclear Energy Act for removing uranium impurities from the products (Hydrometallurgical Ni-factory and Co-factory). Radiation safety has been assessed according to the new Radiation Act, and the exposure is below reference levels,
- Cu-smelter notified STUK about elevated uranium levels in the Cu-concentrate (500-1500 ppm, nuclear material) coming from a hydrometallurgical Cu-Zn-Co plant in Finland. They also have dust filters with Pb-210 and Po-210. Assessment is not finished,
- Iron ore has low concentrations which results in no NORM in the primary iron production (e.g. blast furnace slag),

- At least two mineral technology laboratories in Finland make pilot tests for hydrometallurgy and smelting. Sometimes the raw materials come from overseas and have concentrations much higher than 1 Bq/g. Assessment is required, but not completed.

NORM-contaminated scrap metals (and Cs-137 contaminated materials)

- Scrap metal cases arise regularly (annually few tons), usually the detection of radiating material is made at scrap yards,
- In most cases the waste has gone to landfills for hazardous waste.

Groundwater treatment plants

- 65 % from the Finnish household water is groundwater or artificial groundwater,
- The full extent of NORM-occurrences at Finnish groundwater treatment plants is not yet known. A pilot study completed in 2021 confirmed that at least in some cases NORM is present (anthracite and other carbon filters, precipitates from aeration and sludges from backwash of sand filters),
- Activated carbon filters may be a problem due to external gamma dose rate.

Coal-fired power plants, maintenance of boilers (includes peat fired plants and disabling of boilers)

- There are numerous wood/peat/coal fired plants in Finland and most of the ash is re-used. The natural radionuclides Th-232, Ra-226, K-40 and Cs-137 in ash are relatively well known, but the activity concentrations vary based on the fuel composition, ash type and the process,
- NORM has not been found at Finnish coal-fired plants,
- Cs-137 in fly ash from biofuels potentially needs to be considered in the radiation protection of workers and public,
- Compared to the list in the directive, peat-fired plants and the disabling of coal and peat-fired power plants are included in the list in national legislation. Decommissioning of coal-fired plants is on-going in Finland,
- The obligation for assessment of radiation exposure is applied to power plants in which majority (>50 %) of the fuel is coal and/or peat,
- Activity concentration of Chernobyl Cs-137 of ash may be elevated and it is included in the assessment of ash (and building materials, where ash can be used).

Pigment production, TiO_2 pigment production

- One TiO_2 pigment production facility (has been shut down and will be dismantled)

  - The uranium and thorium content of the raw material varied. The final product does not contain significant radioactivity,

  - The NORM content of the wastes and the process equipment has to be clarified during dismantling of the pigment facility. So far it has been confirmed that NORM-residues are found inside the process equipment, containing both U-series and Th-series daughters.

Fertilizer production

- Few fertilizer production facilities, one producing also phosphoric acid,
- The phosphate fertilizer and phosphoric acid producers are obligated to assess exposure for natural radiation. The level of NORM in fertilizer production is dependent on the raw material. Some materials may require radiation safety considerations,

- Nowadays, fertilizers are mainly produced using Finnish raw phosphate that had very low levels of natural radionuclides (U-238 and Th-232: 10 Bq/kg),
- In the past, fertilizers were produced using both local and transported raw phosphates and the uranium activity concentration varied between 10–5000 Bq/kg,
- In 1970's, the produced by-product gypsum, with high radium content, was used for plasterboard production.

Cement production

- One cement production company with multiple facilities. The activity concentrations of the raw materials and cement kiln dusts were shown to be clearly below the clearance level of 1 Bq/g for U-238 and Th-232 series.

Geothermal energy

- Most of the geothermal energy in Finland is used in private households and these systems have closed circuits. Only the drilling waste may occasionally contain elevated amounts of natural radionuclides. Small scale systems and drilling of these systems in private households are not under surveillance. Some companies are planning and starting larger scale utilization of geothermal energy. This industry using open-circuit systems is obligated to measure natural radionuclides, and it will be investigated whether elevated concentrations of natural radionuclides are typical in Finnish deep geothermal plants.

Oil refining

- There are two oil refineries in Finland, and it has been confirmed that they do not contain NORM.

Production of refractory materials for steel industry

- There is one facility in Finland producing refractory materials for the use of steel industry. Some of the raw materials have activity concentrations above the clearance level of U-238 and Th-232 series.

Production of coating pigments for paper and board industry

- There is one facility in Finland producing coating pigments for paper and board industry. The zirconium containing raw materials have activity concentration above the clearance level of U-238 series.

Activities excluded from EU BSS positive list or additional ones included

No activities are excluded from the EU BSS list of industries. In addition to the EU-BSS list, in the Finnish Governmental Decree there is the addition of oil and gas refineries (instead of just oil and gas production) and the use, maintenance and decommissioning of peat-fired energy production (instead of just coal). Also, for smelters, the metals are not specified but the requirement is for all metal smelters. Additions were made to the Finnish Governmental Decree in 2022 and now the list contains also the enrichment of ore other than uranium ore (instead of just mining of ore).

The addition of metal processing factories (also hydrometallurgical and possibly other techniques, not just smelters) and scrap-metal recycling + steelworks are the main additions that should be made to the list based on the Finnish experience.

In some industries the occurrence of NORM is yet unknown and needs to be clarified. An example of an industry that is not included in the list, but where occurrence of NORM has been indicated by scrap-metal findings, is the

paper and pulp industry. The possible occurrence of NORM in the Finnish paper and pulp industry needs to be studied, as this is a major industry in Finland and there are also some indications of NORM from literature.

The content of natural radionuclides in waste incineration ash was investigated in STUK during 2021. It was shown that the activity concentrations were very low and the further use or treatment of ash is not restricted by its radioactivity.

3.3 Iceland

Geothermal energy production is the only NORM industrial sector in Iceland that is listed in Annex VI in the EU BSS. Only two geothermal power station produce scaling that is considered NORM. The radioactive scaling found, contains only Pb-210, Bi-210 and Po-210.

3.4 Norway

Integrated radiation protection legislation applies to all industries, including NORM processing ones, and concerns radioactive waste management and disposal as well as radioactive discharge. According to the lists published in EU Directive 2013/59 and IAEA BSS, there have been identified NORM industries of radiation protection concern in Norway. The Norwegian Radiation and Nuclear Safety Authority (DSA) has issued about 210 permits for waste management and pollution, in total. Majority of those (about 170) are for NORM related activities, mostly oil and gas industry.

However, all industries that potentially could have radioactive waste or radioactive discharges that could pose an environmental risk have a duty to do mapping and investigation of their waste and releases in order to find out if any of these are radioactive.

Examples of NORM industries already under regulatory control or identified as to have the potential for radioactive waste production or/radioactive pollution are:

Oil and gas production

- One of the largest contributors to radioactive discharges in Norway. With Ra-226 as an indicator, discharges from the Norwegian continental shelf are 47 % of the amount discharged in the OSPAR area. The industry is also the second largest generator of radioactive waste in Norway.
- The Norwegian Radiation and Nuclear Safety Authority regulates producing fields on Norwegian Continental Shelf (49 active permits). The Norwegian Radiation and Nuclear Safety Authority gives permits for use of tritium traces in exploration drilling and permits for discharges following the production of oil (in total 9 permits in 2021). There is also one land installation for processions of gas that has a permit and around 28 permits for supply bases and waste handling business related to the oil and gas industry. For producing fields, the focus is regulation of discharge of produced water containing NORM. All producing fields must reinject the discharges into the rock formation, if possible. Unfortunately, it is not possible everywhere due to types of reservoirs. If not possible, the amount of discharges follows the production.
- Main waste types produced by the oil and gas industry is waste from separators and scale from contaminated pipes/equipment. Waste is sent to a cavern type repository which is licensed for NORM waste.

Construction activities that include drilling and excavation in the areas with bedrock rich in alum shale or other rocks with potential for acidic leaching of NORM

- Part of Norway consists of alum shale rocks with potential for acidic leaching of metals and naturally occurring radionuclides in the favourable environmental conditions. Environmental impact assessment regarding the aspect of radioactivity (pollution, waste) is always requested when above mentioned construction activities, such as building of roads, railway tracks, tunnels etc., are planned.
- There are several permits issued by DSA for such current activities, while process of regulation of legacy site of an old alum shale disposal site, with identified environmental contamination, has been ongoing.

Extraction of rare earth elements

- Large depositions of rare earth elements (REE) exist in the volcanic bedrock of geologically specific Fen Complex area in Norway. Interest for ore exploration has been expressed on several occasions recently. Potential undertakings are informed that they will need to assess the possible radiological impact on public and biota, and that consequently, a proper regulation might be needed when mining and exploitation activities start.

Phosphate industry

- There are two facilities for mineral based NPK-phosphate fertilizers production situated in Norway. As production is based on chemical processes that include use of raw material phosphates, which commonly contains NORM, radioactive discharge to water bodies and atmosphere and production of radioactive waste have been identified.
- Permits for these were given in 2013 and annual reports, including results from environmental monitoring programmes, have been regularly sent to DSA.

Production of titanium dioxide pigments

- Facility producing titanium dioxide (TiO_2) slag and high purity iron from raw material ilmenite exists in Norway.
- Permit for radioactive discharge of NORM, from production processes into the water body and air, has been given by DSA. No radioactive waste has been identified, while material accumulated on electro-filters in the production is further sent to be used as raw material in zinc (Zn) production in a nearby metal production company.
- Annual reports are sent to DSA providing the information about radioactive discharge and environmental monitoring that is in place.

Processing and production of niobium (Nb)

- No active processing and production of Nb exists currently in Norway. However, a former, decommissioned Nb mining site Søve in the Fen Complex (1953-1965) presents a site with existing radiation exposure, i.e., legacy with radioactive waste improperly deposited on the site. After somewhat difficult assignment of responsibility for conducting the site remediation, cleaning-up process has currently been ongoing.

Production of thorium (Th) and thorium containing products

- Although interest has been expressed in production of Th and Th-containing products since large naturally occurring Th-ore resources exist in the Fen Complex in south-eastern Norway no active production has started yet.

Mining of ores other than uranium ore

- Certain mapping and evaluation of active and closed mines, which potentially can be of concern regarding radiation protection, have been done in the last decades. Beside above mentioned former

Nb mining site, there have additionally been identified few legacy radiation exposure sites that need further regulatory consideration.

- No radiation protection issues have been found at currently active investigated sites.
- However, it should be highlighted that further mapping and investigation, which should include higher number of both active and closed mining sites, is necessary and such activity is planned in near future.

Production of tin (Sn), copper (Cu), aluminium (Al), zinc (Zn), lead (Pb), iron (Fe) and steel

- There are numerous active metal production sites in Norway. Certain number (e.g., some of the activities of Al, Ni, Fe production and/or handling) of such production activities are under proper regulatory control of potential radioactive pollution and/or radioactive waste production, with issued permits in place.
- However, DSA has plan to continue, in close future, with new activities on mapping of potential NORM industries that might be of radiological concern, and in that process, a broader range of this type industries will be investigated.

Activities excluded from EU BSS positive list or additional ones included

- Norway has a research and development centre whose research includes raw materials containing NORM. The centre is licensed from DSA.

Further mapping of NORM processing industries

- In addition to here described NORM industries, DSA will soon start a process of further mapping of relevant industries in order to review and potentially identify those that have a potential of radioactive releases and handling of radioactive waste but not yet are under regulatory control. Some examples of these could be cement production, maintenance of clinker ovens, different metal mining and production, coal combustion, etc.

3.5 Sweden

Based on previous and ongoing identification of practices involving NORM, it appears that some of the more relevant industrial processes of concern from a regulatory point of view include:

Mining of ores other than uranium ore

- There are 12 active metal mines in Sweden (2019). Many of them have an enrichment facility on site. The tailings from the enrichment process are often deposited in a close by tailings dam. Most of the ore produced in Sweden have a low content of radionuclides.
- Only one mining site has reported activity levels above the exemption level, found in dust filters. More measurements are needed to identify NORM above the exemption level amongst these facilities. Some enrichment facilities process imported ore with activity concentrations above the exemption and clearance levels.

Ground water filtration facilities (production of drinking water)

- A handful of municipal facilities for drinking water filters out uranium to improve the quality of the drinking water. This results in NORM-waste, often in liquid phase, which in some cases is released to the sewage system or directly into the recipient body of water.
- The regulation of NORM in Sweden does not state exemption or clearance level for liquids. The management of NORM-waste from ground water filtration facilities is currently under investigation, which might result in new detailed regulation in this area.

- Other processes, e.g. softening of the water, results in higher concentrations of radionuclides in sludge and other solid by-products or waste. Sludge can be spread on farmland, depending on its contents of pollutants.

NORM-contaminated scrap metal

- Recycling companies, scrap yards and steelworks regularly discover contaminated material. The steelworks are very cautious to allow any contaminated material into their production. The contamination is often NORM, e.g. scale in pipes and other metallic parts from the pulp and paper industry, and other industries.

Metal smelting

- There are around 10 metal smelters in Sweden. More measurements are needed to identify NORM above the exemption level amongst these facilities.

Primary iron production

- There are seven smelters for primary ion production in Sweden. Po- 210 and Pb-210 have been found in the flue gas cleaning sludge and gaseous emissions.

Oil refineries

- There is no gas- or oil production in Sweden, but there are a handful of oil refineries. Measurements carried out so far show no activity concentrations above the exemption levels, but more measurements are needed.

Zircon and zirconium industry

- Zircon sand, or zircon silicate, is used in industries for various reasons. The sand may contain radionuclides above the exemption level, typically around 3.5 kBq/kg for nuclides in the U-series. The use of zircon sand is not expected to cause high doses to workers. No milling of zircon sand, which may cause higher doses, is done in Sweden.

Thorium-containing products

- Products containing thorium are not defined as NORM in Sweden, if the thorium has been added deliberately. However, there is waste consisting of thorium -alloys. The authority has not yet reached a decision on how to manage this waste.

Legacy sites

- There are around a hundred legacy sites in Sweden with NORM-waste, mainly burnt alum shale and mining residues. Measurements of gamma radiation at the surface show levels of 0.5 - 2 mSv/h.

Cement production

- There are five cement production plants in Sweden. No activity concentrations above the exemption level has been found, but more measurements are needed.

Geothermal energy

- There is one geothermal energy plant in Sweden. No activity concentrations above the exemption level have been found at the site.

4 NORM waste – identified waste streams and disposal options

4.1 Denmark

4.1.1 NORM waste streams

Until now, there have been recognised NORM waste generated from the following industries in Denmark:

- Oil and gas industry,
- Geothermal energy production,
- Service industry (decontamination and decommissioning),
- Industrial use of natural materials,
- Storage of ore and tailings, borehole cores and geological sample materials (rocks and minerals),
- Recycling industries,
- Waste processing facilities, and
- Coal-fired power plants.

The majority of the NORM waste (approximately 95 %) arises from the production of oil and gas, whereas other industries only produce minor amount of NORM wastes. Amongst the other industries it is the waste from the geothermal plant that dominates.

4.1.2 NORM waste management and disposal

Legislative requirements for the disposal of radioactive waste including NORM waste are in place, requiring a license to a specially designated company, requirement for undertaking a safety assessment and referring to a general dose constraint criterion of 0.01 mSv/year. However, Denmark does not have an operational disposal facility for radioactive waste nor a dedicated waste disposal facility for NORM waste. Parliamentary resolution B 90 on a long-term solution for radioactive waste in Denmark was adopted in 2018, stipulating that all radioactive waste from decommissioning of the nuclear facilities in Denmark must be disposed of in a geological disposal facility by 2073 at the latest. The Parliamentary resolution opens the possibility that all NORM waste may also be disposed of in the same facility.

The legislation states that radioactive waste must be disposed of as soon as reasonably achievable and may only be stored for a maximum of 12 months. In certain cases, however, authorised storage for more than 12 months can be approved by the Danish Health Authority this applies to NORM waste as no suitable means of disposal is available. Therefore, the NORM waste owner (the producing company) is responsible for the safe handling and storage of the NORM waste, until a disposal option for the waste is available.

Typically, each individual company producing NORM waste has a storage for NORM waste. However, some companies also have a licence to store NORM waste on the behalf of other companies. The NORM storage facilities must comply to the general requirements given in Executive Order no. 670/2019, §§ 35, 36 concerning storage of radioactive materials with regards to safety and security of the storage facilities, storage environment, organisation of the storage, the waste packages, identification of waste packages.

Furthermore, the legislation requires that the companies producing radioactive waste, including NORM waste plan and optimise their production (or use) in such a way that NORM waste in storage is kept to a minimum cf. §§ 32, 34 in Executive Order no. 670/2019.

4.2 Finland

4.2.1 NORM waste streams

An updated list of NORM wastes in Finland has been compiled 2020-2021, the previous listing and report about NORM in Finland is from 2005 (in Finnish).

Known NORM-waste streams:

Mining and milling

- One operating mine producing gypsum + metal hydroxide waste with 1.3 Bq/g U-238, goes to a hazardous waste landfill at the mine
- Small amounts of liquid NORM-waste from gold-ore enrichment, goes to hazardous acid waste treatment facility
- 40 closed old mine sites, some with multiple waste areas, and only some of the areas are remediated
    - some are known to be NORM-waste containing sites (e.g., small pilot uranium mines, metal sulphide-ores with uranium, enriched lanthanide from Pb-REE -ore)
    - 11 known acid mine drainage cases, where limited or no data on radionuclides

Metal processing

- Hydrometallurgical plants are actively producing waste sludges with few 100's of ppm uranium, these go to hazardous waste landfill
- At previous times, African raw material with elevated uranium and radium content was used in cobalt production. In the process the uranium was removed but the radium and its progenies were left in waste. There was approximately 30 000 tons of this waste sludge, which had radium-226 content of 17 000 Bq/kg. The waste was disposed in 1998 at a landfill, at the industrial area of the production facility.

Thorium-metal waste

- Parts from old Draken fighters (1.5 tons) disposed in hazardous waste landfill in 2005, applying mixing and dilution with metal-contaminated soil (200 m^3). Activity concentration of metal approximately 150 kBq/kg. The material was classified as nuclear material based on the Nuclear Energy Act.
- There have been two cases with smaller amounts of Th-alloy metals, from dismantled gas turbines of the energy industry.

NORM-contaminated scrap metals (and Cs-137 contaminated materials)

- Scrap metal -cases arise regularly (annually few tons), in most cases the waste has gone to landfills for hazardous waste

Energy production

- Some ash waste contains > 1 Bq/g Pb-210 (and Po-210) and would be classified as NORM-waste in the new regulations. If new such cases are found, approval is required before disposal. However, the

energy industry is trying to reduce waste and most of the ash is nowadays used in building materials and not disposed as waste.

4.2.2 NORM waste exposure scenarios

There are very few calculated detailed dose assessments for the disposal of specific NORM-wastes in Finland. In the past it has been in many cases considered acceptable to use landfill for hazardous waste without detailed assessment, because the waste has usually low radiation risk, the landfills occur at large industrial complexes with no public access, the landfills are subject to environmental permits (e.g., dust and heavy metals) and land use is restricted. There are some generic calculations for how much activity could be buried in the ground before a detailed assessment is needed, but the disposal of waste directly to the ground is not likely due to chemical hazards. There are also assessments about the relative importance of different exposure pathways to the public from discharge of a NORM-site.

As most of the NORM-waste tonnage in Finland is mining waste or uranium-containing sludges from metal industry, the main exposure scenario of concern is the mobilization of uranium from the waste and the possibility of transport to drinking water. The exposure of the workers from external radiation is very small in these cases, but internal exposure from inhalation of dust is possible if the waste produces dust before being covered. For scrap metal recycling, the exposure of workers from external radiation, and internal exposure if metals are cleaned, are of some concern.

The radiation exposure of biota has not been systematically assessed, but the ERICA-tool has been tested in some projects. The Governmental Decree on Environmental Impact Assessments (EIA) from 2017 now specifies 'radiation' as an aspect to be assessed in the EIA, but the level of these assessments remains to be seen. The EIA-process is handled by the environmental authorities.

4.2.3 NORM waste disposal options

The radioactive waste repository is not a possible disposal site for large-volume NORM-waste in Finland. Only for some special cases of high-activity and small volumes it might be considered (e.g. small amounts of nuclear material). There are no specific repositories for NORM-waste. In Finland NORM-wastes are most often disposed in landfills for hazardous waste. This is generally possible because it is not considered as radioactive waste. Small amounts of material have been approved for ordinary landfill. Dilution by mixing is at least a theoretical option, but it has not been used recently for solid NORM-waste. Most often the other pollutants are limiting the waste disposal from industry and the waste goes to a hazardous waste-site anyway.

Some theoretical options for NORM-waste disposal in Finland are (with approval from STUK and demonstration of exposure below reference levels):

- dilution/mixing to below clearance levels and exempted from radiation regulation (unlikely)
- buried directly into soil with or without dilution (unlikely)
- landfill for non-hazardous waste (used)
- landfill for hazardous waste (used)
- radioactive waste repository (used for very small amounts of material with higher activity).

4.3 Iceland

4.3.1 Radioactive NORM waste

In 2015, NORM waste was discovered in Iceland for the first time. The discovery was at a geothermal power plant and consequently, a survey was carried out, including all large geothermal power plants in Iceland but NORM was only found in two of them; Reykjanesvirkjun and Hellisheiðarvirkjun. The latter only produces a small amount of Po-210 which must be kept for a couple of years for the activity to fall below the clearance limits. Reykjanesvirkjun produces around 2-5 tonnes/year of scales with Pb-210 and Po-210. No other industries have been identified in Iceland that could produce NORM.

4.3.2 Issue of NORM waste disposal

Iceland has no waste disposal site or repository for NORM as the geology of Iceland is not ideal for disposal of radioactive waste. Geislavarnir ríkisins published a report in 1996 that concludes "Iceland is a region where radioactive waste disposal is difficult. The country is geologically highly active with frequent volcanic eruptions, large earthquakes, tectonic fracturing, extreme ground water discharge, very high thermal gradient, extreme low crustal viscosity and high sensitivity to climatic deterioration." Currently the NORM scales from the geothermal power plant in Reykjanesvirkjun is kept on site until long term solution has been worked out.

4.4 Norway

4.4.1 Identified NORM waste streams

Until now, the main NORM waste streams that have been identified in Norway are:

- rock waste with potential for acidic radioactive leaching (such as alum shale containing waste) from different construction activities in specific bedrock areas rich in NORM,
- waste from NORM process industries, with the main contribution from oil and gas industry.

The Norwegian radioactive waste strategy, which also includes NORM waste, is currently under the development. The highest amounts in tons of radioactive waste in Norway is rock waste with potential for acidic radioactive leaching (Figure 1). Management of this waste must consider that the rock may be pyrophoric and have a potential for acidic radioactive leaching.

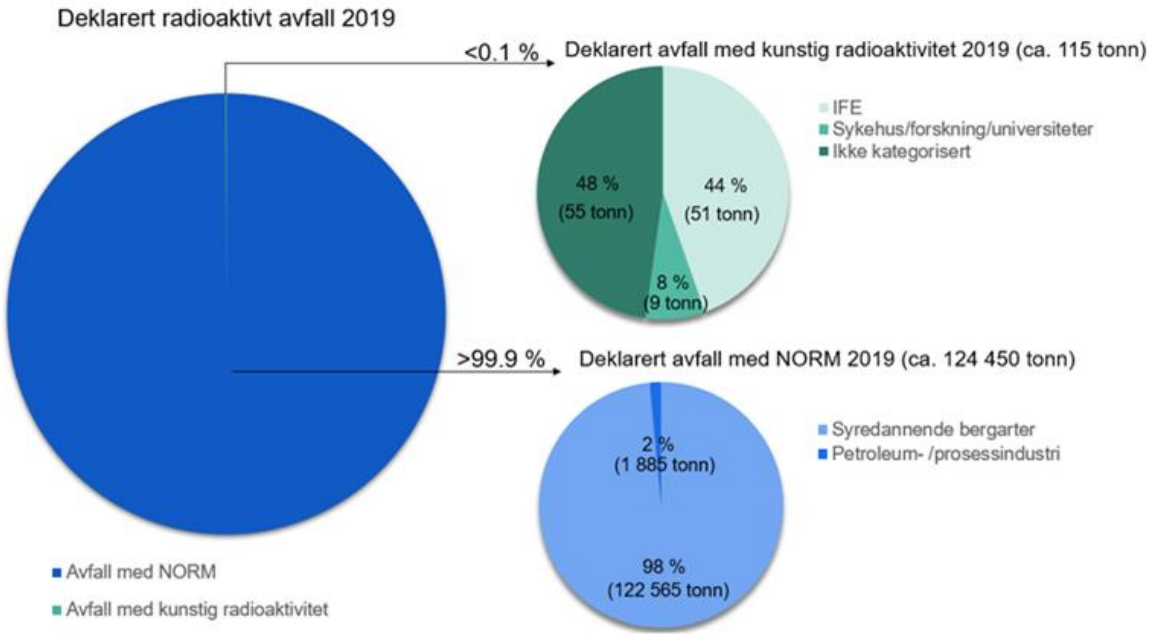

Figure 1. Overview of main waste streams ratio declared in Norway in 2019.

An overview of declared radioactive NORM waste in the period 2011-2019 for sectors oil and gas/NORM process industry in contrast to amount of rock waste with potential for acidic radioactive leaching is given as illustration in Figure 2.

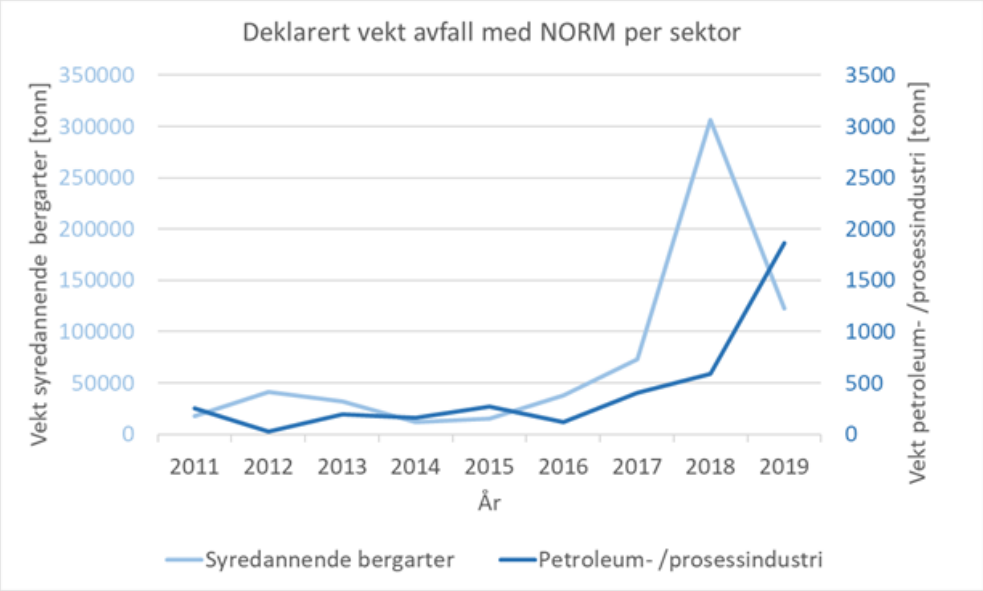

Figure 2. NORM waste from Norwegian oil and gas industry.

4.4.2 Graded approach for waste disposal

A graded approach for control and disposal of radioactive waste has been developed based on limit values for both specific activity concentrations and total activity of Th-232, U-238 and their progeny in waste defined by

Regulations on the application of the Pollution Control Act to radioactive pollution and radioactive waste (2010). Generally:

- Waste with NORM activity concentration below 1 Bq/g is not considered as radioactive waste,
- Waste with specific activity of NORM between 1 and 10 Bq/g, which is also hazardous waste, may be send to a disposal facility that has a licence either for hazardous waste issued by Norwegian Environment Agency, if the waste is both classified as radioactive and hazardous waste, and there is no possibility of radioactive discharges, or for radioactive waste issued by DSA. As deposition of radioactive waste will always have a potential for radioactive discharge, disposal sites should have a permit issued by DSA,
- Waste with specific activity of NORM higher than 10 Bq/g and total activity higher than 10.000 Bq must be sent to a proper repository holding the licence for radioactive waste for final disposal issued by the DSA.

4.4.3 Disposal sites and exposure scenarios

There are currently four active repositories in Norway that may receive radioactive waste with NORM:

- Heggvin Alun (disposal of rock waste with potential for acidic radioactive leaching and waste from mining industry)
- NOAH Langøya (disposal of rock waste with potential for acidic radioactive leaching, waste from mining industry, radioactive waste from oil and gas industry and radioactive waste from land-based industry)
- Wergeland-Halsvik (waste from oil and gas industry and radioactive waste from land-based industries with heavy metals and hydrocarbons)
- Bjorstaddalen Næring AS (disposal of phosphate sand from phosphate production Yara Norway, Porsgrunn)

Application procedure for giving a license to repositories for handling and disposal of NORM radioactive waste includes impact and risk assessment reports. Exposure scenarios evaluated in these assessments must consider aspects of workers, public health and biota radiation protection. In the specific situations, the environment per se has to be considered. Repositories for radioactive waste should have multiple barriers against external environment. All repositories for radioactive waste should include a financial security to ensure safe closure of the repository. Environmental monitoring is a requirement in a license from DSA. No exact exposure scenarios that need to be evaluated within each application procedure have been defined, it is rather a case specific decision making.

As mentioned above, rock waste with potential for acidic radioactive leaching is the largest fraction of radioactive waste in Norway. DSA works to ensure that there will be enough capacity to receive this fraction. Radioactive waste from oil and gas industry is the second largest fraction of radioactive waste in Norway. Since 2008 Wergeland-Halsvik has had a license to receive radioactive waste from oil and gas industry with specific activity of NORM higher than 10 Bq/g and total activity higher than 10 000 Bq.

Borge pukkverk deponi that received rock waste with potential for acidic radioactive leaching have recently been closed, and NOAH Langøya is soon to be closed. There is ongoing work to find a new repository for hazardous waste in Norway.

Current estimation of expected and/or highest magnitude of future's NORM radioactive waste (Fig. 3) will exceed capacity of all existing disposal sites in Norway. Nowadays, capacity of existing disposal site is big enough for

only the lowest estimation of waste quantity (1.000.000 tons). Therefore, DSAs position is that a new disposal site for hazardous waste should also include radioactive waste with NORM.

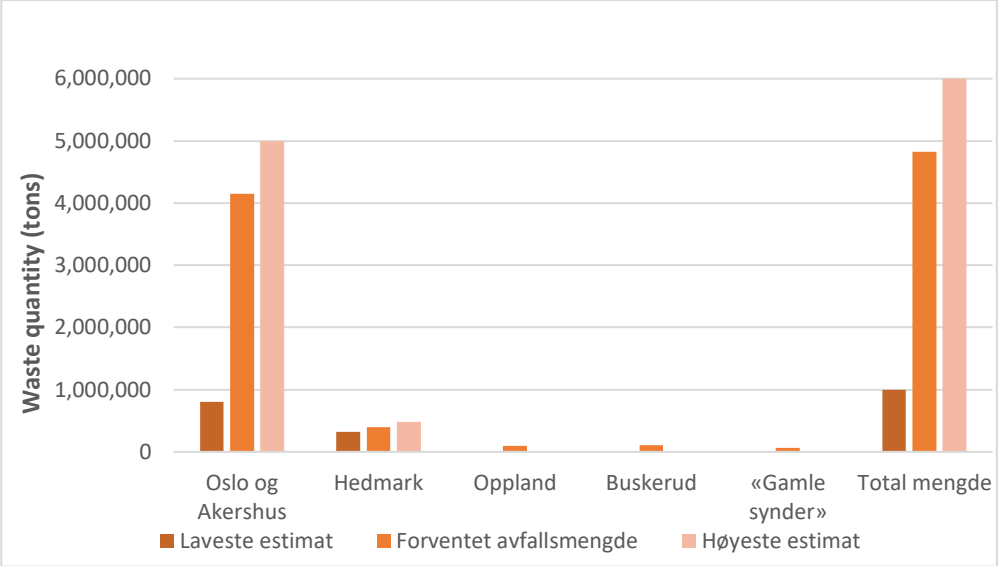

Figure 3. Prediction of magnitude of NORM containing radioactive waste (rocks including alum shale).

4.5 Sweden

4.5.1 NORM waste streams

The waste streams for NORM are:

- Landfills for NORM with activity concentrations below 10 kBq/kg as regards nuclides in the uranium and thorium series, and below 100 kBq/kg as regards K-40.
- Reuse of materials from demolition of buildings and reuse of ash for construction purposes (though not as building materials).
- NORM exceeding 10 kBq/kg as regards nuclides in the uranium and thorium series and exceeding 100 kBq/kg as regards K-40, should be managed as radioactive waste. However, at the present time there is no repository in Sweden for this type of waste. It is possible to make exemptions (specific clearance) in individual cases, for placement of NORM in landfills for hazardous waste. SSM is concerned that there is a lack of control over the total amount of activity in these landfills.

4.5.2 NORM waste disposal

NORM originating from Sweden and having activity concentrations below 10 kBq/kg as regards nuclides in the uranium and thorium series, and below 100 kBq/kg as regards K-40 if the material may be placed in a landfill for non-hazardous waste.

Water filters from individual households in Sweden may be disposed of as household waste without any consideration of its radioactive properties [Section 12 of SSMFS 2018:4].

Materials from demolition of buildings in Sweden may be placed in a landfill or reused for construction purposes (though not as building materials) without having to take into account their activity concentration [Section 12 of SSMFS 2018:4].

At the present time, there is no final solution in Sweden applying to NORM waste having activity concentrations above 10 kBq/kg as regards nuclides in the uranium and thorium series, and above 100 kBq/kg as regards K-40. Such NORM waste sometimes ends up in scrapyards or at recycling companies. Sweden does not have a repository that is designed for NORM.

5 Concluding remarks

An overview of the current national legislations in the Nordic countries in place for regulatory control of NORM and NORM processing industries has been provided together with explanatory notes. Although each of the Nordic countries' legislation exhibits some specificities, similar requirements are identified for NORM processing industries. Values of activity concentrations for U-238, Th-232 (1 Bq/g) and K-40 (10 Bq/g) are given in legislations as main quantitative criteria for decision-making on graded regulatory approaches, while principles of the justification, optimization and dose constraints are fundamentally used in combination with supplementary requirements, in one or another way.

Differences have also been seen in regulation of NORM management, e.g., in relation to waste management, disposal and discharge control requirements. Reference level of 1 mSv/y for the members of public has been included in the legislation of the Nordic countries. However, somewhat different and stricter dose constraints and reference levels applicable for single operators are in use to account for the possibility of public exposure from multiple operations. Still, it is not always straightforward and clearly developed how these dose criteria should be applied in practice. For instance, decision making in Norway is exclusively based on limit values for U-238 and Th-232 decay chains radionuclides (activity concentrations and total activity), while there is possibility for exemption and/or clearance based on defined dose criteria in Finland, Sweden and Denmark.

Furthermore, somewhat different approaches to control of environmental discharge from NORM processing industry, and thus related requirements, have also been identified. As illustration, environmental impact and dose assessment regarding NORM, concerning both general public and biota, is in Norway included in the procedure for licensing and/or permits issuing and commonly considered in regulatory practice by the DSA. In Finland, Denmark and Sweden, management of NORM may also be a subject to the provisions regarding environmental impact assessment, but the process is conducted independently from licensing processes as regards radiation protection. Furthermore, somewhat different approach to certain NORM activities in terms of exemption/clearance from radiation protection legislation have been seen. With respect to that, sharing, comparison and discussion of national cases related to safety analysis, EIA, monitoring and inspections as well as cases of exemption/clearance based on dose criteria can be of importance for Nordic countries.

List of industrial activities, given in the EU BSS and IAEA BSS, is in use in regulatory practice in the Nordic countries. Current status of mapping of NORM-processing industries that might be of radiological concern is somewhat different, but each of the countries does see need for further activities in this field. Collaboration and discussion how to approach industries and how to communicate regulatory framework with them, but also with stakeholders, what challenges can be seen in particular industries, sharing of existing experience are some of the topics to be included on agenda for future WG Nordic-Nat work.

6 Potential topics for further joint activities

Based on discussions done in the WG Nordic-Nat and overview given this report, some of the potential topics for future Nordic-Nat group work can be listed:

- Application of exemption and clearance concepts in regulatory control of NORM material/practice – sharing existing national experiences,
- NORM waste and discharge – regulatory approaches, safety and environmental assessments,
- Inspections, exchanges on regulatory practices,
- Environmental monitoring related to cases of NORM processing industries - comparison of practices, challenges and good practice, case studies,
- Transboundary movement of NORM waste for disposal and NORM contaminated materials for processing,
- NORM legacy sites and remediation process,
- Update of Nordic flag book -publication "Naturally Occurring Radiation in the Nordic Countries – Recommendations, 2000,
- Stakeholder engagement and risk communication in NORM (in relation to NORM industry and NORM existing exposure situations), and
- Exchange on international events/activities related to NORM (regulatory and scientific aspects) as a standing point for exchange.

Annex

Information (links) on available legislation, guidance and other valuable national material related to NORM regulation

Denmark

Legislation

- Act No. 23 of 15/01/2018 - Act on Ionising Radiation and Radiation Protection (The radiation Protection Act)
- Order No. 669 of 01/07/2019 - Executive Order on Ionising Radiation and Radiation Protection
- Order No. 670 of 01/07/209 -Executive Order on Use of Radioactive Substances
- Parliamentary Resolution B 90 of 14/03/2018 on a Long-Term Solution for Denmark's Radioactive Waste - Forslag til folketingsbeslutning om en langsigtet løsning for Danmarks radioaktive affald

Guidance documents (in Danish)

- Brug af åbne radioaktive kilder (Vejledning)
- Sikkerhedsvurderinger (Vejledning)

A specific guidance on the use of NORM is under development.

Finland

Finnish legislation (in Swedish and English)

- Strålsäkerhetslag 859/2018 (from 15.12.2018); Radiation Act
- Statsrådets förordning om joniserande strålning 1034/2018 (from 15.12.2018); Governmental decree on ionizing radiation
- Social- och hälsovårdsministeriets förordning om joniserande strålning 1044/2018 (from 15.12.2018); Ministerial decree on ionizing radiation
- Strålsäkerhetscentralens föreskrift om verksamhet som medför exponering för naturlig strålning STUK S/6/2022 (from 15.2.2022); Radiation and Nuclear Safety Authority Regulation on Practices that cause exposure to natural radiation STUK S/6/2022
- Strålsäkerhetscentralens föreskrift om frigränser och friklassningsnivåer STUK SY/1/2018 (14.12.2018); Radiation and Nuclear Safety AuthorityRegulation on Exemption and Clearance levels STUK SY/1/2018
- Strålsäkerhetscentralens föreskrift om strålningsverksamhet som kräver säkerhetstillstånd STUK S/6/2019 (from 2.7.2019); Radiation and Nuclear Safety Authority Regulation on Radiation practices subject to a safety license STUK S/6/2019
- Guide on mining: Natural Radiation in Mining (in English), Naturlig strålning inom gruvdrift (in Swedish) (10/2019)
- STUK's webpages (in English and Swedish)
- Sammio (https://sammio.stuk.fi/etusivu#/?lang=en) is STUK's regulatory and guidance service for radiation legislation. Requirements can be sought from different levels of legislation and from

STUK's regulations. The requirements are accompanied by rationale and free-form guidance. (in English and Swedish)

Norway

Legislation

- Act of 13 March 1981 No.6 Concerning Protection Against Pollution and Concerning Waste in relation to radioactive pollution and waste (from 1. January 2011)
- Regulations on the application of the Pollution Control Act to radioactive pollution and radioactive waste (PDF-file)
- Act on Radiation Protection and Use of Radiation (No. 36 of 12 May 2000)
- Regulations on Radiation Protection and Use of Radiation (Radiation Protection Regulations) (PDF-file)
- forskrift om gjenvinning og behandling av avfall (avfallsforskriften) kapittel 16 (In Norwegian)
- forskrift om begrensning av forurensning (forurensningsforskriften) (In Norwegian)

Guidance and other publications (available in Norwegian language)

- Guidance for application for permits on radioactive pollution and handling of radioactive waste https://www.dsa.no/filer/2c040291d0.pdf
- Guidance for annual reports for undertakings that produce/handle radioactive waste

  https://www.dsa.no/filer/606a400585.pdf
- Guidance about radioactive pollution and radioactive waste in oil and gas industry

  https://www.dsa.no/filer/12f1cbefc5.pdf
- Guidance for disposal sites that need licence from DSA

  Retningslinjer for søknad om tillatelse

Other documents regarding NORM in Norway (available in the Norwegian language)

- DSA info: alum shale – source for radioactive pollution and radioactive waste

  https://www.dsa.no/filer/73e8ffc937.pdf
- DSA info: radioactive waste

  https://www.dsa.no/temaartikler/94907/radioaktivt-avfall

Sweden

Legislation

- Act on Environmental Protection, Miljöbalk (1998:808)

  https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/miljobalk-1998808_sfs-1998-808 - In Swedish
- Radiation Protection Act, Strålskyddslag (2018:396)

  https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/stralskyddslag-2018396_sfs-2018-396 - In Swedish

- Radiation Protection Ordinance, Strålskyddsförordning (2018:506)

  https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/stralskyddsforordning-2018506_sfs-2018-506 - In Swedish

- Strålsäkerhetsmyndighetens föreskrifter (SSMFS 2018:4) om naurligt förekommande radioaktivt material och byggnadsmaterial

  https://www.stralsakerhetsmyndigheten.se/publikationer/foreskrifter/ssmfs-2018/ssmfs-20184/ - In Swedish

- Act on Nuclear Activities (1984:3), Lag (1984:3) om kärnteknisk verksamhet

  https://www.riksdagen.se/sv/dokument-lagar/dokument/svensk-forfattningssamling/lag-19843-om-karnteknisk-verksamhet_sfs-1984-3 - In Swedish


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