REMEDIATION OF A LEGACY NORM SITE IN NORWAY

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04 DISPOSAL ALTERNATIVES

05 STATUS AND CONCLUSION

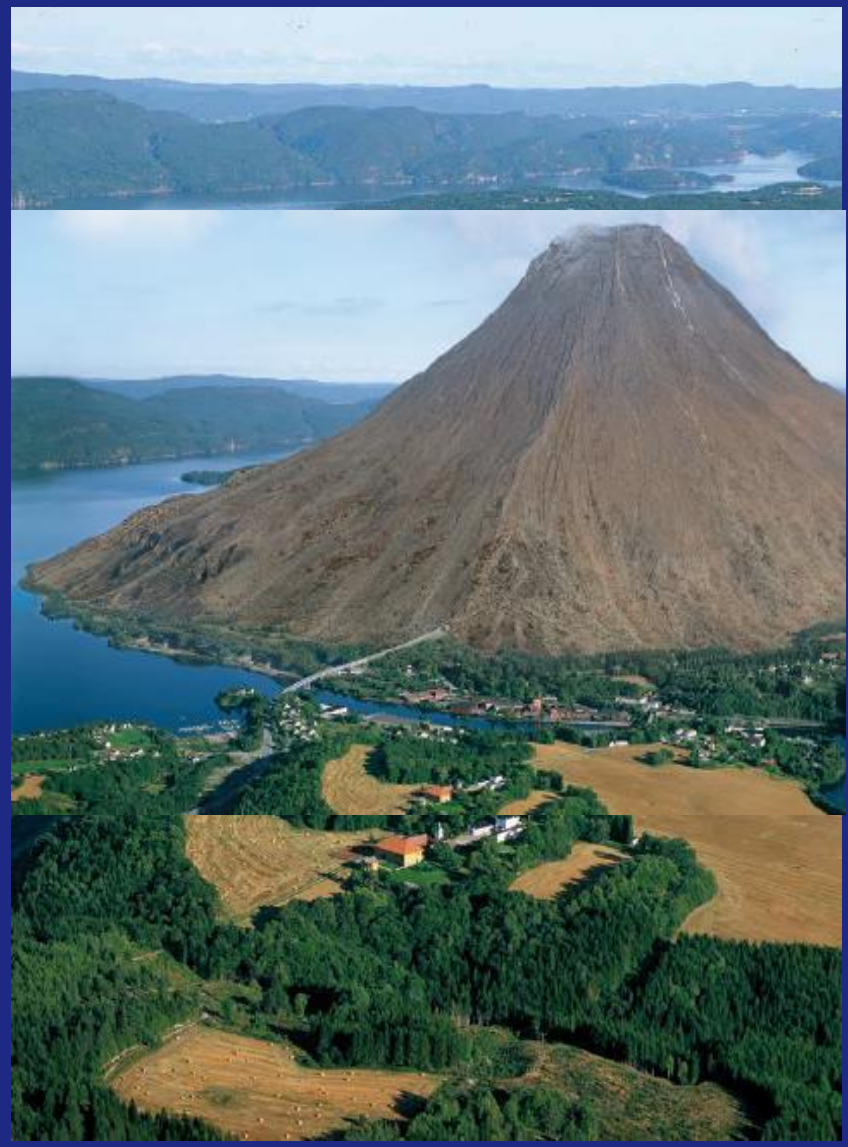
The Fen complex

Location: Vestfold and Telemark county, Norway

Area: 4.5 km^2

Eruption of a volcano 580 M years ago

Erosion has removed any signs of the volcano



The Fen area today

(Gea Norvegica)

Minerals in Fen

Unique occurence of carbonatite minerals. Søvitt contains Nb

The minerals have elevated concentrations of Th and U





Broad band of Søvitt visible in rock formation

(Gea Norvegica, Fen)

Geological analogue

Area in East-Africa with
Geological similar area in East-Africa

Active volcano with carbonatite
formation in the lava stream





Ol Doynio Lengai, Tanzania

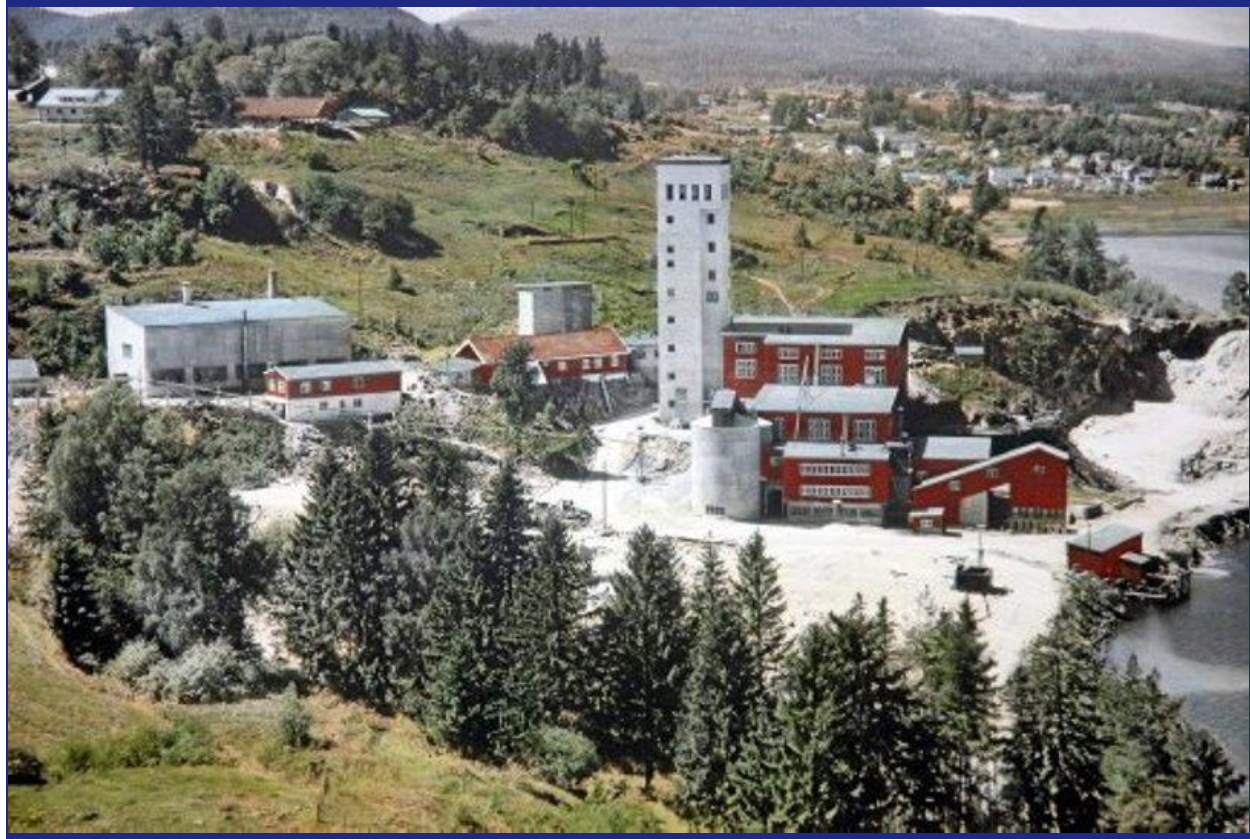
(Gea Norvegica)

Mining at Søve

From 1951-1965 niobium mineral concentrate was produced

Refined into ferro-niobium at the metallurgical facility using aluminothermic reactions

High demand for niobium used as a steel alloy



Søve mines in operation

(Photo 1964)

Metallurgical facility

The slag heap was formed by slag stored outside

The building is still in use by a local company

Pipeline for disposal of liquid $CaCo_3$ waste from the Wash House to the Pond



Metallurgical facility

(Photo 1964)

Arial view

Current view of the site and surroundings

Location close to lake Norsjø



Arial view

(Google maps 2021)

Remaining buildings

Some buildings from the mining period are left

Vegetation has taken over the site



Current view - site seen from road

(Photo NND)

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Norwegian legislation

Radioactive contamination part of pollution act from 2011

Categories of waste are:

- -Below limit for radioactive waste
- -Radioactive waste
- -Radioactive waste w/disposal requirement

Radionuclide	Radioactive waste	Disposal requirement
Th-nat	1 Bq/g	1 Bq/g
U-nat	1 Bq/g	1 Bq/g
Th-228	1 Bq/g	1 Bq/g
Ra-226	1 Bq/g	10 Bq/g
Ra-228	1 Bq/g	10 Bq/g
Pb-210	1 Bq/g	10 Bq/g

Activity limits relevant for Søve mines

(FOR 1394)

Norwegian legislation

The regulations also set limit for annual release to environment

Relevant for repository safety case

-Must be able to demonstrate that annual release is below limit

Radionuclide	Total activity released	Specific activity released
Th-nat	100 Bq	0.1 Bq/g
U-nat	100 Bq	0.1 Bq/g

Annual release limits

(FOR 1394)

Order for remediation

Issued by the radiation protection authority now DSA) to Ministry of Trade, Industry and Fisheries (NFD)

Purpose of the remediation was:

«ensure that the radioactive waste does not lead to any harm to humans or the environment»

«no restriction on future use of the area»

Remediation should be finished 31.12.2014 at the latest, later delayed to 2017

Reason for delay is lack of repository solution, also realised by DSA



Top of the Slag Heap

(Photo NND)

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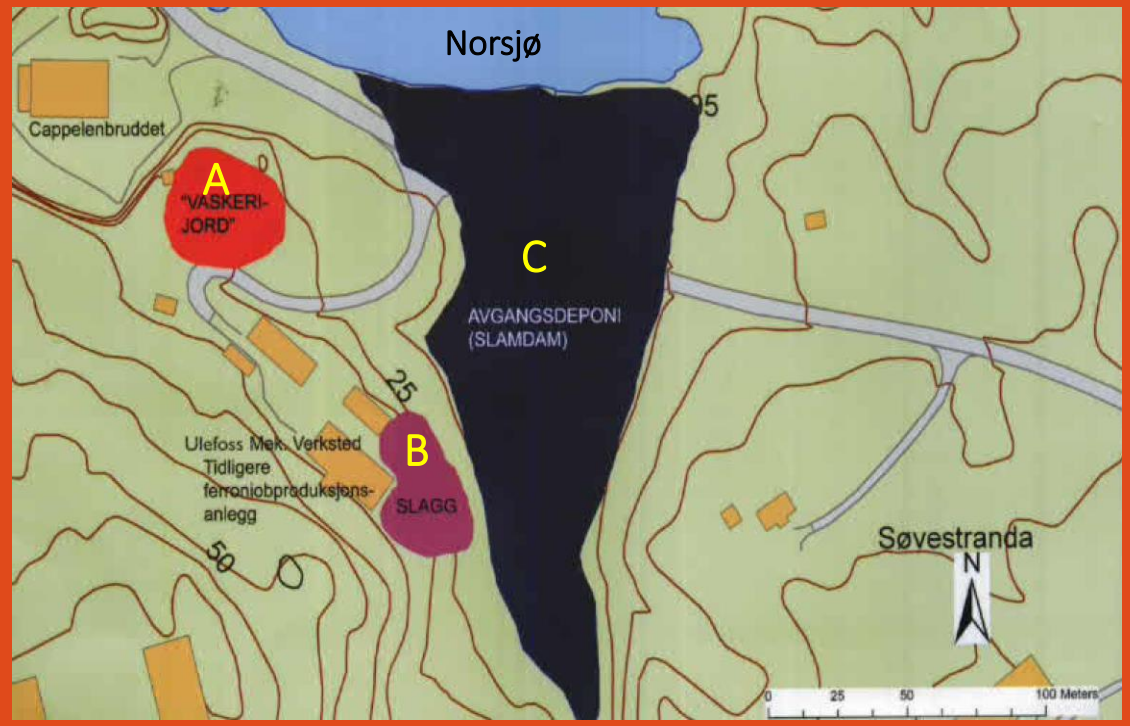
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Areas of radiological concern

Spill from crushing and cleaning of Nb concentrate
- -Wash House Soil (A)
- -Volume approx. 500 m^3

Slag from production of ferro-niobium
- - Slag Heap (B)
- -Volume approx. 2000 m^3

Scattered Slag lumps
- -Pond (C)
- -Volume of little significance



A: Wash House soil

B: Slag Heap

C: Pond

(Dahlgren 2005)

Radiological mapping

Several projects on site characterization

-IFE 2006
-PORANO 2010-2011

Field measurements focused on dose rate above ground level

Combination of field measurements and laboratory analysis of samples

-Gamma spectrometric measurements of U and Th progeny

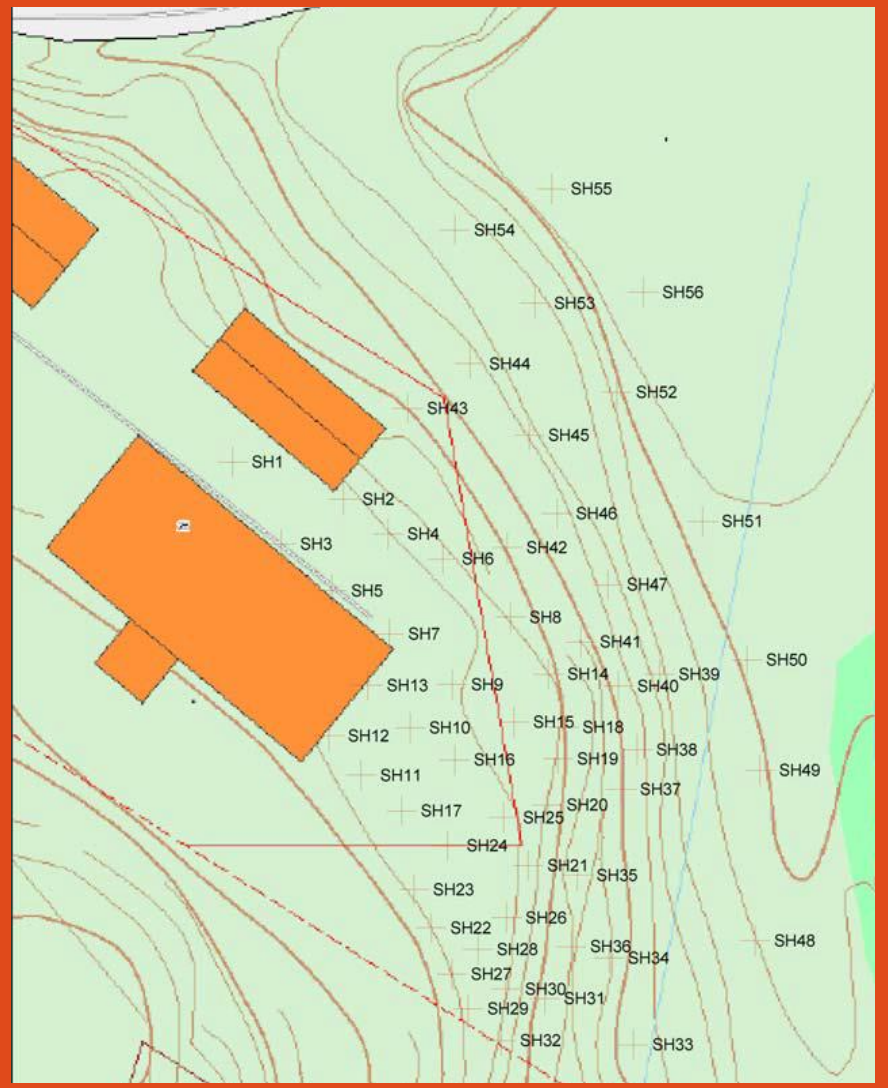
-Direct analysis of ^{232}Th and ^{238}U by neutron activation techniques (by ^{239}Np and ^{233}Pa)



Activity measurements

Activity concentration of Th-232 in samples [Bq/g]

Sample	Th-232	Ra-228	Th-228
Wash House soil 1	15.4 ± 1.8	18.8 ± 0.8	19.5 ± 0.8
Wash House soil 1	7.7 ± 0.5	8.7 ± 0.3	8.3 ± 0.2
Wash House soil 3	1.0 ± 0.6	1.0 ± 0.07	1.1 ± 0.1
Slag lump 1	54.0 ± 10.0	74.0 ± 4.0	74.0 ± 3.0
Slag lump 2	29.0 ± 1.8	29.1 ± 0.9	27.1 ± 0.8
Soil (close to Slag Heap)	0.2 ± 0.04	0.2 ± 0.03	0.2 ± 0.01



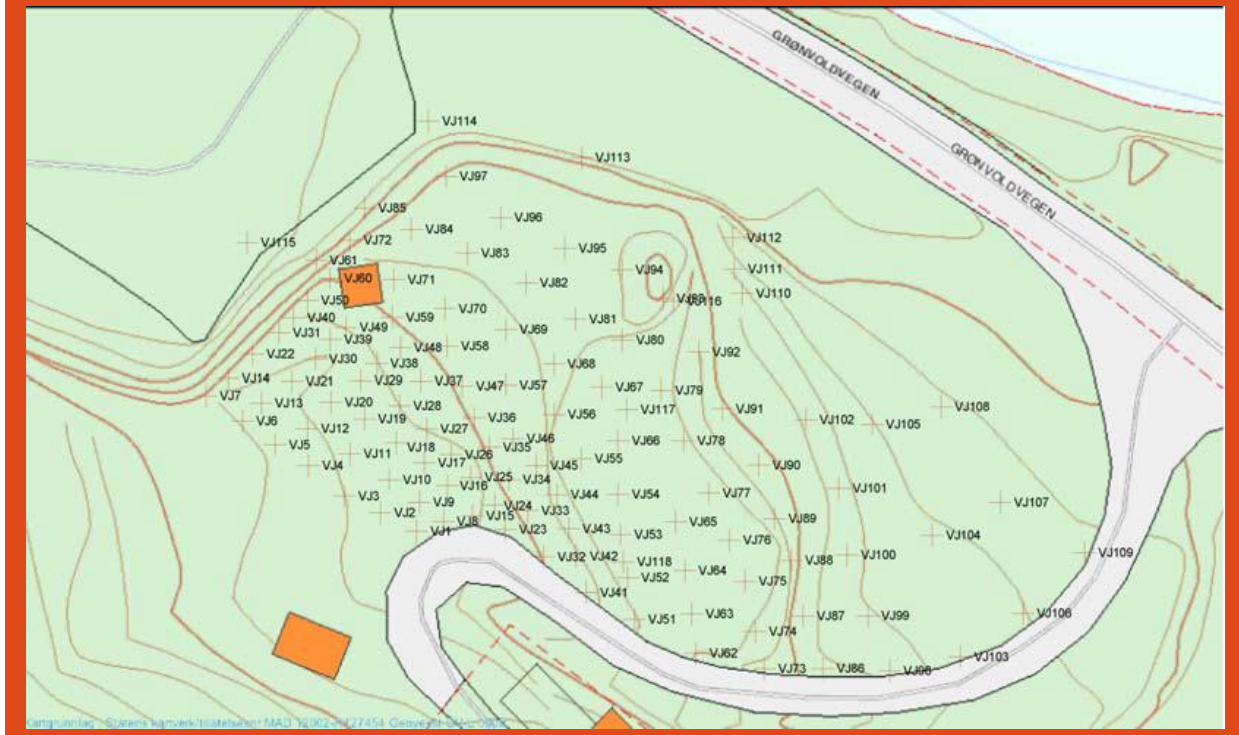
Sampling points in Slag Heap and surroundings

(IFE 2006)

Activity measurements

Activity concentration of U-238 in samples [Bq/g]

Sample	Th-232	Ra-228	Th-228
Wash House soil 1	10.9 ± 2.2	12.5 ± 1.8	13.6 ± 1.8
Wash House soil 1	5.2 ± 0.3	3.3 ± 0.5	2.7 ± 0.3
Wash House soil 3	1.0 ± 0.5	0.9 ± 0.04	0.9 ± 0.1
Slag lump 1	66.0 ± 14.0	55.0 ± 8.0	60.0 ± 40.0
Slag lump 2	9.6 ± 0.5	9.3 ± 1.4	8.6 ± 1.2
Soil (close to Slag Heap)	0.2 ± 0.05	0.2 ± 0.03	0.2 ± 0.07



Sampling points in Wash House soil and surroundings

(IFE 2006)

Activity measurements

Activity concentration at various depth in Wash House soil [Bq/g]

Depth [m]	Point No.	Th-232	U-238
0.6	1	9.0 ± 0.6	4.6 ± 0.8
0.8	1	1.3 ± 0.1	0.81 ± 0.06
1.1	1	0.06 ± 0.01	0.74 ± 0.03
1.5	1	0.08 ± 0.01	0.68 ± 0.01
0.2	2	1.3 ± 0.1	0.81 ± 0.05
0.6	2	1.3 ± 0.1	0.64 ± 0.04
1.2	2	0.07 ± 0.01	0.07 ± 0.01



Ambient dose rate mapping

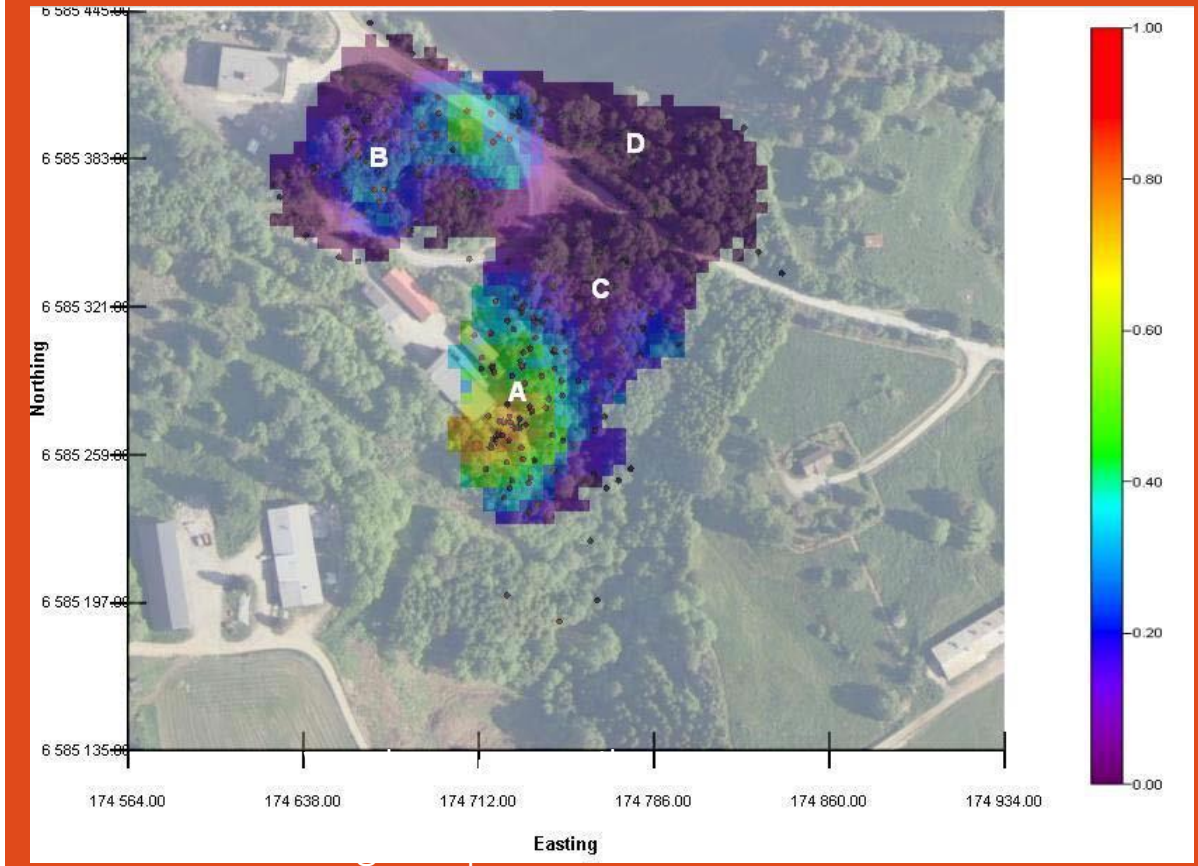
Fixed grid measurements 1 m above ground level

Coordinates from portable GPS

Distribution in depth, density, moisture and cover thickness influences results

Probability map for exceeding an H*(10) rate of 0.34 µSv/h

potential to cause a maximum yearly external exposure of 3 mSv



Probability map of H*(10) of exceedance 0.34 µSv/h.

A: Slag Heap, B: Wash House Soil, C: Pond, D: Shore of lake Norsjø

(Dowdall 2012)

Activity measurements

Elevated concentration of U and Th above limit

Approximate equilibrium between U, Th and their progeny

Activity evenly distributed in Wash House soil with a thickness of 1 m

Ambient dose rate measurements in grid shows location of «hot» areas – little depth profile information available



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Repository on-site

Solution has the benefit of avoiding transport

Use of the mine has been evaluated but deemed to be impossible as the shaft has been filled up

Excavating in the local rock formation should be avoided

- contains Th and U at a level that probably will define the excavated masses as NORM

Building a concrete cell on-site is an option

Location close to the lake Norsjø (drinking water resource) and the possibility leakage of radioactive contamination are factors of concern



Søve pond area with a creek

(Photo: NND)

Semi-local repository

Nome municipality has an area of 430 km^2, largly unpopulated.

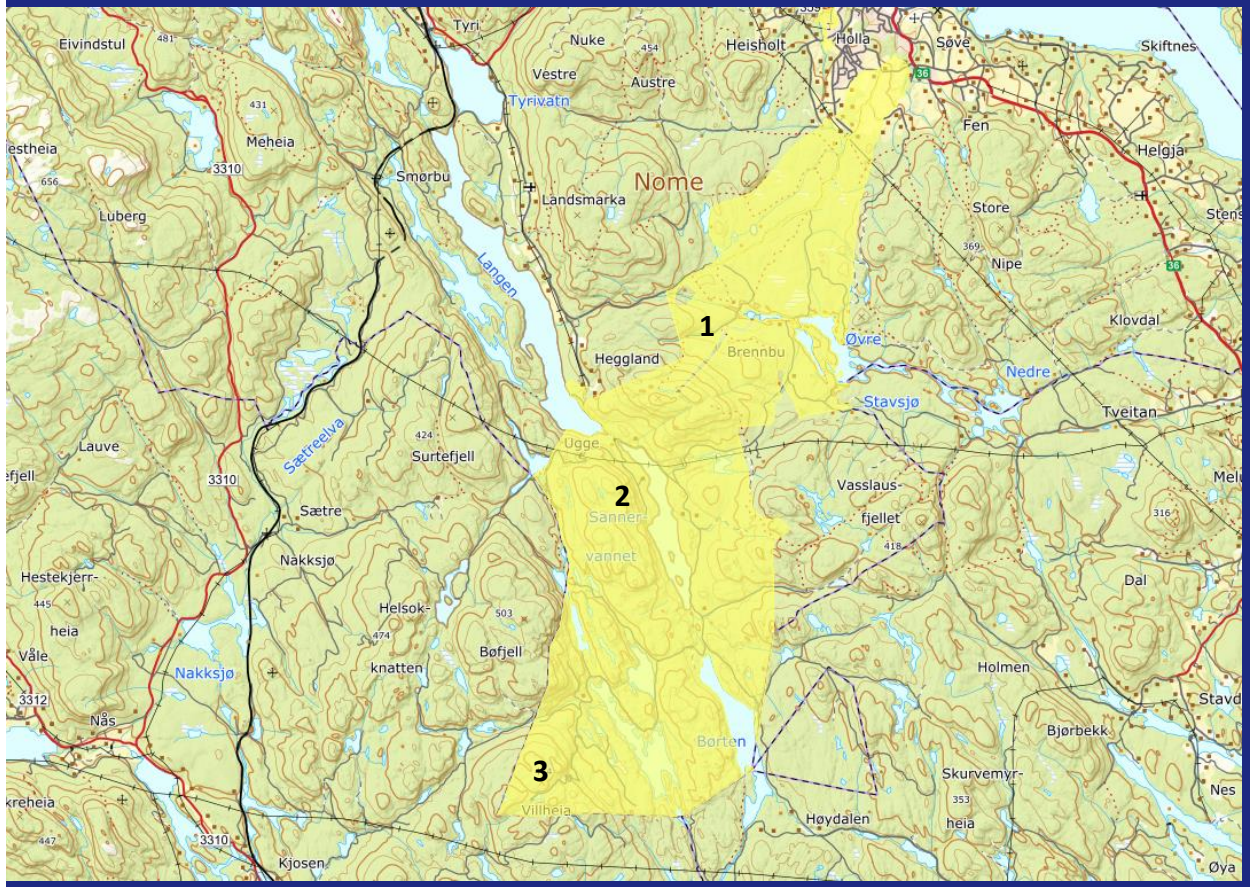
Exept for the Fen complex, it consists of stable bedrock (granite, gneiss, quartzite and amphibolite)

Building a rock cavern repository in rock formation in Nome has been evaluated

Criteria for site location

- -Stable formation without cracking influx of water
- -Acessibilty from existing road
- -Transport route avoiding population centra
- -Minimum impact on pulic use of the area
- -Landowner must be willing to transfer ownership

The municipality authority has pointed at 3 possible locations for building a dedicated Søve repository



1: Ormtjern

2: Teigemoen

3: Blomtjønnkleiva

(Ill. Kartverket)

Use of existing repositories (1)

Sløvåg NORM repository has a permit to accept Søve type material

Annual limit 1500 tonnes of NORM

Waste conditioning requirement – use 210 L HDPE drums

-Void volume due to weight limit

Søve waste would exhaust repository capacity for years



Sløvåg NORM repository (Wergeland-Halsvik)

(Photo: Varskog, P.)

Use of existing repositories (2)

Several repositories for hazardous waste in operation

Will require extension of permit to cover NORM

This option has been chosen in two previous attempts for remediation

In 2012, the ministry (NFD) awarded a contract to a contractor with NOAHs repository at Langøya as repository solution

The operator declined to accept Søve waste



Langøya repository (NOAH)

(Photo: Varden)

Use of existing repositories (3)

In 2016, the ministry (NFD) issued a new tender with a turnkey contract including remediation of Søve and a repository with permit and capacity

The contract was awarded to a contractor with the aim of disposing the waste at an Alum shale repository

- Heggvin Alun, later changed to Borge massemottak

Lack of public acceptance for radioactive waste made this solution impossible



Heggvin Alun

(Photo: NGm3)

Use of existing repositories (4)

Another approach: Build dedicated cell at existing repository site

Provides isolation of NORM material

Safety case developed for repository cell to demonstrate isolation

Infrastructure for transport and handling already in place

1

2

Joint solution

NND shall is to establish establishing repository capacity for all anthropogenic radioactive waste at a centralised national waste repository, rincluding HLW, ILW and LLW

Decommissioning of IFEs research reactors will require a substansial capacity for LLW waste from building materials and contaminated soil

Using the same repository capacity for permament disposal of NORM is under evaluation



NND shall establish a national site for permnent disposal of all radioactive waste. Estimated to be finished by 2040.

(Ill.: NND)

Søve Waste as resource

the waste contains a considerable amount of rare earth elements (REE) in addition to Nb (50% production loss)

Demand and price for REE have increased substantially, supply is limited

Earlier analysis has shown that the cost of setting up an industrial process to extract REE from the waste is too high to make the process sustainable

Plans for mining for REE at Fen are in progress

If realised, Søve waste may be included as raw material

REE extraction itself will require large repository capacity, co-location with Søve waste possible



Core samling for investigation of REE minerals in the Fen complex

(Photo: Kanalen)

Repository options

Several of the options discussed are deemed to be viable

Probability for successful implementation must be evaluated

Time scale must be considered

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Status

The grant from Norwegian state was substantially increased in 2021. A total of approximately 150 MNOK (16 MEUR) is now available for remediation, including final disposal

Early 2021, NND was given the responsibilty for remediation of Søve gruver

A revised competition where final disposal was included, was announced in 2021

The tender specified the date for finalizing the remediation as early 2024

Due to a legal controversy over the procurement process, the competion is currently cancelled

It is estimated that completion of the remediation will be further delayed by at least one year, 2025

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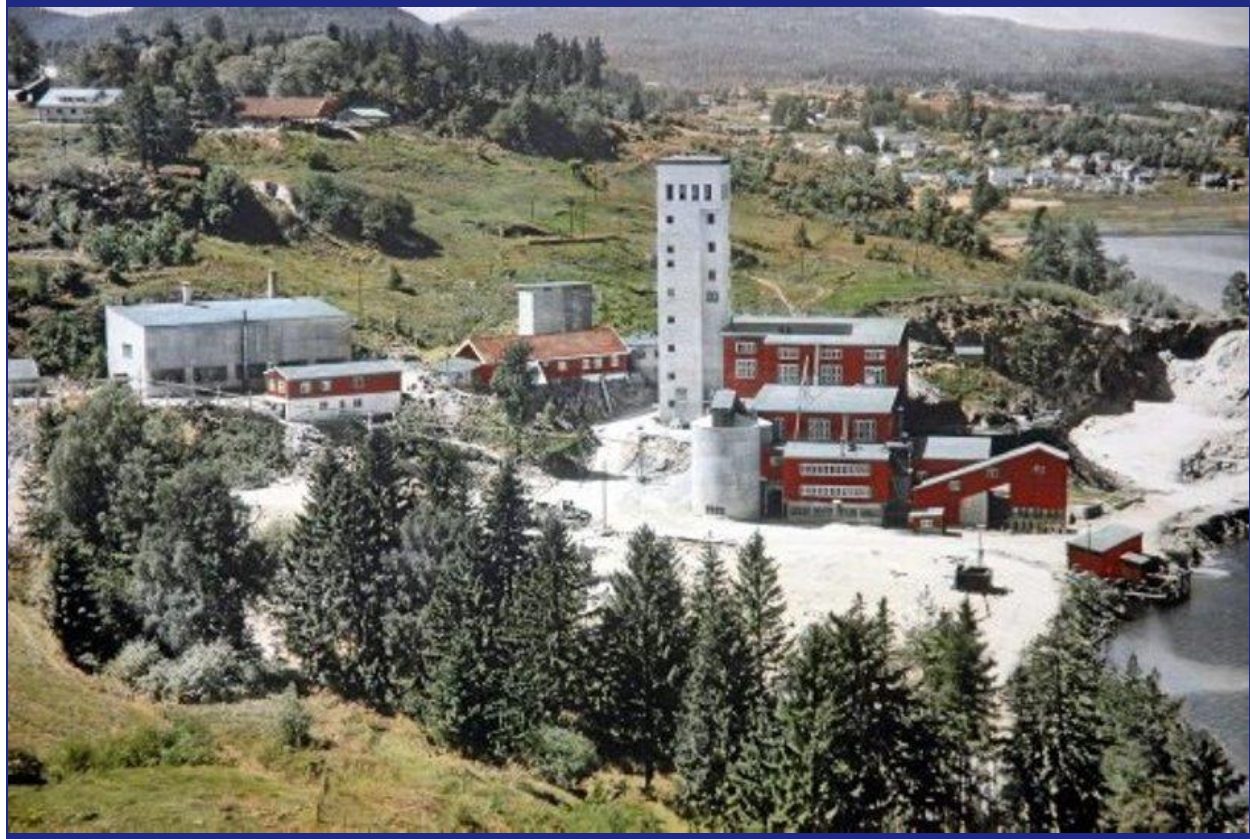
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Conclusion

Despite of several efforts, remediation of the former mining site at Søve has proved to be difficult to achieve

The efforts have stranded on the lack of suitable repository capacity

A suitable repository is one that has the required permits from the radiation protection authority and municipality authorities and most important - public acceptance



Thank You!

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