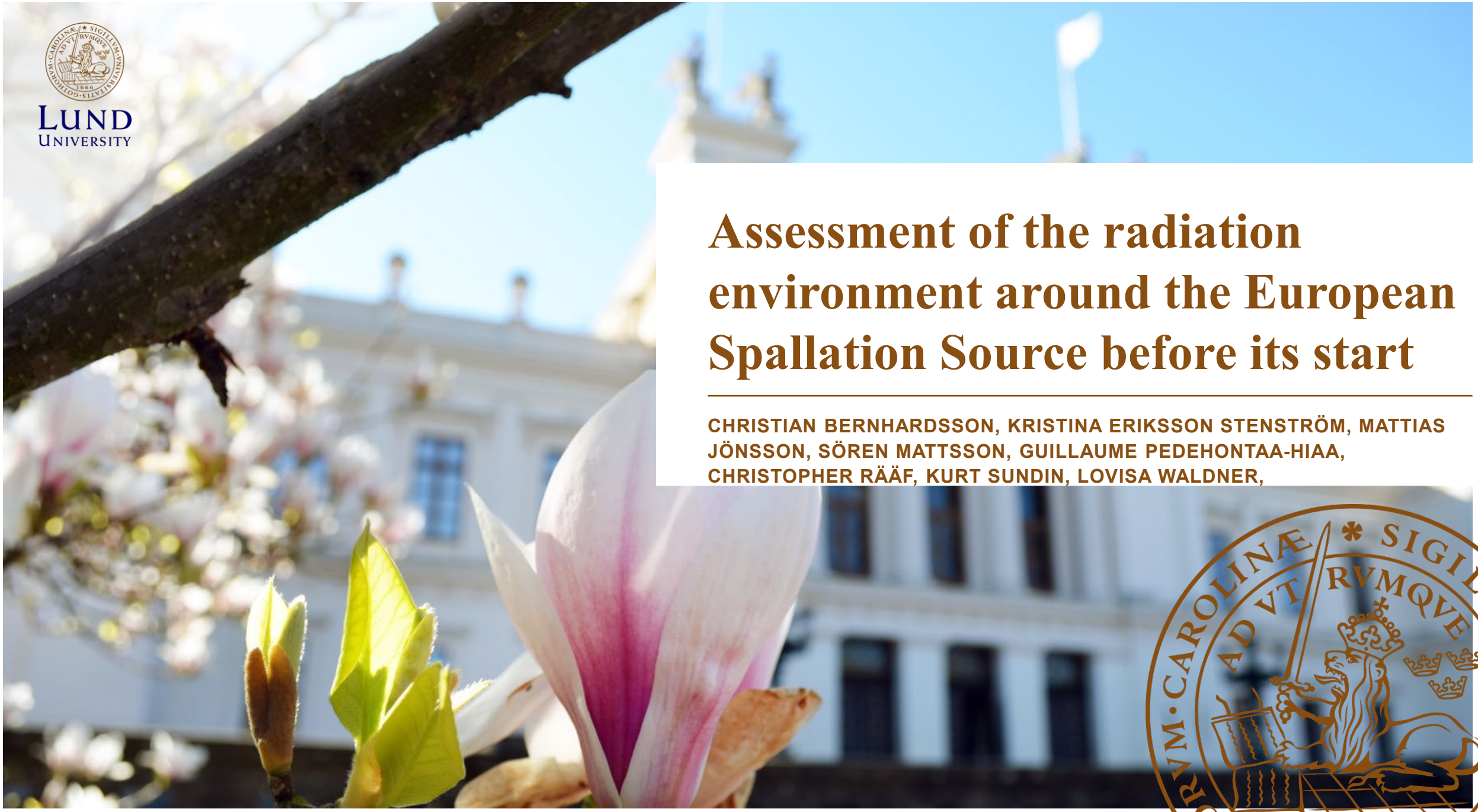


Assessment of the radiation environment around the European Spallation Source before its start

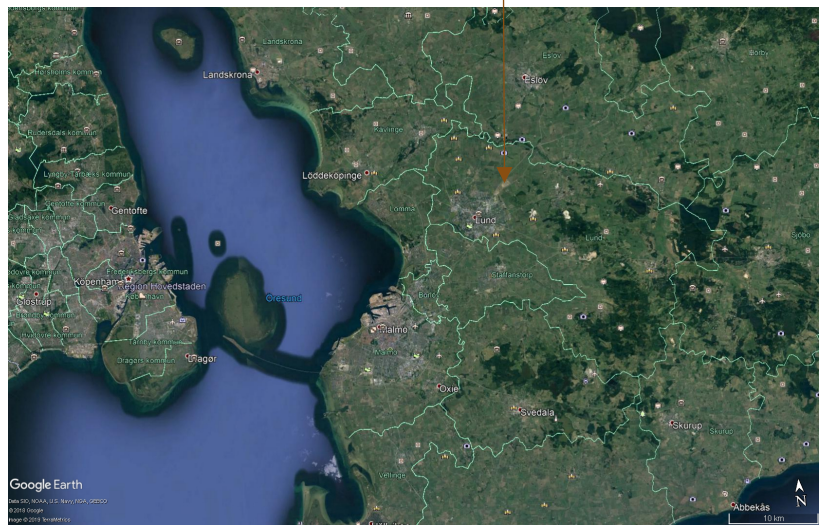
CHRISTIAN BERNHARDSSON, KRISTINA ERIKSSON STENSTRÖM, MATTIAS JÖNSSON, SÖREN MATTSSON, GUILLAUME PEDEHONTAA-HIAA, CHRISTOPHER RÄÄF, KURT SUNDIN, LOVISA WALDNER,

The European Spallation Source (ESS), ERIC

- One of the worlds most powerful spallation source (energy of 2 GeV and 5 MW power)
- Built in the north-eastern part of Lund, Sweden
- Start of operation ~2023 (beam on target)

→Potential releases of radionuclides to the environment

esss.se



The initial zero point assessments around ESS

- The Swedish Radiation Safety Authority (SSM) state that a nuclear facility should not increase the annual effective dose (public) with more than 0.1 mSv
  - ESS have goal not to exceed 0.05 mSv/year
- As an independent laboratory LU (medical radiation physics, Malmö; nuclear physics, Lund) was asked by ESS to establish a baseline of the zero point radiation environment
- In 2017-2018 this was done according to previous research on assessing the radiation environment

Aim of program

To establish a baseline of the radiological situation in the environmental compartments: land, air and water.

The initial zero point assessments around ESS

- **The purpose of the assessments is to provide:**
  - a baseline of the radiation environment and its variability,
  - background data for diffuse long-term discharges,
  - basis for measures/improvements,
  - data for reporting to authorities,
  - basis for information to the public,
  - basis for research and development.

Motivation

- **Gamma** emitting radionuclides: there are present and past sources that are responsible for the current day radiation environment.
  - *Natural: Cosmogenic-, primordial-*
    - *ex. $D(^{40}K) \sim 0.2\ mGy\ y^{-1}$*
    - *Man-made: nuclear weapons tests, accidental/operational releases from the nuclear industry, hospitals*

Motivation

- **Gamma** emitting radionuclides: there are present and past sources that are responsible for the current day radiation environment.

- **Tritium** (^{3}H): will be produced and released from ESS during normal operation, long half-life (12.3 years), high environmental mobility.
  - *Natural: cosmogenic production (bkg. 0.1 – 0.6 Bq l^{-1}, D(^{3}H) ~0.01 µSv y^{-1})*
  - *Man-made: nuclear weapons tests (×3), hospital/research, nuclear power industry, NPP accidents*

Motivation

- **Gamma** emitting radionuclides: there are present and past sources that are responsible for the current day radiation environment.

- **Tritium** (^{3}H): will be produced and released from ESS during normal operation, long half-life (12.3 years), high environmental mobility.

- **Carbon-14** (^{14}C): long half-life (5730 years), high environmental mobility
  - *Natural: cosmogenic production (ex. 10^{-10}% of C is ^{14}C, 12 μSv y^{-1})*
  - *Man-made: nuclear weapon tests (×2), nuclear power industry, radiolabelling labs*

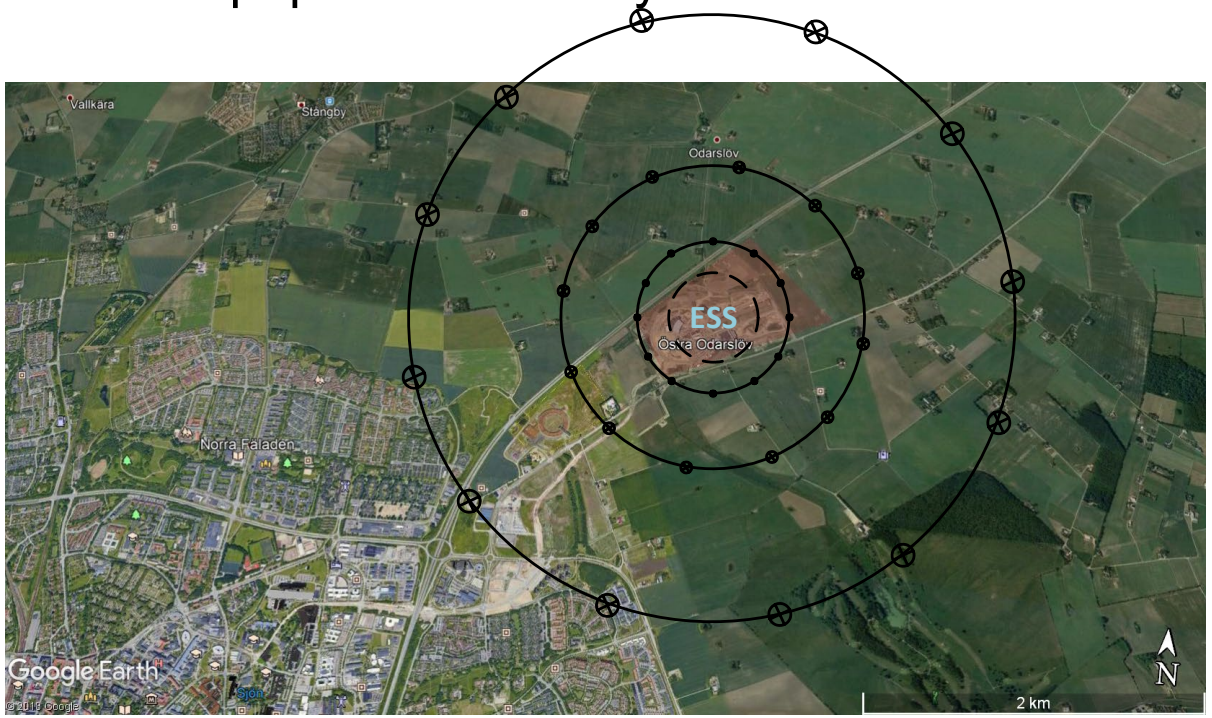
  - *^{3}H as well as ^{14}C are used in research in the Lund area. Environmental contamination may occur (observed for ^{14}C in the past, e.g. chestnut leaves in 2009: 26% above background).*

The ESS Zero Point project: Selection of sites

- **Reference sites**
  - Cover all directions from the ESS site,
  - preferably be preserved over time and available in the future,
  - be representative and reflect the current population density in the area.

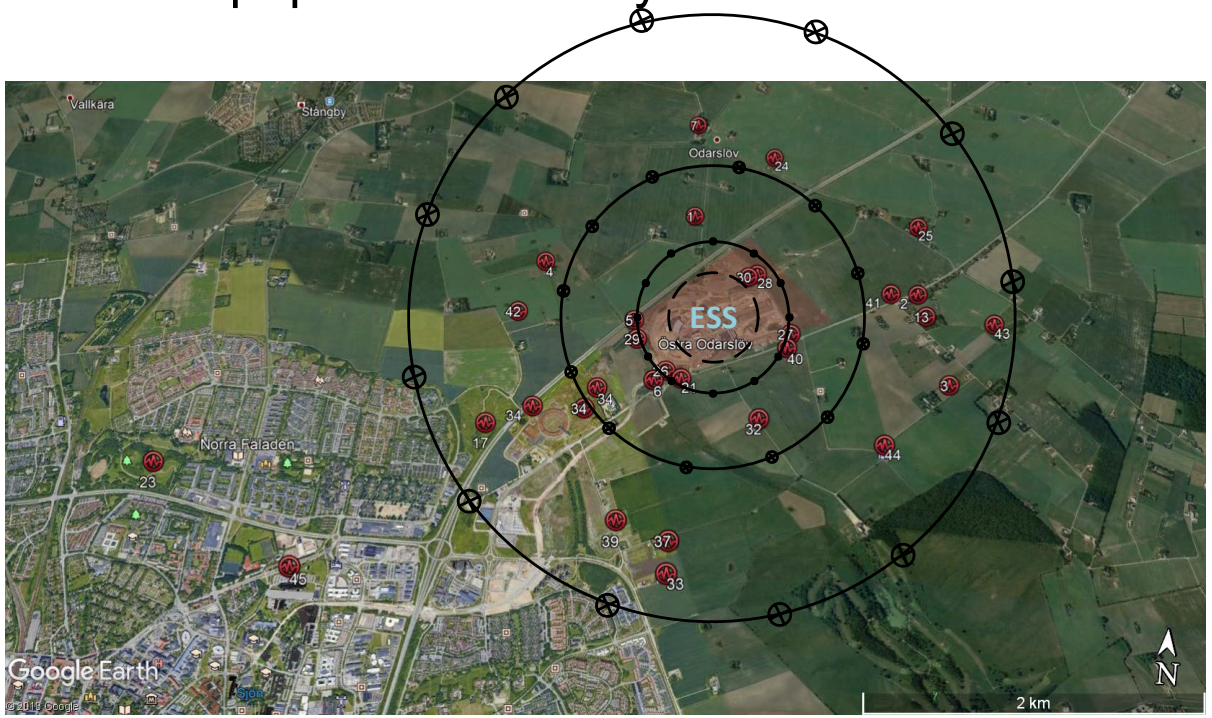
The ESS Zero Point project: Selection of sites

- **Reference sites**
  - Cover all directions from the ESS site,
  - preferably be preserved over time and available in the future,
  - be representative and reflect the current population density in the area.



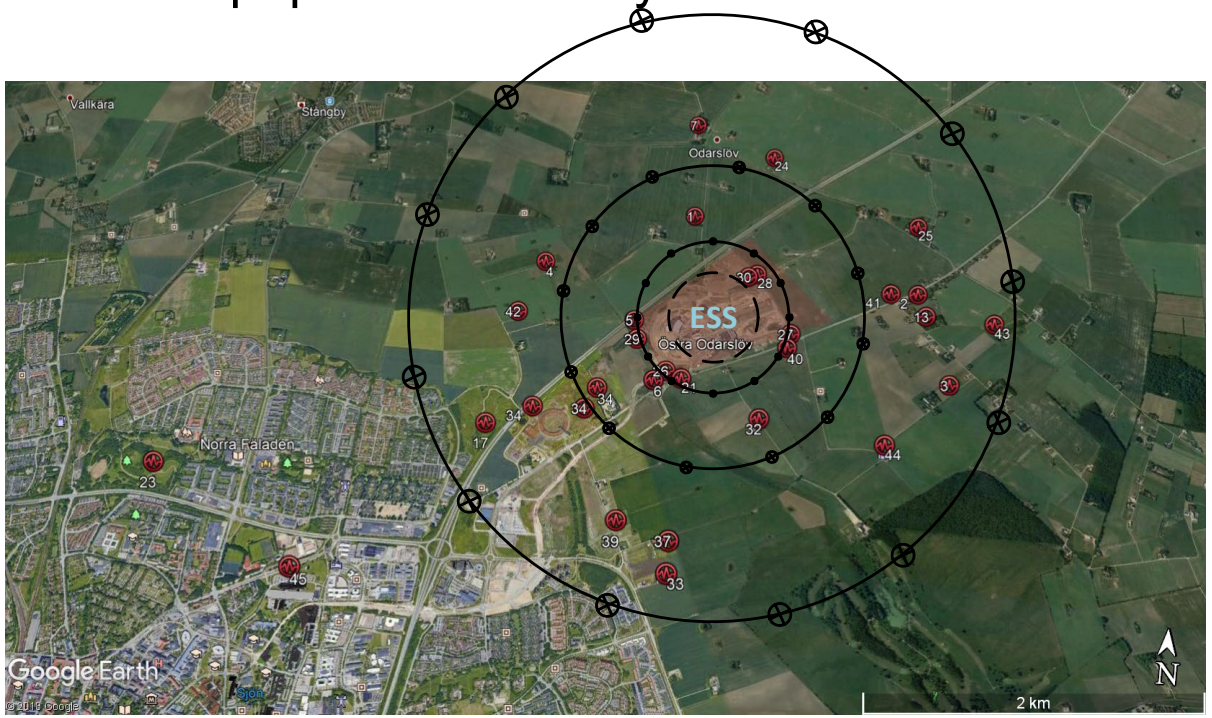
The ESS Zero Point project: Selection of sites

- **Reference sites**
  - Cover all directions from the ESS site,
  - preferably be preserved over time and available in the future,
  - be representative and reflect the current population density in the area.



The ESS Zero Point project: Selection of sites

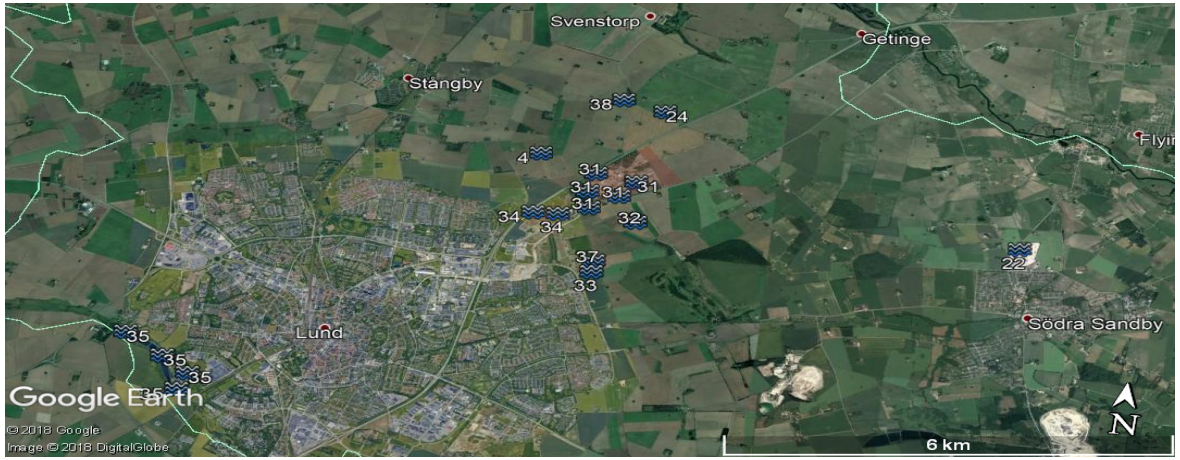
- **Reference sites**
  - Cover all directions from the ESS site,
  - preferably be preserved over time and available in the future,
  - be representative and reflect the current population density in the area.



- **Sampling sites**
  - Bioindicators (moss, spruce needles, lichen)
  - Grass
  - Crops (11 farmlands)
  - Milk, animal feed, ensilage, grass (one farmer)
  - Sewage sludge collected montly during one year

ESS Zero Point: Selection of sites

- **Sites for ^{3}H assessment:**
  - ground water (drilled holes) on/off ESS site
  - surface water (ponds) on ESS site
  - surface water (ponds) off ESS site
  - private wells
  - water in sewage sludge
  - milk and beetroot



Water sampling sites around ESS and at Lund sewage treatment facility.

Water sampling sites at the ESS site.

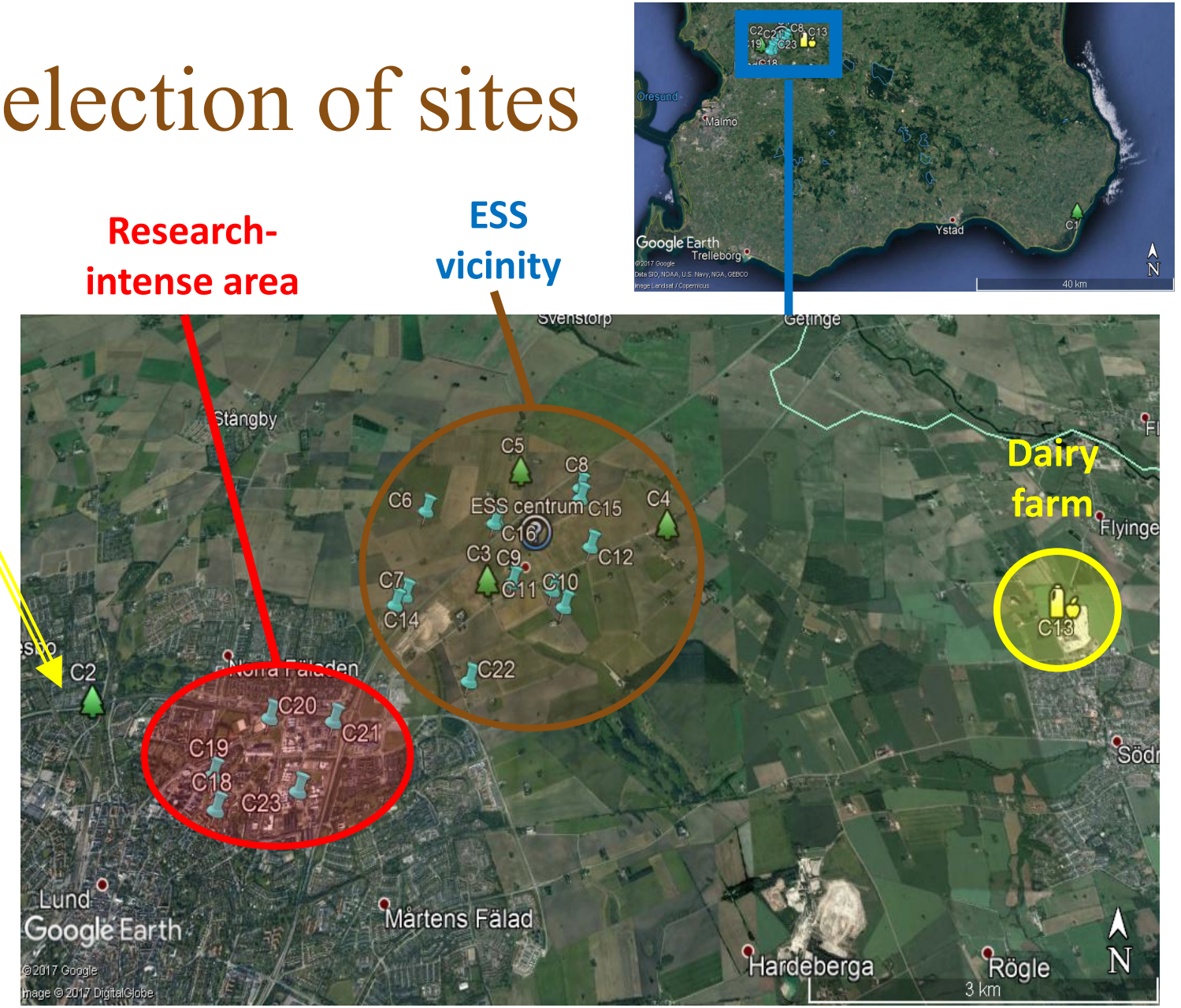
ESS Zero Point: Selection of sites

- **Sites for ^{14}C assessment:**
- Urban background site (C2),

4.6 km from ESS, rural 70 km from ESS

- ESS vicinity
- Research-intense area
- Dairy farm

- Samples include: *tree rings, grass, moss, grains, fruit, fodder, silage, milk, fullerene soot monitors*



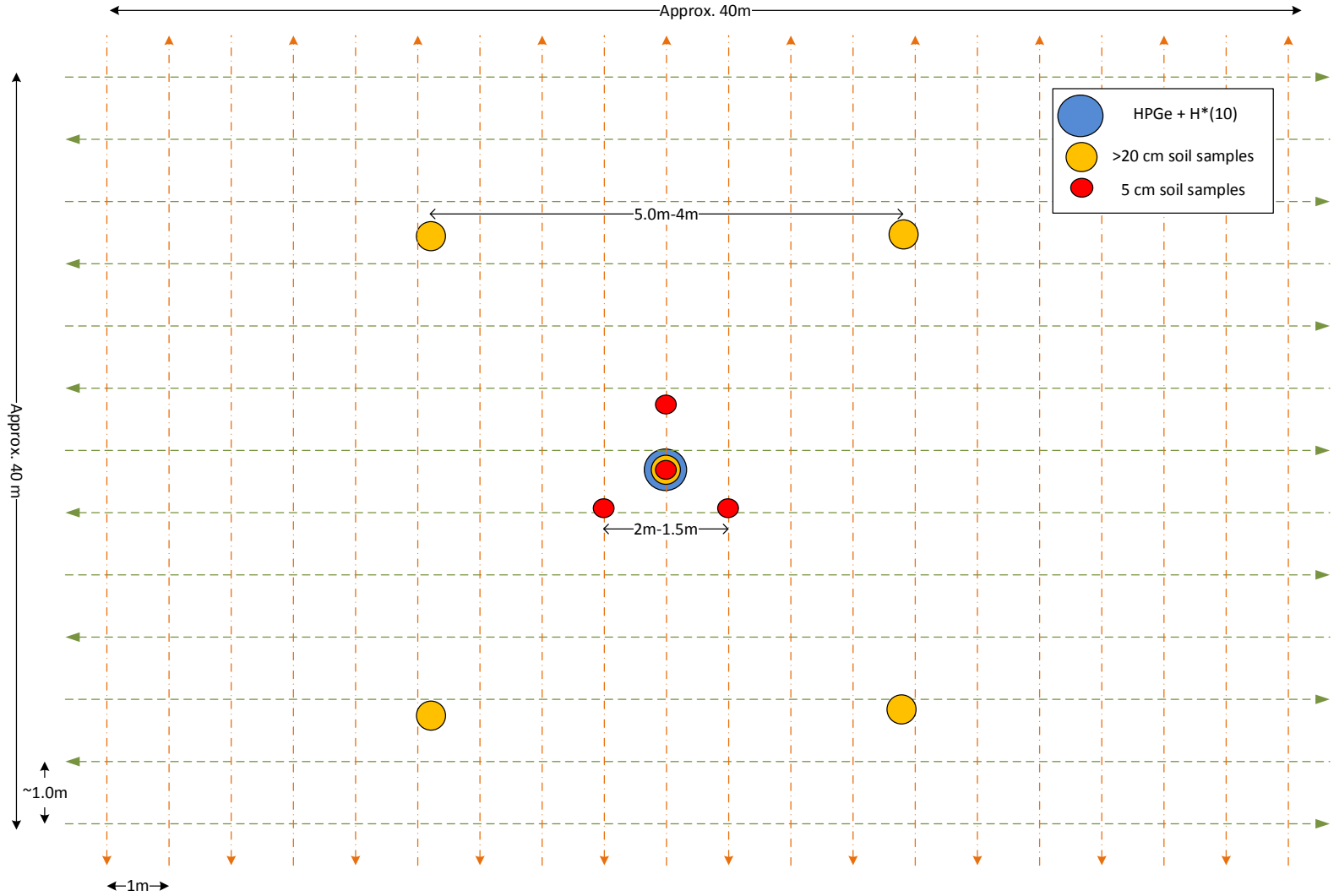
Assessment and analysis methods

- **Reference sites**
- $\dot{H}^*(10)$
  - Plastic (75 mmø×75mm) scintillator (4 positions)
- *In situ* gamma spectrometry
  - 123% HPGe
  - (26.10% HPGe)
- Mobile gamma spectrometry
  - At the sites
    - $LaBr_3$:Ce (76.2 mm×76.2 mm), *by foot*
  - Between the sites
    - 123% HPGe, *by car*
    - 2×3 litre NaI(Tl), *by car*

- **Sampling sites**
- Laboratory HPGe spectrometry
- Liquid scintillator counter
- Accelerator mass spectrometry

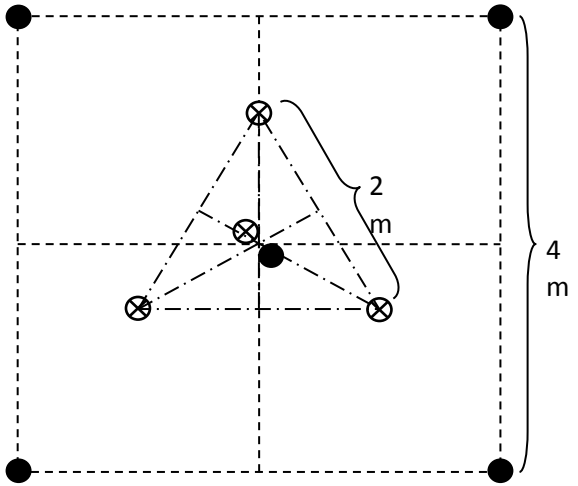
Assessment and analysis methods

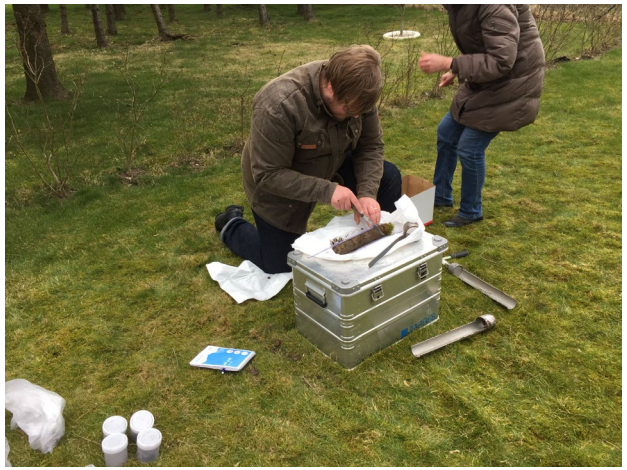
- **Reference sites (flat and opened, >40×40 m²)**



Sampling methods

- **Soil sampling at reference sites**





Split tube sampler (STS)

Emergency preparedness sampler (EPS)

Sampling methods

- **At various sites**

Bioindicators

Grass

Area of 1 m^2

Crops/grains

Svenstorps gods

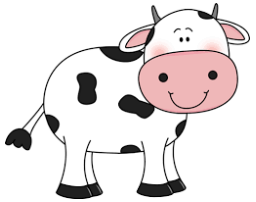
Air (^{14}C)

Fruit

Sewage sludge

Källby (VASYD)

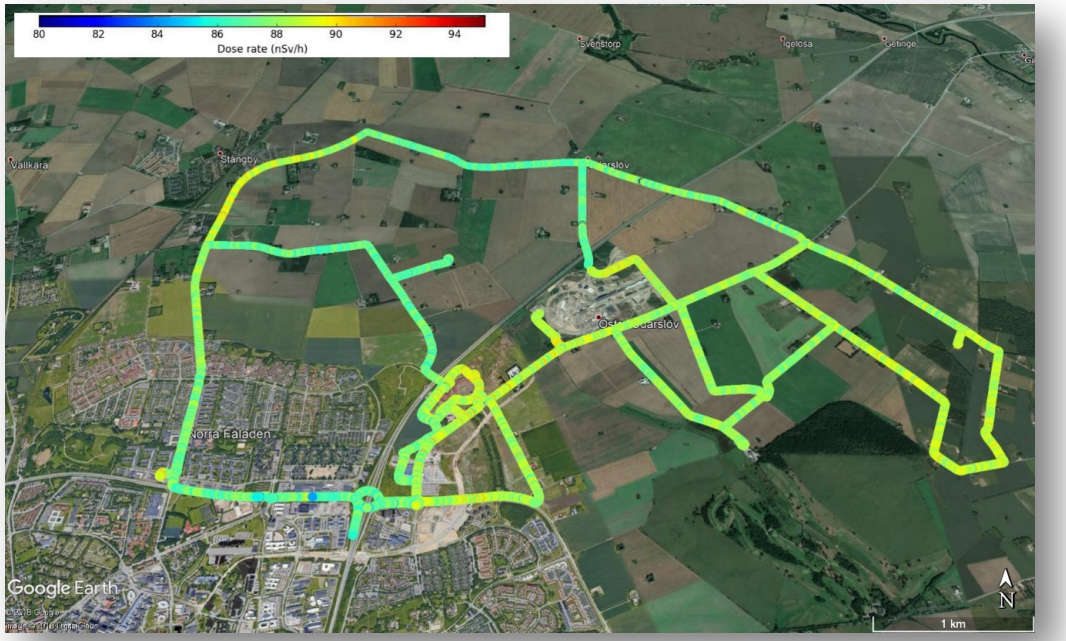
Cow forage and milk

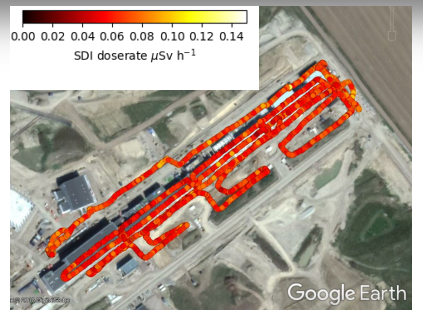


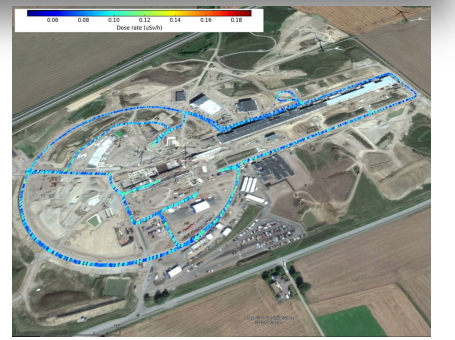
Water

Results - ambient dose equivalent and *in situ* gamma spectrometry

- **Average ambient dose equivalent (29 sites)**
- At the sites: 85±17 nSv/h
  - Slightly higher at “construction areas”
- Within the sites (by foot): ~20% variation
- Between the sites (by car): <3% variation



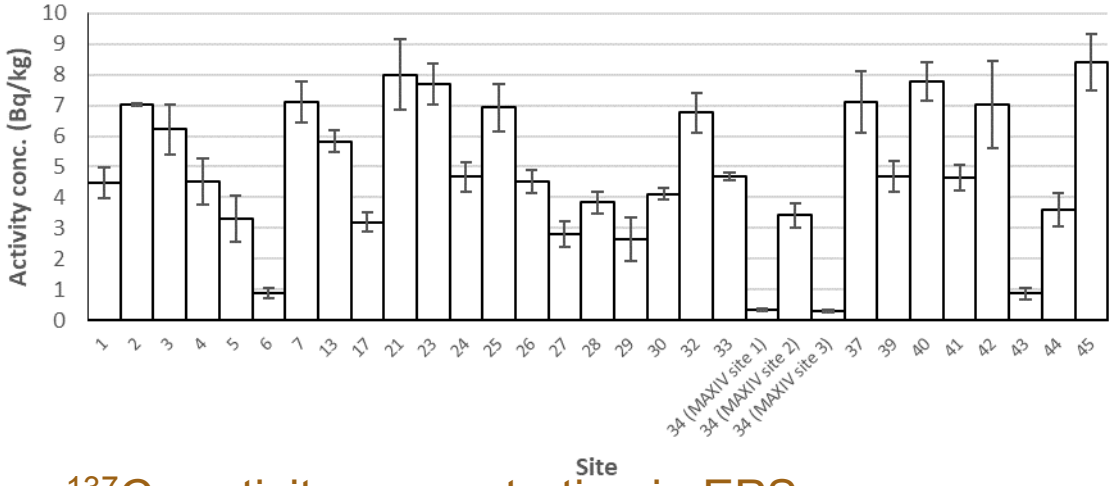




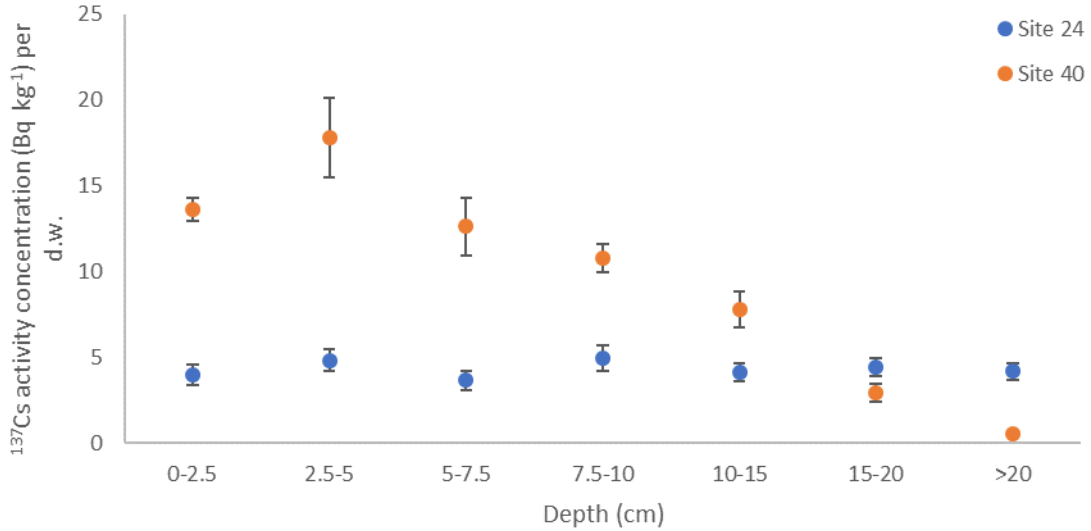
- **Average activity concentrations (*in situ* at 24 sites)**
- As equivalent surface activity: 249 Bq/m^2 (^{7}Be), 121 Bq/m^2 (^{137}Cs)
- Activity concentration: 407 Bq/kg (^{40}K), 42 Bq/kg (^{226}Ra), 21 Bq/kg (^{228}Ac)

Results – laboratory gamma spectrometry

- **Soil**
- EPS (7 cm, surface cores)
- STS (20 cm, deep cores)



^{137}Cs activity concentration in EPS cores.



Example of ^{137}Cs activity concentration in STS cores.

Average activity concentration within the STS cores

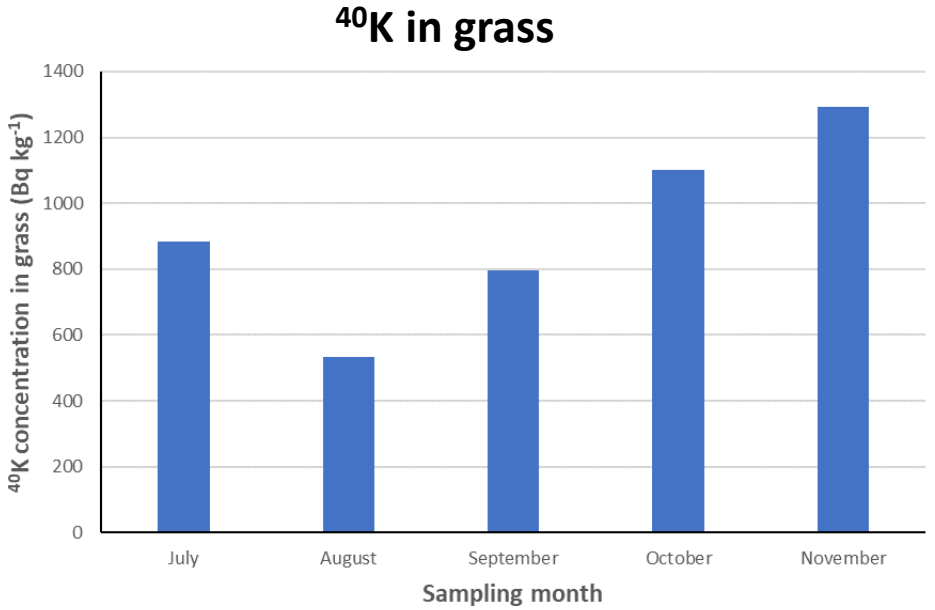
^{226}Ra: 75 Bq/kg (56-100)

^{228}Ac: 35 Bq/kg (24-45)

^{40}K: 695 Bq/kg (593-910)

Results – laboratory gamma spectrometry

- **Grass**
  - ^{137}Cs, ^{226}Ra, ^{228}Ac, ^{131}I below MDA
- **Milk**
  - ^{40}K = 67±8 Bq/l and 54±8 Bq/l
- **Crops**
  - ^{137}Cs, ^{226}Ra, ^{228}Ac, ^{131}I below MDA
  - $^{40}K_{avg}$ = 179 Bq/kg
- **Bioindicators**
  - Small amounts of sample material
- **Sewage sludge**
  - $A_{conc}(^{137}Cs)$<MDA; $A_{conc}(^{131}I)$ 0.5-5 kBq/kg (decay corr.)



Results – ^{3}H and ^{14}C

- **Ground and surface water, sewage sludge, bioindicators and fodder**
- Activity concentration of ^{3}H generally below the MDA (of 14 Bq/l and 29 Bq/l) POSTER S9-P6
- For ^{14}C: no signs of anthropogenic contamination in tree rings, vegetation, milk or air

Material	Proportion carbon $\left(\frac{\text{g carbon}}{\text{kg wet weight}}\right)$	Activity concentration of ^{14}C (Bq/kg wet weight)
Cow milk	65 (62 to 69)	15 (14 to 16)
Grass or green feed	100 (40 to 160)	23 (9 to 36)
Silage	130 (65 to 180)	30 (15 to 41)
Grains	390 (360 to 430)	89 (82 to 98)
Fruits	62 (31 to 100)	14 (7 to 23)

Conclusion:

No evidence of local ^{3}H or ^{14}C contamination in the Lund area in 2017

(including fullerene soot measurements)

Conclusion

- **At the 46 sites surveyed for gamma emitting radionuclides:**
  - The natural as well as anthropogenic radionuclides concentrations were as anticipated, except for predicted variations in ^{137}Cs (in soil) and hospital radionuclides (not yet determined fully)
- **At the 13 sites surveyed for ^{3}H concentration (in various samples):**
  - The concentration was below the MDA in all samples (except for some samples of sewage sludge)
- **At the 4 (tree rings) plus 23 (biota) sites surveyed for ^{12}C:**
  - The sites show no signs of local anthropogenic contamination of ^{14}C.

Continuation of this program

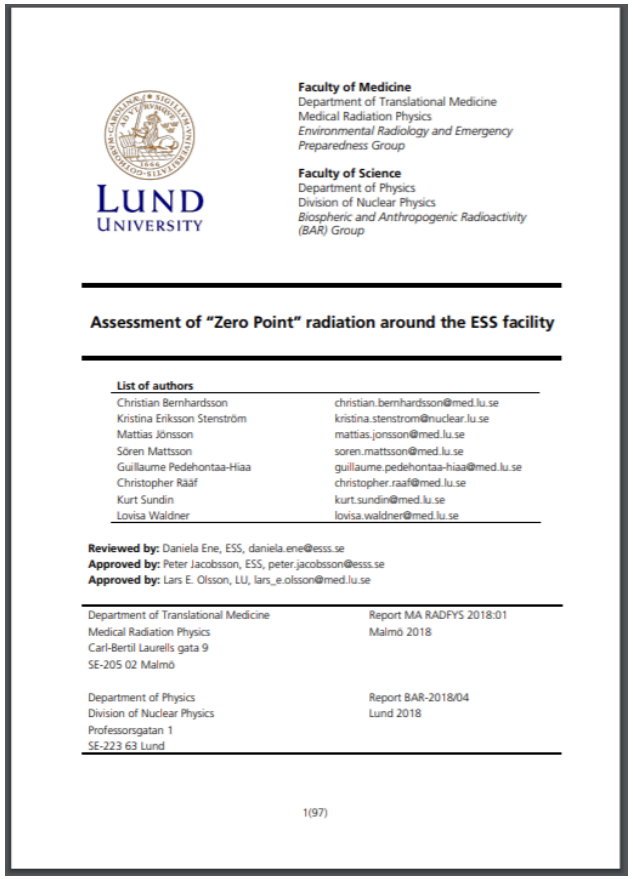
- **A first baseline of the radiation environment around ESS is established**

  - For this program:
    - further assessments are suggested in order to include seasonal variations, additional samples of relevant crops and bioindicators, and short-lived hospital radionuclides in sewage sludge, ^{3}H and ^{14}C in additional samples of importance

  - Apply the same program around Astravets (Belarus) NPP in 2019

Communication of results

- **The outcome of the program was published as a technical report and a summary for the public (as well as presentations to stakeholders)**



LUND UNIVERSITY

Faculty of Medicine
Department of Translational Medicine
Medical Radiation Physics
Environmental Radiology and Emergency Preparedness Group

Faculty of Science
Department of Physics
Division of Nuclear Physics
Biospheric and Anthropogenic Radioactivity (BAR) Group

Assessment of "Zero Point" radiation around the ESS facility

List of authors

Christian Bernhardsson	christian.bernhardsson@med.lu.se
Kristina Eriksson Stenström	kristina.stenstrom@nuclear.lu.se
Mattias Jönsson	mattias.jonsson@med.lu.se
Sören Mattsson	soren.mattsson@med.lu.se
Guillaume Pedehontaa-Hiaa	guillaume.pedehontaa-hiaa@med.lu.se
Christopher Rääf	christopher.raaf@med.lu.se
Kurt Sundin	kurt.sundin@med.lu.se
Lovisa Waldner	lovisa.waldner@med.lu.se

Reviewed by: Daniela Ene, ESS, daniela.ene@esss.se
Approved by: Peter Jacobsson, ESS, peter.jacobsson@esss.se
Approved by: Lars E. Olsson, LU, lars_e.olsson@med.lu.se

Department of Translational Medicine
Medical Radiation Physics
Carl-Bertil Laurells gata 9
SE-205 02 Malmö

Report MA RADFYS 2018:01
Malmö 2018

Department of Physics
Division of Nuclear Physics
Professorsgatan 1
SE-223 63 Lund

Report BAR-2018/04
Lund 2018

Available at: https://portal.research.lu.se/portal/files/57600811/ESS_Zero_Point_public_190204.pdf

Lunds universitet informerar om bakgrundsmätningar av strålningsnivån kring ESS

LUNDS UNIVERSITET
Medicinsk Strålningsfysik, Malmö
Kärnfysik, Lund

Under år 2017 och 2018 utförde Lunds universitet omfattande mätningar av strålningsmiljön kring forskningsanläggningen European Spallation Source (ESS) i Lund.

Här svarar vi kortfattat på några frågor om mätningarna.

Available at: www.med.lu.se/msf

LUND
UNIVERSITY