Drinking water radioactivity and NORM issues in Finland

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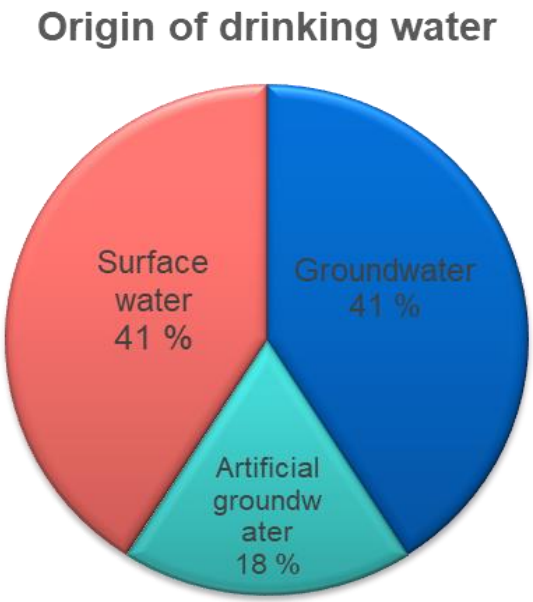
Outline

- Drinking water production
- Drinking water radioactivity and regulation
- NORM regulation
- NORM in water treatment

Drinking water production in Finland

- 1600 water suppliers (over 50 persons)
- 10 % of population has a private well (500 000)
- 60 % of supplied water is derived from groundwater
- 18 % of supplied water is artificial groundwater
- Large water suppliers (>1000 m^3/d): water for 4,5 million people
  - Radioactivity and uranium concentration meet the requirements in the supply network
- Small water suppliers (<1000 m^3/d): 500 000 people
- If drinking water is derived from surface water: radioactivity is not a problem/measured



Quality of Finnish groundwater in water production

- Mostly groundwater from the soil
  - Slightly acidic, pH 6-7
  - Soft
  - CO_2
  - Corrosive
  - Iron
  - Manganese

- Groundwater from the bedrock
  - Drilled wells are used mainly by private households and small units (<10 m3/d)
  - May have other contaminants to be removed (As, Rn, U)

Radionuclides in Finnish drinking water

Radionuclide	Water distributed by waterworks	Dug well	Drilled well
Rn-222 (Bq/l)	27	50	460
U-234 (Bq/l)	0,02	0,02	0,35
U-238 (Bq/l)	0,015	0,015	0,26
U-238 (µq/l)	0,23* 0,90**	1,2-1,7	21-24
Ra-226 (Bq/l)	0,003	0,016	0,05
Ra-228 (Bq/l)	-	-	0,03
Po-210 (Bq/l)	0,003	0,007	0,048
Pb-210 (Bq/l)	0,003	0,013	0,040

*derived from surface water; ** derived from groundwater (STUK-A256, 2013)

Groundwater treatment in Finland, large suppliers

- Typically treated to reduce the corrosivity or remove unwanted elements such as manganese and iron
  - Aeration
  - Filtration
  - Lime softening
  - NaOH
- The natural radionuclides are not often intentionally removed from the water (Rn-222)
- Untreated groundwater is also common
- Disinfection by UV and/or chemically
- Other unwanted compounds may be removed e.g. by granular activated carbon filtration

Regulation of radioactivity in drinking water

- Decree of the Ministry of Social Affairs and Health relating to the quality and monitoring of water intended for human consumption1352/2015 and 2013/51/Euratom
  - Radon and total indicative dose are determined, if water is not derived from surface water
  - Total indicative dose is screened by measuring alpha-activity (>0,1 mSv/a)
  - If the total indicative dose 0,1 mSv/a may be exceeded, radionuclides are analyzed for the total indicative dose: Ra-226, U-234, U-238, Po-210, Ra-228 and Pb-210

Parameter	Quality recommendation	Maximum/Requirement
Radon (^{222}Rn)	300 Bq/l	1000 Bq/l
Total indicative dose*		0,1 mSv/a
Tritium (^{3}H)		100 Bq/l

*Excluding ^{3}H, ^{40}K, ^{222}Rn and its decay products

- Limiting measures: considered if > 300 Bq/l; applied if > 1000 Bq/l

Artificial radionuclides in drinking water

City	Date	Cs-137 (Bq/l)	Sr-90 (Bq/l	H-3 (Bq/l)
Helsinki	3.5.2019	0,011	0,0045	1,0
Oulu	29.4.2019	0,0018	0,0026	<1,0
Rovaniemi	29.4.2019	<0,0002	<0,0001	<1,0
Tampere	17.5.2019	0,0018	0,0042	<1,0
Turku	30.4.2019	<0,0004	<0,0001	<1,0

- Surveillance by STUK (2000/473/Euratom)
- Tritium is usually below detection limit
- Maximum for tritium in legislation is **100 Bq/l**

Report on the radioactivity of distributed drinking water 2016-2018

- Surveillance by municipal health protection authority
  - 1287 results on the radioactivity of drinking water

Radon	2016	2017	2018	Total
<300 Bq/l	302	187	245	734
300-600 Bq/l	6	1	3	10
600-1000 Bq/l	4	1	0	5
>1000 Bq/l	1	1	3	5**

Total indicative dose	2016	2017	2018	Total
<0,060 mSv/a*	176	170	178	524
0,060-0,10 mSv/a	1	2	0	3
>0,10 mSv/a	0	0	6	6**

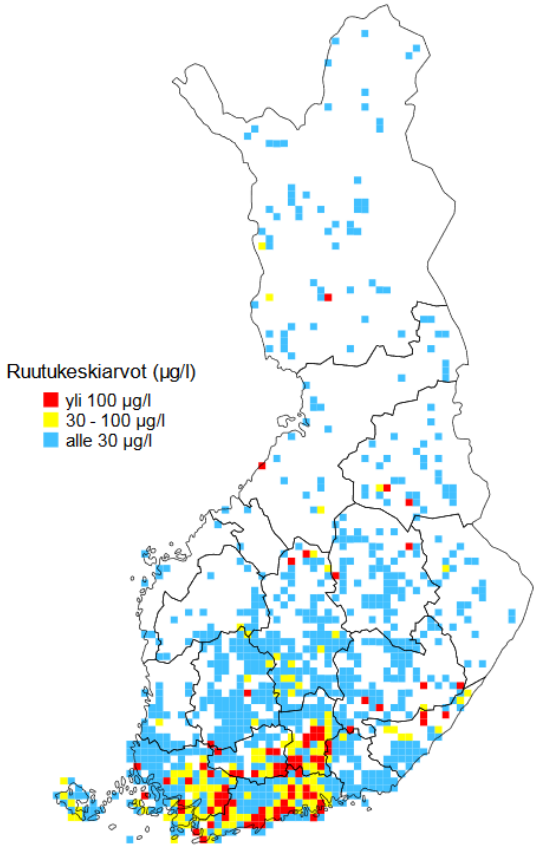
*91 % below detection limit 0,05 mSv/a
** raw water or small supplier

Conclusions of the report

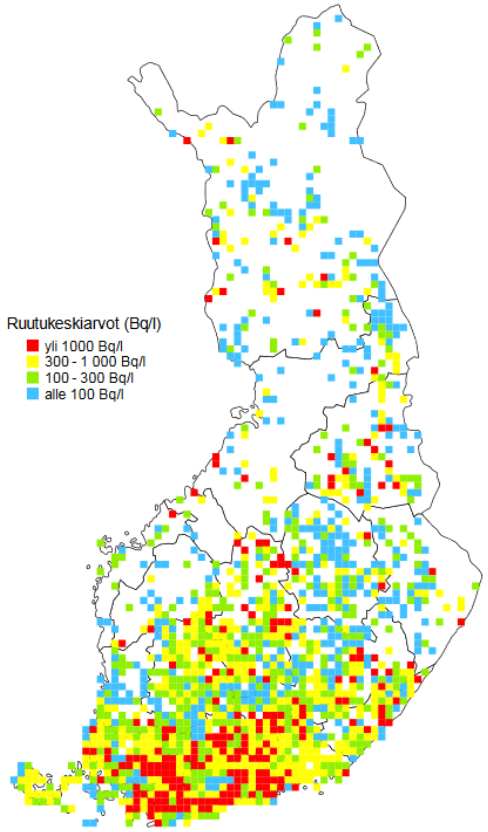
- No specific geologic area where radon would be a problem (supplied water)
- Radon concentration increases: Surface water > artificial groundwater > groundwater from the soil> groundwater from the bedrock
- Total indicative dose values meet the requirements (91 % below detection limit of 0,05 mSv/a)
- Higher alpha-activities and radon concentration are seen at the water plant than in the supplied water

Uranium and radon concentration in private wells drilled in the bedrock

Porakaivoveden uraanipitoisuus
Aritmeettinen keskiarvo 10 x 10 km:n ruudussa
Vähintään yksi uraanimittaus/ruutu
Noin 5 000 porakaivoveden uraanimittausta.



Porakaivoveden radonpitoisuus
Aritmeettinen keskiarvo 10 x 10 km:n ruudussa
Vähintään yksi radonmittaus/ruutu
Noin 11 300 porakaivoveden radonmittausta



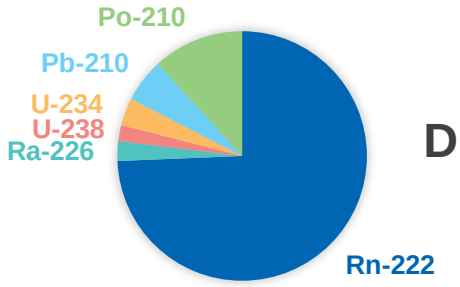
Radiation dose from drinking water

- Most of the radiation dose of the drinking water is from Rn-222, followed by Pb-210 and Po-210
- Average radiation dose from the water for the people using
  - Drilled well: 0,97 mSv/a
  - Well dug in soil: 0,11 mSv/a
  - Supplied water: <0,07 mSv/a
- STUK estimates:
  - 20 000 people use a drilled well: radon > 1000 Bq/l
  - 26 000 people use a drilled well: uranium > 30 µg/l

Distribution of dose in private wells

OLD RADON DOSE CONVERSION FACTOR

INGESTED 0,39 mSv/a

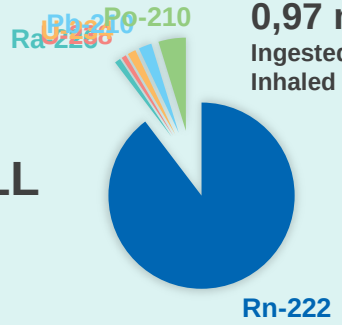


DRILLED WELL

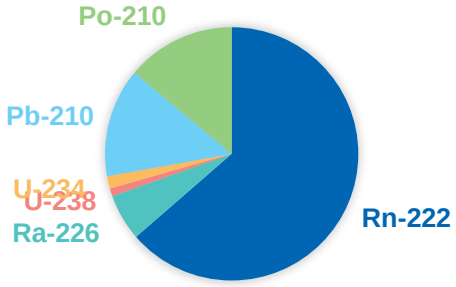
NEW : ICRP 137

INGESTED AND INHALED

0,97 mSv/a
Ingested 0,16
Inhaled 0,81



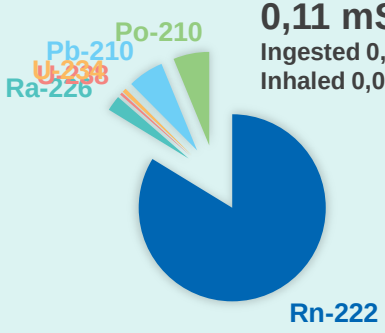
INGESTED 0,050 mSv/a



DUG WELL

INGESTED AND INHALED

0,11 mSv/a
Ingested 0,025
Inhaled 0,088



Regulatory requirements for water treatment facility operators (NORM)

- Groundwater treatment is listed as industrial sector involving NORM:
  - Governmental decree 1034/2018: **Production of household water in groundwater treatment plants**

- Obligation to make an assessment of the exposure to natural radiation
  - Analysis of natural radionuclides in materials
  - If the activity concentrations of U-238,Th-232 and their decay products are shown to be <1 Bq/g in all relevant material in all stages of handling, the radiation exposure for public and workers need **not** to be assessed
  - Reference values: effective dose 1 mSv/a for worker and 0,1 mSv/a for public, excluding natural background radiation, radon and cosmic radiation

Regulatory requirements:

Licensing

- If reference values for natural radiation are exceeded even after the application of dose limiting measures
  - Potential exposure is considered
  - Baseline surveys and monitoring are required
  - Optimization applies

Notification

- Notification to STUK prior to starting the operation if U-238 or Th-232 and their decay products > 1 Bq/g

Regulatory requirements: NORM waste

- NORM waste is classified as other than radioactive waste
- Radiation protection aspects apply, if radiation safety considerations are required
- Approval from STUK for disposal if U-238 or Th-232 series activity concentration is in solid wastes > 1 Bq/g (decay series in equilibrium) (clearance levels)
- If < 1 Bq/g, the waste act applies

Regulatory requirements for radon at water treatment facilities

- Radon concentration must be measured at the waterworks if the water is not derived solely from surface water and has contact with indoor air (Radiation Act 859/2018)
- 212 radon measurements in water treatment facilities 2015-2019
  - 81 measurements < 300 Bq/m3
  - 129 measurements > 300 Bq/m3
  - 63 measurements > 1000 Bq/m3
  - If reference values are exceeded and working time >600 h/a
    - Exposure to radon is estimated or measured and exposure possibly restricted
    - Reference value for workers 500 000 Bq h/m3/a

NORM in Finnish waterworks has not been characterized

Effects of water treatment processes on natural radionuclide concentrations, STUK-A206, Hämäläinen et al. 2004:

- Alkalization did not affect on the concentrations (pH may affect)
- Aeration removes Rn-222
- Filtrations (sand, anthracite) remove Ra-226, U-238, U-234, Po-210
- Distribution system removes Ra-226, Rn-222 (decay)
- Generally radionuclide activity concentrations decreased raw>treated>distribution network, except for Pb-210

- Water quality, biology in the filters and biofilms → same treatments can have varying effects on radionuclide concentrations (solubility)

NORM waste in Finnish water treatment

- Suspected waste
  - Filters (Ra-226, Ra-228, U-238, U-234, Po-210, Pb-210)
  - Precipitated material in the piping (Pb-210)
  - Waters from filter backwash/slurries (Ra-226, Ra-228, U-238, U-234, Po-210, Pb-210)
  - Reverse osmosis and ion exchange (small suppliers, less waste)
- Exposure is expected to be generally low
  - Filters changed rarely
  - Filters located under water
  - Workers are not working continuously at water treatment facility
- Special attention must be paid if filter materials are reused

Survey on NORM at groundwater treatment plants

- Spring-summer 2020
- 10 groundwater treatment plants
  - Measurements at the plant
  - Water samples
  - Material samples, mostly filters, rinsing slurries/waters, precipitates
- Selected based on geology, water quality and production volumes
  - aim is to find the highest possible activities in the materials
- Based on the results water suppliers are informed
  - how to fulfil the statutory obligations
  - good practices with wastes
  - radiation safety of the workers and public

Current practices in NORM management

- Most NORM-waste in Finland is placed using a case-by-case flexible approach
- Assessment of exposure to natural radiation (2020)

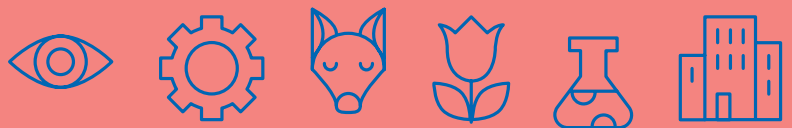
The legislation is new and the practices are in progress, aims:

- Recommendations for the practical enforcement of regulations
- Industry should identify the NORM involving processes
- NORM occurrences in different processes are described
- No unexpected NORM occurrences

Conclusions

- Highest radionuclide concentrations are found in drilled wells
- Despite the geology, the radionuclides of the supplied water are not a problem
- Treatment of the water for the radioactivity is more common in private households and small distributors
- Enforcing the NORM regulations is still in progress
- NORM issues at waterworks need further clarification in Finland

stuk



Thank you!