Creation of NORM in filter materials – why, how and what magnitude. Situation in Estonia

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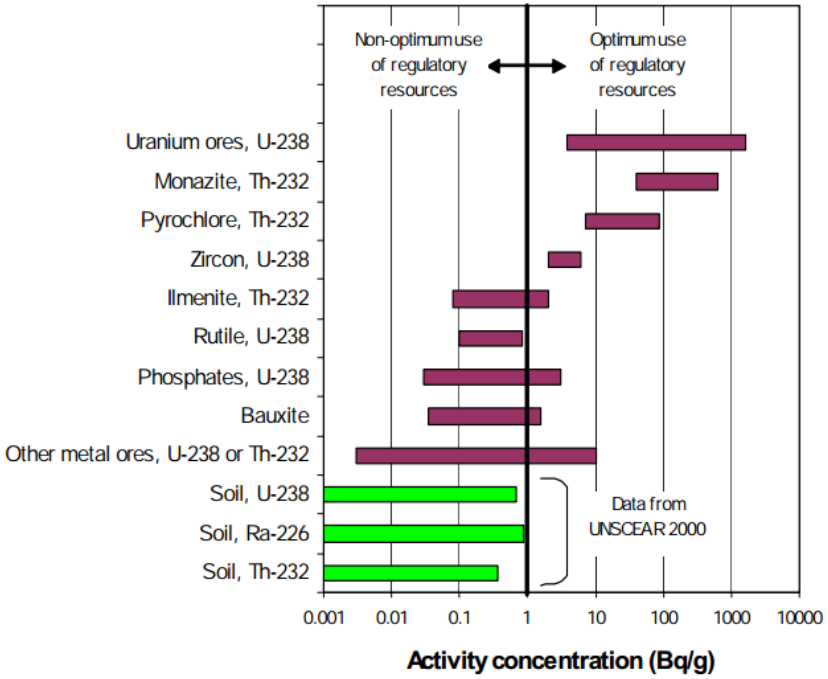
What is NORM?



- NORM – naturally occurring radioactive material.
- Material giving rise to enhanced exposure due to radionuclides of natural origin, 238U and 232Th decay series and 40K.
- Practical considerations! [1]

  Represent the upper bounds of the ranges of activity concentration found in normal rocks and soil.

Natural radionuclides from the U-238 series	1 kBq kg^{-1}
Natural radionuclides from the Th-232 series	1 kBq kg^{-1}
K-40	10 kBq kg^{-1}

- Set as clearance and exemption values [2]

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Management of NORM Residues, IAEA-TECDOC-1712, IAEA, Vienna (2013).
[2] European Parliament, 2014. Council Directive 2013/59/Euratom of 5 December 2013 laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom a, Off J Eur Commun L13

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Where is NORM created?

- Through human activities in processing minerals and raw materials.
  - — Extraction of rare earths from monazite
  - — Processing of niobium/tantalum ore
  - — Oil and gas production
  - — Geothermal energy production
  - — Zircon and zirconium industry
  - — Production of phosphate fertilisers
  - — Cement production, maintenance of clinker ovens
  - — Coal-fired power plants, maintenance of boilers
  - — Phosphoric acid production,
  - — Primary iron production,
  - — Groundwater filtration facilities,
  - — …

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NORM specifics

- Generally low radionuclide activity concentration, compared to radioactive waste from nuclear industry;
- Large amounts, can be up to millions of tonnes (E.g. aluminum production; phosphate fertilizer production);
- Can exhibit large heterogeneity in chemical as well as radiological composition.

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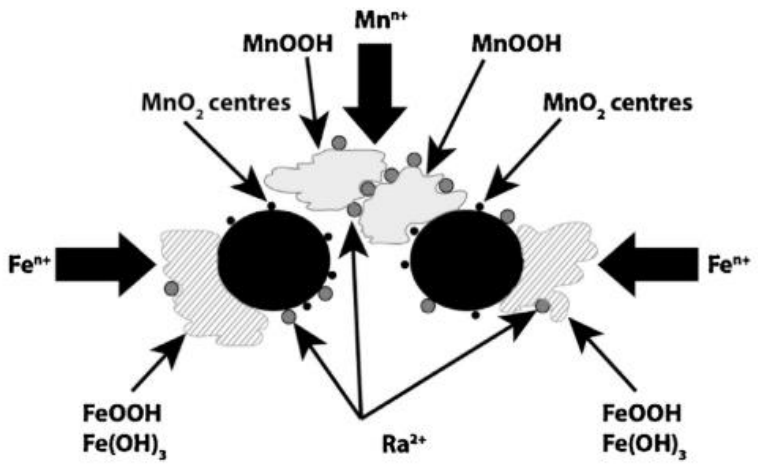
NORM in drinking water treatment plants (DWTP)



- Not that widespread issue in Europe. Estonia stands out!
- Main concern in Estonia is with elevated concentrations of 226Ra and 228Ra.
- Main processes in radionuclide accumulation:
  - Radionuclide adsorption onto filter material. The magnitude depends on the used filter material;
  - Formed sludge containing insoluble Fe-compounds where Ra is co-precipitated.

    Sludge may get trapped between filter material particles and is not completely removed during filter backwash.

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Where can NORM be created?

- WTP-s designed for radionuclide removal:

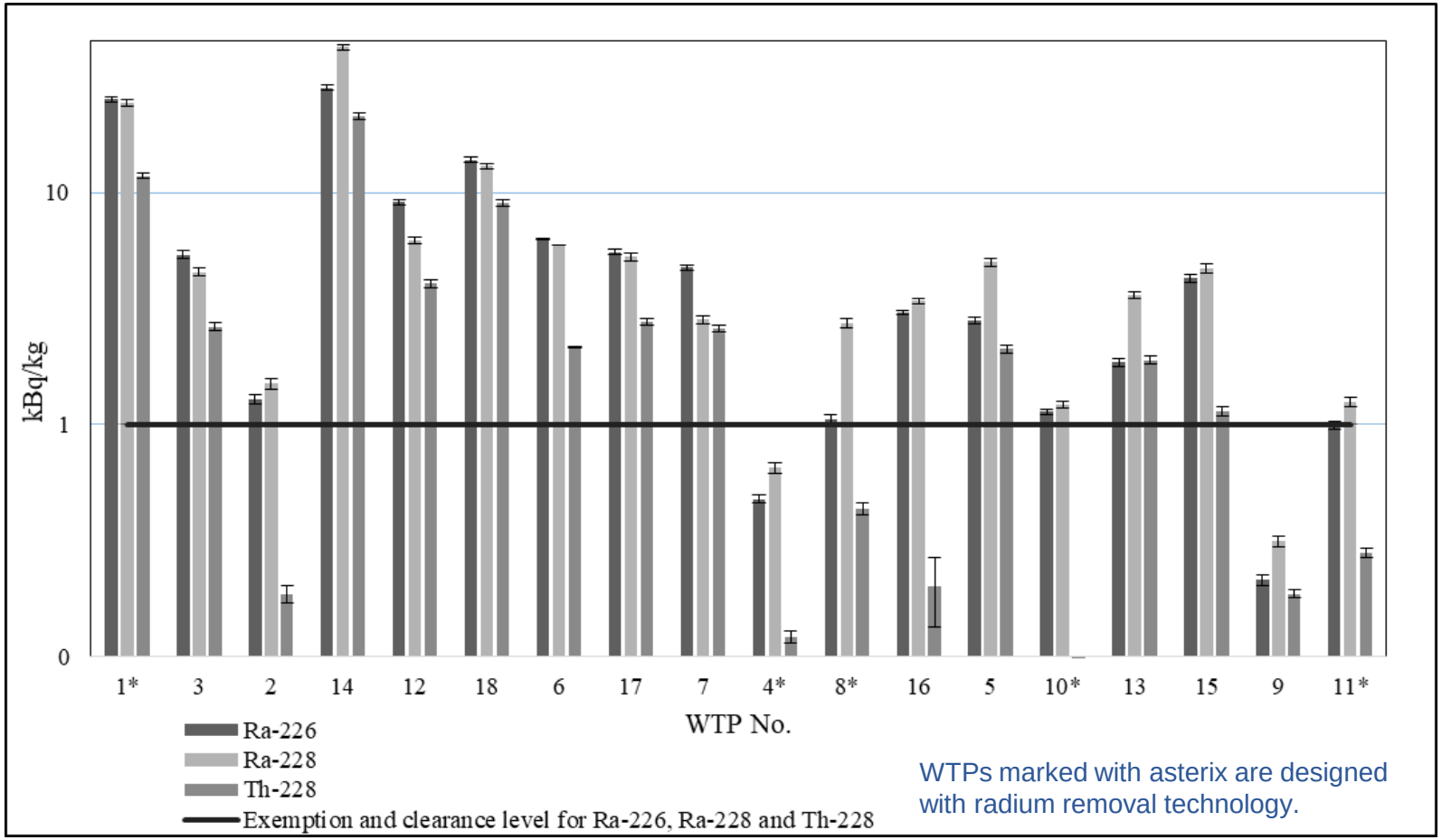
Usage of catalytic filter material(s)

- WTP-s not designed for radionuclide removal:

May be unintentional consequence during a removal process of Fe and Mn, as co-precipitation/adsorption processes still can take place

Previous study on NORM creation in DWTP in Estonia

- Study[3] on Cambrian-Vendian (Cm-V) fed treatment plants was carried out in 2014-2015.
- Selection was ~ 50% of national Cm-V groundwater production (18 DWTPs).



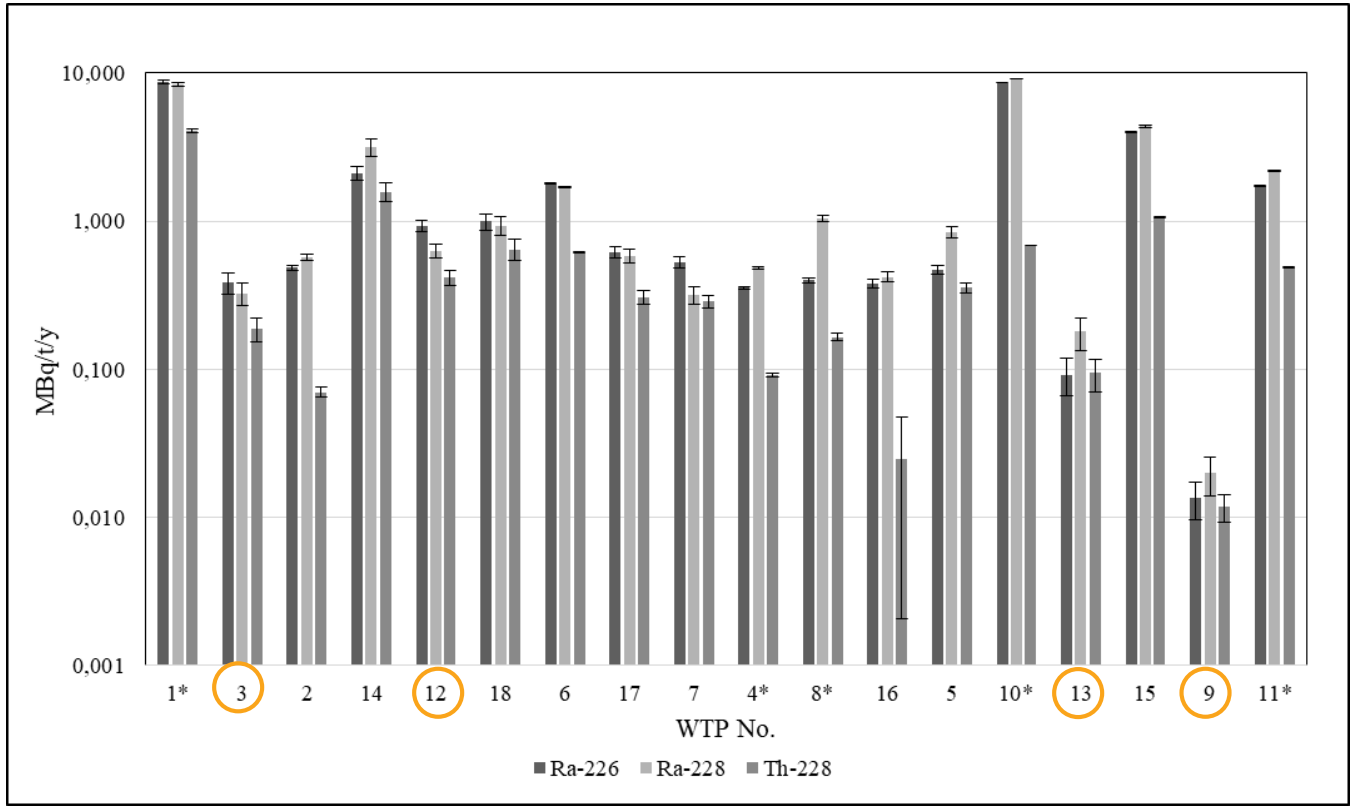
WTPs marked with asterix are designed with radium removal technology.

Average values:
Ra-226 - 7.6 kBq/kg
Ra-228 - 8.0 kBq/kg
Th-228 - 5.6 kBq/kg

Filter material exceeding exemption levels – approximately **300 tonnes**

[3] Leier, M., Kiisk, M., Suursoo, S., Vaasma, T., Putk, K., 2018. Formation of radioactive waste in Estonian water treatment plants. J. Radiol. Prot. 39, 1–10.

NORM accumulation



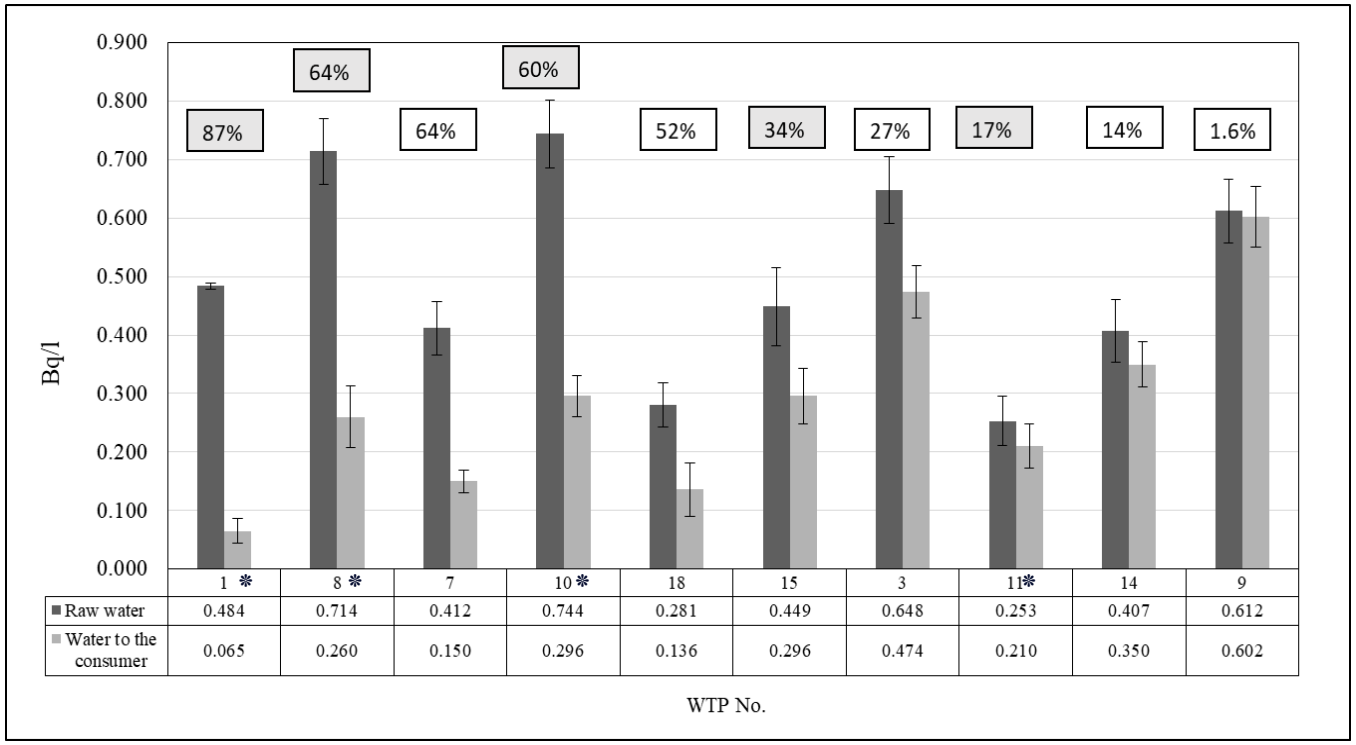
Group A- WTPs using only silica or crushed granite as a filter material

Group B - WTPs using MnO2-coated filter material

Yearly growth (kBq/kg/y)

Ra-226	SD	Ra-228	SD
Group A			
0.38	0.36	**0.34**	0.26
Group B			
2.56	3.51	**2.80**	3.59

Purification efficiency



	1 ❋	8 ❋	7	10 ❋	18	15	3	11❋	14	9
Raw water	0.484	0.714	0.412	0.744	0.281	0.449	0.648	0.253	0.407	0.612
Water to the consumer	0.065	0.260	0.150	0.296	0.136	0.296	0.474	0.210	0.350	0.602

- In general, high Ra purification effeciency where Ra-removal is employed.
- With other filter media, significant part of radionuclides is not removed from groundwater.

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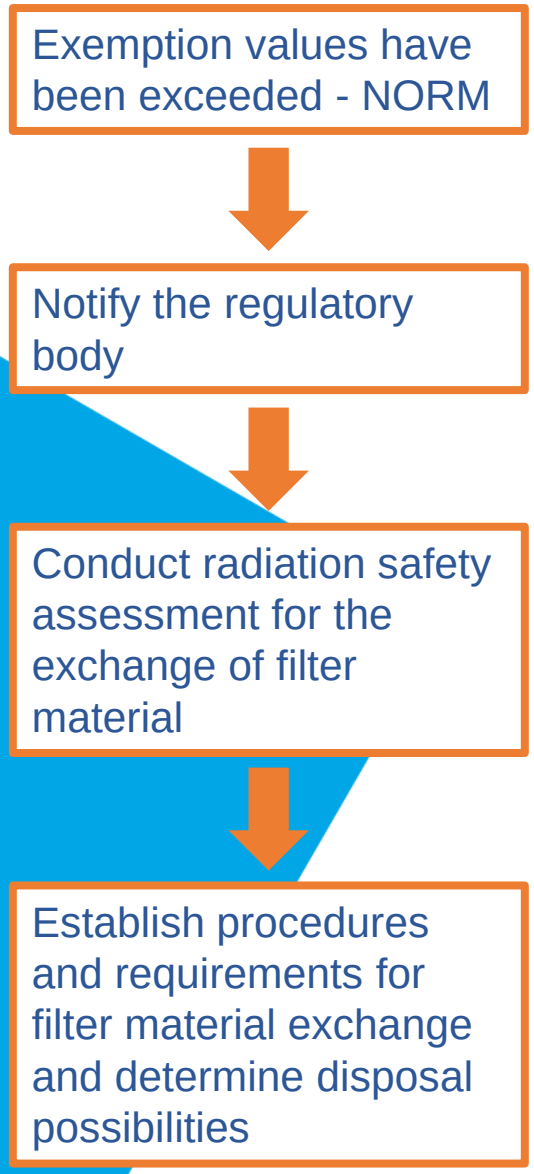
If NORM has been created, what then?



- Filter material can still be used.
- DWTPs obtaining water from Cm-V aquifer should determine the radionuclide activity concentrations in filter material prior filter material exchange:
  - Protect the workers from receiving additional doses;
  - Find suitable disposal option for the material, reduce possible hazards to humans and environment;
- Exchanging material that is NORM.
- Requirements for measurement and monitoring are derived from the European Basic Safety Standard directive.

Radiation safety assessment – why?

- Necessary to determine possible radiation exposure situations for workers (general public), to ensure their exposure to additional doses is limited.
- Exposure situations:
  - During normal operation – radon inhalation, external gamma radiation;
  - During maintenance work – radon/thoron inhalation, external gamma radiation, ingestion of radionuclides (via dust);
  - During accident, e.g. fire in the DWTP; breakage of the filter columns.

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Prevention/slowing down the creation of NORM

- Frequent backwashing of filters?
  - Additional costs with energy consuption and water use;
  - May have low efficiency with filter materials designed for Ra removal.
- Frequent exchange of filter material?
  - Economically not sustainable if the filter material is still functioning.
- Alternative technologies?
  - HMO based treatment technology – ensuring compliance with indicative dose in consumer water as well as prevent/slow down the creation of NORM.

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Management of NORM

- Main considered management and disposal options:
  - Recycle and reuse
  - Municipal, industrial or hazardous material landfill
  - Radioactive waste disposal site
  - NORM disposal site
- Belgium example of NORM disposal –

  Landfilling as the main disposal option

Type of treatment	Activity concentration		
	Input (single batch of residues)		Output (after processing)
Landfill for hazardous waste	$C_{exemption}$	RP 122 II	$C_{average}$ < 0.2 kBq/kg
	C_{max}	50 kBq/kg	
Landfill for non-hazardous or inert waste	$C_{exemption}$	RP 122 II	$C_{average}$ < 0.2 kBq/kg
	C_{max}	10 kBq/kg	

Exemption criteria based on RP 122 – **0.3 mSv/y**
EU BSS – **1 mSv/y**

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Remaining questions on NORM management

- Clearance and exemption levels for NORM in secular equilibrium:

Natural radionuclides from the U-238 series	1 kBq kg^{-1}
Natural radionuclides from the Th-232 series	1 kBq kg^{-1}
K-40	10 kBq kg^{-1}

- **If not in equilibrium** – values from EU BSS Table B, Part 2.
  - **10 kBq/kg for Ra226 and Ra228**
  - Valid for moderate amounts!
- Moderate amount – in the magnitude of **one tonne!**
- NORM amounts in most cases higher!
- When to conduct the radiation safety assessment?

*COMMISSION OF THE EUROPEAN COMMUNITIES, Principles and Methods for Establishing Concentrations and Quantities (Exemption Values) below Which Reporting is not Required in the European Directive, RP-65, CEC, Luxembourg (1993).
*INTERNATIONAL ATOMIC ENERGY AGENCY, Derivation of Activity Concentration Levels for Exclusion, Exemption and Clearance, Safety Report Series no.44, IAEA, Vienna, 2004.

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Information on NORM

- National development plan for radiation safety (2018-2027) *("Kiirgusohutuse riikliku arengukava 2018-2027“)* - https://www.envir.ee/et/eesmargid-tegevused/kiirgus/kiirgusohutuse-riiklik-arengukava-2018-2027
- National action plan for management of radioactive waste *(Radioaktiivsete jäätmete käitlemise riikliku tegevuskava)* - https://www.envir.ee/sites/default/files/tegevuskava_200715.pdf
- Study by UT for the transposition of the requirements from the EU BSS, involving NORM - https://www.envir.ee/et/eesmargid-tegevused/kiirgus/looduslikud-radionukliidid/uuring-direktiivi-201359euratom-looduslike

Take home messages

- NORM is problematic globally and gaining increased amount of attention for safe handling and disposal options.
- Estonia has quite unique situation in terms of NORM generation from DWTPs.
- First practice of landfilling NORM from DWTP has been established.
- **One of the key importance is the increase of awareness on NORM and its creation** – understanding the main processes and potential risks that are involved.
- DWTP operators:
  - Ensure the drinking water compliance with the radiological parameters to ensure population safety;
  - Monitoring and correct management of NORM to ensure safety of workers and general public;
- If possible, reduce/avoid generation of NORM in the filter – **HMO based treatment technology?** Avoid:
  - Amount of filter material characterization needed;
  - Conducting radiation safety assessments;
  - Filter exchange to be licensed activity;
  - Transport issues with filter material;
  - Elevated indoor radon levels and doses to workers;
  - …..

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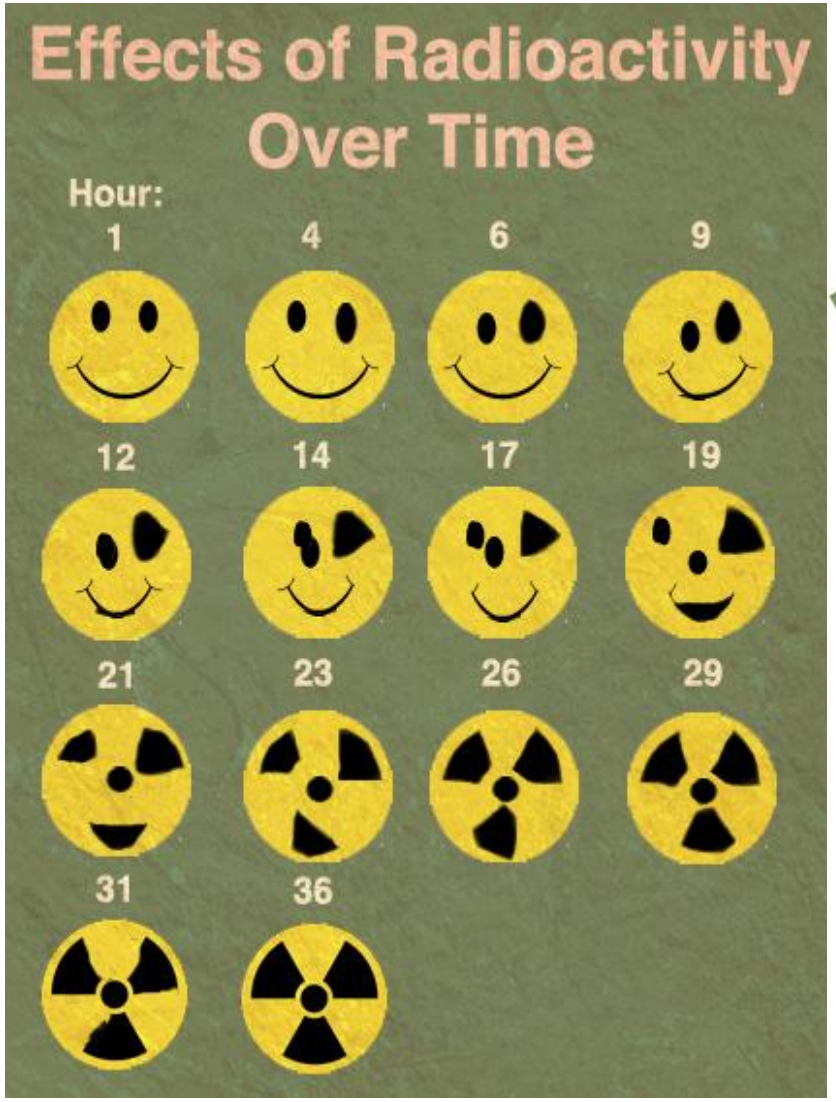

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