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Using World Reference Base soil maps for biosphere models of radioactive waste disposals

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1: Introduction

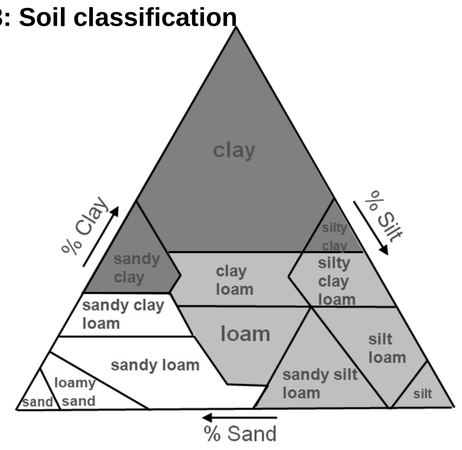
Many countries plan the long-term disposal of waste from the nuclear fuel cycle in deep geological formations. Within the long-term safety assessment compliance with safety criteria has to be demonstrated. This includes considerations on the release of radionuclides from the repository, migration through the host rock and dispersion in the biosphere, where they may cause exposure to humans via various pathways.
To determine radionuclide uptake through ingestion of food, inhalation of dust particles in air and external exposure, the contamination of surface soil by radionuclides in groundwater has to be assessed. Soil properties like soil texture, pH, redox potential and content of organic substances influence the distribution of radionuclides between water and soil, as well as the accumulation of radionuclides over long time frames. The transfer of radionuclides from soil to plants is likewise determined by soil type and properties. Soil parameters used in biosphere models like transfer factors from soil to plant or distribution coefficients are often presented for a certain soil in publications or are collected for the soil texture/ organic matter types sand, loam, clay and organic in data bases. To integrate these parameters with biosphere models, we propose the use of maps from the European Soil Bureau showing the distribution of World Reference Base for Soil Resources (WRB) soil types in Europe.

2: Soil Types

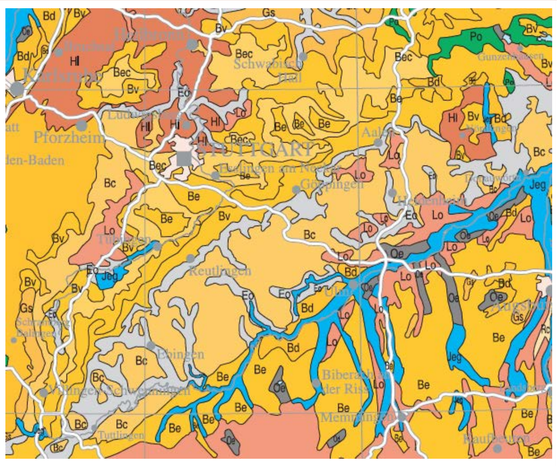
The WRB classification of soils is based on soil properties defined in terms of diagnostic horizons, properties and materials. The selection of diagnostic characteristics takes into account their relationship with soil forming processes (FAO 2006).
Data bases for radioecological parameters are often based on texture/organic matter criterions (IAEA 2009, 2010). On the left a table for converting WRB soil types into texture/OM criterion soil types is proposed. This is done for the WRB soil horizon, where the root zone of agricultural plants is located.

WRB Soil Type	Organic matter content	pH	Water Content	Proposed texture/ organic matter type
Albeluvisol	medium	acidic	high	**Loam**
Arenosol	low	acidic	low	**Sand**
Calcisol	arm	base rich	medium	**Loam**
Cambisol	medium	acidic to base rich	medium	**Sand**
Chernozem	high	base rich	medium	**Loam**
Fluvisol	medium	acidic	high	**Sand**
Gleysol	high	acidic	high	**Loam**
Histosol	very high	acidic	high	**Organic**
Luvisol	medium	acidic	medium	**Loam**
Podsol	low	acidic	low	**Sand**
Umbrisol	high	acidic	high	**Loam**
Vertisol	low	base rich	Low-high	**Clay**

3: Soil classification

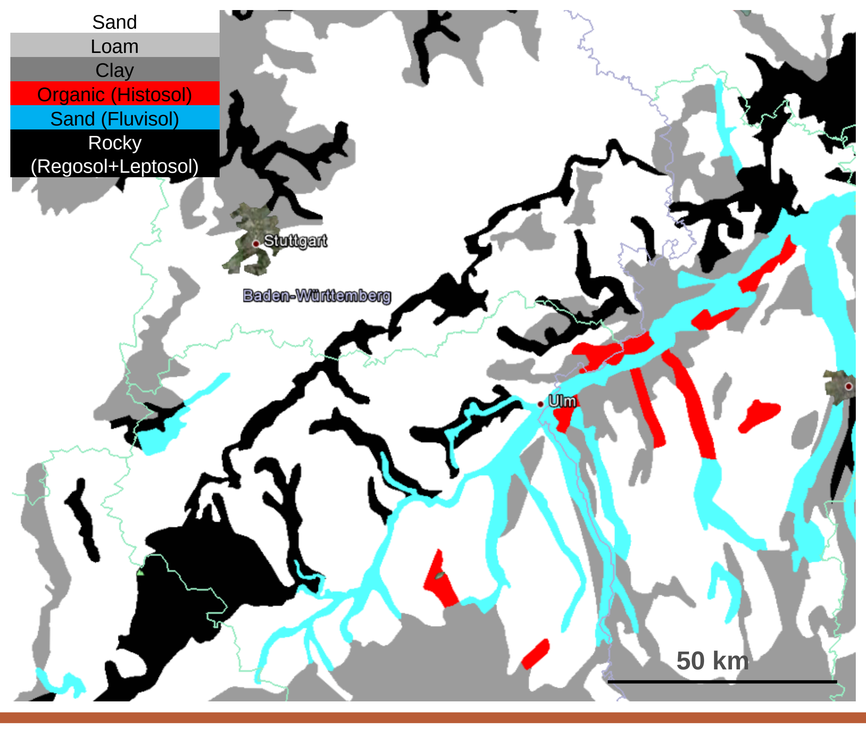


USDA soil classes



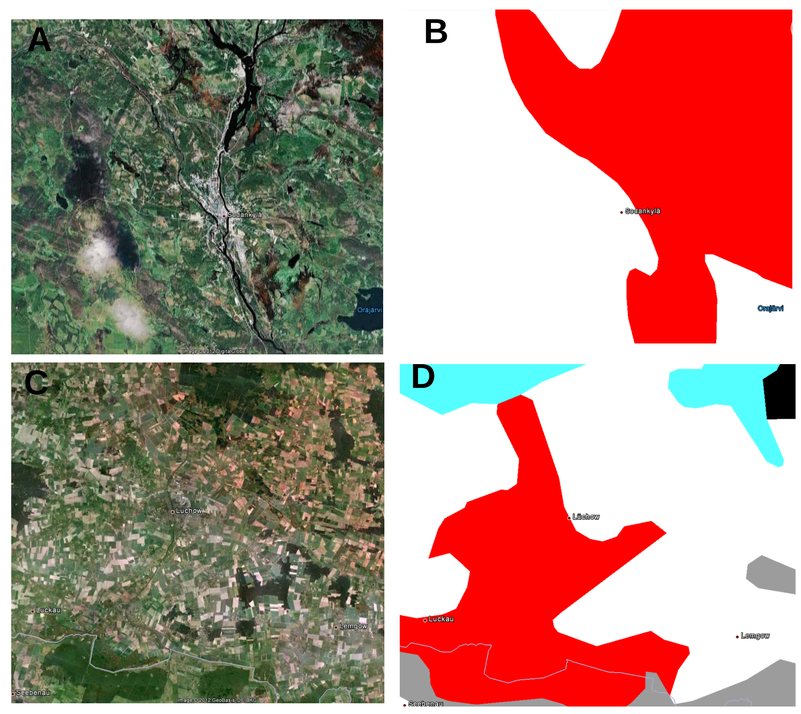
WRB Soil Maps, Soil Atlas of Europe

Google Earth



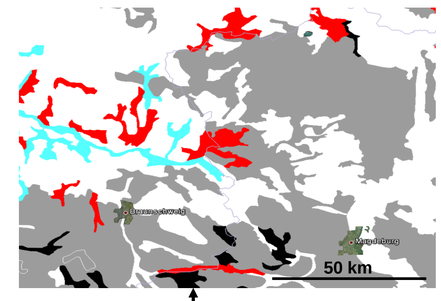
4: Comparison with actual agricultural use of the soil

Regions with the same soil type may be used differently, depending on where they are located. To integrate land use, satellite images (Google Earth) from the corresponding regions can be used. In A), a satellite image from Finland is shown and on the B) a corresponding image showing the soil types according to the texture/OM criterion. Most of the organic, histosol region shown in red is natural bog.
In C), a satellite image from Germany is shown together with a corresponding image for the soil types according to the texture/Om criterion in D).



Here most of the histosol regions shown in red are drained former bogs and are now used for agriculture. Such combination images may be used to further refine the soil characteristics needed for parameterization of soil types for biosphere models.
In addition to this, regularly flooded soils, like Fluvisols, may be accentuated. This was done with a blue color in D). In addition to their texture/organic matter classification, such soils may need a different set of parameters, to reflect their high water content.

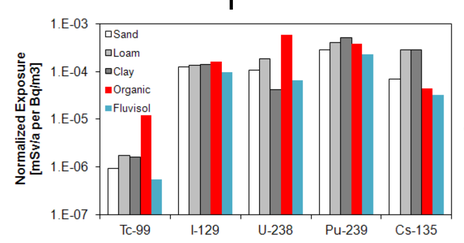
5: Use of soil maps for reference biosphere models

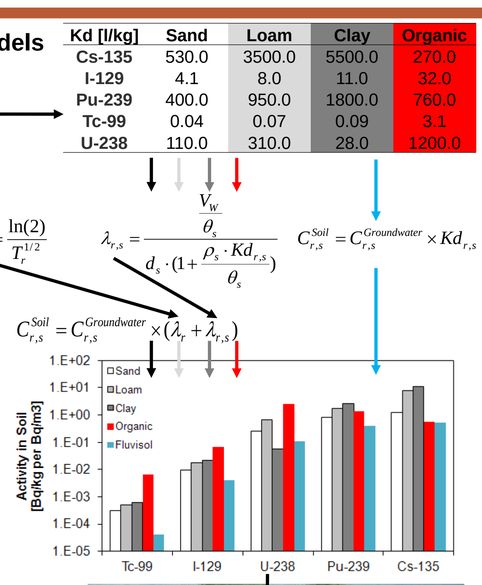


Kd [l/kg]	Sand	Loam	Clay	Organic
Cs-135	530.0	3500.0	5500.0	270.0
I-129	4.1	8.0	11.0	32.0
Pu-239	400.0	950.0	1800.0	760.0
Tc-99	0.04	0.07	0.09	3.1
U-238	110.0	310.0	28.0	1200.0

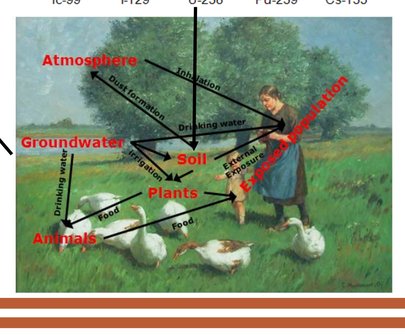
$$\lambda_r = \frac{\ln(2)}{T_r^{1/2}} \qquad \lambda_{r,s} = \frac{\frac{V_w}{\theta_s}}{d_s \cdot (1 + \frac{\rho_s \cdot Kd_{r,s}}{\theta_s})} \qquad C_{r,s}^{Soil} = C_{r,s}^{Groundwater} \times Kd_{r,s}$$

$$C_{r,s}^{Soil} = C_{r,s}^{Groundwater} \times (\lambda_r + \lambda_{r,s})$$





F_b	Sand	Loam	Clay	Organic
Cs-135	3.9E-02	2.0E-02	1.1E-02	4.3E-02
I-129	5.8E-03	3.6E-04	5.7E-04	6.3E-04
Pu-239	1.0E-05	4.9E-06	7.4E-06	5.4E-04
Tc-99	1.3E+00	1.3E+00	1.3E+00	1.3E+00
U-238	8.9E-03	7.7E-03	3.8E-03	6.2E-03



6: Conclusion

The proposed integration of WRB soil maps with texture/organic matter based databases for soil dependent radioecological parameters is an additional tool for assessments of the long term safety of radioactive waste repositories. These integrated soil maps can be used to increase the geographical resolution and applicability of biosphere models.
Depending on the parameter source, more characteristics of the soil, like pH or water saturation, may be used to further refine the assessment. These maps may also be used for other applications like an evaluation of the effect of fallout derived radionuclides on a defined region.

Literature

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