Combination of Field Measurements, Laboratory Analysis and Statistics as an Effektive Approach to Characterize Large Amounts of NORM Contaminated Materials

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Overview

- Introduction
- General approach of in-situ measurements of NORM contamination at WISMUT GmbH
- Case study: Determination of the contamination of scrap metal and the release for Smelting
- Case study: Control of the cleanup of an area by contamination measurements
- Conclusions

Introduction (I)

- SDAG WISMUT – in the past one of the biggest Uranium mining companies worldwide
- 1946 – 1990 total Uranium production: 231,000 t
- Since 1991 remediation works

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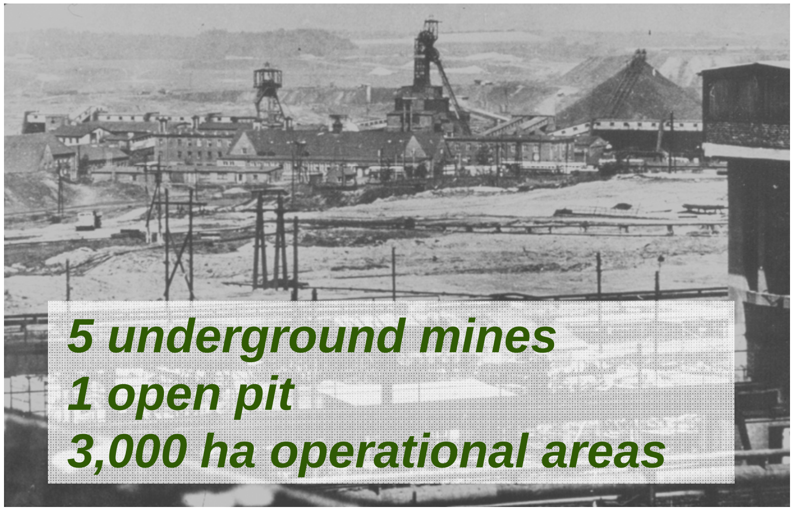
Introduction (II)
Situation at Termination of Uranium Mining by WISMUT 1990/91



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Introduction (III)

- Tasks (as parts of remediation at WISMUT)
  - Scrap metal should be recycled as far as possible
  - Quality assurance of the remediation of areas with a total removal of mining and milling residues (operational areas, footprint areas of relocated waste rock dumps)
- Need of effective measuring and assessment methods for:
  - NORM contamination of scrap metal
  - NORM contamination of soil/waste
    - Control of the removal of contamination by in situ measurements
    - Verification of successful remediation

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Characterization of NORM contamination at WISMUT

- Basic types of radioactive contamination
  (valid for scrap metal as well as for contaminated areas):
  - Uranium ore-type (all nuclides of the U-Ra-decay chain)
  - Yellowcake-type (uranium after a chemical separation)
  - Tailings-type (uranium ore milling waste product)
  - Pb-210-type (ventilation shafts)

General approach of in-situ measurements of NORM contamination at WISMUT

The problem:
Contamination at NORM sites may be wide spread and inhomogenously distributed

→

The concept:
Intelligent combination of field and lab measurements

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Step 1:
Identification of the contamination type (determination of the nuclide vector by sampling and lab analyses)

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Step 2:
Selection of an appropriate field (in-situ) measurement method

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Step 3:
Problem related „connecting" calibration between field and lab measurements

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Step 4:
In-situ measurements (with a quality assurance by lab analysis

↓

Step 5:
Statistical assessment of the field data

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Case study: Determination of the contamination of scrap metal and the release for smelting

- Total mass of scrap metal at WISMUT: ca. 300,000 t
- Origin:
  - Underground mine equipment
  - Daylight mine equipment
  - Equipment from the mills

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Examples of scrap metal

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Recommendation of the German Commission on Radiological Protection (SSK)

- Radiological protection principles concerning the release of scrap from the shutdown of uranium mining plants (published 1991)
  - Definition of a release level of the Total Surface Alpha Activity (TAA) of 0.5 Bq/cm² for the scrap metal observing the following conditions:
    - Use of the scrap metal is restricted to smelting
    - Exclusion of the re-utilisation of parts of the scrap
    - Size of parts of the scrap have to be ready for smelting
    - Measurements of TAA have to be representative for the whole batch
  - Procedure of release has to be upon with the competent authority

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Scrap metal processing at WISMUT

- Implementation of the guidelines of the SSK-recommendation
- Sorting of the scrap metal by origin, similar technological processes and same features
- Cutting according to the requirements of the smelter
- Configuration of batches for the measurement/assessment

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Step 1: Identification of the contamination type (nuclide vector)

- Contamination of scrap is located in a surface layer (due to corrosion contaminated layer could have dimensions in the order of magnitude of mm)
- Sampling (scratching of rust from surface)
- Determination of the nuclide vector, identification of the dominating nuclide (high resolution gamma spectrometry)

Material	Ra-226	U-238	Th-230	Rn-222	Pb-210
Waste rocks	**1**	0.95	0.95	0.94	0.91
U concentrated	0.0013	**1**	0.0013	0.0009	0.00067
Tailings	**1**	0.04	0.64	0.88	0.95
^{210}Pb/^{210}Po	0.024	0.024	0.021	0.024	**1**

normed to the dominating nuclide (=1)

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Step 2: Selection of an appropriate in-situ measurement method (I)

- In situ gamma-measurements are problematic (special equipment necessary, activity of thin contaminated layers is low compared with environmental influence, U and Pb-210 hardly detectable)
- In-situ alpha-measurements are failed by absorption processes in the most cases (influence of rust, rough surfaces, air gaps)
- In-situ beta-measurements were identified as the preferred measuring method (correlation between alpha und beta decays in the U-Ra-decay chain, influences of measuring conditions are much smaller compared with alpha-measurements)

→ Implementation of the beta-measurement procedure and the development of assessment routines at WISMUT by IAF Radioökologie (1995)

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Step 2: Selection of an appropriate in-situ measurement method (II)

- In-situ beta-contamination measurements
  - Determination of the Total Surface Alpha Activity (TAA) by means of measurement of the beta net count rate
  - Beta net count rate requires a double measurement (without Al 3 mm shielding – N_{total}; with Al 3 mm shielding - $N_{background}$)
  - Using hand-held portable instruments (α-β or β-γ monitor, α shielded by plastic foil)

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Step 3: Calibration of beta-measurements (I)

$$TAA\ [Bq/cm^2] = k_\beta \cdot N_\beta = k_\beta \cdot (N_{total} - N_{background})$$

- Calibration pads:
  - Four types of calibration pads specified to the four different radionuclide vectors according to the contamination types
  - not commercially available; self-made by IAF Radioökologie

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Step 3: Calibration of beta-measurements (II)

- Calibration for special geometries
  - Investigation and determination of geometric factors for special geometries like rails or tubes
  - Manufacturing of special masks (Al)

Step 4: In-situ measurements (I)

- In the case of demolished scrap or mobile equipment:
  In-situ beta-measurements of sorted batches on scrap storages

- Randomly selected measuring points allows to determine parameters which are representative for the batch

Step 4: In-situ measurements (II)

- between 50 and 80 screening measurements for a scrap pile of 50 tons
- On-site input of the data into a software running on a field computer
- Measurement termination after a certain level of uncertainty for the representative parameter (TAA) is reached
- 1 scratch sample of the batch for QA (gamma spectrometry in the lab)

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Step 4: In-situ measurements (III)

- If possible, measurements are executed before demolition of the facilities (for instance: shaft housings or railways)
- Advantages regarding the sorting of scrap

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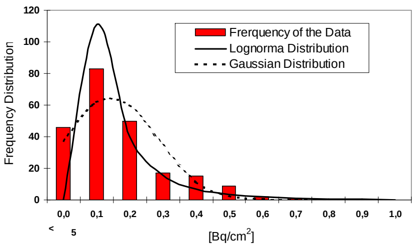
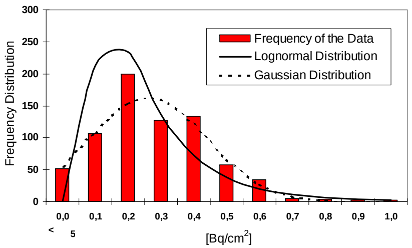
Step 5: Statistical assessment of the field data (I)

- Investigation of the type of statistical distribution (normal [i. e. Gaussian] distribution via log-normal distribution)

note: data on environmental contamination are as a rule lognormal-distributed !





- Detection of non-plausible values; exclusion of these values from data interpretation

- Determination of the relevant statistical parameters (X_{mean}, standard deviation σ, uncertainty Δ, percentile P_α ; confidence interval for a given level of confidence α)

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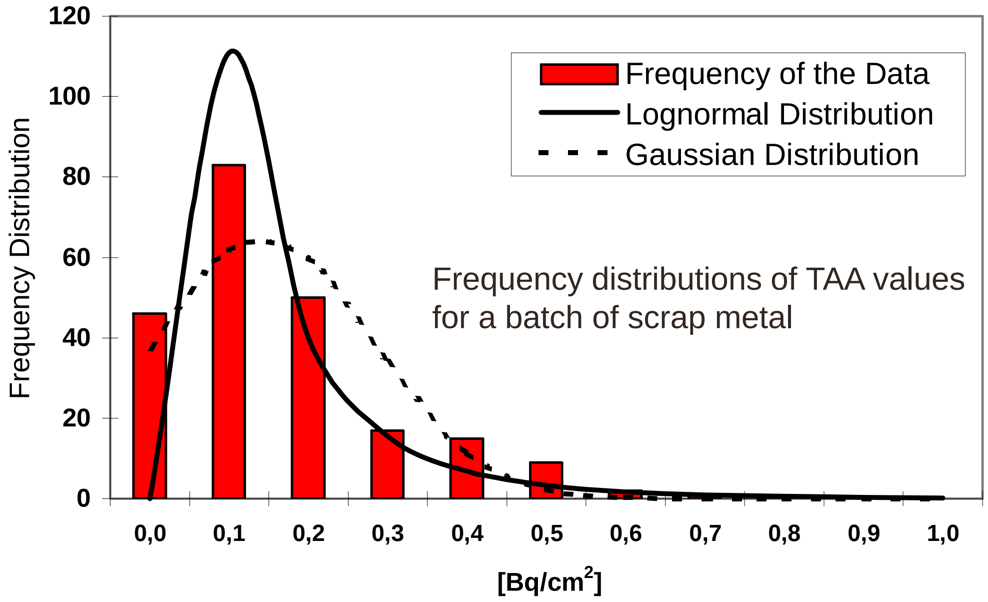
Step 5: Statistical assessment of the field data (II)

- Comparison of the TAA reference value (0.5 Bq/cm²) with the upper limit of the confidence interval (95 % confidence value)



- TAA mean value = 0.11 Bq/cm²
- Upper limit of the confidence interval = 0.14 Bq/cm²

→ Release of the batch for smelting

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Case study: Control of the cleanup of an area by contamination measurements

- Situation at the Crossen site:
  - Complete relocation of the waste rock dump Bergehalde Crossen (used for the remediation of the tailing pond Helmsdorf)
  - Excavation of the last layer above the geogenic footprint area
- Tasks:
  - Control the excavation by contamination measurements
  - Verification of the sufficient removal of contamination
- Problem:
  - Leached Uranium had seeped with water into the upper soil
- Target (according to the licence):
  - Nuclide-specific activity in the soil must be lower than 1 Bq/g

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Bergehalde Crossen (aerial photo 1991)

Bergehalde Crossen (2012, situation after termination of the first section of remediation)

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Removal of waste rock material from the footprint area of the Bergehalde Crossen and refilling

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Combination of various measuring methods adapted to the site conditions (in part repetitive action)

- Ambient dose rate (in-situ)
  - Obligatory measurements 1 m above ground for Uranium ore or tailings type of cont.
  - Additional gamma measurements direct on the ground (obtains a higher focus)
- Beta-measurements (in-situ)
  - Suspicion of Yellowcake type of contamination (for instance: intrusion of dissolved Uranium into the ground)
  - Under complicated geometric conditions (control of the removal of contamination)
- Gamma-spectrometry (HPGe-detector in Lab)
  - Direct determination of the nuclide specific activity of samples
  - Selection of the testing time according to the required accuracy of the result
    - Short term screening analyses of samples with an instant result (with a lower accuracy but a high frequency, samples not dryed)
    - High quality analyses of single samples within 24 h
  - Quality assurance of the beta-measurements

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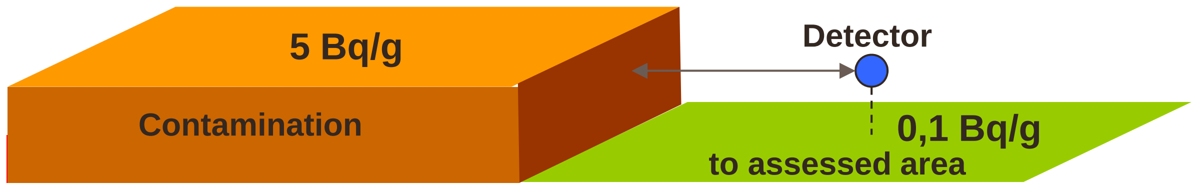
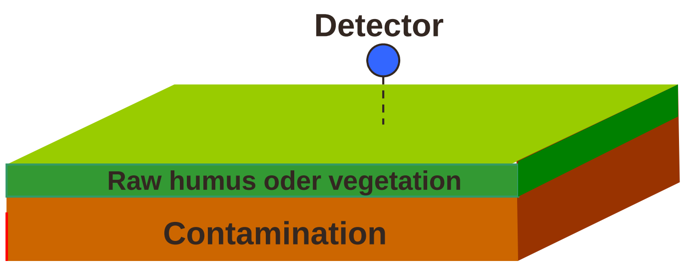
Problematic cases of the ambient dose rate measurement

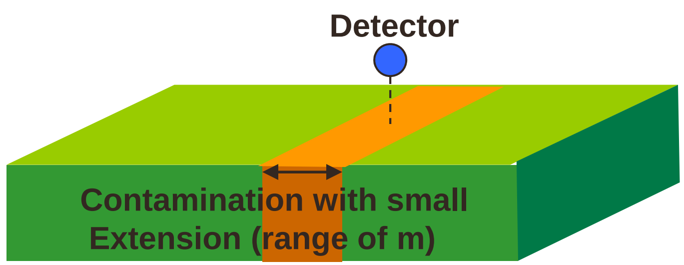
Side by side of contaminated and clean areas



Influence of attenuation effect of vegetation and of humus layers



Small dimensions of contamination



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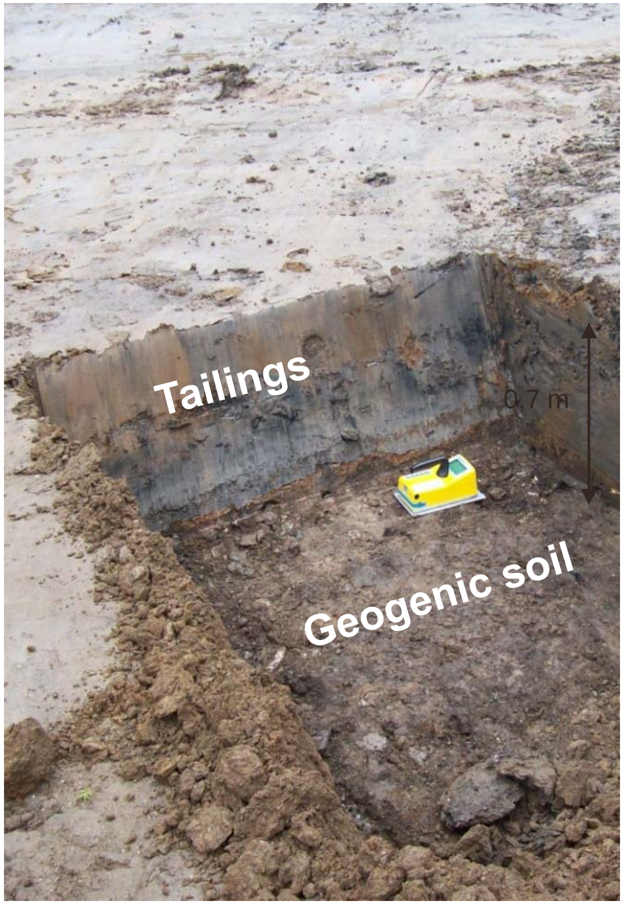
In-situ beta-measurements on areas - example



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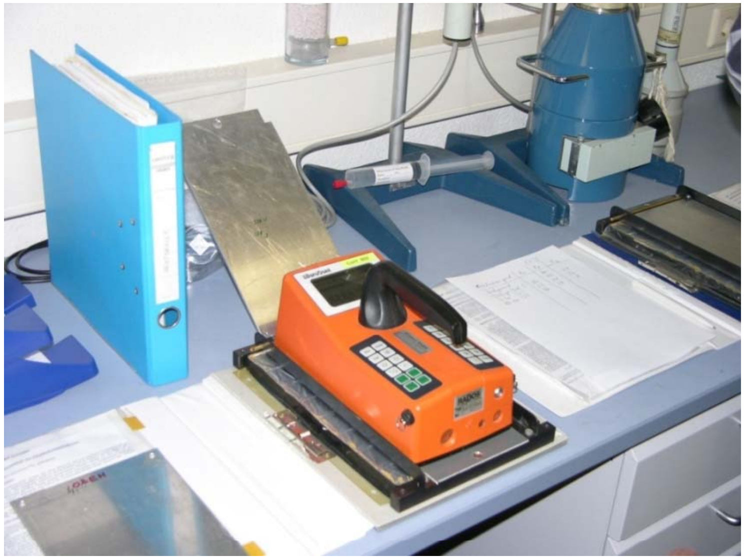
In-situ beta-measurements on areas - calibration

- Same procedure like for scrap measurements, but modification of the calibration
- Calibration have to manage the link between the beta net count rate (in [pps - pulses per second]) and the **specific activity** of U contaminated soil (in [Bq/g])
  - 5 calibration pads:
    - containment filled with soil; 4 contamination types + K-40
    - soil thickness > range of the beta particles in soil
    - lab analyses of the soil by gamma spectrometry



Conclusions

- The intelligent combination of field measurements and laboratory analyses taking into account screening measurements and the statistical interpretation of the screening data is an efficient approach to determine representative parameters for big amounts of NORM.
- The approach is very practicable, arrives quickly at a certain level of information to decide (for instance to release NORM, or to verify the cleanup state before release of a contaminated area).
- Understanding of the physical background is needed to introduce the method and to manage the calibration which is the key element in implementing the approach.
- Application of the method allowed WISMUT to release more than 70% of metallic scrap arising from decommissioning and demolition of the U production facility for smelting, - an important economic result has been achieved.