Transfer of $^{238}\text{U}$ and $^{226}\text{Ra}$ to Chinese cabbage from soil containing elevated levels of natural radionuclides

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Presentation outline

• Introduction – aim of the study
• Experimental design, methodology
• Results
• Discussion
• Conclusions

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Introduction

• Mining and milling of U ore may enhance the levels of natural radionuclides in the environment

• Certain plants may accumulate radionuclides in above ground organs – soil to plant transfer of $^{238}\text{U}$ and $^{226}\text{Ra}$ reported for different plant species in the soil contaminated with U-mill tailings

• The *Brassica* plants (cabbage) have capability to accumulate radionuclides in higher quantities – radiological risk if ingested
Experimental (1)

• Transfer of $^{238}$U and $^{226}$Ra from soil contaminated with UMT to *Brassica rapa* L. supsp. *pekinensis* (Lour.) Hanelt

• Tested plants grown in pots in laboratory environment – controlled conditions

• Different levels of soil contamination under various growing conditions – different contamination scenarios

• Soil properties were considered as they directly affect availability of radionuclides to plants
Experimental (2)

Pot experiment – statistical ANOVA design considering 3 different soils and 4 levels of soil contamination
UMT contaminated soils prepared by mixing garden soils with UMT

Three different soils: A, B and C

Soil contamination levels: control, 20, 40 and 60 % of UMT in the soil

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Experimental (3)

The plants were grown in controlled conditions:
• Temperature: 22-25 ºC
• Relative humidity: 40-60%
• 12 h daily light irradiation: 54-94 µmol s⁻¹ m⁻²
• Daily soil irrigation with deionised water to field capacity
• Garden mat to protect dust resuspension
Experimental (4)

Plants:
- Washing with tap water, oven drying at 40 ºC, milling; $^{226}$Ra by $\gamma$-ray spectrometry (well type HPGe), $^{238}$U by $k_0$ NAA (via $^{239}$Np)

Soils:
- Oven drying at 60 ºC, crushing, sieving; $^{226}$Ra and $^{238}$U by $\gamma$-ray spectrometry
### Results (1)

#### $^{238}$U in soil:

<table>
<thead>
<tr>
<th>Soil</th>
<th>Control</th>
<th>20 % UMT</th>
<th>40 % UMT</th>
<th>60 % UMT</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>50.3 ± 5.4</td>
<td>254 ± 31</td>
<td>459 ± 41</td>
<td>710 ± 83</td>
</tr>
<tr>
<td>B</td>
<td>40.5 ± 1.5</td>
<td>270 ± 9</td>
<td>489 ± 8</td>
<td>712 ± 77</td>
</tr>
<tr>
<td>C</td>
<td>54.0 ± 3.7</td>
<td>286 ± 23</td>
<td>540 ± 38</td>
<td>770 ± 59</td>
</tr>
</tbody>
</table>

#### $^{226}$Ra in soil:

<table>
<thead>
<tr>
<th>Soil</th>
<th>Control</th>
<th>20 % UMT</th>
<th>40 % UMT</th>
<th>60 % UMT</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>51.2 ± 0.3</td>
<td>1745 ± 32</td>
<td>3394 ± 53</td>
<td>5105 ± 216</td>
</tr>
<tr>
<td>B</td>
<td>63.7 ± 1.2</td>
<td>1822 ± 24</td>
<td>3581 ± 68</td>
<td>5143 ± 66</td>
</tr>
<tr>
<td>C</td>
<td>101.7 ± 1.2</td>
<td>2064 ± 86</td>
<td>3839 ± 29</td>
<td>5390 ± 94</td>
</tr>
</tbody>
</table>
Results (2)
Results (3)

Pearson’s correlation coefficients for $^{238}$U

<table>
<thead>
<tr>
<th>Pedological parameter</th>
<th>U-238 in Chinese cabbage-B</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>No correlation</td>
</tr>
<tr>
<td>Available $\text{P}_2\text{O}_5$ [mg/kg]</td>
<td>$r = -0.9803$ (p = 1.879E-5)</td>
</tr>
<tr>
<td>Available $\text{K}_2\text{O}$ [mg/kg]</td>
<td>$r = -0.9075$ (p = 0.0018)</td>
</tr>
<tr>
<td>Organic matter [%]</td>
<td>$r = -0.9562$ (p = 0.0002)</td>
</tr>
<tr>
<td>CEC [cmol/kg]</td>
<td>$r = 0.9236$ (p = 0.0011)</td>
</tr>
<tr>
<td>Organic C [%]</td>
<td>$r = -0.9519$ (p = 0.0003)</td>
</tr>
<tr>
<td>N [%]</td>
<td>$r = -0.8775$ (p = 0.0042)</td>
</tr>
<tr>
<td>C/N</td>
<td>$r = -0.7638$ (p = 0.0274)</td>
</tr>
</tbody>
</table>
### Results (4)

**Pearson correlation coefficients for $^{226}$Ra**

<table>
<thead>
<tr>
<th>Pedological parameter</th>
<th>Ra-226 in Chinese cabbage-B</th>
<th>Ra-226 in Chinese cabbage-C</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>No correlation</td>
<td>No correlation</td>
</tr>
<tr>
<td>Available P$_2$O$_5$ [mg/kg]</td>
<td>$r = -0.6901 \ (p = 0.0188)$</td>
<td>$r = -0.7737 \ (p = 0.0032)$</td>
</tr>
<tr>
<td>Available K$_2$O [mg/kg]</td>
<td>$r = -0.6029 \ (p = 0.0496)$</td>
<td>$r = -0.7685 \ (p = 0.0035)$</td>
</tr>
<tr>
<td>Organic matter [%]</td>
<td>$r = -0.7443 \ (p = 0.0086)$</td>
<td>$r = -0.8038 \ (p = 0.0016)$</td>
</tr>
<tr>
<td>CEC [cmol/kg]</td>
<td>$r = 0.6823 \ (p = 0.0207)$</td>
<td>$r = 0.7605 \ (p = 0.0041)$</td>
</tr>
<tr>
<td>Organic C [%]</td>
<td>$r = -0.7464 \ (p = 0.0083)$</td>
<td>$r = -0.7966 \ (p = 0.0019)$</td>
</tr>
<tr>
<td>N [%]</td>
<td>$r = -0.5929 \ (p = 0.0545)$</td>
<td>$r = -0.8006 \ (p = 0.0018)$</td>
</tr>
<tr>
<td>C/N</td>
<td>$r = -0.7686 \ (p = 0.0057)$</td>
<td>$r = -0.6025 \ (p = 0.0382)$</td>
</tr>
</tbody>
</table>

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Discussion (1)

- Low transfer of $^{238}$U to cabbage; possible factors:
  - Low nutrient availability in the UMT contaminated soil
  - Cabbage tolerance to presence of $^{238}$U in soil
  - Adsorption or complexation processes of U
- $^{238}$U in cabbage positively correlated with CEC, but negatively with other soil properties – possible reduction of U uptake
- Concentration ratio (CR) values (0.006) about 30 times lower than literature data (0.180)
Discussion (2)

- High transfer of $^{226}$Ra to cabbage; possible factors:
  - High mobility of $^{226}$Ra in test soil – high fraction of exchangeable $^{226}$Ra in test soil
  - Root uptake similar to root uptake of Ca
- $^{226}$Ra in cabbage positively correlated with CEC, but negatively with other soil properties – possible reduction of $^{226}$Ra uptake
- $^{226}$Ra concentration positively correlated to the plant biomass – dilution in plants with high biomass
- CR values (0.04-0.12) comparable to literature data (0.022-0.068)
Conclusions (1)

• The applied experimental design shown as appropriate for determination of cabbage CR for $^{238}\text{U}$ and $^{226}\text{Ra}$ in contaminated soils – statistically significant correlations

• Chinese cabbage have capability to take up U and Ra in edible parts, despite their non-essential role

• Soil to plant transfer was higher for Ra than for U

• CRs for U were lower than literature data, CRs for Ra were comparable
Conclusions (2)

• Transfer of Ra could be explained by its chemical analogy with Ca that is taken up as an essential element.

• Soil to plant transfer depends on particular radionuclide, its activity concentration in soil and soil properties – CEC is an important factor affecting availability of U and Ra, whilst other factors reduces the availability.

• Further site-specific studies are needed for more accurate model-based dose assessments.
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