Could plutonium be a substitute of 137Cs for tracing soil erosion?

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Could plutonium be a substitute of $^{137}$Cs for tracing soil erosion?

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◆ The most widely used soil erosion tracer---$^{137}$Cs

$^{137}$Cs (30.17 yr)

\[ 1.17 \text{ MeV (5\%)} \beta^- \]

\[ 0.51 \text{ MeV (95\%)} \beta^- \]

$^{137m}$Ba

\[ 0.662 \text{ MeV } \gamma \]

$^{137}$Ba (stable)
The application of $^{137}$Cs for soil erosion study will be difficult in future

---find a substitute
Pu isotopes (\(^{239}\text{Pu}\) and \(^{240}\text{Pu}\)) --- potential substitutes of \(^{137}\text{Cs}\) for tracing soil erosion

- Same dominating source of global fallout worldwide as \(^{137}\text{Cs}\)
- Much longer half-lives (\(^{239}\text{Pu}\) and \(^{240}\text{Pu}\)) than \(^{137}\text{Cs}\)
- High particle affinity and low mobility in soil
- More sensitive detection supported by measurement techniques of mass spectrometry
Plutonium in soils collected from northeast China

Sampling sites
Plutonium in soils collected from northeast China

Spatial distribution of plutonium in surface soils

- $^{240}\text{Pu}/^{239}\text{Pu}$ atomic ratio $\sim 0.18$
- $^{239+240}\text{Pu}/^{137}\text{Cs}$ activity ratio $\sim 0.045$

--- major source of Pu in northeast China should be the global fallout Pu from NWT

Pu conc. in surface soils varying with land types, Pu conc. in grass land were significantly higher than those in cultivated land

--- migration behavior of Pu influenced by land use patterns and human activities
Correlation between the concentration of $^{239+240}\text{Pu}$ and $^{137}\text{Cs}$ in surface soils

- **Grass land**: $y = -0.005 + 0.043x$, $R^2 = 0.95$
- **Saline land**: $y = 0.027 + 0.036x$, $R^2 = 0.51$
- **Cultivated land**: $y = -0.018 + 0.052x$, $R^2 = 0.97$

High correlation between the conc. of Pu and $^{137}\text{Cs}$ were observed in surface soils, especially in grass land and saline land.
Vertical distribution of plutonium in soil cores

- The atomic ratio of $^{240}\text{Pu}/^{239}\text{Pu}$ in two cores $\sim 0.18$

- The sub-surface maximum of Pu conc. in DL-01 core (reference core)

- Pu concentration exponentially decreased with soil depth in both cores

- Small peak values of Pu conc. in deep layers---roots, organic matter content
Comparison of the profiles of Pu and $^{137}$Cs in each soil core

The physical transport of $^{239+240}$Pu and $^{137}$Cs in soils should be very similar, they could convey similar information about erosion and redistribution of soils in a small area.
◆ The feasibility of using Pu as soil erosion tracer

Table 1 The inventories of Pu and $^{137}$Cs in soil cores$^a$.

<table>
<thead>
<tr>
<th>Depth (cm)</th>
<th>$^{239+240}$Pu (Bq/m²)</th>
<th>$^{239+240}$Pu inventory distribution (%)</th>
<th>$^{137}$Cs$^b$ (Bq/m²)</th>
<th>$^{137}$Cs inventory distribution (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DL-01</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(reference core)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-6</td>
<td>41.8 ± 2.5</td>
<td>48</td>
<td>916 ± 19</td>
<td>54</td>
</tr>
<tr>
<td>6-20</td>
<td>33.6 ± 1.9</td>
<td>39</td>
<td>650 ± 25</td>
<td>38</td>
</tr>
<tr>
<td>&gt; 20</td>
<td>11.5 ± 0.3</td>
<td>13</td>
<td>138 ± 40</td>
<td>8</td>
</tr>
<tr>
<td>Total</td>
<td>86.9 ± 3.1</td>
<td></td>
<td>1704 ± 40</td>
<td></td>
</tr>
<tr>
<td>DL-02</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(studied core)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-6</td>
<td>24.5 ± 0.6</td>
<td>56</td>
<td>426 ± 17</td>
<td>56</td>
</tr>
<tr>
<td>6-20</td>
<td>11.3 ± 0.4</td>
<td>26</td>
<td>175 ± 22</td>
<td>23</td>
</tr>
<tr>
<td>&gt; 20</td>
<td>8.2 ± 0.4</td>
<td>18</td>
<td>163 ± 46</td>
<td>21</td>
</tr>
<tr>
<td>Total</td>
<td>44.1 ± 0.9 ($51%)^c$</td>
<td></td>
<td>764 ± 47 ($45%)^c$</td>
<td></td>
</tr>
</tbody>
</table>

$^a$ All given uncertainties are one standard deviation.
$^b$ $^{137}$Cs activities were decay corrected to 1st Sept. 2009.
$^c$ Numbers in parentheses indicate percentages relative to the inventory of the reference core DL-01.
The feasibility of using Pu as soil erosion tracer

- Comparing the Pu profiles between the two soil cores, deducing that the top ~6 cm soil in the site of DL-02 core might be eroded;

- Similar conclusion could also be deduced based on the $^{137}$Cs profiles

--- Pu could be an ideal substitute of relative short-lived fallout $^{137}$Cs for tracing soil erosion and redistribution in the future.
Future work

✓ To estimate the intensity of the erosion in a specific site of the area, more comprehensive work involving analysis of Pu profiles in a series of soil cores and modeling of downwards migration of Pu has to be carried out.