238U in sediments of the Kastela Bay, Adriatic Sea (Croatia)

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WHY KASTELA BAY?

- the biggest urban agglomeration on the east Adriatic coast
- assumed discharge of the TENORM
  - by-product of the coal burning
  - former “Adriavinil” factory
- radionuclides very poorly researched
PURPOSE OF THE WORK

- to study a spatial distribution of $^{238}$U in the sediment of the Bay
  - horizontal and vertical distribution
  - to a 50 cm depth
- to research a connection between potential $^{238}$U sources and its distribution
- to assess anthropogenic influence on the sediments
- to assess the condition of the environment
**SAMPLING AND ANALYSING**

- sampling: June 2005 – May 2008
- 95 stations, 604 samples

**Sampling and Analyzing**

- regular grid 1 × 1 km across the whole Bay
- 500 × 500 m around the “Adriavinil” factory
- a profile next to the factory
- segmenting – 8 segments in a 50 cm sediment core
- gamma-spectrometry – $^{238}\text{U}$ ($^{234}\text{Th}$)

Sampling map of the Kastela Bay sediments
Summarized basic statistical parameters of $^{238}$U massic activities in Kastela Bay sediments in eight layers to a 50 cm depth; $\bar{x}$ – mean value; N – number of results, SD – standard deviation

<table>
<thead>
<tr>
<th>Layer (Depth)</th>
<th>Statistical parameter</th>
<th>$^{238}$U (Bq/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 8 (0 - 50 cm)</td>
<td>$\bar{x}$</td>
<td>34</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>604</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td>Minimum</td>
<td>6.7</td>
</tr>
<tr>
<td></td>
<td>Maximum</td>
<td>603</td>
</tr>
<tr>
<td></td>
<td>Median</td>
<td>28</td>
</tr>
</tbody>
</table>

- wide activity range
  - minimum – layers 2 and 8 (5 – 10 cm and 40 – 50 cm depth)
  - maximum – layer 5 (20 – 25 cm depth)
- massic activities are mostly typical for marine sediments
  - other authors: 8.6 – 49.4 Bq/kg
- some locally elevated activities ("outliers")
Box & whisker plot of $^{238}\text{U}$ massic activities in Kastela Bay sediments in eight layers to a 50 cm depth; MV – mean value, SE – standard error of the mean value, SD – standard deviation

- mean values almost constant or with a weak trend
- irregular standard deviation ranges $\rightarrow$ disturbed process stability
- two groups of layers
  - layers 1 – 6
    - wide standard deviation ranges
    - unhomogeneous sediment
    - probable anthropogenic material
  - layers 7 and 8
    - narrow standard deviation ranges
    - homogeneous sediment
    - natural origin of the material
Elevated $^{238}$U activities:

- north coast of the Split peninsula (K43)
- south coast of the Split peninsula (K63, K64, K65)
- next to the “Adriavinil” factory (K90)
- anthropogenic origin
- higher activities in deeper parts of the Bay
- seabed depth
- sediment mineral composition
- granulometric composition

Map of the $^{238}$U massic activities distribution in Kastela Bay sediments in eight layers at 0 – 50 cm depth; a) Layer 1 (0 - 5 cm); b) Layer 2 (5 - 10 cm); c) Layer 3 (10 - 15 cm); d) Layer 4 (15 - 20 cm); e) Layer 5 (20 - 25 cm); f) Layer 6 (25 - 30 cm); g) Layer 7 (30 - 40 cm); h) Layer 8 (40 - 50 cm); Massic activities are expressed in Bq/kg.
- two groups of elevated $^{238}$U massic activities
  - moderately elevated
  - very elevated

- comparison of the researched sediment
  - typical Adriatic coastal sediment (AS) – 18.2 Bq/kg
  - average uncontaminated Kastela Bay sediment (KS) – 38.8 Bq/kg
Comparison of moderately elevated $^{238}$U massic activities in Kastela Bay sediments with massic activities in typical Adriatic coastal sediments (AS) and in average Kastela Bay sediment (KS)

<table>
<thead>
<tr>
<th>Sample label</th>
<th>$a^{(238}U$ (Bq/kg)</th>
<th>Elevated $^{238}$U massic activities Compared to AS</th>
<th>Compared to KS</th>
</tr>
</thead>
<tbody>
<tr>
<td>K4302</td>
<td>66</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>K4303</td>
<td>89</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>K4304</td>
<td>84</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>K4305</td>
<td>96</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>K4306</td>
<td>127</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>K4307</td>
<td>123</td>
<td>7</td>
<td>3</td>
</tr>
<tr>
<td>K4308</td>
<td>102</td>
<td>6</td>
<td>3</td>
</tr>
<tr>
<td>K6303</td>
<td>71</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>K6304</td>
<td>62</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>K6305</td>
<td>80</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>K6306</td>
<td>69</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>K6307</td>
<td>62</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>K6308</td>
<td>78</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>K6402</td>
<td>191</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>K6403</td>
<td>75</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>K6404</td>
<td>92</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>K6503</td>
<td>56</td>
<td>3</td>
<td>1,5</td>
</tr>
<tr>
<td>K6504</td>
<td>67</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>K9007</td>
<td>102</td>
<td>6</td>
<td>3</td>
</tr>
</tbody>
</table>

Sampling map of the Kastela Bay sediments; red circles denote stations with moderately elevated $^{238}$U massic activities

- **moderately elevated activities**
  - at stations K43, K63, K64, K65 and K90
    - compared to AS: 3 – 10 times
    - compared to KS: 1,5 – 5 times

Comparison of moderately elevated $^{238}$U massic activities in Kastela Bay sediments with massic activities in typical Adriatic coastal sediments (AS) and in average Kastela Bay sediment (KS)
Comparison of very elevated $^{238}$U massic activities in Kastela Bay sediments with massic activities in typical Adriatic coastal sediments (AS) and in average Kastela Bay sediment (KS)

- very elevated activities
- only at station K90 (layers 1 – 6)
  - compared to AS: 22 – 33 times
  - compared to KS: 10 – 16 times

<table>
<thead>
<tr>
<th>Sample label</th>
<th>$^{238}$U (Bq/kg)</th>
<th>Elevated $^{238}$U massic activities</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Compared to AS</td>
</tr>
<tr>
<td>K9001</td>
<td>392</td>
<td>22</td>
</tr>
<tr>
<td>K9002</td>
<td>419</td>
<td>23</td>
</tr>
<tr>
<td>K9003</td>
<td>456</td>
<td>25</td>
</tr>
<tr>
<td>K9004</td>
<td>420</td>
<td>23</td>
</tr>
<tr>
<td>K9005</td>
<td>603</td>
<td>33</td>
</tr>
<tr>
<td>K9006</td>
<td>462</td>
<td>25</td>
</tr>
</tbody>
</table>

Sampling map of the Kastela Bay sediments; red circle denotes a station with very elevated $^{238}$U massic activities
CONCLUSION

- detectable anthropogenic influence
  - local discharge of the TENORM (coal bottom ash) into the sea
- only locally elevated $^{238}$U massic activities
  - five stations – around the Split peninsula and next to the “Adriavinil” factory
  - area around the factory is the most influenced
- Kastela Bay sediment has a naturally higher $^{238}$U activities than the tipical Adriatic coastal sediment
THANK YOU FOR YOUR ATTENTION!

QUESTIONS?