Multivariate analysis of release data and environmental monitoring data

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What

- A statistical study of correlations between releases and environmental concentrations
- A project conducted by Rolf Bergman Consulting
Aim of the study

- Investigate if there are correlations between measured releases and measured concentrations in the environment
- See how different species can work as indicators for releases
- Input for revision of the Swedish environmental surveillance programmes
Sites

- Oskarshamn, Forsmark and Studsvik:
  - Releases to water and air and corresponding species were analysed
  - Summarised here

- Ringhals
  - Only water releases and marine species were analysed
  - Not described here
Radionuclides

NPP:s
- Co-58
- Co-60
- Cs-137
- Zn-65
- Mn-54
- Fe-59

Studsvik
- Co-60
- Cs-134
- Cs-137
- Eu-152
- Eu-154
- Mn-54
Method – Multivariate analysis

- Statistical tool
- Many different variables
- Dependent variables
- Few observations (missing data)
- Further details
  - References
Results

- Quantifiable correlations between releases and environmental concentrations
- Several samples showed significant correlations and mathematical models were identified
- Models valid for activity within the interval that was used in the analysis
- Models can indicate deviations, e.g. when a non-monitored release has occurred
Results Oskarshamn

- Significant models for
  - Water: 5 of 6 nuclides, not Fe-59 (probably due to few data)
  - Air: Zn-65

- Sufficient to measure 1 variable
## Results Oskarshamn cont.

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Number of variables (n)</th>
<th>Prediction ability (%)</th>
<th>One variable (station species)</th>
<th>Prediction ability (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-58 water</td>
<td>3</td>
<td>91,7</td>
<td>S12_bladder wrack</td>
<td>76,7</td>
</tr>
<tr>
<td>Co-60 water</td>
<td>4</td>
<td>90,0</td>
<td>S12_bladder wrack</td>
<td>89,5</td>
</tr>
<tr>
<td>Cs-137 water</td>
<td>18</td>
<td>79,4</td>
<td>S17_bladder wrack</td>
<td>72,0</td>
</tr>
<tr>
<td>Mn-54 water</td>
<td>3</td>
<td>70,0</td>
<td>S12_bladder wrack</td>
<td>64,2</td>
</tr>
<tr>
<td>Zn-65 water</td>
<td>10</td>
<td>75,8</td>
<td>S1_yellow eel</td>
<td>59,6</td>
</tr>
<tr>
<td>Zn-65 air</td>
<td>4</td>
<td>76,3</td>
<td>SB_dryopteris filix-mas</td>
<td>71,4</td>
</tr>
</tbody>
</table>
Results Forsmark

- Significant models for
  - Water: 5 of 6 nuclides, not Fe-59 (probably due to few data)
  - Air: Co-60

- 1 variable models for all above except
  - Mn-54 to water
  - Co-60 to air

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### Results Forsmark cont.

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<th>Prediction ability (%)</th>
<th>One variable (station_species)</th>
<th>Prediction ability (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-58 water</td>
<td>3</td>
<td>96,7</td>
<td>S101_ongrowth</td>
<td>89,7</td>
</tr>
<tr>
<td>Co-60 water</td>
<td>11</td>
<td>85,9</td>
<td>S101_ongrowth</td>
<td>93,6</td>
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<tr>
<td>Cs-137 water</td>
<td>11</td>
<td>37,9</td>
<td>S101_ongrowth</td>
<td>72,9</td>
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<tr>
<td>Mn-54 water</td>
<td>2</td>
<td>64,9</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Zn-65 water</td>
<td>4</td>
<td>90,3</td>
<td>S104_bladder wrack</td>
<td>93,7</td>
</tr>
<tr>
<td>Co-60 air</td>
<td>2</td>
<td>86,2</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Results Forsmark cont.

Co-58 to water, station S101, ongrowth sample, prediction ability 89.7 %

\[ y = 1 \times -1.488 \times 10^{-6} \]
\[ R^2 = 0.906 \]
Results Studsvik

- Significant models for
  - Water: all nuclides
  - Air: Cs-134, Cs-137

- 1 variable models for all above except
  - Cs-134 to water and air
Conclusions

- Possible to identify the most reliable environmental samples to reflect releases
- In general, the more variables the better the prediction ability
  - Not always true
  - Cs-137 in Forsmark and Studsvik, can be due to Chernobyl fallout
Conclusions cont.

- Specific variables contribute significantly to the prediction of releases
  - Bladder wrack / fucus
  - In Forsmark also ongrowth samples

- Similar results for Ringhals
References

- Reports for Oskarshamn, Forsmark and Studsvik can be found on SSM:s website (in Swedish):
  - http://www.stralsakerhetsmyndigheten.se/Publikationer/Rapport/Stralskydd/2013/201312/
  - http://www.stralsakerhetsmyndigheten.se/Publikationer/Rapport/Stralskydd/2014/201414/
  - http://www.stralsakerhetsmyndigheten.se/Publikationer/Rapport/Stralskydd/2014/201415/

- Further information about the tools can be found at www.umetrics.com
Thank you for your attention!