



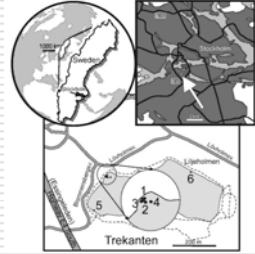
Exposure to contaminated sediments during recreational activities at a public bathing place

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Lake Trekanten

- Small lake contaminated by heavy metals and organic pollutants
- Only deep sediments in the middle of the lake have previously been investigated
- Concern about potential health risks during recreational activities
 - bathing
 - fishing



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A view from space



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Approach

- Sampling and chemical analysis
- Selection of exposure models
- Exposure factor data from literature and through observation studies and questionnaires
- Data analysis and exposure calculations
- Risk characterization

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Sampling

- 4 grab samples of sediment around the bathing place and 2 in other locations
- 6 water samples in the same locations



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Chemical analysis

- Initial screening (2006)
 - 16 elements
 - Organics (16 PAH, 7 PCB, 62 pesticides, and 115 other)
- New series (2007)
 - More sensitive methods (56 metallic elements and 16 PAH)



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Low levels of contamination around the bathing place

Concentrations of arsenic, chromium, and PAH as BaP-equivalents in sediments (mg/kg) at the bathing place and in lake water (mg/L)

| | n | Mean | SD | Min | Median | Max |
|------------------|---|--------|--------|--------|--------|--------|
| Sediments | | | | | | |
| As | 5 | 0.5 | 0.071 | 0.4 | 0.5 | 0.6 |
| Cr | 5 | 13 | 2.0 | 9.9 | 13 | 16 |
| BaP | 5 | 0.018 | 0.032 | 0.0033 | 0.0034 | 0.074 |
| Water | | | | | | |
| As | 6 | <0.01 | 0 | <0.01 | <0.01 | <0.01 |
| Cr | 6 | 0.11 | 0.033 | 0.050 | 0.11 | 0.15 |
| BaP | 6 | 1.0E-5 | 3.5E-6 | 7.0E-6 | 9.2E-6 | 1.5E-5 |



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Exposure factors

1. Concentration in water, mg/L (CW)
2. Concentration in sediment, mg/kg (CS)
3. Water intake while swimming, L/h (CR)
4. Exposure time, h/day (ET)
5. Exposure frequency, days/year (EF)
6. Exposure duration, years (ED)
7. Body weight, kg (BW)
8. Period over which exposure is averaged, days (AT)
9. Intake of sediment, mg/day (IR)
10. Conversion factor, 10^{-6} (CF)
11. Skin surface area, cm^2 (SA)
12. Sediment to skin adherence factor, mg/cm^2 (AF)
13. Absorption factor (ABS)



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Exposure model

- Oral intake of water

$$\frac{CW \times CR \times ET \times EF \times ED}{BW \times AT}$$

- Oral intake of sediment

$$\frac{CS \times IR \times CF \times EF \times ED}{BW \times AT}$$

- Dermal uptake

$$\frac{CS \times CF \times SA \times AF \times ABS \times EF \times ED}{BW \times AT}$$



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Deterministic exposure calculations for As and PAH

| | Oral intake | | Absorbed dose | | Total intake | |
|--|-------------|---------|---------------|---------|--------------|---------|
| | Best | RME | Best | RME | Best | RME |
| Arsenic | | | | | | |
| Exposure in age 1-13 years | 2.0E-07 | 1.0E-05 | 3.3E-08 | 1.6E-07 | 2.3E-07 | 1.1E-05 |
| Exposure in age 1-42 years | 2.3E-07 | 1.2E-05 | 4.3E-08 | 2.6E-07 | 2.8E-07 | 1.2E-05 |
| Exposure during 13 years as adult | 1.0E-08 | 5.1E-07 | 4.5E-09 | 3.7E-08 | 1.4E-08 | 5.5E-07 |
| Exposure during 42 years as adult | 3.2E-08 | 1.7E-06 | 1.4E-08 | 1.2E-07 | 4.7E-08 | 1.6E-06 |
| Exposure during a whole life-time (1-80 years) | 2.6E-07 | 1.4E-05 | 5.6E-08 | 3.7E-07 | 3.2E-07 | 1.4E-05 |
| BaP-equivalents | | | | | | |
| Exposure in age 1-13 years | 1.8E-09 | 5.8E-08 | 2.5E-09 | 9.6E-08 | 4.4E-09 | 1.5E-07 |
| Exposure in age 1-42 years | 2.1E-09 | 6.8E-08 | 3.3E-09 | 1.4E-07 | 5.4E-09 | 2.1E-07 |
| Exposure during 13 years as adult | 1.1E-10 | 3.3E-09 | 3.4E-10 | 2.0E-08 | 4.5E-10 | 2.3E-08 |
| Exposure during 42 years as adult | 3.5E-10 | 1.1E-08 | 1.1E-09 | 6.4E-08 | 1.5E-09 | 7.4E-08 |
| Exposure during a whole life-time (1-80 years) | 2.5E-09 | 7.7E-08 | 4.3E-09 | 2.0E-07 | 6.8E-09 | 2.8E-07 |

Intake equal to a cancer risk of $1E-6$; As=6E-6 and BaP 8.3E-7 mg/kg-day.



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Preliminary conclusion

- Intake of chromium was far below the TDI of 1.5 mg/kg-day
- The RMEs for arsenic are twice the risk-based daily intake for those living in the vicinity as children
 - Substantial uncertainty in the intake estimates is due to the non-detects in lake water
 - The RMEs were estimated assuming water concentrations at the detection limit, which is likely to exaggerate the maximum exposure
- The RMEs for benzo[a]pyrene are below the risk-based daily intake



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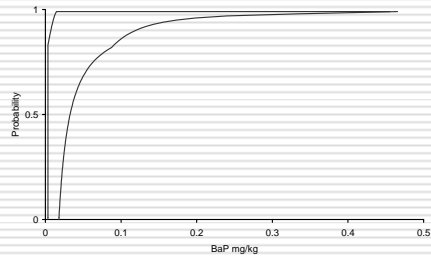
Probability bounds analysis

- The deterministic intake calculations for BaP-equivalents were supplemented by probabilistic estimates
- Available information was used to specify p-boxes
 - A p-box is a class of distribution functions $F(x)$ bounded by two cumulative distribution functions $F_1(x)$ and $F_2(x)$ such that $F_1(x) \leq F(x) \leq F_2(x)$ for all x
 - Available pieces of information (min, max, statistics, and percentiles) is used to construct constraints for the class of possible distributions



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A p-box for BaP-equivalents in sediments



Minimum = 0.0033, mean = 0.018, standard deviation = 0.032

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Other exposure factors

| Exposure factor | Probability box |
|---|---|
| BaP-equivalent conc. in sediment, CS (mg/kg) | CSBaP: minimum = 0.0033, mean = 0.018, standard deviation = 0.032 |
| BaP-equivalent conc. in water, CW (mg/kg) | CWBaP: minimum = 7.0E-06, mean = 1.0E-05, standard deviation = 3.5E-06 |
| Absorption factor, ABS (-) | ABS = [0, 0.13] |
| Sediment to skin adherence factor, AF (mg/cm ²) | AFchild: minimum = 0.1, maximum = 2, mean = [0.36, 1.17] AFadult: minimum = 0.01, maximum = 1, mean = [0.07, 0.39] |
| Exposure frequency, EF (days/year) | EFchild: minimum = 3.5, maximum = 70, mean = 32 EFadult: minimum = 2, maximum = 70, mean = 16 |
| Exposure time, i.e. time spent in water, ET (h/day) | ETchild: minimum = 0.1, maximum = 4, mean = 1 ETadult: minimum = 0.1, maximum = 2, mean = 0.5 |
| Intake of sediment, children, IR (mg/dag) | IRchild: minimum = 5, maximum = 400, mean = 200 IRadult: minimum = 1, maximum = 100, mean = 50 |

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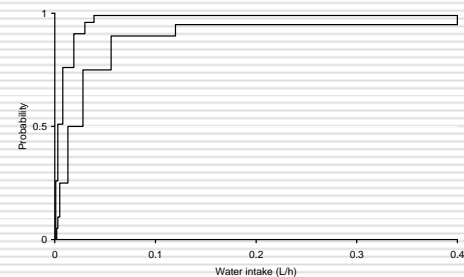
Detailed information

| Statistic | Value or interval |
|--------------------|-------------------|
| Minimum | 0.001 |
| Maximum | 0.4 |
| Mean | [0.016, 0.045] |
| Standard deviation | [0.023, 0.164] |
| 5th percentile | [0.001, 0.002] |
| 10th percentile | [0.001, 0.003] |
| 25th percentile | [0.003, 0.005] |
| 50th percentile | [0.008, 0.013] |
| 75th percentile | [0.019, 0.028] |
| 90th percentile | [0.030, 0.056] |
| 95th percentile | [0.039, 0.120] |

- Eleven statistics defining a p-box for the intake of water by female adults during swimming
- Such detailed information was available for body weight, skin surface area, and water intake

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The p-box for water intake



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Independence between factors?

- Most exposure factors can be assumed to be independent
- Exceptions, where dependence is likely:
 - Body weight and skin surface area
 - Body weight and intake estimates
 - Skin surface area and sediment intake
 - Skin adherence factor and absorption factor

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Uncertainty in intake

- This risk-based comparison value for benzo[a]pyrene is 8.3E-7 mg/kg-day
- The comparison value is slightly exceeded only when partial dependencies are assumed

| Exposure duration | Independence | | Partial dependencies | |
|-------------------|--------------------|--------------------|----------------------|--------------------|
| | Median | 95th percentile | Median | 95th percentile |
| Age 1-6 years | [1.1E-11, 1.9E-08] | [1.5E-10, 1.8E-07] | [3.0E-12, 7.2E-08] | [2.1E-11, 5.6E-07] |
| Age 1-13 years | [1.7E-11, 3.7E-08] | [2.4E-10, 3.5E-07] | [4.3E-12, 1.4E-07] | [3.1E-11, 9.9E-07] |
| 13 years as adult | [5.2E-13, 3.9E-09] | [6.2E-12, 4.8E-08] | [2.2E-13, 3.3E-08] | [1.6E-12, 2.7E-07] |
| 42 years as adult | [1.7E-12, 1.3E-08] | [2.0E-11, 1.5E-07] | [7.2E-13, 1.1E-07] | [5.2E-12, 8.8E-07] |

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Discussion

- Recreational and outdoor activities are important to the well-being of people in urban areas
- We expect that the general outline of this assessment and the exposure factors herein can be reused to assess similar exposure situations elsewhere
- For example, this investigation indicates that beach visitors spend less time at the beach and in the water as compared to the standard assumptions

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Discussion cont.

- The oral intake constitutes a major part of the exposure to metals, highlighting the importance of correctly estimating the intake of sediment and water
- Skin absorption is assumed to account for major uptake of PAH, however, the absorption factors could be overestimated
- Further experimental investigations are therefore needed

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Discussion cont.

- The application of probability bounds analysis enabled a full description of uncertainty and variability in the exposure assessment from the data available
- It is interesting to note that the upper bounds of the uncertainty are at least twice the point estimates
- The probabilistic method thus seems better suited to provide a conservative and protective exposure estimate

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Conclusions

- A general conclusion from this study is that currently the contamination in the deeper part of the lake should not cause concern for using the public bathing place
- *The exposure for polycyclic aromatic hydrocarbons and metals while bathing in Lake Trekanten, at the presently measured levels, cannot be anticipated to cause any significant adverse influence on public health*

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Conclusions cont.

- Changes in the deep sediments and a subsequent release of toxic materials could occur if the redox conditions are altered or if the sediments are physically disturbed
- A long-term monitoring of the contamination in the lake therefore seems justified
- Fishing is another important recreational activity that could contribute to the exposure, but this route is not covered here

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Thank you for your attention!



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