GAPRAD - Filling knowledge gaps in radiation protection methodologies for non-human biota

NKS-B

Justin Brown
Norwegian Radiation Protection Authority

Armémuseum, Stockholm, 26th - 27th March 2009

The Talk plan

- Background and rationale
- Identifying data gaps
- Aquatic study
- Terrestrial study
- Po in man
- Conclusions

The Activity

- Started May 2007, Completed December 2008
- Involved :
  - Norwegian Radiation Protection Authority, (Runhild Gjelsvik)
  - University of Lund in Sweden, (Elis Holm)
  - RISØ national laboratory in Denmark (Per Roos)
  - Nuclear Safety Authority (STUK) in Finland (Ritva Saxen + Iisa Outola)
- Total Budget (NKS-supported)
  - 150 KDKK in 2007
  - 260 KDKK in 2008

Environmental Impact Assessment

- Substantial efforts have been made over the last decade or so in the development of frameworks to allow impact assessments for the environment to be conducted including :
  - International Commission on Radiological Protection – Committee 5.
  - EC-EURATOM project “Environmental Risk from Ionising Contaminants: Assessment and Management”
- The frameworks generally have transfer, dosimetric and effects analyses components.

ICRP

- Developing a system to assess the impact on wild flora and fauna explicitly (ICRP, 2003)
  - Has been included in a chapter of the basic recommendations
  - Committee 5
- Draws on the methodologies developed in ERICA (but also elsewhere)
  - Main focus on developing concept of reference animals and plants
  - Dosimetry (Task Group) – DCC intercomparison
  - Transfer : work in progress

ICRP (2003). A framework for assessing the impact of ionising radiation on non human species. Annals of the ICRP, 91, pp.201-266.

ERICA

- Risk assessment methodology - completed : March 2007 – new datasets available for analyses
  - Time to ”take stock” : where are there weaknesses/problems in the approach ?
- Considerations :
  - Uses reference organisms – ‘*a series of entities that provide a basis for the estimation of radiation dose rate. These estimates, in turn, provide the basis for assessing the likelihood and degree of radiation effects to a range of organisms which are typical, or representative of a contaminated environment*.’
  - Transfer considered using CRs (terrestrial, freshwater + marine)
  - Points of reference may be used for the purpose of assessing the potential consequences of exposures to radiation on non-human biota. These are (a) natural background dose rates and (b) dose rates known to have specific biological effects on individual organisms (Pentreath, 2002).

Pentreath, R.J. (2002). Radiation protection of people and the environment: developing a common approach. *J. Radiol. Prot.* **22**: 45-56.

Reference organisms

Soil Invertebrate (earthworm)	Detritivorous invertebrate	**Flying insects (Bee)**
Gastropod	Lichen & bryophytes	**Grasses & Herbs (Wild grass)**
Shrub	**Tree (Pine tree)**	**Mammal (Rat)**
Mammal (Deer)	**Bird (Duck)**	**Bird egg (Duck egg)**
Reptile	**Amphibian (Frog)**	

Phytoplankton	Vascular plant	Zooplankton
Insect larvae	Bivalve mollusc	Gastropod
Crustacean	Benthic fish	**Pelagic fish (Salmonid/trout)**
Bird (Duck)	Mammal	**Amphibian (Frog)**

What was evident in analysing background and transfer data?

- Numerous data deficiencies were uncovered, especially in the cases of terrestrial, brackish and freshwater environments.
  - For example, there were no activity concentration data available on natural series radionuclides in freshwater amphibians, birds and mammals even at the global level. Po-210 transfer factors for soil invertebrates are entirely uncharacterised and currently recourse must be made to other quite unrelated organism types to provide even an indication of possible biota contamination levels. A similar situation is the case for isotopes of Pu.
- It was evident that some of these data deficiencies could be easily mitigated with limited, but focussed, effort involving field-work and analysis.

Initial Activity objectives

- To establish where data gaps (or limited data) exist in relation to natural background activity concentrations and transfer
- Devise focussed studies to fill some gaps.
- Summarise these in a report

Aquatic data coverage

CR data coverage for freshwater reference organisms **conducted within ERICA** and adapted from Hosseini et al. (2008). The grey cells denote – no data

Element	Cs	Pu	Ra	Po	U	Th	Pb
Benthic fish	N≥20	N≥20	10<N<20		10<N<20	N<10	
Pelagic fish	10<N<20	N≥20	10<N<20	10<N<20	10<N<20	N<10	
Vascular plant	N≥20	N<10	10<N<20	N<10	N<10	N<10	
Bivalve mollusc	10<N<20		N<10	N<10			
Insect larvae							
Phytoplankton	10<N<20	N<10	N<10	N<10	N<10		
Amphibian	N<10						
Crustacean	N<10	N<10	N<10	N<10	N<10		
Gastropod	N<10		N<10	N<10			
Zooplankton	N<10	N<10			N<10		
Bird	N<10						
Mammal							

Hosseini, A., Thørring, H., Brown, J.E., Saxén, R., Ilus E. (2008).Transfer of radionuclides in aquatic ecosystems – Default concentration ratios for aquatic biota in the ERICA Tool. Journal of Environmental Radioactivity, Volume 99, Issue 9, Pages 1408-1429.

Terrestrial data coverage

- CR data coverage for terrestrial reference organisms **conducted within ERICA** and adapted from Beresford et al. (2008). The grey cells denote – no data.

Element	Cs	Pu	Po	Ra	U	Pb	Th
Soil Invertebrate (Worm)	N ≤ 20	N ≤ 20			N = ?	N > 20	
Detritivorous invertebrate	N > 20	N > 20		N = ?		N > 20	
Flying insects	N > 20	N > 20				N ≤ 20	
Gastropod	N ≤ 20	N ≤ 20		N ≤ 20		N > 20	
Lichen & bryophytes	N > 20		N ≤ 20	N ≤ 20	N = ?	N > 20	N ≤ 20
Grasses & Herbs	N > 20	N > 20	N > 20	N > 20	N > 20	N > 20	N ≤ 20
Shrub	N > 20		N ≤ 20	N ≤ 20	N > 20	N > 20	N = ?
Tree	N > 20		N ≤ 20	N ≤ 20	N > 20	N > 20	N > 20
Mammal (Rat)	N > 20	N > 20	N > 20	N > 20	N ≤ 20	N > 20	N ≤ 20
Mammal (Deer)	N > 20	N > 20	N > 20	N > 20	N ≤ 20	N > 20	N ≤ 20
Bird	N > 20			N > 20	N = ?	N > 20	N = ?
Bird egg	N = ?						
Reptile	N ≤ 20						
Amphibian	N > 20					N > 20	

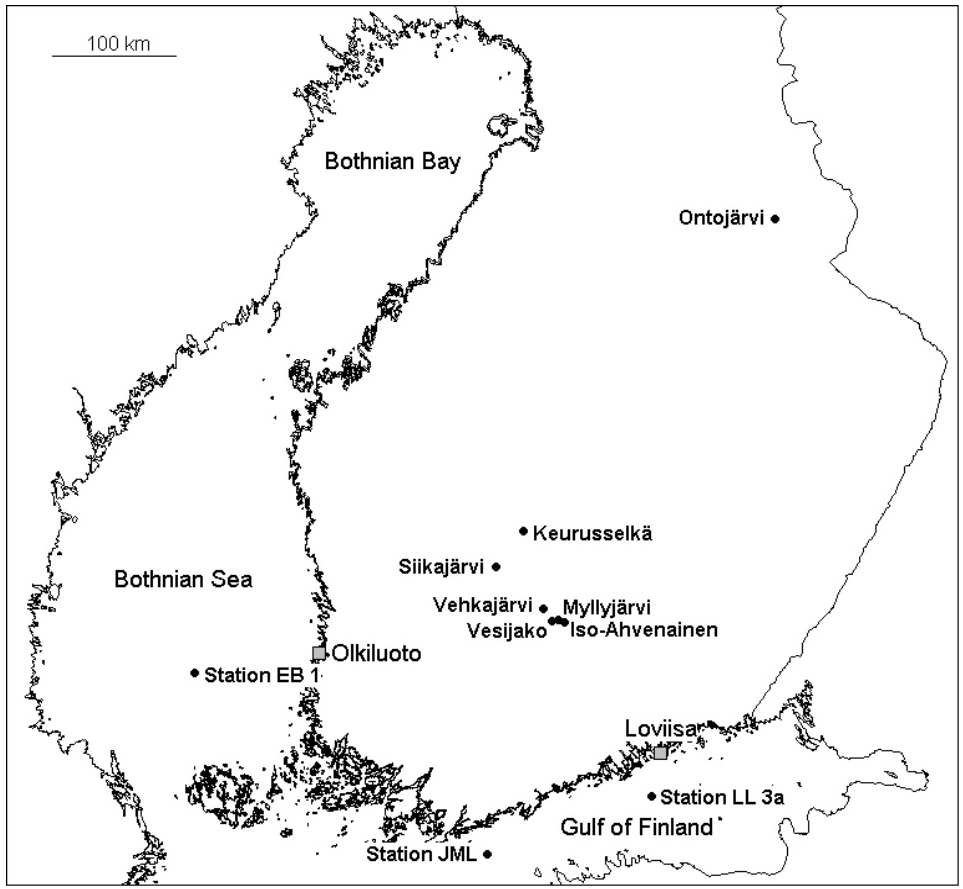
Beresford, N.A., Barnett, C.L., Howard, B.J., Scott, W.A., Brown, J.E., D. Copplestone (2008). Derivation of transfer parameters for use within the ERICA Tool and the default concentration ratios for terrestrial biota. Journal of Environmental Radioactivity, Volume 99, Issue 9, Pages 1393-1407.

Activity objectives – 2nd phase

- Collated new information on
  - Natural radionuclides (U-238, U-234, Ra-226, Ra-228, **Po-210, Pb-210**) in biota brackish waters and sediments
  - Po-210 in soil fauna, small mammals and soil
- Furthermore, to attain new information on gastrointestinal update and residence time in mammals (using "man" as the reference species) through experimentation.

Aquatic study

- Lake water and fish for ^{210}Po and ^{210}Pb analyses were sampled in 2007 from four lakes: Iso-Ahvenainen, Myllyjärvi, Vesijako and Miestämä.
- Five fish species were studied: perch (*Perca fluviatilis*), pike (*Esox lucius*), bream (*Abramis brama*,), white fish (*Coregonus lavaretus*) and vendace (*Coregonus albula*). Lake mussel (*Anodonta sp*) and water samples were collected from lake Keurusselkä in 2007.
- Fish samples from various parts of the Baltic Sea and from lakes, belonging to the monitoring programme of STUK in 2005, were analysed for Po and Pb.
- A benthic isopod *(Saduria entomon)* and a bird, swan *(Cygnus olor),* were collected from the environments of Finnish nuclear power plants in Loviisa.



Aquatic study main results I

Activity concentrations of ^{210}Po and ^{210}Pb in freshwater fish in 2007.

Fish	Lake	Parts analyzed	dry matter %	^{210}Po Bq/kg f.w. ± unc %	^{210}Pb Bq/kg f.w. ± unc %
Perch	Vesijakojärvi	edible parts	27,67	0,139 ± 19	0,057 ± 17
		other parts	33,72	3,632 ± 18	0,161 ±17
		whole fish		**1,345**	**0,093**
Pike	Myllyjärvi	edible parts	22,22	0,939 ± 18	0,075 ± 18
Pike	Iso-Ahvenainen	edible parts	22,29	0,428 ± 18	0,045 ± 18
Pike	Vesijako	edible parts	21,70	0,664 ± 18	0,115 ± 18
		other parts	25,45	2,905 ± 18	0,140 ± 17
		whole fish		**2,152**	**0,132**
Pike	Vesijako	edible parts	23,59	1,157 ± 18	0,056 ± 18
Pike-perch	Vesijako	edible parts	23,49	0,079 ± 22	0,014 ± 19
		other parts	33,27	1,492 ± 18	0,123 ± 17
		whole fish		**1,015**	**0,086**
Bream	Iso-Ahvenainen	edible part	22,14	0,138 ± 19	0,053 ± 19
Bream	Myllyjärvi	edible parts	20,01	0,380 ± 18	0,130 ± 18
		other parts	28,69	8,950 ± 18	1,507 ± 16
		whole fish		**6,532**	**1,119**
Bream	Vesijako	edible part	21,68	0,860 ± 19	0,047 ± 17
Vendace	Vesijako	edible part	24,8	1,863 ± 19	0,697 ± 16
Whitefish	Iso-Ahvenainen	edible part	25,31	0,157 ± 20	0,030 ± 18

- Whole fish > edible
- Po-210/Pb-210 from 5-15; high relative to earlier review (Parfenov, 1974)

Parvenov, Y.D. (1974) Polonium-210 in the environment and in the human organism. At. Energy Rev., 12, pp.75-143.

Aquatic study main results II

	CR, ^{210}Po		CR ^{210}Pb	
Organism	**GAPRAD study**	**ERICA**	**GAPRAD study**	**ERICA**
fish	**670 - 5300**	44000±120000* 240**	***13-84***	4400±14000* 300**
crustacean	**>9300**	56000±66000* 9900 ±1400**	***770***	7500±2100* 7500**
bird	**>510**	30000* 240**	***190***	19000* 300**

Brackish water

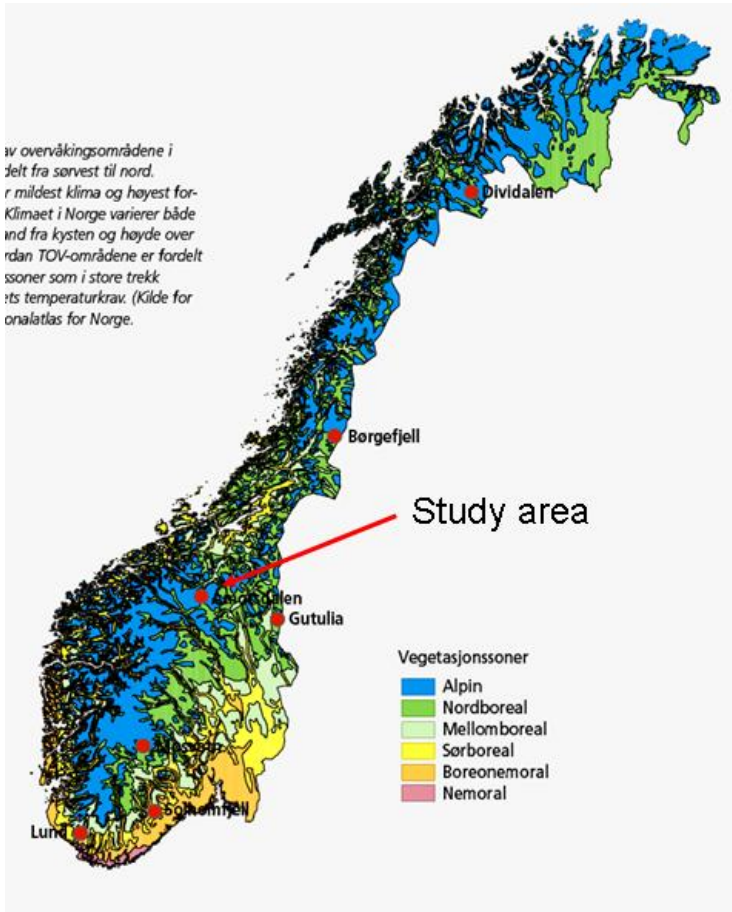
* marine; ** freshwater

	CR, ^{210}Po		CR ^{210}Pb	
Organism	**GAPRAD study**	**ERICA**	**GAPRAD study**	**ERICA**
fish benthic	**630-9250**	240	**16-340**	300
mollusc bivalve	**1740**	38000±49000	**530**	1400

Freshwater

- Brackish - ^{210}Po CRs fall towards the lower end of aquatic CR data from the ERICA databases; ^{210}Pb CR data are below ERICA values for all organism types.
- Freshwater - CRs for ^{210}Po in the GAPRAD study appear to be somewhat higher for benthic fish and somewhat lower for bivalve mollusc than those contained within the ERICA databases.

Polonium in terrestrial environment



Dovre, Central part of Norway during the period 17-20th June 2007

Sampling I

- Eight soil profiles were collected during the field expedition. These profiles were split into an overlying humus layer and thereafter 3 cm (predominantly mineral soil) increments to a depth of 9 cm using a custom-designed soil corer.

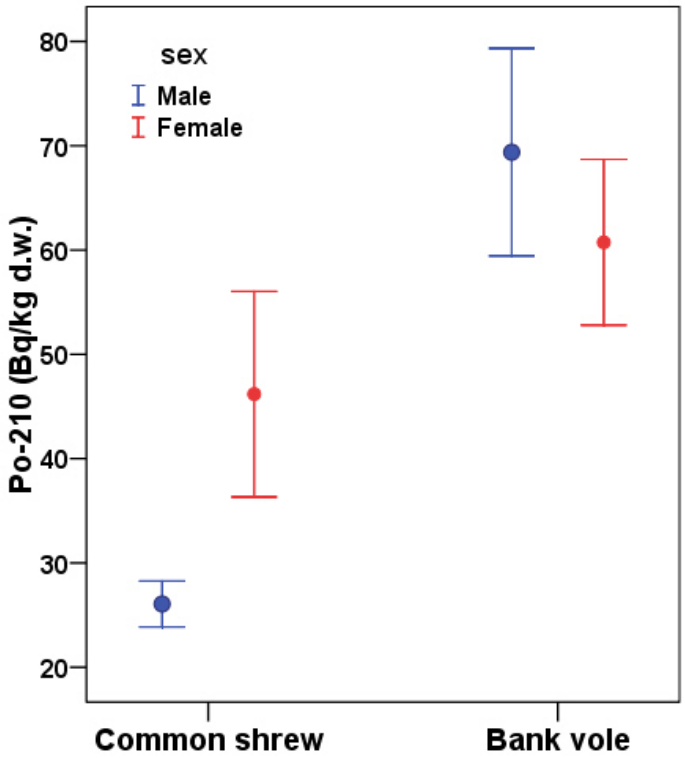
Samples of bilberry and lichen collected by hand
Two earthworm species were collected in areas of brown earth using a spade in the period 07-17 June 2007.

Sampling II

- Baited traps were used in the collection of various small mammals including Bank Vole (*Clethrionomys glareolus*) and the Common Shrew (*Sorex araneus*).

Small mammals – results and stats test

- 39 – 85 Bq kg^{-1} d.w. ^{210}Po for bank vole (n=8) and 20 – 83 Bq kg^{-1} d.w. ^{210}Po for the common shrew (n=9)
- non-parametric Mann-Whitney test has been applied in order to determine whether the shrew and vole data are statistically different.
- null hypothesis (that the 2 dataset have been taken from a common population) can be rejected at the $p < 0.011$ level
- Pb-210 levels low; mostly unsupported Po-210; high Po-210:Pb-210 ratios
- These activity concentrations are considerably higher than the levels reported earlier



Polonium in man - background

- Aim : to establish radiobiological parameters, important in dosimetry, such as fractional uptake parameter gastrointestinal absorption factors f1 and biological retention times of radioisotopes Po-209 and Po-210 in the body
- Gastrointestinal absorption factors have been established in earlier studies with a wide range of results
  - ICRP has increased their reported f1 from 10% (1979) to 50% (1993)
  - Caribou meat ➔ 0.56±0.04 (Thompson et al., 2001)
  - Hunt *et al* (1993) reported f1 values in the range of 0.6-0.94 with a mean of 0.76 for ingestion of crab meat

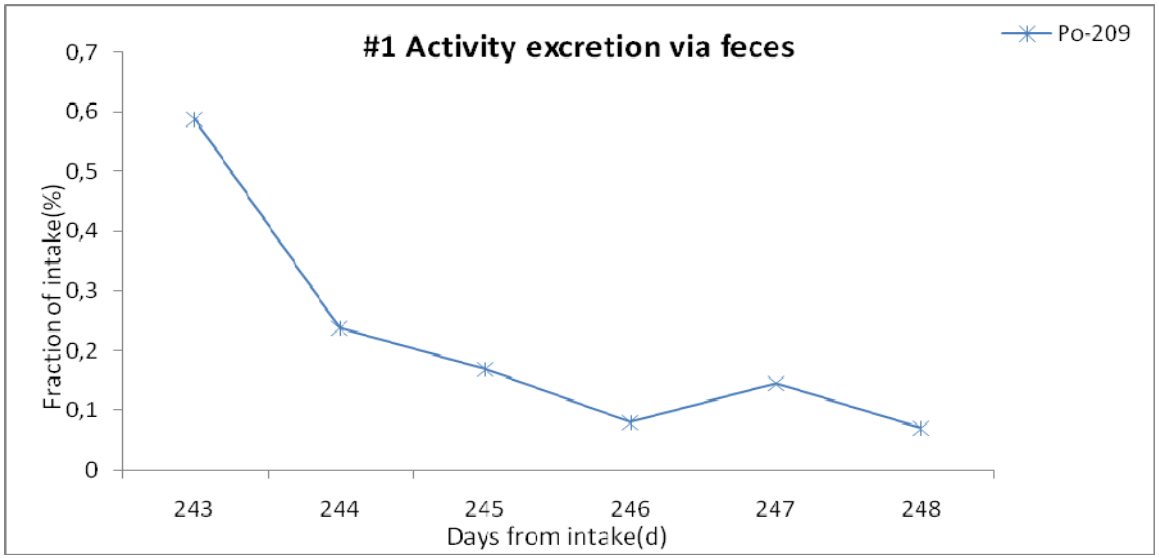
Thomas, P. A., Fisenne, I., Chorney, D., Baweja, A.S., Tracy B. L.(2001). Human absorption and retention of Polonium-210 from caribou meat. Radiation Protection Dosimetry vol. 97, No. 3 pp. 241-250 (2001) Nuclear Technology Publishing.

Hunt, G.J. & Allington, D.J. (1993), Absorption of environmental Polonium-210 by the human gut. Journal of Radiological protection vol. 13 No 2 119-126.

Polonium in man - experimental

- **Expt 1** : One person was given 50 mBq of Polonium 209 with an oral intake frequency of 24 hours
  - Continue intake frequency until constant radioactive output from urine and feces was maintained, i.e. equilibrium
  - 24h urine samples were collected a few times every month until 320 days from the first intake.
  - the intake of ^{209}Po and urine sampling stopped and 24h faeces sampling for a week begun
- **Expt 2 :** Acute oral intake to two persons of 10 Bq and then study the immediate body burden response by spectrometric analysis of urine and feces.

Polonium in man - results



- slow decreasing excretion of ^{209}Po in faeces in the range 0.59%-0.07% of consumed activity.
- Urine samples analysis showed a fluctuating value of ^{209}Po excretion with a maximum peak value of about 1 % 40 days from the first intake

- In the acute oral intake study, the maximum daily excretion rates in faeces of 18-50 % can be measured 3 days after intake

- **A GI factor of 0.50-0.75 was derived from analyses of data ➔ correlate well with recent biokinetic studies of polonium in man.**

Conclusions

- GAPRAD has provided some new data for the provision of more robust radionuclide transfer prognoses and background dose-rates. These include :
  - Freshwater : ^{210}Po and ^{210}Pb activity concentrations and CRs for fish, benthic invertebrates and birds ➔ values in available EIA databases may need to be modified.
  - Terrestrial : ^{210}Po and ^{210}Pb activity concentrations in small mammals (+ other components vegetation, soil invertebrates) ➔ levels considerably greater than anticipated.
- Studies of Po in man
  - Not directly related to EIA but may provide useful additional information for parametrisation of biokinetic models for the environment.
- **End Users** : The proposed end-users are first and foremost the radiation protection authorities in the participating Nordic countries. The new data sets developed in this study will fill knowledge gaps and provide more robust underpinning scientific data to support impact assessments.

References

- NKS (2009) *Knowledge gaps in relation to radionuclide levels and transfer to wild plants and animals, in the context of environmental impact assessements, and a strategy to fill them.* J.E. Brown (ed.):
- NKS (2009) *Po-210 and other radionuclides in terrestrial and freshwater environments.* Runhild Gjelsvik and Justin Brown (editors):
- NKS (2009) – Final Report.
- Brown, J.E., Gjelsvik, R., Kålås, J.A. & Roos, P. (2008). Background radiation dose-rates in a high mountain habitat in Norway. In : Proceedings from the International Conference on Radioecology and Environmental Radioactivity (Poster Proceedings - Part 1), Bergen, Norway 15-20th June 2008, Strand, P., Brown J. & Jølle T. (Eds). Norwegian Radiation Protection Authority, Østerås, Norway, pp. 181-184.