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Hot Particle Dosimetry
Does it really matter?

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STAR Workshop

Corynne McGuire, SEPA

Hot Particles

- Radioactive particles are defined as a localised aggregation of radioactive atoms that give rise to an inhomogeneous distribution of radionuclides significantly different from that of the matrix background (IAEA, 2011)

- Hot particles deliver a radiation dose to a small area rather than in a diffuse manner.

Exposure pathways

- Ingestion
- Skin contact
- Inhalation
- Direct radiation

Particular to particles:

- Stuck on the body, under finger nails etc.
- Single one off high dose events, potential for deterministic effects

When hot particles could occur

- Practices
  - Nuclear fuel cycle (e.g. Dounreay, Sellafield)
  - NORM scale from oil and gas industry
- Existing situations/ historical
  - Nuclear weapons testing
  - Dalgety Bay
- Emergency situations
  - Reactor accidents (e.g. Chernobyl, Fukushima)

Risks from internal emitters

- There is some dispute over whether or not hot particles within the body are more dangerous than external emitters delivering the same dose of radiation in a diffused manner.

- The Committee Examining Radiation Risks of Internal Emitters (CERRIE) carried out a review into the risks of internal emitters but the study failed to reach consensus

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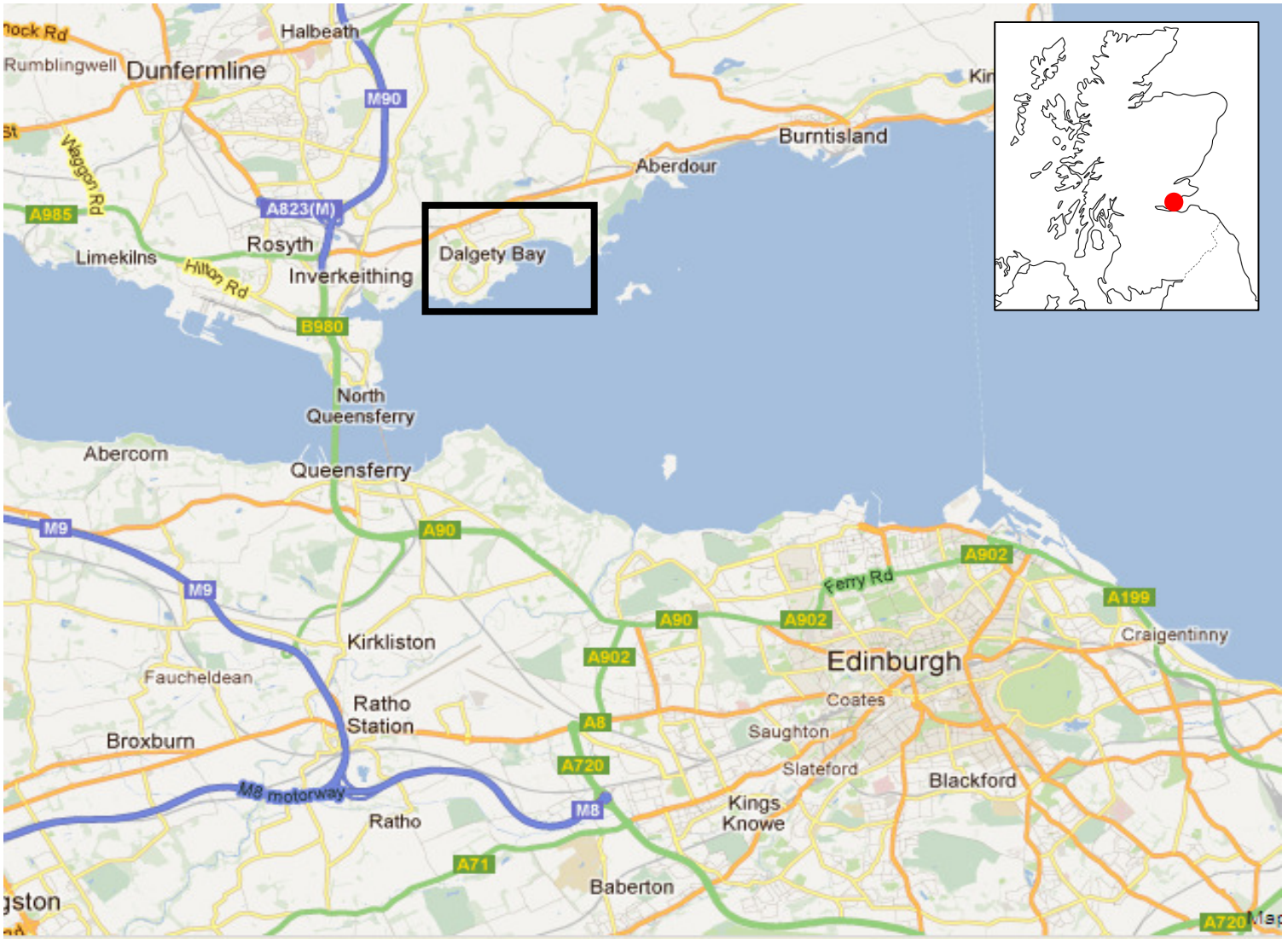
An example - Dalgety Bay



History of the site

- Dalgety Bay is the site of a former MoD airfield (RNAS Donibristle/HMS Merlin)
- Site was operational between 1917 – 1959
- Main role was as an aircraft repair, re-fitting and salvage yard
- Ra-226 used in paint for dials and other instruments in aircraft
- There is evidence that waste material from the aircraft was incinerated and subsequently disposed of on site

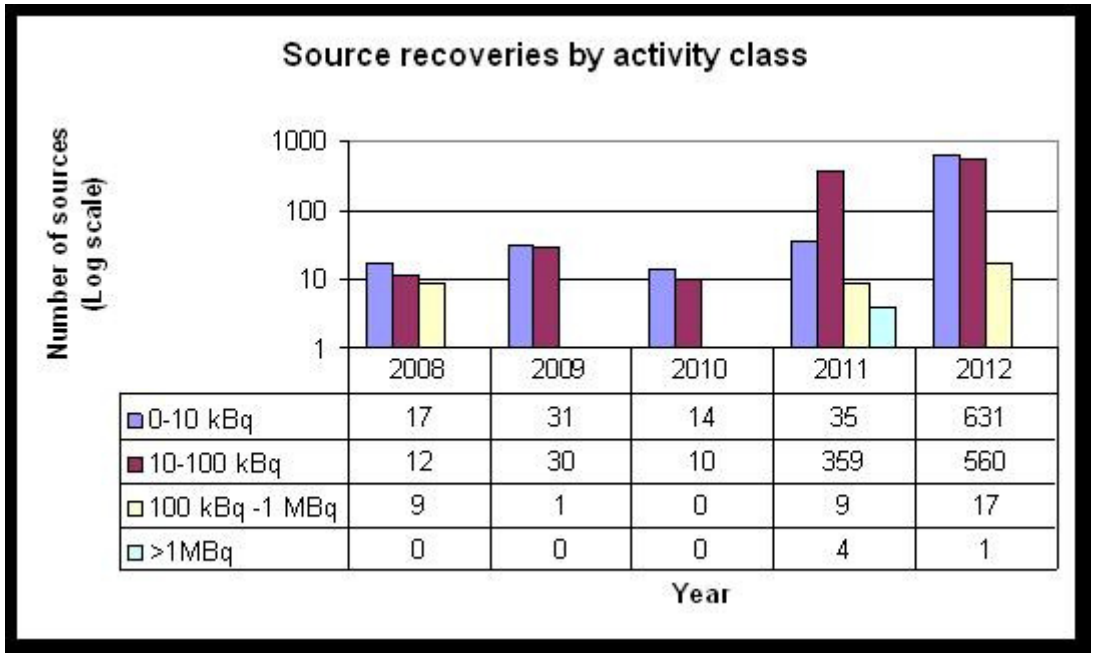
RNAS Donibristle/HMS Merlin

Dalgety Bay


Fife Coastal Path
Firth of Forth
SSSI/SPA/Ramsar
site
Moray Way
The Spinneys
Inchcolme
Vet Service
The Spinneys
The Wynd
Moray Way
Glamis Gardens
Glamis Pl
The Beeches
The Knowe
The Wynd
The Coach
House
Donibristle Gardens
Sailing Club

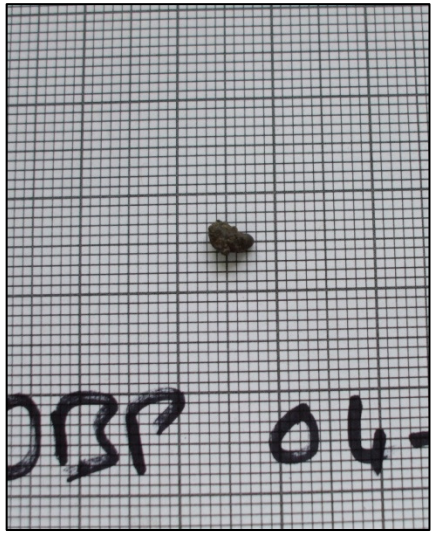
Particle Characterisation

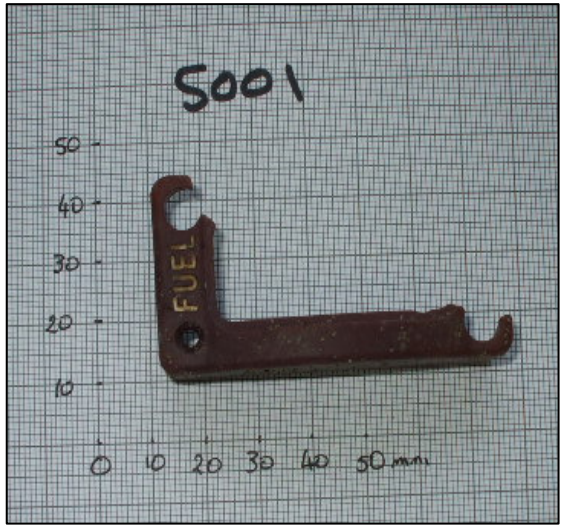
- Particles ranged from the size of a grain of sand to large lumps of clinker
- Activities ranged from 10kBq to 76MBq
- Some particles were breaking down

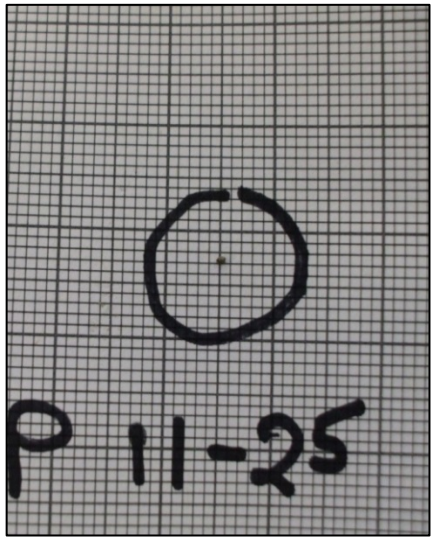


	2008	2009	2010	2011	2012
0-10 kBq	17	31	14	35	631
10-100 kBq	12	30	10	359	560
100 kBq -1 MBq	9	1	0	9	17
>1MBq	0	0	0	4	1

Range of particles







Doses from inadvertent ingestion

Table 3: Doses arising from ingestion of a source with maximum solubility (to 2 sf)

Solubility =	35.78 %	Dose mSv					
Original Activity (Bq)	Activity in sol. (Bq)	3 months	1 year	5 years	10 years	15 years	Adult
1,000	357.8	14	4.8	2.	1.9	1.8	0.78
10,000	3,578	140	48	26	19	18	7.8
100,000	35,780	1,400	480	260	190	180	78
1,000,000	357,800	14,000	4800	2600	1900	1800	780

Table 4: Doses arising from ingesting a particle of given activity with mean solubility of 7.59%

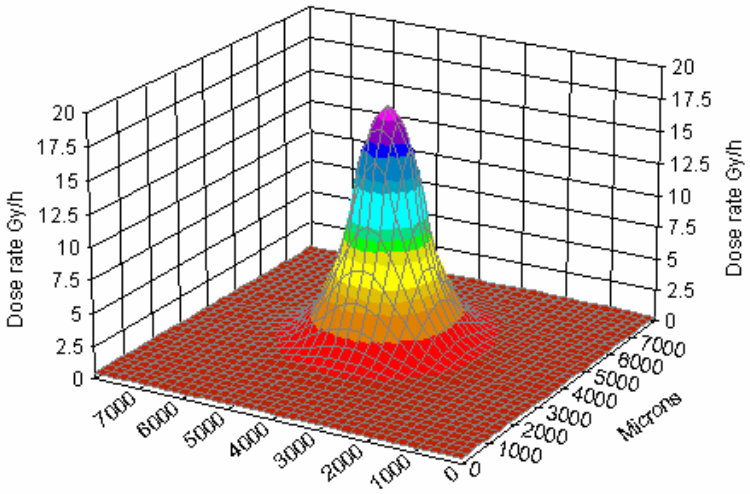
Solubility =	7.59 %	Dose mSv					
Original Activity (Bq)	Activity in sol. (Bq)	3 months	1 year	5 years	10 years	15 years	Adult
1,000	75.9	3	1	0.55	0.40	0.38	0.16
10,000	759	30	10	5.5	4.0	3.8	1.6
100,000	7,590	300	100	55	40	38	16
1,000,000	75,900	3000	1000	550	400	380	164

Skin Contact

Table 8 Dose rate for Dalgety Bay sources

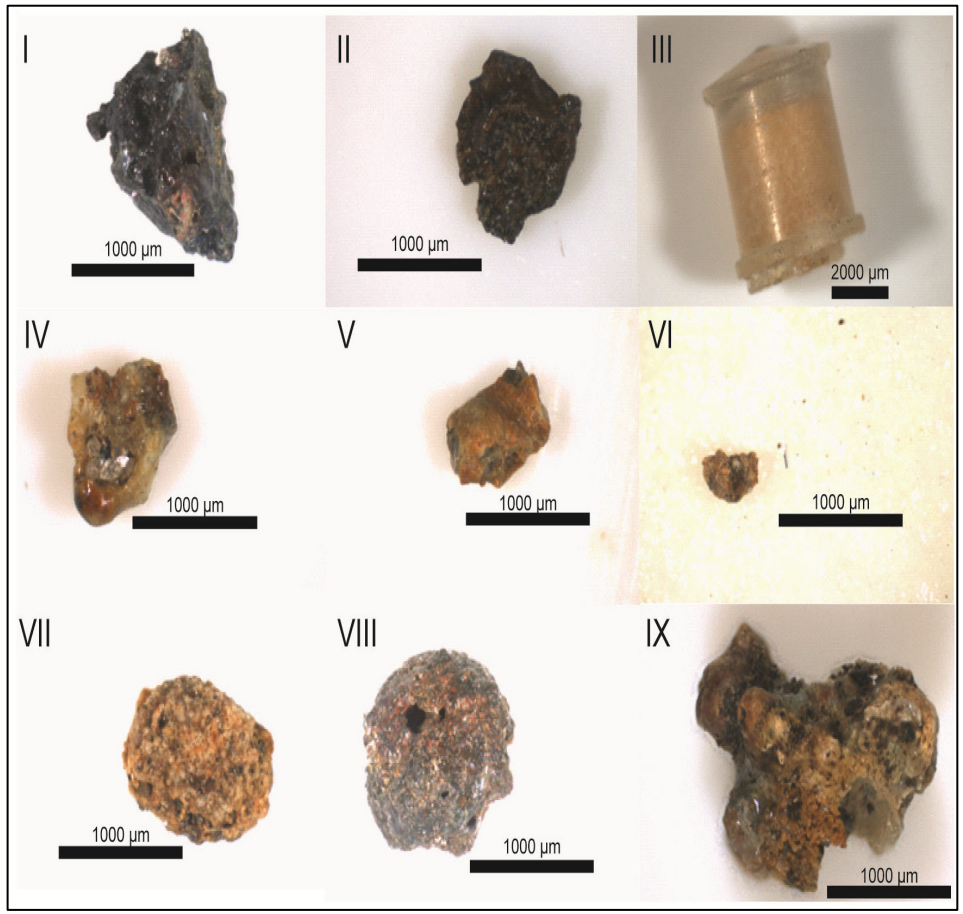
Activity	Dose rate	Time to:			
^{226}Ra Bq	Gy h^{-1}	ICRP limit (public) 50mSv	ICRP limit (workers) 0.5Gy	Threshold 2 Gray	ED_{50} 10 Gray
100,000,000	≥100	≤2 seconds	≤18 seconds	≤ 72 seconds	≤ 6 minutes
10,000,000	≥10	≤18 seconds	≤3 minutes	≤12 minutes	≤1 hour
1,000,000	1	3 minutes	30 minutes	2 hours	10 hours
100,000	0.1	30 minutes	5 hours	20 hours	4 days
10,000	0.01	5 hours	2 days	8 days	6 weeks
1,000	0.001	2 days	3 weeks	2 months	1 year

Integration over 1cm^2 may not be appropriate for particles which are physically smaller



Inhalation

- Inhalation pathway not thought to be significant at present
- However, particle breakdown may lead to smaller particles being produced



Habits survey

In order to undertake a risk assessment a habits survey was conducted in the Dalgety Bay area to determine:

- How long people spend in the area;
- Activities they undertake in the area

Combining the habits data with the particle hazard data allowed us to calculate the probability of a person coming into contact with a particle

Chance of encounter

Table 20. Chance of contact with a higher activity source (1 in….) per year			
	Inadvertent Ingestion	Skin contact (wet and dry)	Overall – all pathways
Adults	3 million	494	334
Children	7 million	2280	1640
Infants	1.1 million	4185	2317

Overall chance of contact (all users, 1 in …..) per year. For higher activity sources only			
	Inadvertent Ingestion	Skin contact (wet and dry)	Overall – all pathways
All users	700,000	300	200

Assessment uncertainties

- Particle activities
  - Measurement uncertainties
  - Heterogeneity of activity
  - Ongoing release of particles
- Numbers of sources
  - Survey uncertainties
  - Ongoing release of particles
- Source breakdown
  - Changes exposure pathways

Assessment uncertainties

- Particle solubility
  - Shown to be variable
  - Ongoing release of particles
- Skin doses
  - Integration over 1cm^2 may not be appropriate for particles which are smaller
- Habits data
  - Survey limitations; temporal, metrological, seasonal

Implications for wildlife assessments

- Uncertainties highlighted by the Dalgety Bay work would also be applicable to a wildlife assessment as well as:
  - The need to assess the impact on a population
  - Susceptibility of different individuals/populations/species

Implications for wildlife assessments

- Behaviours of different species as this would influence their probability of encounter
- Likelihood of morbidity/mortality leading to increase predation – food chain impacts

Dalgety Bay wildlife assessment?

- To date a risk assessment for wildlife at Dalgety Bay has not been undertaken
- Current assessment methodologies, such as the ERICA tool, do not allow for assessment of heterogeneous contamination
- Particle activities cannot be meaningfully translated into an activity concentration (Bq/kg or Bq/m^3) or discharge rate (Bq/s) as required by the ERICA tool

Scottish Statutory Guidance

- SEPA should regard significant harm as being caused to non-human species when lasting exposure gives rise to dose rates that exceed one or more of the following:
  - 40 µGy hr-1 to terrestrial biota or plants
  - 400 µGy hr-1 to aquatic biota or plants

- SEPA should regard the possibility of significant harm being caused to non-human species as significant when on the balance of probabilities it is judged more likely than not to be caused

When would it matter to wildlife?

- Based on our statutory guidance for most heterogeneous contamination situations it may not require consideration

- However, if a population of a limited number of individuals or top predators were to be impacted it could require some consideration

Potential discussion points

- Do we need a methodology to assess doses to wildlife from hot particles?
- If yes, how could this be achieved?
- And under what circumstances would an assessment be required?
- Do we need to consider the heterogeneity of contamination beyond the scope of hot particles?

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Thank you for listening

Questions?

corynne.mcguire@sepa.org.uk