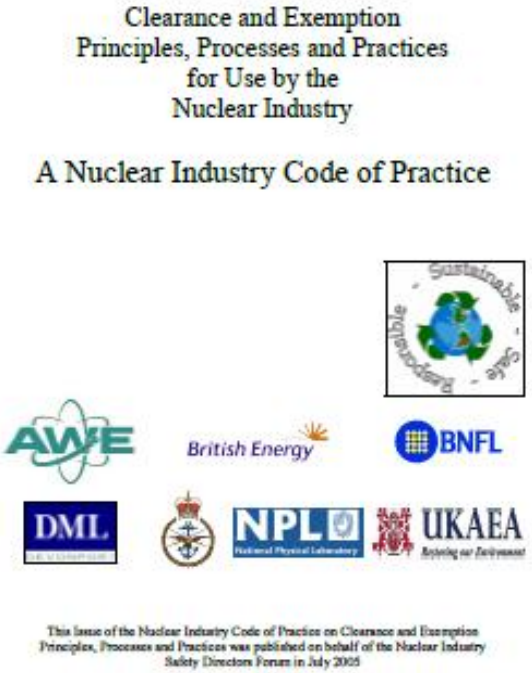
What the changes in the EOs mean at the practical level

Pete Burgess

The clearance and exemption process

- **Most of the UK nuclear industry (and many other organisations) refer to the Clearance and Exemption Working Group Code of Practice when managing potentially exempt waste**
- **A set of flow charts and management principles that helps determine whether waste is exempt or not**
- **Backed up by technical guidance**
- **See http://www.cewg.safety-directors-forum.org**


Clearance and Exemption
Principles, Processes and Practices
for Use by the
Nuclear Industry

A Nuclear Industry Code of Practice

AWE British Energy BNFL DML NPL UKAEA

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Benefits of Exemption and Exclusion

- **Waste not subject to regulation as radioactive waste**
- **Able to avoid costly radioactive waste sentencing practices**
- **Avoids sending waste to LLWR**
- **Potential to re-use or re-cycle waste elsewhere**

The nuclear industry and artificial radionuclides

- The aim was to demonstrate that it complied with the Substances of Low Activity Exemption Order (SoLA)
- Material was still radioactive in law
- Total activity limit of 0.4 Bq/g for solids which are substantially insoluble in water
- Dated back to 1986 in the most recent form
- Moving to a mainly exclusion (out of scope) based process – materials below the defined levels are not radioactive in law

Weaknesses of SoLA

- **Long seen as illogical – not dose based**
- **Radiologically insignificant nuclides such as Fe-55 (short half life, only 2 keV of X-rays per decay) were treated the same way as long half life alpha emitters**
- **Material where the major constituent was low toxicity was pointlessly sent to LLWR if >0.4 Bq g^{-1}**
- **Potential (in theory) for steel contaminated by Co-60 at 0.4 Bq g^{-1} to be released onto the open market**
- **Hence the potential for significant population doses**

What's in and what is out?

Table 2.1a: NORM Industrial Activities (part a)
Production and use of thorium, or thorium compounds, and the production of products where thorium is deliberately added
Production and use of uranium or uranium compounds, and the production of products where uranium is deliberately added

NORM

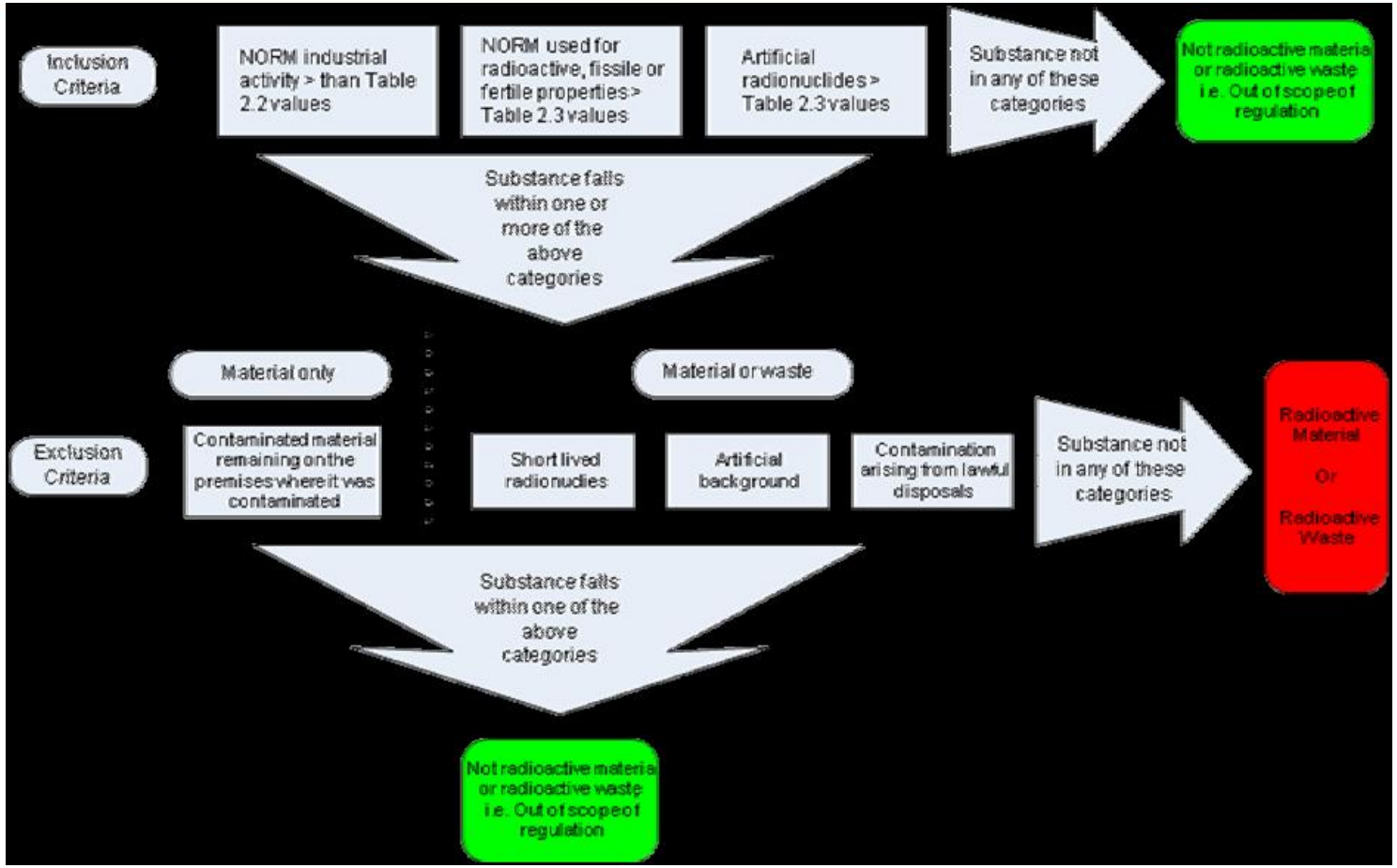
Table 2.1b: NORM Industrial Activities (part b)
Extraction, production and use of rare earth elements and rare earth element alloys
Mining and processing of ores other than uranium ore
Production (but not storage, distribution or use) of oil and gas
Removal and management of radioactive scales and precipitates from equipment associated with industrial activities
Any industrial activity utilising phosphate ore
Manufacture of titanium dioxide pigments
The extraction and refining of zircon and manufacture of zirconium compounds
Production of tin, copper, aluminium, zinc, lead and iron and steel
Activities related to coal mine de-watering plants
Water treatment associated with provision of drinking water
China clay extraction
The remediation of contamination from other NORM industrial activities

Useful DEFRA guidance

Where radioactive material must be chemically or mechanically processed prior to disposal, averaging of concentrations over reasonable quantities of (non-radioactive) waste in mixtures is permissible, but deliberate dilution to render a mixture of waste below the relevant levels is not. The regulators will provide guidance on sampling and averaging in such cases.

Any substance or article is not regarded as radioactive material or radioactive waste unless the concentration of any artificial radionuclide is above the levels *'found normally in such a substance'*[16].

We aim for half way down the left hand side



Nuclide classification

- **Low toxicity nuclides generally emit beta or X rays, have relatively low decay energies, short half lives and low biological incorporation**
- **High toxicity ones include alpha emitters and very energetic gamma emitters**
- **European Commission RP122 and IAEA RS-G-1.7 give values of suggested clearance levels based on dose modelling**

New levels

- Based on RP122 Part 1 values with additional values by HPA
- The reference value is 10 μSv per annum to the most exposed people
- Additional recommendations for liquids and gases by HPA
- 0.01 Bq g^{-1} to 10 kBq g^{-1}
  - **A range of 1 million!**
- In the future (5 years?), BSS may move to RS-G-1.7 values, leading to a further change in UK exclusion levels.
- Main change seems to be Cs-137, moving from 1 Bq g^{-1} to 0.1 Bq g^{-1}

Some examples of low toxicity nuclides

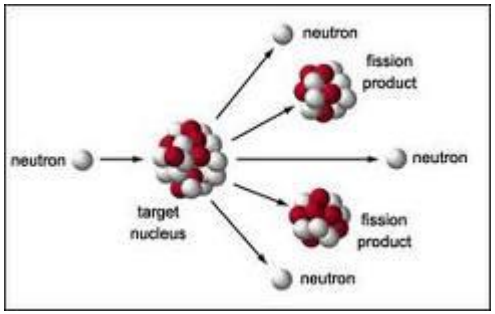
Nuclide	Decay energy, type, probability and half life	RP122 value (Bq g^{-1})	Production
Fe-55	5.9 keV X-rays, 36 %, 2.73 y	100	Activated steel
Ni-63	67 keV beta, 100 %, 100 y	100	Activated steel
H-3	18.6 keV beta, 100 %, 12.3 y	100	Activation and ternary fission
Ca-45	257 keV beta, 100 %, 163 days	100	Activated concrete
C-14	156 keV beta, 100 %, 5730 y	10	Activated nitrogen
Tl-204	764 keV beta, 97 %, 3.78 y	10	Activated Tl-203

Some examples of high toxicity nuclides

Nuclide	Decay energy, type, probability and half life	RP122 value (Bq g^{-1})	Production
Co-60	1.17 and 1.33 MeV gamma, 200 %, 5.27 y	0.1	Activated steel
Cs-137	0.662 keV gamma, 85 %, 30 y	1	Uranium fission
Pu-239	5.1 MeV alpha, 100 %, 24110 y	0.1	Uranium activation
U-238+ including Th-234, Pa-234m and Pa-234	4.2 MeV alpha, 2.27 MeV beta, 100 % + 100 %, 4.47 x 10^9 y	1	Separated uranium
Ra-226+ including Rn-222, Po-218, Pb-214, Bi-214 and Po-214	Four alphas, plus beta and gamma , 1600 y	0.01	Natural

Essentials to think about

- **Waste characterisation often refers to a fingerprint, rather than quantifying individual nuclides**
- **There is not, and there never will be, a Bq meter**
- **Any detection mechanism is radiation type and energy dependent**
- **Many waste assessments rely on one or two easily detectable nuclides**
- **Cs-137 for fission, Co-60 for activation, Bi-214 for radium**
- **So getting the fingerprint right is vital**



The limiting activity – nuclide specific

- **Express each nuclide as a fraction of the total activity (e.g. 15% Co-60)**
- **Divide each fraction by the limiting activity (e.g. 15% Co-60/0.1 + 85% others/100)**
- **Sum the results (in the example above this will be 1.509)**
- **Divide the fraction of the nuclide to be measured by this sum to get a limiting Bq g^{-1} value**
- **Taking Co-60 as the most likely nuclide to be measured this is 15%/1.509 = 0.099 Bq g^{-1}**
- **Sounds complicated but isn't**

Will more or less waste be subject to regulation?

- **Activated steel with a significant Co-60, Fe-55 and Ni-63 content**
- **Average Harwell Fe-55/Co-60 ratio was 10**
- **Hence limiting Co-60 activity was 0.04 Bq g^{-1} under SoLA**
- **Fe-55 and Ni-63 effectively disappear under proposed regime**
- **Co-60 limit now close to 0.1 Bq g^{-1}**
- **Hence higher total activity can be cleared**

Another winner

- **Tritium is extremely mobile**
- **Diffuses into concrete to cm depths**
- **Much further than any other nuclide**
- **Hence large volumes of concrete can end up being contaminated by tritium alone**
- **Clearance activity concentration will be 250 times higher under the new arrangements**
- **Heavy water moderated reactors such as SGHWR at Winfrith**

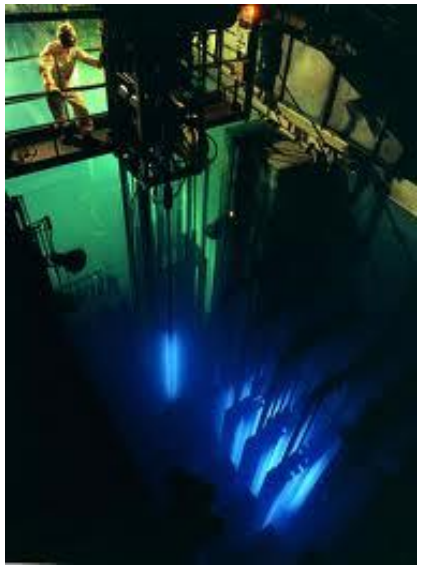
Post Irradiation examination building

- **Total activity limit for the fingerprint shown is 0.88 Bq g^{-1}**
- **But if we move to RS-G-1.7 values, Cs-137 goes to 0.1Bq g^{-1}**
- **Resulting value then equals 0.12 Bq g^{-1}**

Nuclide	Major emission	Fraction (%)	RP122 limit (Bq/g)
Pu-238	Alpha	0.1	0.1
Pu-239	Alpha	0.2	0.1
Pu-240	Alpha	0.3	0.1
Cm-244	Alpha	0.3	0.1
Am-241	Alpha + low E gamma	0.5	0.1
Pu-241	Very low E beta	1.8	1
Sr-90 (+Y-90)	High E beta	13.3	1
Ni-63	Low E beta	1.6	100
Cs-137	Gamma + medium E Beta	81.6	1
Co-60	Gamma + low E Beta	0.4	0.1

Fuel cooling pond

- **Total activity limit = 0.46 Bq g^{-1}**
- **Again susceptible to changes for Cs-137**
- **Moves to 0.16 Bq g^{-1}**



Nuclide	Major emission	Fraction (%)	RP122 limit (Bq/g)
Cs-137	Gamma + medium E Beta	46	1
Co-60	Gamma + low E Beta	17	0.1
H-3	Very low E beta	23	100
Fe-55	Very low E X-ray	4	100
Ni-63	Low E beta	7	100
C-14	Low E beta	2	10
Sr-90 (+Y-90)	High E beta	1	1

Activation and fission product contamination

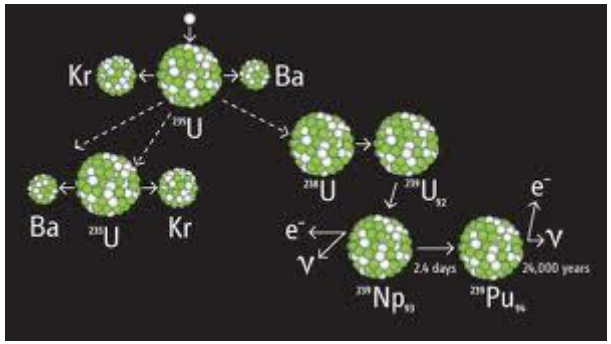
- **Total activity limit is**
- **0.112 Bq g^{-1}**

Nuclide	Major emission	Fraction (%)	RP122 limit (Bq/g)
Co-60	Gamma + low E Beta	44.8	0.1
Eu-154		15.9	0.1
Cs-137	Gamma + medium E Beta	13.9	1
Sr90 (+Y-90)	High E beta	7.0	1
Eu-152	High energy gamma + beta	6.0	0.1
Ni-63	Low E beta	5.0	100
Cd-113m	Medium energy beta	2.0	0.01
Fe-55	Very low E X-ray	2.0	100
Eu-155		2.0	10
Pu-241	Very low E beta	1.0	1
Am-241	Alpha + low E gamma	0.2	0.1
Pu-238	Alpha	0.1	0.1

*Likely limit will be 1 Bq g^{-1}

Plutonium from high burn-up fuel

- **Total activity limit is 0.73 Bq g^{-1}**
- **Dominated by the very high fraction of Pu-241**
- **Very low energy beta emitter**
- **Decay product is Am-241**
- **Concentration will peak at about 3.3 % of original Pu-241 activity**



Nuclide	Major emission	Fraction (%)	RP122 limit (Bq/g)
Pu-238	Alpha	0.25	0.1
Pu-239	Alpha	1.1	0.1
Pu-240	Alpha	1.1	0.1
Pu-241	Beta	95.9	1
Am-241	Alpha + low E gamma	1.6	0.1

Other advantages

- **Where measurement uses the highest toxicity radionuclide present, conservatism can be reduced**
- **Consider an activated steel fingerprint**
- **Co-60 might vary from 10 to 20 % of the total activity depending on the original cobalt content of the steel**
- **Currently will be sentenced at 0.04 Bq g^{-1} Co-60**
- **Some of this steel will be incorrectly classified as LLW**

Under the new values

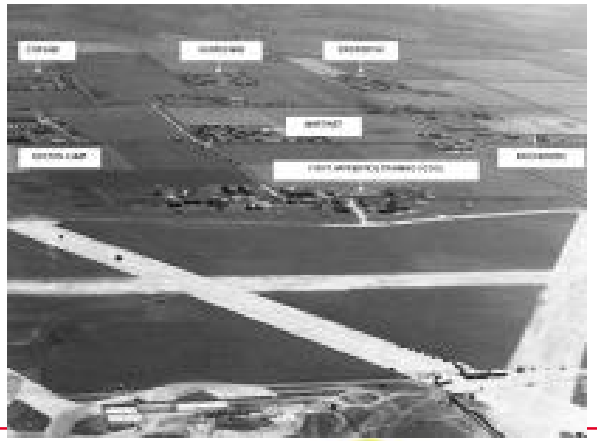
- **Calculate limiting Co-60 value for 10 and 20 % Co-60 at 0.1 Bq g^{-1} and Fe-55 + Ni-63 at 90 to 80 % at 100 Bq g^{-1}**
- **10 % gives 0.0991 Bq g^{-1} Co-60**
- **20 % gives 0.0996 Bq g^{-1} Co-60**
- **Hence effectively 0.1 Bq g^{-1} independent of Co-60 fraction**
- **So no over-classification**

Real difficulties

- **Fingerprints containing very high toxicity radionuclides - nuclides at 0.01 Bq g^{-1}**
- **Generally naturals – long decay chains, many alpha stages, plus energetic gammas and betas**
- **High external gamma dose rates from bulk waste**
- **High dose per unit intake**

Where present?

- **Fuel manufacture from uranium ore concentrate**
- **Research establishments like Harwell**
- **Sites with a possible history of radium luminised instruments**
- **Old airfields commonly**



Measurement difficulties

- **U-238, U-235 and Th-232 complete chains and the Ra-226 chain are at 0.01 Bq g^{-1} head of chain activity**
- **Simple explanation – U-238 complete chain contains 8 alpha decay stages plus beta stages and also generates significant gamma radiation**
- **Generally below the limit of *in situ* gamma detection**
- **Present in building materials, soil etc naturally**
- **How can we see an enhancement of Ra-226 activity of 0.01 Bq g^{-1} over natural levels in excess of 0.1 Bq g^{-1} U-238?**

Useful DEFRA guidance

Waste managers would be expected to use good practice to determine the radiochemical assay of the waste, but where the difference between the level '*found normally in such a substance*' and the increment due to additional contamination

genuinely cannot be separated or reasonably measured, then the entire material can be considered as 'out of scope'.

For the purposes of calculating the total activity in wastes, the head of the chain may be taken to already include all radionuclides in a decay chain (in the case of radionuclides followed by the term 'sec'), or all the listed radionuclides (in the case of the term '+').

Summary

- **Some exclusion levels will be higher than 0.4 Bq/g and some lower**
- **Moving to RS-G-1.7 values would dramatically reduce the level for fission product waste**
- **Have confidence in fingerprints**
- **History will be critical to exclude 0.01 Bq g^{-1} nuclides on some sites**