



# Management of Slightly Contaminated Materials: Status and Issues

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Usually, when values in risk assessment are discussed, e.g., within RISCO and VALDOR, it is said, that there are values behind the risk assessment by the experts and that these values are hidden within the basic assumptions made and are not easily visible, especially to the higher-level decision-makers. It is shown in this paper, that the opposite can also happen: the decision-makers, those that set the standards, may not be aware of the all the relevant facts or they may ignore them because of how their institutional role and mandate are framed. In particular, it is important to realise that while nuclear power by-products are indeed specifically recognised for their radioactive hazard, radioactive products, by-products and “wastes” also arise from practices other than nuclear power generation. As the threshold radioactivity levels for classifying a material as waste – or, what is the same, for allowing it for free release – become lower and lower, a larger and larger amount of by-products of human activities become concerned by the question “is this radioactively dangerous material?” and how to deal with it. A holistic look at radioactivity both of man-made and natural origin needs to be implemented in order to claim and achieve consistency in the protection of public health and avoid issues of intra- and intergenerational equity.

## 1. Introduction

Radioactive materials as well as radioactive waste are also often perceived as specific to nuclear power. It is important, however, to realise that while nuclear power by-products are indeed specifically recognised for their radioactive hazard, radioactive products, by-products and “wastes” also arise from practices other than nuclear power generation. In particular, more than about 280 million tonnes of coal ash (fly ash and bottom ash combined) are produced annually world-wide. These are contaminated with low levels of radioactivity. Table I illustrates some of the Technologically Enhanced Naturally-Occurring Radioactive Materials (TENORM) arising annually in the United States.  $^{226}\text{Ra}$  with a half-life of 1600 years is by far the

most important radionuclide. More or less comparable quantities of TENORM arise in Europe, with similar concentrations of radioactivity.

**Table I: Some TENORM Quantities in the US (Summarised from [1])**

Waste Stream	Prod. rate Million ton/yr	U + Th + Ra Bq/g
Phosphates	50	up to 3700
Petroleum Production	0.26	up to 3700
Water Treatment	0.3	up to 1500
Mineral Processing	1000	up to 1100
Coal Ash	61	up to 2

Slightly contaminated materials arising from the nuclear installations and candidate for re-cycle and re-use are in the order of 30 to 80 thousands tons per year (Europe + USA). The critical radionuclides are mostly  $^{60}\text{Co}$  and  $^{137}\text{Cs}$ , with 6-yr and 30-yr half-life, respectively.

Whereas there exists significant uniformity of views for dealing with materials and situations where radioactive contamination is substantial and these materials are regarded as waste, there is no common view regarding radioactivity levels at which materials can be released, e.g., for disposal in non-nuclear waste sites, recycle, or re-use. The same general situation is true for the release of former nuclear sites. On the other hand, as the threshold radioactivity levels become lower and lower, a larger and larger amount of by-products of human activities become concerned by the question "is this radioactively dangerous material?" and how to deal with it. Indeed, regardless of its origin, the same radioactive dose leads to the same damage and, in principle, similar approaches should be undertaken to management of all slightly contaminated materials. On the other hand, this is not necessarily the case, and the unequal treatment of radioactive materials from different sources leads to issues of intra- and intergenerational equity, sustainability of energy choices, and consistency in the protection of public health.

## 2. Terminology

In connection with the regulation for dealing with slightly contaminated materials, the following words are conventionally in use within the system of radiation protection to denote specific conditions:

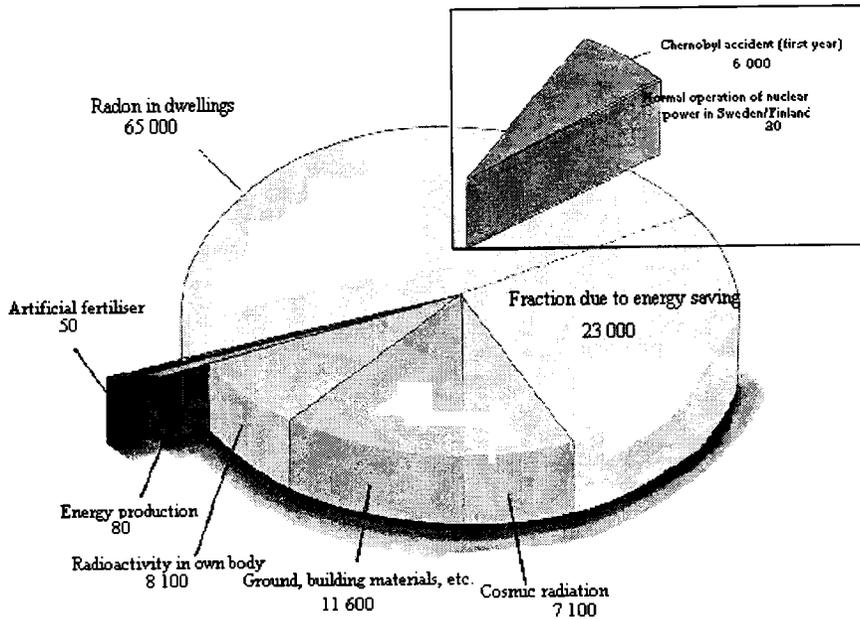
- **Exclusion** covers activity sources not amenable to control, such as K-40 in the human body, cosmic radiation, etc.

- **Exemption** denotes radioactive materials that never enter the regulatory regime because it is considered that they give rise to low risks, and control would be a waste of societal resources
- **Clearance** refers to materials that have been regulated earlier but is now released from regulatory control.

It is to be noted that the above are “legal” jargon, and that both “exempted” and “cleared” materials have, at the same activity levels, the same radiological impacts.

### **3. Radiological Impact of NORM and TENORM**

A characteristic of NORM is that, because of their wide distribution from many sources, they give rise to a collective radiological doses to the public that is relatively large in comparison to those caused by the nuclear industry. This is vividly illustrated in a study, made in 1990, by the radiation protection authorities from the five Nordic countries, on the annual collective dose to their populations from natural radioactive sources, including some TENORM-related ones. A pie diagram (Figure 1) was prepared in connection with the report, showing the respective contributions of the various sources and comparing them with the collective dose taken by the Nordic populations during the first year after the Chernobyl accident as well as with the annual collective dose from the operation of the 16 nuclear reactors in Sweden and Finland.



**Figure 1:** Average annual collective dose to population in Nordic Countries from natural radioactive sources (person-Sievert/yr). For the purpose of comparison, also given are the collective doses from the Chernobyl accident (first year) and from normal operation of nuclear power plants in the Nordic Countries, i.e. from Sweden and Finland.

Source: NKS Nordic Nuclear Safety Research RAS 430 (1990)

Most striking is the large increase in collective dose from concentrating radon in houses (23 000 person-Sv/year), which results from the practice of sealing them to save heat. This is a recognised TENORM problem by the National Academy of Sciences [2].

On closer examination, the comparative impacts of some of the NORM-related industries are even more significant than shown.

The 20 person-Sv/year from the operation of the nuclear reactors is mostly occupational doses to the operating personnel. The total collective dose to the general public from plant emissions is less than 1 person-Sv/year.

The annual 50 person-Sv dose shown in the figure coming from artificial fertiliser covers only the internal doses taken by the Nordic public, through ingestion of food produced on the fertilised soil. The external

doses have not been included. The figure also does not cover the use of the by-product, gypsum, as a building material. Even a modest use of gypsum in homes could lead to an annual collective dose of about 100 person-Sv.

- The figure of 80 person-Sv/year due to energy production from coal (mainly in Denmark) and from peat (mainly in Finland) refers only to radioactive emissions from the power plants. Not shown are the effects of the use of some of the fly ash in concrete, which increases the external gamma radiation in buildings and is likely to dominate the total dose from the use of coal and peat. The report mentions that most of the bottom ash ends up on municipal tips but does not attempt to estimate the radiological impact. Coal ash is indeed an important issue as it will be described later in this paper.

The Nordic study thus shows that the collective dose from the operation of the 16 nuclear plants is 1 person-Sv, while the use of artificial fertiliser and the operation of coal and peat for energy production causes at least two to three orders of magnitude higher collective population doses. The study does not show the dose from the reuse and re-cycle of materials from nuclear power plants, but, due to the much smaller amounts and much stricter release criteria for these materials, the impact is likely to be insignificant vis-à-vis those already identified. For instance, the company Studsvik that melts contaminated scrap is allowed to release ingots contaminated at no more than 1 Bq/g. These ingots are sent for re-melting at metal producing smelters where there is a further dilution by a factor of 3 to 10. Thus, the slightly contaminated materials that are released by the nuclear installations are contaminated at insignificant levels. This is also illustrated, indirectly, through a quote by the IAEA that refers to low-level “waste”. Namely:

“Low level waste, which consists largely of minimally contaminated clothing, machine parts and industrial resins, can be placed in containers and disposed of in trenches covered with soil. The waste does not require shielding during handling or transportation and can be less radioactive than the equivalent weight of coal plant fly ash or even coffee beans, Brazil nuts and fertilizer which contain natural radioactive material.” [4]

The above general results are not confined to only Sweden, of course. A recent study of exposure in work places observes that dusty working conditions are quite common and, in situations where the management is not aware of the presence of NORM, this can easily lead to individual doses to workers of several mSv per year. “The dose to workers in NORM industries is potentially much higher than in the nuclear industry, where internal contamination is usually very well controlled.”[5]

Another interesting study illustrating the comparative impact of nuclear facilities and TENORM was published recently in Sweden [6]. The dose to individuals in a critical group from radioactive emissions from three sources were compared:

- The Barsebäck nuclear power plant with 2 x 500 MWe BWRs (each 1800 MWt, 7000 h/year),
- The 50 MWt Materials Testing Reactor, R2, at Studsvik,
- The 8 MWt wood chip briquette burning plant, used for heating office buildings at the Studsvik site. Even such a source as wood chips has NORM, which is released during combustion.

The results are shown in the following Table II.

**Table II: Radioactive emissions from various sources  
(Calculated annual doses)**

	<b>Individual dose to critical group nSv (1995)</b>	<b>C-14 (calculated) nSv</b>	<b>Generated Power GWh(t)</b>	<b>nSv/GWh(t)</b>
Barsebäck	37	570	25 200	0.024
R2 (mostly Argon)	6	–	0	–
Wood chip plant	2.4	–	14	0.17

At the same site as the R2 reactor and the wood chip plant, Studsvik RadWaste has an incinerator for burning dry active waste from both nuclear plants and hospitals, as well as a melting facility for recycling contaminated metal scrap from nuclear power plants. During 1996, the incinerator gave rise to a dose of 11 nSv to members of critical group (mostly due to tritium in waste from hospitals and pharmaceutical manufacturers) and the melting facility, which treated 500 t of metal during the year, caused a dose of 0.9 nSv.

In summary, per GWh heat generated, the wood chip burning plant at Studsvik releases 7 times as much radioactivity to the atmosphere and dose to the public than the two BWRs at the Barsebäck Nuclear Power Plant. The radioactive emissions from the wood chip plant are also almost 3 times that from the neighbouring facility, which melts contaminated scrap from nuclear power plants.

#### **4. Release of Materials from Nuclear Installations**

Figure 2 shows that materials of different nature may be free-released either for disposal or for re-cycle, or may be released with some restrictions such as for controlled re-cycling or for disposal under special conditions.

**Figure 2: Example of materials from nuclear installations that may be considered for release [7]**

<b>Project</b>	<b>Category</b>	<b>Technology</b>
BWR preheater	Free release / recycling	Melting
Driptray-reprocessing plant	Free release / recycling	Decontamination / measurement
Eurochemic pilot project	Free release / unrestricted disposal	Measurement
Concrete from G3	Free release / unrestricted disposal	Measurement / crushing
Heads of prestressing cables-G3	Free release / unrestricted disposal	Measurement
Contaminated soil	Restricted release / authorised disposal	Measurement
G2/G3 glasswool	Restricted release / authorised disposal	Measurement
Nuclear centre scrap	Restricted release / controlled disposal	Decontamination / melting
...		
...		

Containment and retention of materials that may otherwise be released could imply significant economic penalties, as shown by a study by a NEA Task group on recycle and reuse of materials from dismantling of nuclear facilities.[7] In particular, how the material is categorised will affect the ultimate disposal cost. In the USA such costs could range from 1 to 10 cents per pound, if it can be disposed of in a landfill, to up to 10 dollars a pound if it has to go to a low-level waste disposal site, such as Barnwell.

Recycle and re-use (R&R) has evident value from the point of view of sustainability:

- Storage/disposal space is freed up
- Resources are used more efficiently
- No need to incur additional risks in looking for alternative materials
- Lower overall costs

On the other hand, the fear of radioactivity is real, and its detectability at extremely low levels is a significant deterrent for, say, the steel industry which could find itself with producing “radioactive” steels, or for regulators who may find themselves facing an angry public.

## 5. An “Empirical” Criterion for Free Release of Materials

The basic issue behind re-cycling and re-using materials is at what levels can they be exempted/cleared, and thus, in the end, what is radioactive waste? Society at large seems to have given a response to this question. By examining practices world-wide in the free release of large amounts of materials where natural radioactivity is artificially concentrated, it can be seen that a free release criterion is as follows:

*“Radioactively contaminated materials can be exempted from regulation and be freely released into the general economy and the environment if they result in individual doses not significantly larger than 1 000  $\mu\text{Sv}/\text{yr}$ .”*

The reference situation for this value is the unrestricted release of coal ash, which represents one of the largest volumes of slightly contaminated materials produced yearly world wide. Coal ash concentrates the natural radioactivity of primordial radionuclides present in coal, and owing to its use in building materials, many people are being exposed to this radioactive source. Other uses of coal ash also result in actual doses received by people. The International Committee on Radiation Protection [3] depicts the situation as follows: “More than about 280 million tonnes of coal ash (fly ash and bottom ash combined) are produced annually. About 40 million tonnes are used in the production of bricks and cement, and a great deal as a road stabiliser, road fill, asphalt mix, and fertiliser. Some large users of coal as filling materials are not included in this figure. ...Residents of buildings constructed with these materials can incur annual doses of up to several mSv.”

To put into perspective this and other figures quoted in this paper, it is important to remember that an average adult has about 5 000 Bq of radioactivity of natural origin in his/her body, which results in a dose of about 300  $\mu\text{Sv}/\text{yr}$ . Medical X-rays routinely expose a person to between 100 and 1 000  $\mu\text{Sv}$  per procedure<sup>1</sup>.

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1 Not all those procedures are possibly necessary.

## 6. Actual Criteria for the Release of Materials

At present, slightly contaminated materials of nuclear and non-nuclear origin are dealt with under different legal frameworks and therefore under different institutional arrangements. Different standards for these two “types” of waste are thus proposed and/or implemented. We have seen the case of the radioactivity of coal ash, for instance, which is not even regulated in a nuclear sense. At the same time, different standards and practices can exist also within the same industry.

*Some example practices within the same country: the USA*

At the time of writing this paper, the situation in the USA is as follows:

- By choice, no metal with detectable radioactivity is released by the DOE. The latter does not define “No detectability”. This same organization does have criteria to release other types of materials.
- Site property must be cleared to:
  - a 250  $\mu\text{Sv}/\text{yr}$  standard, according to the NRC:
  - a 250  $\mu\text{Sv}/\text{yr}$  standard plus 40  $\mu\text{Sv}/\text{yr}$  groundwater standard According to some States
  - a 150  $\mu\text{Sv}/\text{yr}$  standard according to the USEPA
- Draft criteria by the NRC have set clearance and exemption criteria for the nuclear industry at 10  $\mu\text{Sv}/\text{yr}$ . The Health Physics Society endorses this as does the American National Standards Institute (ANSI). On the other hand, the ANSI’s draft guide for release levels of TENORM (Technologically Enhance Naturally Occurring Radioactive Materials) is based on a maximum of 100  $\mu\text{Sv}/\text{yr}$ .
- In the US the EPA has exempted from regulation 6 millions tons of coal ash per year from thermal power plants<sup>2</sup>. To this effect the NRC has

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2. About 61 million tons of coal ash were generated by thermal power production in 1990 [1]. At present, such ash is either disposed or utilised for various industrial uses (more than half for the production of concrete/cement). The current distribution between these two alternatives is about 80% disposal to 20% utilisation. The American Coal Ash Association hopes to ultimately reverse this distribution to 20% disposal and 80% utilisation. It is pointed out that such a high utilisation rate is technically achievable, as rates up to 70% utilisation are not uncommon in Europe. The USEPA has however concluded that a utilisation rate of about 30% is more realistic. Its exemption of coal ash from regulation and the radiological consequences should be viewed against this background [1].

noted that, in practice, the resulting individual dose to the public can be about 100  $\mu\text{Sv}/\text{yr}$  and “could be viewed as a precedent benchmark for possible NRC release levels”[10].

- Further still, in the US, materials are being released using the conditions of the [NRC regulatory guide 1.86 which allows release of materials with surface contamination of 5 000 dpm on a surface of 100 square centimeters, which is equivalent to 0.83  $\text{Bq}/\text{cm}^2$ .

Similar inconsistencies exist across other national frameworks. [8]

#### *Examples of international standards*

Present decisions on free release of very low contaminated materials from the nuclear industry are based mostly on an individual dose criterion of maximum 10  $\mu\text{Sv}/\text{yr}$ .

In May 1996, the EC promulgated a new Directive with revised basic safety standards (BSS) for the radiation protection of both workers and the general public [9]. The Directive covers radioactivity in both nuclear and non-nuclear industries and was to be ratified by member states by May 2000. In the BSS, industries are divided into “practices” (where radionuclides are, or have been processed in view of their fissile or fertile properties) and “work activities” (where the presence of radioactivity is incidental). Broadly speaking, “practices” refer to the nuclear industries, while “work activities” to the non-nuclear ones. The latter are large producers of TENORM, i.e., of materials where the natural radioactivity is concentrated as a side effect of the industrial processes. Besides coal ash, other industries with by-products with significantly enhanced radioactivity are petroleum processing, mineral processing, phosphate production, geothermal plants and paper mills.

The table of exemption values in the new EC-BSS covers only practices and are based on the 10 $\mu\text{Sv}/\text{year}/\text{practice}$  individual dose constraint. The exemption values for work activities are not explicitly given. It is not clear in the BSS what is proposed for the TENORM industries. However, both in Germany [11] and in Holland [12] the level of 1 000  $\mu\text{Sv}/\text{yr}$  individual dose is being used.

The current international recommendations for the *exemption* of radioactive material from being regulated and the *clearance* (release) of such material already regulated are both based on criteria laid down by the IAEA Safety Series 89\* regarding individual doses and collective doses. Clearance values are set to 10  $\mu\text{Sv}/\text{year}$ .

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About 30 million tons of coal ash are generated in Europe every year. If the American Coal Ash Association is correct, about 21 million tons are utilised. What are the resulting individual doses to the public? Have the EC made any studies?

\* This document is presently under revision.

Exemption levels are a factor 10 higher. The explanation is that exemption from regulation is intended to be applied to moderate quantities of material (say 1-10 t), while clearance (release) concerns large quantities (10 000 t/year used in European studies). By contrast, we have seen as well that – e.g., for coal ash – the quantities that are released into the general economy or in the environment are huge, in the order of tens of millions of tonnes per year, and the de facto exemption level is of several thousands  $\mu\text{Sv}/\text{year}$ .

## 7. Some Issues to be Dealt with

There must be consistency in what should be considered as radioactive waste and disposed of in special facilities. This consistency is required on several grounds.

*Intragenerational equity.* Doesn't this state of affairs translate into a waste of resources that could be more usefully dedicated to other causes?

*Public health and protection of the environment.* Why should every-day refuse or foods, which may be more radioactive than radioactive waste<sup>3</sup>, not be checked against radioactive release criteria? Alternatively, is the public correctly protected if the radiological protection criteria are not applied uniformly across the board?

*Sustainability.* Some industries appear to be favoured by a dual standard regarding release levels of radioactivity. Thus, the nuclear industry may become less favourable as an energy choice on faulty grounds, and its sustainability put in question, which may deprive future generations of alternatives for their development. Isn't there an issue of intergenerational equity?

*Institutional frames.* There exist, within the same country, different legal Acts and therefore different institutions and even internal bureaucracies in the same institutions dealing with materials of nuclear and non-nuclear origin. Are the bases for these legal frameworks and institutional arrangements consistent with the nowadays holistic approach to environment protection?

These issues are not unknown and will be addressed more and more in the coming years, which is a reason of optimism. It is already admitted, for instance, that the current system of radiation protection is incoherent and not providing the degree of consistency that is desirable [13]. Reasons for optimism are that:

- A large number of initiatives are afoot on inventories, costs, dose assessments, etc., which implies that more and better basic data will be produced.
- The issue of risk governance is becoming dearer to governments, which implies a larger role for the public at large and specific stakeholders.

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3 Recall the "coffee-beans" example of the IAEA (section 3).

Hopefully, this will force the discussion of issues from all angles, and not only a debate on “numbers”.

## 8. Conclusions

There is a heightened awareness in society of the possible adverse environmental impact of the exploitation of natural resources and, particularly, of energy sources with emphasis on conservation of resources, long term protection of the environment, and sustainable development. There is also increasing awareness of the scale of the remediation problems to be faced as a result of some former, unsafe practices regarding the management of various forms of waste that may lead today to the need of intervention. This applies to contamination of both chemical *and* radioactive nature.

Usually, when values in risk assessment are discussed, e.g., within RISCO and VALDOR, it is said, that there are values behind the risk assessment by the experts and that these values are hidden within the basic assumptions made and are not easily visible, especially to the higher-level decision-makers. It is shown in this paper, that the opposite can also happen: the decision-makers, those that set the standards, may not be aware of the all the relevant facts or they may ignore them because of how their institutional role and mandate are framed. A holistic look at radioactivity both of man-made and natural origin needs to be implemented in order to claim and achieve consistency in the protection of public health and avoid issues of intra- and intergenerational equity. In particular, consistency is needed of regulatory frames within and amongst countries in accordance with modern principles of environmental protection.

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