# RELEASE OF LOW-CONTAMINATED REACTOR WASTES FOR UNRESTRICTED USE

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## ABSTRACT

A generic methodology has been used to evaluate the dose contributions to an individual and to the population of five categories of low-contaminated reactor wastes produced according to the Swedish program and released for unrestricted handling and use. A reference quantity with a surface dose rate below a predetermined level is followed along the whole commercial pathway from the reactor station to the final product consumer and/or a municipal waste station. Dose contributions are calculated for each step in a normal pathway under maximally unfavourable conditions.

## INTRODUCTION

Large amounts of low-contaminated or potentially contaminated material or wastes are generated during the ordinary operation of nuclear power stations. At present they must either be stored for a long time at the site or, according to rules which are set by the Swedish Radiation Protection Agency (SSI) from case to case, be released for special depositories, treatments or recycling. In the absence of firm and fixed norms as to the applicable radiation levels which would automatically allow an unrestricted use and/or recycling of wastes of various types, their storage requires expensive storage space, continuous survey and registration, and an almost unlimited storage time.

SSI is investigating ways and possibilities of establishing unrestricted release rules which are also acceptable to society and the public for the following important waste categories:

- Scrap metals such as stainless steel and aluminium alloys
- Oil-water mixtures
- Combustible solid wastes such as paper, plastics, wood and organic ion exchangers
- Construction, ballast and filling material such as concrete, silt, gravel for blast-engines, bitumen, sand, epoxy resins and filter masses

- Various equipment and apparatus which is brought into (and taken out from) the stations for routine operation and service purposes.

The research station at Studsvik has been given the task of assessing the probable individual and population doses which would follow from a "declassification" of these waste categories. A generic methodology was used in our evaluation, which is similar to but more approximate than that used in an American estimate of potential radiation doses to man from the recycling of radioactively contaminated scrap metals reclaimed from decommissioned nuclear facilities (NUREG/CR 0134, 1978).

A reference quantity of waste material containing a reference level of potentially contaminative radionuclides (Co-60 and Cs-137) was followed along the whole recycling pathway from the reactor station to the final product and consumer level, or to a final public waste station. A possible renewed recycling as scrap material was included in the calculations. At each storage, manufacturing or consuming station along the pathways, maximum individual and population doses were calculated for each identified exposed person (population group) and for members of the general public. When applicable, it was assumed that the original reference quantity was kept together as an entirety as long as appeared reasonably probable.

## ASSUMPTIONS AND CALCULATION BASIS

A completely commercial procedure without any restrictions due to the radioactive content was assumed to be used for all management and handling steps of the five waste categories, from the pickup at the reactor station throughout the whole pathway. Shipments are made by truck - normally in standard containers - over distances and by roads which on average are the same as for similar non-radioactive transports. The recycling of wastes of commercial value, such as scrap metal and waste-oils, is done at large scrap areas and factories of modern construction and with the use of up-to-date methods. Waste categories of no commercial value are shipped directly to a large municipal waste station and handled (burned, buried) simultaneously with other waste deliveries.

### Activity Distribution And Radionuclides

The activity was assumed to be homogeneously distributed throughout the waste material as soon as this could reasonably be assumed to approximate to the actual facts. This is the case for scrap metals and waste-oils from the pickup at the reactor station and has also been assumed to be valid for the other three waste categories when handled in volumes of the size of one transport container (30 $m^3$) or larger. For smallêr units, e.g. polyethylene bags and steel barrels, averaged measurements at the reactor sites of the relationship between maximum dose rate and activity content were used to approximate the surface dose in question.

According to experience at the reactor sites, the following radionuclides have been detected in amounts of any importance for a waste recycling after a storage time of at least a couple of months: Cr-51, Co-60, Zn-65, Sr-90, Zr-95, Sb-125, Cs-134 and Cs-137. The detectable activity in larger quantities is always dominated by the decay of Co-60, with a percentage of at least 80 and usually more than 90. Compared to the other nuclides, Co-60 has one of the longer half-lives and the most penetrating $\gamma$-radiation. Our dose calculations were therefore always based on a 100 % content of Co-60 but were supplemented by an assumed content of 10-20 % Cs-137 in air-borne or water-borne releases to the outer environment.

<u>Source Geometry</u>

The radiation dose for all persons directly exposed to the radiation of the source was assumed to be roughly approximated by one of the four following source geometry cases.

Notations: $d_o$ original surface dose in mrem/h at a distance of 1 cm in air from the source
$d$ exposure dose rate in mrem/h
$r$ source radius (averaged) in m
$s$ distance to the source in m

- Near contact to a large extended source ($s \sim 0.01$)

  $$d = d_o$$

- Point source ($s >> r$)

  $$d = \frac{d_o \cdot 10^{-4}}{s^2}$$

- Surface source approximated with the radius r; $s > r$

  $$d = k \cdot \ln(1 + \frac{r^2}{s^2}); \; k = \frac{d_o}{\ln(1 + 10^4 r^2)}$$

- Line source of considerable length

  $$d = \frac{d_o \cdot 10^{-2}}{s}$$

## Dose Calculations

All radiation exposures were calculated as whole-body doses, but they were reduced in consideration of the successive radioactive decay of Co-60 along the pathway. Dose factors were assumed to vary linearly and to be additive. They were derived for a normal commercial handling procedure along the whole pathway, however, assuming the worst possible conditions, and can therefore be regarded as very conservative.

Direct external exposures were calculated by applying the equation given above with the best fit to the actual conditions. Radiation absorption phenomena were neglected.

Internal exposure from ingestion and inhalation as well as exposure to the public caused by air and water emissions were determined according to standard conditions and standard methods used in Studsvik for similar calculations. We also assumed that 0.1 % of an unfixed substance is ingested by each person who remains within 6 m of a dust-producing surface.

## PROJECT IMPLEMENTATION

Visits were made to each of the five Swedish nuclear power stations in operation, to collect data on the annual production of low-contaminated waste suitable for unrestricted recycling, on their present handling and storage procedures, average surface and bulk contamination levels, nuclide distributions etc. On the basis of the information obtained for each of the five waste categories considered, a suitable volume of waste that is optimal from a transport point of view was chosen as the reference volume.

Visits were also made to each process step along the commercial pathway which the different waste categories would most probably take from the reactor station to a final consumer or a final disposal site, including for example scrap dealers, remelting facilities, foundry factories, distributors, wholesale firms, retailers, and municipal combustion and waste stations. Parameters of importance for the application of the source geometry formulas and for the final dose calculations were approximately estimated and averaged; these include exposure time and distance, number of exposed persons, dilution factors and emissions to the environment.

Scrap Metals

Reference quantity: 100 metric tons of stainless steel in the form of thick sheets with a homogeneous bulk contamination of 10 mCi and a surface dose rate (1 cm) of 0.5 mrem/h.

14 steps in the pathway were analysed. They include pickup, loading (unloading), storage (packageing) and treatment at scrap yard, remelter, slag handling, product goods manufacturer, wholesale dealer, retailer, final consumer and scrap recycling as well as all transport.

The manufacture of 5 different product articles was included in the study: electric hot-plate, kitchen sink, sawblade and tubes for water pipes or for the manufacture of home furniture. All these products are likely to have a long life-time and to give a maximally high dose to the consumer during their use.

Waste-Oils

All waste-oils at Swedish reactor stations are separated to give an almost water-free oil phase (< 1 %) with a low activity content by passing a two-step filter-centrifuge process.

Reference quantity: One tank container of 30 $m^3$ oil with a homogeneously distributed content of 0.3 mCi and a surface dose rate of 0.02 mrem/h.

Two different pathways were analysed, the first involving the direct combustion of the oil in an oil-powered heating station and the second oil refining and recirculation. The analysed steps comprised transport, storage, combustion, ash treatment and deposition and oil refining with recirculation to consumers.

Combustible Solid Wastes

Reference quantity: One container of 30 $m^3$ loaded with 3 tons of wastes packed in 100 l polyethylene bags. The total activity, 0.5 mCi, is non-homogeneously distributed within the polyethylene bags but was assumed to be almost homogeneous within the container. The surface dose from bags and container was set at 5 mrem/h in conformity with actual measurements on the bags.

The analysis was performed in 8 steps comprising transport to and unloading at a large municipal waste station , storage, combustion, ash treatment and final burial of the ash in a layered earth deposit. The last step also includes dose commitments to the public during a 100-year period, assuming that the waste site is available for public use after 30 years.

Building And Filter Materials

Reference quantity: One container of 30 $m^3$ loaded with 30 tons of wastes packed in 200 l steel barrels. The total activity, 0.5 mCi, is almost homogeneously distributed, but in the absence of reliable surface dose measurements the dose rate is assumed to be 5 mrem/h in conformity with the earlier case.

The analysis pathway was almost the same as for the combustible wastes except for a direct transportation of the wastes to the municipal burial site.

Routine Equipment, Tools And Apparatus

According to rules set by the Swedish radiation authorities, equipment etc which has been brought into an active area is free for unrestricted use after decontamination to a surface level $< 0.1$ mrem/h, i.e. the common detection limit of the instruments used for monitoring.

In the analysis it was assumed that each contaminated item of the types discussed which was brought out from the reactor stations has a contamination level equal to 0.1 mrem/h and will be used by the same technician during a useful life-time of 10 years for 200 hours per year on average.

## RESULTS

The results of the calculations for each of the first four waste categories are summarized in Tables I-IV. Internal dose contributions are only given when these are significant in comparison with the external doses, which are usually incomparably greater.

The results for the recycling of 100 tons of scrap stainless steel (Table I) are valid for the product article "kitchen sink", which gives the highest contribution in the manufacturing, distribution and storage steps. However, a higher contribution is obtained during the use of the product articles "water-pipes" (individual dose 40 mrem) and "steel tube furniture" (population dose 140 rem) which is apparent from the summary term ($\Sigma$) in the table.

Table I. Dose contributions from scrap metals

| | Individual mrem | | Population manrem | |
|---|---|---|---|---|
| | external | internal | external | internal |
| Earlier pathway steps | < 0.1 | < 4 | 0.12 | 0.035 |
| Product manufacture | 23 | - | $50 \cdot 10^{-3}$ | - |
| Product distribution and storage | 6 | - | $7 \cdot 10^{-3}$ | - |
| Product use | 10 | - | 45 | - |
| Σ (max) | 40 | 4 | 140 | 0.035 |

Table II. Dose contributions from waste-oil

| | Individual mrem | Population manrem |
|---|---|---|
| Loading, transport and storage | $4 \cdot 10^{-3}$ | $10^{-5}$ |
| Combustion | - | $2.7 \cdot 10^{-3}$ |
| Ash disposal | $3 \cdot 10^{-2}$ | $3 \cdot 10^{-4}$ |
| Oil refining | $5 \cdot 10^{-5}$ | $2 \cdot 10^{-7}$ |
| Refining wastes | 0.3 | $6 \cdot 10^{-3}$ |
| Refined product | $< 10^{-4}$ | $2 \cdot 10^{-3}$ |
| Σ (max) | 0.3 | $< 10^{-2}$ |

Table III. Dose contributions from combustible solid wastes

| | Individual mrem | Population manrem | |
|---|---|---|---|
| | external | external | internal |
| Loading, transport and storage | 0.22 | $4.5 \cdot 10^{-4}$ | |
| Combustion | $7 \cdot 10^{-4}$ | $2 \cdot 10^{-5}$ | $2 \cdot 10^{-5}$ |
| Ash treatment | 0.02 | $6 \cdot 10^{-5}$ | |
| Ash disposal | < 3 | < 0.04 | 0.01 |
| Σ (max) | < 3 | < 0.04 | 0.01 |

Table IV. Dose contributions from building and filter materials

| | Individual mrem external | Population manrem external | Population manrem internal |
|---|---|---|---|
| Loading and transport | 0.22 | $4.5 \cdot 10^{-4}$ | |
| Burial operations | 0.2 | $4.5 \cdot 10^{-4}$ | |
| Disposal site | < 0.4 | $4.5 \cdot 10^{-3}$ | $10 \cdot 10^{-3}$ |
| Σ (max) | < 0.4 | $5.5 \cdot 10^{-3}$ | $10 \cdot 10^{-3}$ |

Dose contributions due to the annual release of equipment, tools etc of routine character from a reactor station were estimated to have the following maxima:

Individual 0.1 mrem
Population < 1 manrem

Since all parameters used in our calculations are very conservative it is reasonable to assume that the fault factor (its upper limit) for all the results given can hardly be more than 10. This is particularly true for the population doses. Calculations for some extreme but reasonably probable cases can give an individual dose which is a factor of 100 higher. This is not, however, the case for scrap metals which give rise to by far the highest doses.

## DISCUSSION

The only other investigation known to us concerning dose contributions to individuals and population from the unrestricted release of low-contaminated nuclear wastes is the NUREG-report mentioned earlier. In each step of the pathway the results of our analysis for scrap metals agree surprisingly well with the American figures for Co-60, if these are transformed to the same bulk contamination level and reference weight as used by us. The only outstanding exception is the step involving the commercial use of slags obtained in the remelting process, where the American dose contributions are a factor of $10^3$-$10^4$ higher. The reason is obviously that in USA these slags are normally used for other purposes than in Sweden, for example as a constituent of bitumen for road construction.

An estimate has been made of the total dose contributions to an individual and to the population, if in the future all reactor wastes of the categories and activity levels discussed here which are produced annually in the entire Swedish nuclear power program are released for unrestricted use. According to a decision of the Swedish parliament, the program is fixed at a total installed capacity of 9.4 $GW_{el}$ divided into 4 reactor station sites and 12 reactor units.

According to information collected at the reactor sites, a reasonable estimate of the number of reference quantities produced annually in Sweden is as follows:

Scrap metals 3 x 100 tons

Waste-oils 4 x 30 $m^3$

Combustible solid waste 40 x 30 $m^3$

Building materials etc 10 x 30 $m^3$

For geographical reasons, wastes from the five reactor stations will follow different geographical pathways and end up in different municipal waste stations. It is assumed that waste from the same station will mainly be handled by the same individuals except at the consumer level where it is highly unlikely that the same individual will be affected. It is also highly unlikely that more than one reference quantity of scrap metals will be used for the manufacture of consumer products with a high contribution to the population. The figures given in earlier tables have been reduced (added) in accordance with these restrictions and the results are collected in Table V.

Table V. Dose contributions from wastes produced annually in Sweden

| | Individual mrem | Population manrem |
|---|---|---|
| Scrap metals | 40 | < 200 |
| Waste-oils | 0.2 | $< 3 \cdot 10^{-2}$ |
| Combustible solid wastes | | < 0.7 |
| Building materials etc. | 0.8 | < 0.15 |
| Routine equipment etc. | < 0.1 | < 4 |
| All wastes | ≤ 40 | < 210 |