Metal Radioactive Waste Recycling from the Dismantling of Nuclear Facilities

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ABSTRACT

In the dismantling process of nuclear power plants a large amount of metal residues are generated. The residues of interest are stainless steel, copper and aluminium and can be reprocessed either for restricted or unrestricted use. Although there are many questions about the further use of these materials it should be convenient to recycle them. This paper discusses the complexity of the management of these metals.

The radiation protection requirements are the most important principles. For these purposes great efforts in the decontamination have to be made. Regulatory aspects, clearance levels as well as characteristic of steel recycling industry, radiological impact and new developments are discussed.

1.0 INTRODUCTION

The first major nuclear power plants are over thirty years old, and are reaching the end of their useful life. Several power plants have been shut down, and have to be decommissioned. During the dismantling of nuclear power plants a large amount of metal scrapes is generated. This is mainly a radioactive waste disposal problem, but a considerable quantity is only slightly contaminated. Recycled the metal scraps would save natural resources and would minimize the amount of radioactive waste.

The radiation protection requirements are established at a national level. While a great number of codes and standards relate to the commissioning and operation, there are no specific criteria for the exemption from the regulatory control. These criteria should be established in such a way that they would be accepted in most countries as a standard. Metal scraps are traded among countries. Different countries have different regulations. In the European Union the relaxation of the export-import restrictions could lead to further controls (e.g. at the border, at the final destination of the metal) what is extremely undesirable.

The criteria should be prepared very carefully not only because of radiation protection reasons but also for the reason of public adversity. The US Nuclear Regulatory Commission withdrew the Below Regulatory Concern Policy Statement in the 1993 just due to the unfavorable public opinion.

2.0 DEVELOPMENT ON RADIOLOGICAL PROTECTION CRITERIA FOR EXEMPTION

In 1988 IAEA (1) proposed two basic criteria for exemption:

1. The individual risk must be sufficiently low that is not of the regulatory concern. IAEA suggested the appropriate annual individual effective doses were in a range of few tens of mSv.

2. The radiation protection as well as the costs of regulatory control must be optimized. IAEA suggested that if the generic study indicated that the collective dose commitment resulting from one year of unregulated practice would be less than about one manSv, it might be concluded that the total detriment is low enough to permit exemption without more detailed examination of other options.

In 1988 the Commission of the European Communities recommended the criteria which were directly applicable to the recycling of steel scrap from nuclear power stations (2). The recommendations were based on the information that was available in the 1985 and the surface contamination criteria were based on the IAEA transport regulations (3).

In 1990 ICRP published its recommendations (4) where it recognized the concept of exempting a practice from regulatory control on the basis of low individual effective doses and collective doses. ICRP didn't provide numerical values for doses but suggested that, in some circumstances, optimization studies could aid in determining whether the practice could be exempted from regulatory control.

In recent years a number of studies have been conducted by the Commission of the European Communities, by the International Atomic Energy Agency and by individual countries on the recycling of materials from nuclear facilities. These studies relate to steel as well as to other materials such as aluminium, copper and concrete.

The new information from the studies and the ICRP recommendations led the Commission of the European Communities to revise its Basic Safety Standards. The revision is in progress. Among other things activity levels and concentrations below which the requirement for reporting and prior authorization need not apply are revised.

3.0 GENERAL RADIOLOGICAL PROTECTION CRITERIA APPLICABLE TO RECYCLING MATERIALS FROM THE DISMANTLING OF NUCLEAR FACILITIES

Radiological protection criteria

The IAEA Recommendations, laid down in Safety Series No. 89, refers to a "few tens of mSv" as a basis for exemption. Furthermore, IAEA suggests that in order to take account of exposures of individuals from more than one exempt practice, the critical group exposure from one such practice should be of the order of 10 mSv/y.

For comparison, the average exposure from a medical chest X-ray is roughly 50 mSv.

Collective dose criteria

The second exemption criterion laid down in the IAEA recommendation is that, if the estimated collective dose commitment per year of practice is lower than one manSv, the total detriment is low enough to permit exemption without more detailed examination of other options.

In conclusion, collective dose criteria are regarded of minor importance in the context of steel recycling. Nevertheless collective doses to the general public could be further reduced if steel is recycled to nuclear industry, e.g. for the production of radioactive waste storage containers. This option is preferential also from the viewpoint of public acceptance.

4.0 CHARACTERISTICS OF MATERIALS ARISING FROM DISMANTLING

Large volumes of concrete and significant quantities of steels are used in construction of nuclear facilities. Depending on its radioactivity level, concrete may be recycled, disposed of in landfill, or disposed of in a radioactive repository. Recycling possibilities exist but they depend on local needs for granulates. In contrast, steels and other metals will have a scrap value and thus, there is an economic and practical incentive for recycling. For all materials the potential implications of recycling or reuse should be considered. Depending on their precise use in the nuclear installation being dismantled, the steels and other materials can have varying contamination and activation levels. For nuclear power reactors the dominant material is steel, a high proportion of which is stainless steel. However, the quantities of steel will vary depending upon the type of reactor. In other installations, such as enrichment plants, aluminium can be the main constituent of recyclable materials from dismantling, and this has a higher scrap value than steels.

The areas where materials with low levels of radioactivity may arise are not only confined to controlled areas. In a PWR nuclear power plants, for instance parts of the secondary side of the coolant system may not be within a controlled area.

Nuclear Power Plants

Carbon steel is often the most abundant metal used in nuclear power plants construction. It is normally the main constituent of the secondary cooling system, the major structural features and equipment housings. Stainless steels are used in smaller quantities, mainly in the more critical areas of the plant, such as the primary cooling system, liners and tanks. Depending on the precise location and function of the steel in the power plant, it will, on decommissioning, contain varying amounts of activation and contamination products. Furthermore radionuclide composition will change, depending on the time of dismantling after plant shutdown, due to radioactive decay and the decontamination processes undertaken.

Extensive studies have been made for power reactor decommissioning in the US and Europe (5) and nuclear countries are gathering practical experiences. These studies show that the total quantity of steel in the active areas of a large (1000 MWe) pressurized water reactor or boiling water reactor is approximatcly 10,000 tons, of which about half has a potential for recycling with currently available techniques.

Other Nuclear Installations

Other nuclear installations, especially uranium enrichment facilities and nuclear fuel reprocessing plants, can contain significant quantities of steels and other metals. For example, an enrichment facility utilizing gaseous diffusion techniques will contain thousands of tons of steel and aluminium. In general, the materials will be contaminated by uranium isotopes and their short-lived daughters. Depending on the extent to which uranium recycling has occurred in the nuclear fuel cycle, the contamination may include fission products and actinides. Materials from decommissioned reprocessing plants will be contaminated by fission products, some activation products and the full spectrum of actinides could be present.

Finally, there are also other practices associated with nuclear installations, which could produce significant quantities of scrap metals and items on decommissioning. For example, irradiated fuel flasks, used to transport fuel from power stations to reprocessing plants, can reach the end of their life after 30 years or so. These are substantial items, presenting low contamination with a range of fission products and actinides, and having a potential scrap worth.

5.0 CHARACTERISTICS OF THE STEEL RECYCLING INDUSTRY

Furnace Types and Capacities

Three main types of furnaces are commonly used for melting scrap. These are electrical furnaces which can be arc furnaces, induction furnaces, and converters.

In arc furnaces the energy necessary to melt the steel charge is delivered by arching between carbon electrodes and the charge. Electric power is supplied by a high capacity three-phase distribution transformer.

In the induction furnace the heating is generated by an induction coil made of rectangular section copper tube.

In the conversion process oxygen blows through liquid cast iron and changes it into steel. Molten iron is poured into the converter with a controlled amount of lime and scrap. The oxygen causes the combustion of impurities what raises the temperature from 1250°C (molten iron) to 1800°C (molten steel). The amount of scrap in the charge is an important factor in controlling the temperature.

The three types of furnaces can use different proportions of scrap in the charge. Converters use a proportion of up to 35 % scrap whereas substantially higher proportions may be used in arc and induction furnaces.

Steel scrap may be used in the production of different types of steel what means that different types of steel plant may be considered.

There are large differences in the capacities of steel plants. Those that produce special steels, stainless steel included, are generally smaller than carbon steel plants. The sizes of furnaces are related to the capacities of the steel plants. Converters are used in large steel plants and have large capacities, arc furnaces have medium capacities and are used in medium capacity steel plants, induction furnaces have medium or low capacities and are used in medium or low capacity steel plants.

By-Products

Some additives are introduced with the charge in the furnace to help oxidize the impurities; however they increase the quantity of the byproducts, slag and dust.

The characteristics of the furnaces are different regarding the dust and slag production.

The content of radionuclides in the produced steel and in the by-products such as slag and dusts will depend upon several factors.

The first factor is the proportion of contaminated scrap steel versus the total quantity of scrap steel processed in the plant.

The second factor is the proportion of scrap steel in the melting charges which will in turn depend upon the type of steel being produced. In this respect, the quality of steel scrap is important in the production of stainless steel but is relatively less important in the manufacturing of carbon steel where a mixed charge of scrap from several different origins and qualities is often used. As a typical example a mix charge may comprise scrap of around ten different qualities.

The third factor is mixing with steel produced from other foundries, either in the manufacture of items or during any further steel production process.

6.0 POTENTIAL RADIOLOGICAL IMPACT

After the scrap is cleared from regulatory control it is typically sold to a scrap dealer who processes, sorts and sells it. Before the scrap is melted the surface activity can be resuspended and inhaled or transferred to the worker leading to an incorporation of the activity or an external contamination of the skin. Working near the scrap will lead to external irradiation from gamma emissions.

After melting the radioactivity is assumed to be homogeneously distributed throughout the product materials and the doses are calculated using the activity concentration in the substance. To calculate the concentration in the steel or the byproducts another critical factor, the distribution of the radioactive isotopes, is needed. For example the cobalt, iron and nickel isotopes tend to be found in the steel after melting, while the uranium and plutonium isotopes are found in the slag and zinc and cesium in the dust fraction.

Figure 1 shows the schematic flow of radioactivity and the exposure scenarios for ferrous metal scrap cleared from nuclear facilities.

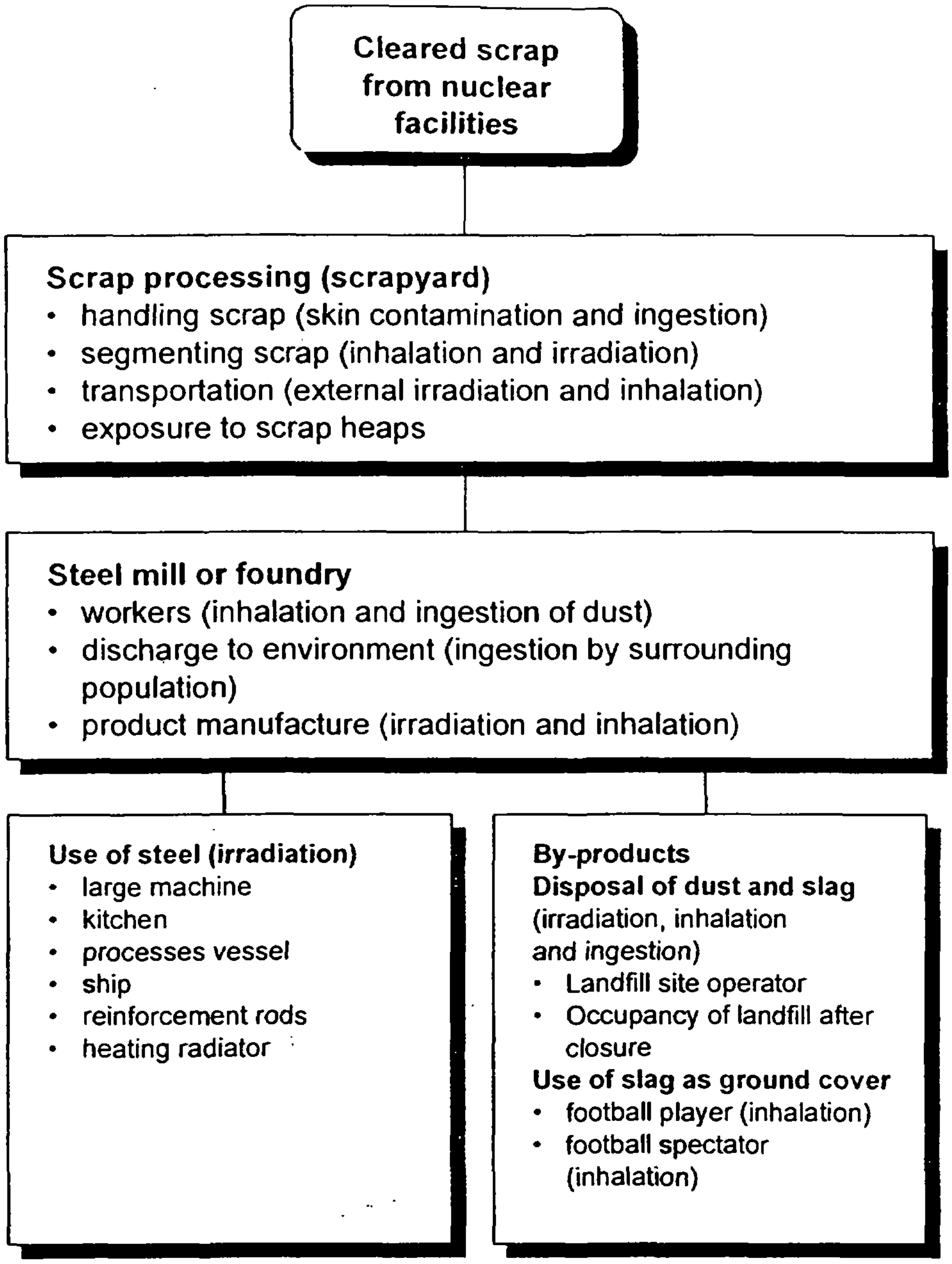

Figure 1

7.0 COPPER BASED METALS

Copper scrap is significantly more valuable than steel scrap, which along with an energy savings of between 80 and 92% compared to refining primary copper, leads to a recycling rate of roughly 80%. In nuclear installations copper metal comes primarily from electrical components like motors, although some power plants use brass in the heat exchangers which after decontamination may be clearable.

Recycling copper scrap

Refining copper scrap is significantly more complicated than recycling steel. The classic recycling process produces, after the electrolysis, a copper quality indistinguishable from grade A primary copper. New and production scrap is ideally suited for direct use in foundries. It is not possible to use mixed scrap or unknown alloys in foundries so that such scrap is always passed through refining works, the number of steps it passes through depends on the desired purity. It is possible, however to melt old copper and copper alloy components directly in foundries, given that the metal is well characterized.

During the refining of copper most of the accompanying metals are removed. In the first two steps (in the smelter and converter) volatile metal oxides like tin, zinc and lead are separated out into the dust and ash fractions while less precious metals like iron, aluminium and cobalt are bound into the slag. These by-products are recycled within the refinery or sold as raw material, for example the slag as building material and the dust to tin alloy and zinc refineries. During the further processing, especially in the electrolysis step, the precious metals are removed from the copper. From the production of 1 ton of copper about 1 to 2 kg of silver can be recovered. Other metals of interest include, gold, selenium, tellurium, arsenic, antimony, nickel and bismuth. Most of the precious metals are in the copper ores and enter the process via black and red primary copper so that the content varies drastically depending on where the ore was mined. The purification and separation processes lead to a 1000 fold and more increase in the concentration of certain metals so that it is important to consider the radiological consequences.

<u>Radiological consequences of recycling radioactive copper scrap</u>

Surface contamination limits for metal scrap are largely independent of the metal type since the transport and handling are similar regardless of the metal. Comparing copper to steel scrap the expected clearable quantity is significantly lesser and therefore can be processed in less time, leading to lower exposures to the radioactive copper scrap. For bulk activity the doses depend on the metal type.

The majority of copper which is potentially clearable comes from electrical equipment and is in the form of cables. Cables are usually coated with an insulating material, very often PVC, which must be separated from the copper before smelting. The remaining insulating material will most likely be disposed of at a landfill but recycling options are being investigated and pilot projects already exist.

Figure 2 shows the schematic flow of radioactivity and the exposure scenarios for recycling of copper scrap cleared from nuclear facilities.

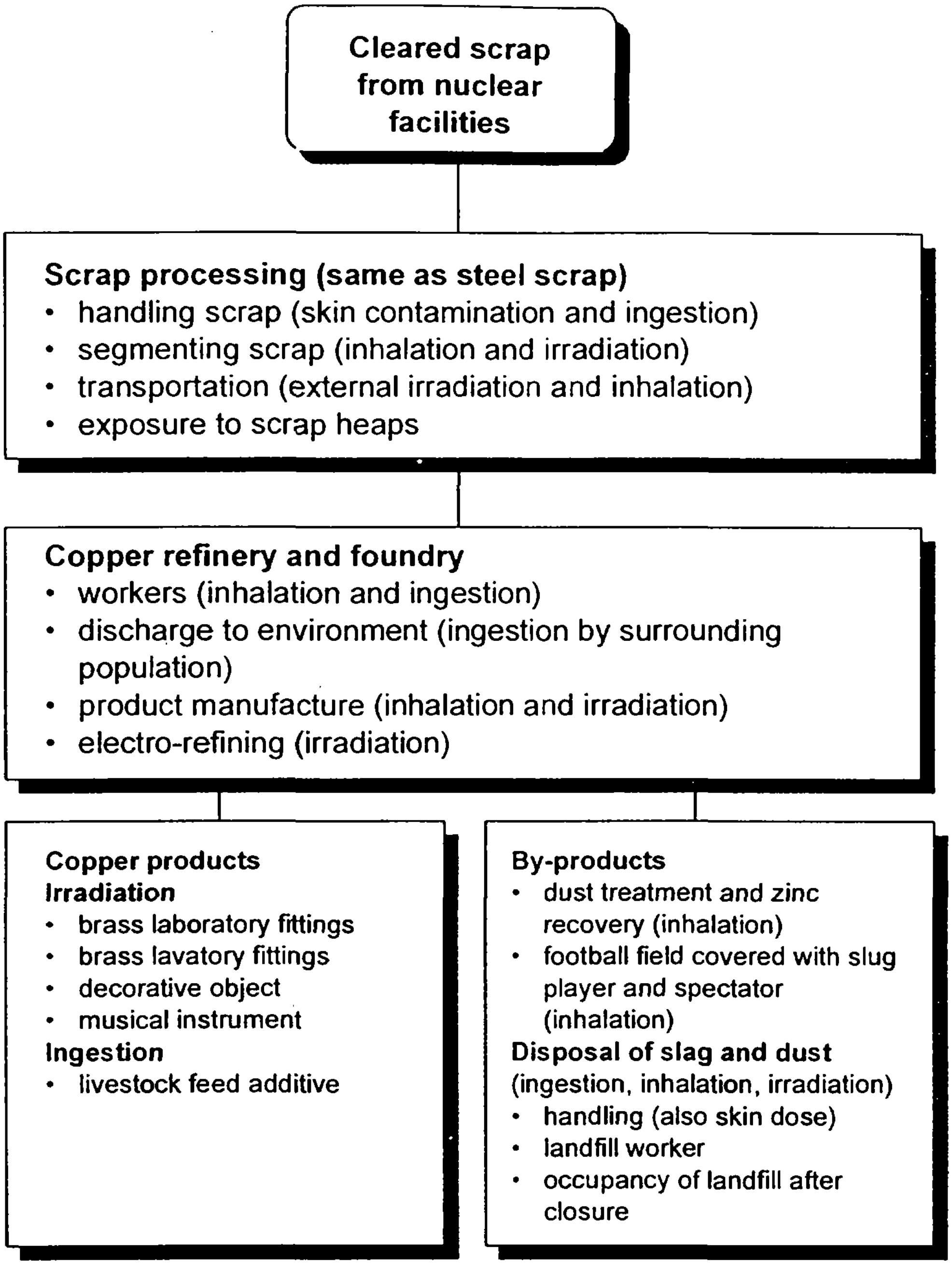

Figure 2

8.0 ALUMINIUM BASED METALS

An active policy of aluminium recycling is pursued since recycling uses up to 95% less energy than refining Bauxite. Aluminium and its alloys are used in nuclear power plants primarily for electrical components and in ventilation ducts. For security reasons the use of aluminium is restricted in power plants. Large amounts of aluminium are used in uranium enrichment facilities, especially in gaseous diffusion plants.

<u>Recycling aluminium scrap</u>

In contrast to steel production, aluminium scrap is not used in the production of primary aluminium from Bauxite. Three types of furnaces, rotary, reverberators and induction, are used to produce secondary aluminium, the rotary being the most important. The furnace capacities vary from 0.5 to 20 tons and use as input aluminium scrap, which is sorted into about 25 categories. The product metal is typically composed of a number of different scrap types which are held in stock piles at the plant and mixed depending on the desired aluminium quality. With present technology it is possible to recycle aluminium without a loss in quality. Nevertheless secondary aluminium is used primarily for casting and primary aluminium for formable aluminium (e.g. cans, sheets, etc.).

The reactivity of aluminium with oxygen requires that it be melted under a liquid salt covering, which leads to a large amount of salt slag which is poured off and forms blocks. The boundary between the aluminium and salt cover (scraper) contains 20 to 50% aluminium and can be recycled after a separation process. Per one ton of aluminium about 300 kg of slag and 3 kg of dust are produced. The possible uses for these by-products are limited what means that the majority is disposed of at landfills, although the slag can be used as an additive in cement. Reprocessing the salt slag within the aluminium smelting works is increasing as disposal costs rise and environmental laws become stricter.

Radiological consequence of recycling radioactive aluminium scrap

The secondary aluminium smelting process nearly guarantees that the scrap will be mixed with a number of other scrap types. During aluminium smelting a nuclide separation among the dust, slag and metal fractions occurs, which is accounted for in the radiological assessment.

Figure 3 shows the schematic flow of radioactivity and the exposure scenarios for recycling of aluminium scrap cleared from nuclear facilities.

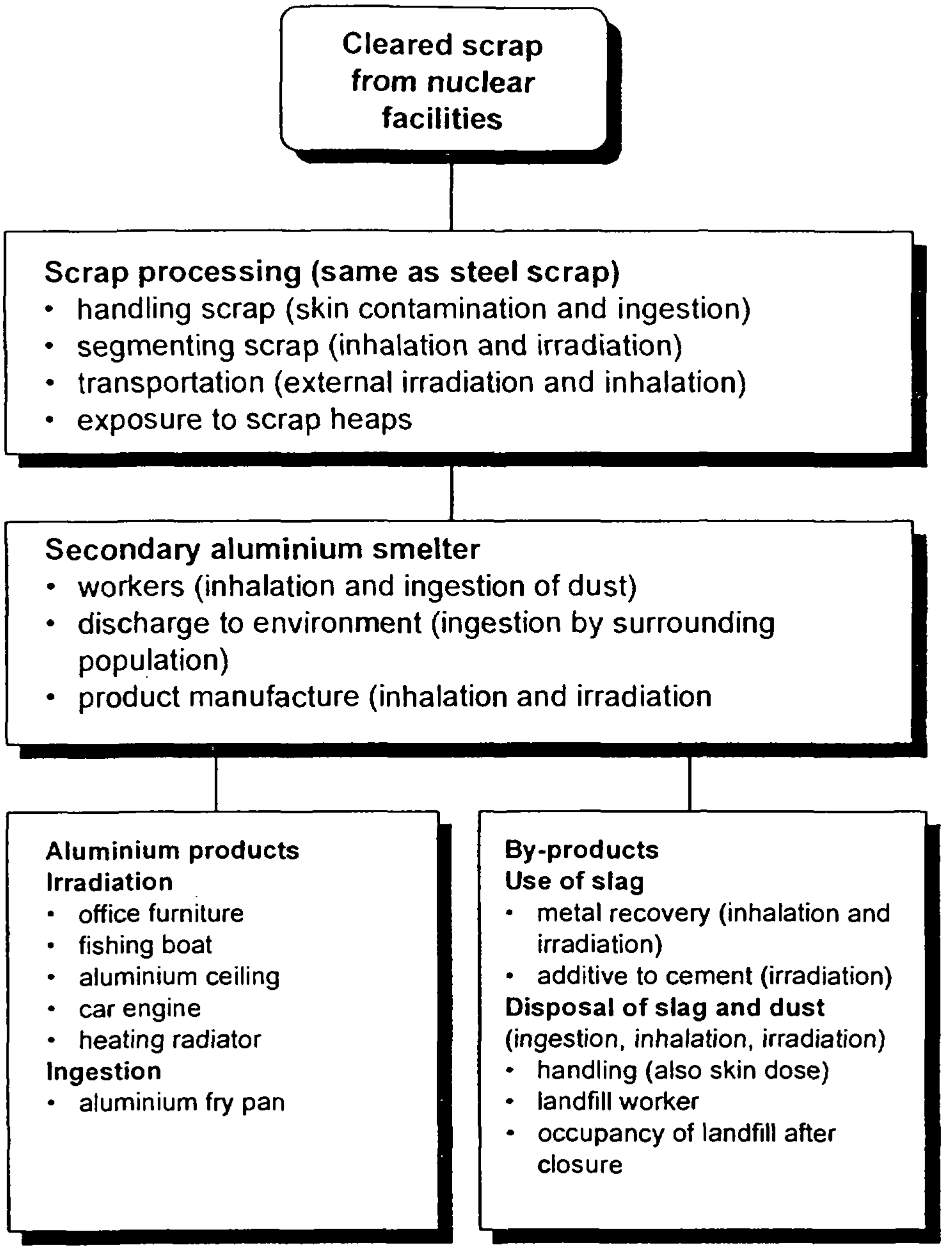

Figure 3

9.0 REFERENCES

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