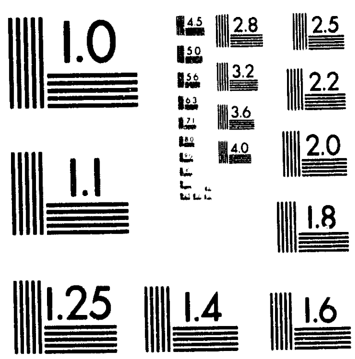
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Health Risk and Impact Evaluation for Recycling of Radioactive Scrap Metal

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The DoE, Office of Environmental Restoration and Waste Management, is participating with the Organization for Economic Cooperation and Development (OECD) in providing analytical support for developing international standards for recycling of radioactive scrap metals (RSM). For this purpose, Argonne National Laboratory is assessing health, environmental and societal implications of recycling and/or disposal process alternatives. This effort includes development of international inventory estimates for contaminated metals; investigation of international scrap metal markets; assessment of radiological and non-radiological human health risks; impacts on environmental quality and resources; and investigation of social and political factors. The RSM disposal option is being assessed with regard to the environmental and health impacts of replacing the metals if they are withdrawn from use. Impact estimates are developed for steel as an illustrative example because steel comprises a major portion of the scrap metal inventory.

Current and potential sources of RSM include nuclear power plants, fuel cycle and weapons production facilities, industrial and medical facilities and equipment, and petroleum and phosphate rock extraction equipment. Millions of metric tons (t) of scrap iron and steel, stainless steel, and copper, as well as lesser quantities of aluminum, nickel, lead, and zirconium, are likely to become available in the future as these facilities are withdrawn from service.

The major alternatives for managing RSM are to either (1) develop a regulatory process for decontamination and recycling that will safeguard human health or (2) dispose of the RSM and replace the metal stocks. To date, relatively small quantities of RSM from various facilities have been recycled for public use. The magnitude of the potentially available supply, and the very low level of radioactivity in a major portion of it, warrant consideration of a broad range of end uses for this material. A tiered system of release criteria has been evaluated because this approach has the advantage of matching RSM supply with demand while controlling public health risks at a very low level. The tiered

[1] Work supported by U.S. Department of energy, Assistant Secretary for Environmental Restoration and Waste Management, under contract W-31-109-Eng-38.

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release concept includes options of unrestricted release of surface-contaminated metal in its existing form (e.g., machinery) for reuse or disposal, unrestricted recycle of ingots cast from RSM after melting in a controlled facility, prescribed initial use of RSM products, and controlled recycle in the nuclear industry.

The alternative to releasing RSM is to dispose of it in a low-level waste disposal facility. This may also involve RSM decontamination to reduce worker exposures and melting to reduce volume. Disposal would result in withdrawal of the RSM from world stocks of metal, major portions of which are normally recycled. Replacing the discarded metal would involve mining of ore, ore enrichment or refining, and metal smelting, casting and fabrication, as well as production of the energy required for these activities.

Relative Magnitude of Health Risks

Both the RSM recycle/reuse and the disposal/replacement alternatives involve public and worker health risks from exposures to radiation and toxic chemicals, as well as from industrial and transportation accidents (summarized in Table 1). For both alternatives, the risks to workers from workplace accidents and to the public from transportation accidents are greater in magnitude than the risks from radioactive materials or chemicals.

Regulatory limits would constrain radiation exposure of workers and the general public to very low levels under either alternative. Unrestricted recycling scrap metal that meets activity limits derived under scenarios for a range of potential product end uses would result in a lifetime cancer fatality risk level of 10^{-6} to 10^{-7} for an individual of the general public from annual exposure (based on Safety Series No. 89 [IAEA 1988]). Risks to commercial metal workers would be of a similar magnitude and could be reduced further by employing protective measures. The total population risk level would be 10^{-2} to 10^{-1} cancer fatalities from an annual recycling practice. For the replacement alternative, some miners could be exposed to naturally occurring radioactivity that could approach the level of the regulatory limit for nuclear workers. Such exposures are more likely for nonferrous metals than for iron mining.

The nonradiological health risks are greater overall than the radiological risks for either alternative. The highest health risk levels are those for fatalities or disabling injuries from workplace accidents. For the recycling alternative, these risks apply to decontamination activities, including controlled smelting, and to commercial smelting. The risks are at least twice as high for the disposal and replacement option because it involves iron mining, coal mining, coke production, and blast furnace operation in addition to steel smelting.

Transportation accident fatality risks are on the order of 10^{-3} for each 100 km that the RSM or replacement materials are shipped. Transportation requirements and, therefore, risks are likely to be several times higher for disposal/replacement. Chemical risks to commercial metal workers and the public from melting RSM would be similar to those generated by smelting metal from ore.

For the portion of scrap metal that is part of the relatively large quantity of suspect, but probably nonradioactive scrap, both the radiological and nonradiological risks to the public and metal workers will be lower for recycling than for replacement because most of the radionuclides and contaminants that naturally occur in ore would have been removed in the original smelting of the RSM. Overall, the recycle option involves controlled risks borne by radiation workers and small increases in risks to commercial metal workers and the public, whereas the disposal and replacement option involves controlled risks to radiation workers and substantial increases in relatively uncontrolled risks to miners and the public. Health risks for the disposal/replacement alternative are at least twice the level for RSM recycling.

Relative Magnitude of Environmental Impacts

Major differences exist in the environmental impacts associated with the recycling and disposal alternatives. In general, recycling RSM would have less of an environmental impact and would require a smaller commitment of natural resources (see Table 1). The disposal and replacement alternative would require substantial land area for RSM disposal, and metal replacement processes would result in major disruption of land for mining and in contamination of land and water with toxic elements. Radionuclides and heavy metals would be released to air and water during refining processes, and much greater energy resources would be required than is the case for recycling scrap metal. For steel, the impacts are orders of magnitude larger for replacement than for recycling in virtually all categories.

Producing 1 t of steel from raw materials requires more than 2 t of iron ore and 0.5 t of coke, and mining the ore and coal results in numerous tons of wastes. Substantial land areas are disturbed or contaminated by toxic metals in this process and are generally not reclaimed. Both toxic and radioactive elements would be released to surface waters, and rivers would be damaged by sedimentation as a result of mining and refining processes for metal replacement. Water quality impacts from RSM recycling, in contrast, are likely to be kept to minimal levels by regulatory controls and good operating practices.

Only in the air emissions category do impacts of recycling approach those of disposal and replacement. The nature of emissions from smelting would be similar in both cases, but quantities of hazardous emissions from melting scrap might be smaller because many impurities would have previously been removed. In addition, recycling scrap steel would require two to three times less energy, thus reducing secondary impacts from fuel combustion as well. For all the processes required, air quality impacts are likely to be somewhat higher from metal replacement than from recycling.

Relative Magnitude of Socioeconomic Impacts

Socioeconomic issues are also summarized in Table 1. Of the socioeconomic issues related to the RSM alternatives, the availability and cost of low-level waste disposal site capacity is one of the most critical. If the RSM is disposed of as low-level waste, it would require greater low-level waste disposal site capacity than is currently available or planned, with all of the attendant problems of site development. In contrast, recycling RSM would require much less low-level waste disposal site capacity to accommodate the residuals from decontamination procedures.

Public acceptability of the concept of recycling materials with traces of radioactivity may be problematic because of the stigma associated with the nuclear industry in most industrialized countries. However, RSM recycling has been carried out successfully in small quantities in a number of countries, and products containing low levels of added or naturally occurring activity are widely used. The risks and impacts of metal replacement activities are of relatively less concern than radiological risks in most countries, even though they are substantially greater and more immediate. Acceptability of RSM recycling may depend on dissemination of information regarding the trade-offs and also on development of an international standard for material release and of the regulatory infrastructure to implement it.

Metal market impacts from either alternative are likely to be minimal because RSM represents a small proportion of total metal production and metal scrap. However, some price effects could occur in regional markets for some metals if a major portion of the available RSM is recycled.

RSM recycling and disposal activities are likely to take place in the countries in which the RSM sources are located. Metal replacement activities, especially mining, will occur in the locations where metal deposits are actively mined. Many of these mines are in less developed countries, which also tend to have less stringent health and environmental regulations and enforcement than the industrialized countries. As a result, RSM disposal and replacement has the potential for shifting the risks of RSM management to countries other than those generating significant quantities of RSM.

Overall, RSM recycling options have lower human health risks and environmental impacts than the disposal and replacement alternative does. The major obstacles to recycling implementation are the lack of international standards for release of contaminated materials and the uncertainties regarding public acceptance.

REFERENCES

International Atomic Energy Agency, 1988, *Principles for the Exemption of Radiation Sources and Practices from Regulatory Control*, IAEA Safety Series No. 89, Vienna, Austria.

TABLE 1 Comparison of Impacts from the Radioactive Scrap Metal Management Alternatives

	Impacts from RSM (Steel) Management Alternatives	
Impact Categories	Recycle/Reuse	Dispose and Replace
Human Health[a]		
Radiological risk	10^{-7} to 10^{-6} fatal cancer risk to metal workers and public; 10^{-2} to 10^{-1} population risk per year of practice	Potential elevated cancer risk to miners
Nonradiological risks		
Accidents (workplace)	About 7 fatalities or serious injuries to workers	About 14 fatalities or serious injuries to workers
Accidents (transportation)	10^{-2} fatality risk to workers and public	10^{-2} fatality risk to workers and public
Chemical exposure from smelting	10^{-3} fatal cancer risk to workers; 10^{-4} to public	10^{-3} fatal cancer risk to workers; 10^{-4} to public
Chemical exposure from coke production	None	1 fatal cancer risk to workers; 10^{-2} to public
Environmental Quality and Resource Use		
Land disturbance	Minimal	Substantial
Water quality degradation	Minimal	Substantial
Air quality degradation	Moderate	Moderate
Mineral resource requirement	Minimal	Substantial
Energy requirement	Moderate	Substantial
Socioeconomic Issues		
Low-level waste site capacity	Minimal	Substantial
Public acceptability	Varies among countries	Generally accepted except for local concerns
Metal market impacts	Minimal	Minimal
Risk distribution	Risk largely borne in country generating RSM	Risk largely shifted to less developed countries
Industrial applications	Minimal	Minimal

[a] Risk estimates represent maximum individual lifetime risk associated with a 50,000-t throughput.

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