SCOPING ANALYSIS:
ECONOMIC IMPACTS OF RADIATION PROTECTION STANDARDS FOR METAL IMPORTS AND EXPORTS

Prepared for:
Radiation Protection Division
Office of Radiation and Indoor Air
U.S. Environmental Protection Agency

Prepared by:
Industrial Economics, Incorporated
2067 Massachusetts Avenue
Cambridge, MA 02140
(617) 354-0074

September 2000

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PREFACE

This report was prepared for the U.S. Environmental Protection Agency (EPA) by Industrial Economics, Incorporated (IEc) under Work Assignment 0-4 of Contract Number 68-D99-018. The EPA work assignment manager was Valentine Anoma of EPA's Office of Radiation and Indoor Air. The IEc project manager was Lisa Robinson; Angela Vitulli was the lead analyst responsible for drafting this report. Other IEc staff who contributed significantly to this report include Jen Renshaw, Marcela Klicova, Lizanne Correa and Douglas Morton.

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All six of the countries discussed in this report import and export some scrap metal, but the quantities involved vary significantly by country as well as by metal type. For example, in 1996, the U.S. imported about 8.5 million tons of iron and steel scrap, and exported 2.6 million tons. Russia is the world's third largest exporter, selling 2.7 million tons in 1996, and imports very little scrap (0.1 million tons of iron and steel in 1996). Exports from Russia may be of the greatest concern, due to the large quantities of radioactive materials available domestically as well as the potentially significant quantity exported. Data on the U.S. suggest that only a negligible amount of iron and steel is imported directly from Russia. However, metals that originate in Russia may be sent to an intermediate country then imported into the U.S.

ECONOMIC CONSEQUENCES

Metals with elevated levels of contamination could have a variety of economic impacts, such as the following.

- Market impacts: Contamination of the metal supply could affect domestic or international markets. For example, if a significant percentage of the metal supply is contaminated, and the substitute sources of uncontaminated scrap (or virgin metals) are constrained, scrap prices could rise.

- Firm impacts: In a competitive market with many firms, contamination could affect some individual firms' profitability without noticeably affecting the overall market. For example, if a firm ships or receives contaminated metals, it may incur the costs associated with characterizing and remediating the contamination.

- Efficiency impacts: Even if the level of contamination is not substantial enough to have noticeable impacts on metal markets, it can effect the efficiency with which the markets operate. For example, the lack of a health-based standard for the acceptance of materials can lead industry to either reject metals that do not pose health risks, or to accept materials that could have adverse impacts on human health. While difficult to quantify, this lack of a target acceptance level can inhibit trade.

The available data suggest that noticeable market impacts are unlikely, at least in the foreseeable future. While the information on domestic inventories of metals with elevated levels of radioactivity is incomplete, comparison of these data to total domestic metal supplies suggests that contaminated metals may represent only a very small proportion of the overall supplies. In addition, the infrequency of alarms at industry sites suggests that, at least in the U.S., the levels of radiation typically found in metals are below levels of concern. Hence the quantities of contaminated metals may not be large enough to cause broad impacts throughout the metal markets currently or in the near future. The more significant concern may be the acute impacts associated with release of highly-radioactive metals or of radioactive sources that may be inadvertently melted with metal scrap.

Currently, the most substantial impacts appear to be on individual firms, and include the costs of addressing accidental meltings and rejected shipments. If elevated levels of radioactivity are detected at international borders or by industry, related costs often include expert assessment, decontamination, waste disposal, and lost productivity, as well as litigation in some cases. Estimates of the costs of individual accidental meltings suggest that each may cost between $2 million and $30 million. These costs may often be borne by the mill because of the difficulties inherent in identifying the party responsible for the source of the contamination. Estimates of the costs of shipments rejected by industry suggest that each incident may cost between $800,000 and $10 million. These costs are more often borne by the supplier rather than the manufacturer, if detection occurs before the materials are mixed or melted with metals from other sources.

Whether an international standard will reduce the numbers of accidental meltings or rejected shipments depends on the numeric criteria selected and the detection and enforcement measures that are implemented. In some cases, these incidents are caused by sources that are shielded and difficult to detect. The costs of identifying these sources at international ports may be high and may offset the economic benefits of preventing related incidents to some (unknown) extent. Although it may reduce the frequency of occurrence of acute events, an international standard is not likely to change industry radiation protection practices. Industry representatives indicate that they are unwilling to rely on external monitoring of radioactivity, and will continue to operate their own monitoring systems even if domestic or international controls are improved. Industries potentially sensitive to the level of radioactivity in metals do not appear to be concerned about the import of contaminated materials. At this time, the supply of metals meeting their acceptance criteria appears ample, and they seem confident in the measures they have taken to avoid the impact of contamination. The most significant effect of an international standard (if adequately enforced), may be a reduction in the frequency of export or import of atypical, relatively highly radioactive, materials.

Given these findings, additional research on the firm-level impacts of imported or exported metals with elevated radioactivity levels may be warranted. This analysis could involve collecting more information on the frequency, types, and costs of incidents associated with elevated radioactivity levels in metal imports and exports, as well as potential future trends. We could then compare this baseline to different options for establishing an international standard (e.g., alternative dose levels), estimating the effects of each option on the frequency and severity of these incidents.

This report does not address human health risks. Reductions of the risks associated with contaminated metals will have economic consequences, reducing the costs of medical care as well as the associated pain and suffering. Establishing an international standard will help ensure that industry does not accept metals with unsafe levels of radioactivity, but does not reject metals that contain radioactivity below levels of concern. Hence it may be desirable to include assessment of population risk (or collective dose) attributable to these incidents in any future analysis.

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INTRODUCTION — CHAPTER ONE

The U.S. Environmental Protection Agency (EPA) has become increasingly concerned about the levels of radioactivity in scrap metal and finished metal products imported by, and exported to, the U.S. and other countries. As a result, it is now working with other U.S. agencies, including the Nuclear Regulatory Commission (NRC), Department of Energy (DOE) and Department of State, as well as with the International Atomic Energy Agency (IAEA) and other interested parties, to develop international standards for allowable levels of radioactivity in traded metals. To support this effort, this report provides preliminary information on the economic consequences of existing practices, which may be affected by efforts to develop international standards.

The purpose of this scoping analysis is two-fold. First, it provides information on current practices and the types of economic impacts that result, based on detailed review of the available English language literature and extensive interviews with knowledgeable experts. Second, it provides the foundation for more detailed assessment of these impacts. The scoping analysis identifies the data gaps as well as the potentially significant effects that could be the focus of additional research. While current practices also result in risks to human health and the environment, these risks are being addressed by separate efforts and are not discussed in detail in this report.

This introductory chapter provides background information on the context for this analysis. It begins with an overview of the lifecycle of radioactive metal, discussing sources of increased levels of radioactivity and options for detection. Next, it discusses the efforts now underway to develop radiation protection standards for metal imports and exports. It also summarizes the implementation issues related to developing effective standards. It is followed by chapters that discuss the domestic generation of radioactive metals, the extent to which these metals are likely to be exported, and the economic consequences of trade in these metals. To provide examples of these impacts, this report focuses on practices in Russia, Spain, Italy, Brazil, and Korea, as well as the U.S.

SOURCES OF RADIOACTIVITY

Exhibit 1-1 provides a simplified overview of the potential sources of radioactivity in traded scrap metal and finished metal products. All metals exhibit some radioactivity resulting from man-made and natural sources; however, these levels are often far below detection limits as well as below levels of concern for human health. As illustrated by the exhibit, several sources may elevate the radioactive content of these materials.

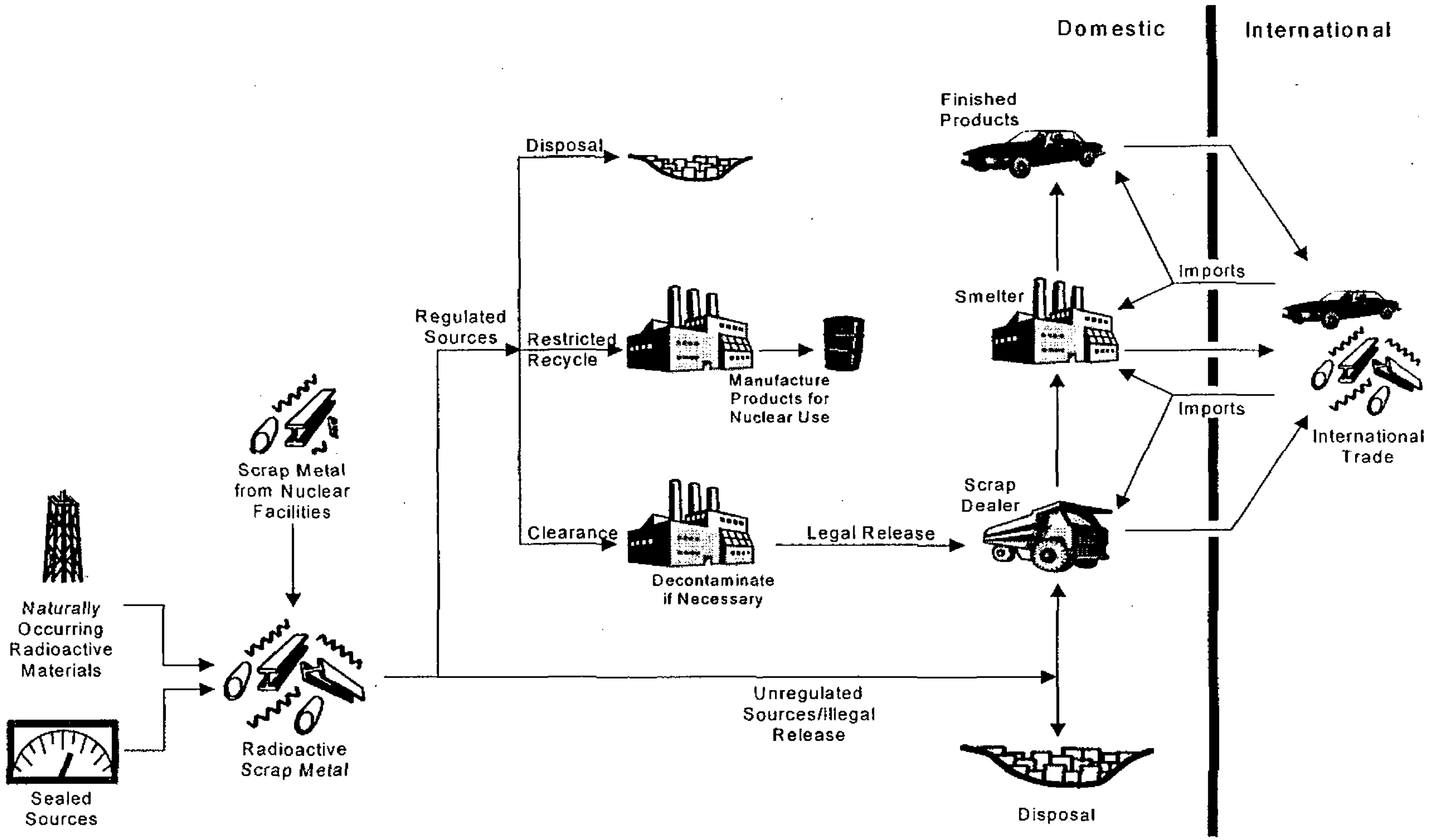
- Metals may be exposed to sources of radiation if they are used at nuclear sites, such as nuclear power plants or weapons production facilities. This exposure may result when metals are used in building structures, internal piping, tanks, or other components, as well as in a reactor.

- Metals used in extractive industries (e.g., oil, gas, and mining) may be exposed to naturally occurring sources of radiation; for example, when used as part of drilling equipment, extraction wells, or piping. These sources are generally referred to as NORM (naturally occurring radioactive materials), although NORM has a more precise definition in some regulatory contexts.

- Metals may also be exposed to radiation when melted with radioactive sources. While these sources may include the types of contaminated metals listed above, the sources of greatest concern are those that are sealed (such as industrial gauges) since they are difficult to detect and may be highly radioactive.

The extent to which release of these metals is regulated depends on the country as well as the source of radiation. For example, in the U.S., the use of metals from nuclear facilities and weapons production sites is more tightly regulated than other sources, due to concerns about the comparatively high radioactivity levels that may be present.

Exhibit 1-1
OVERVIEW OF RADIOACTIVE METAL LIFECYCLE



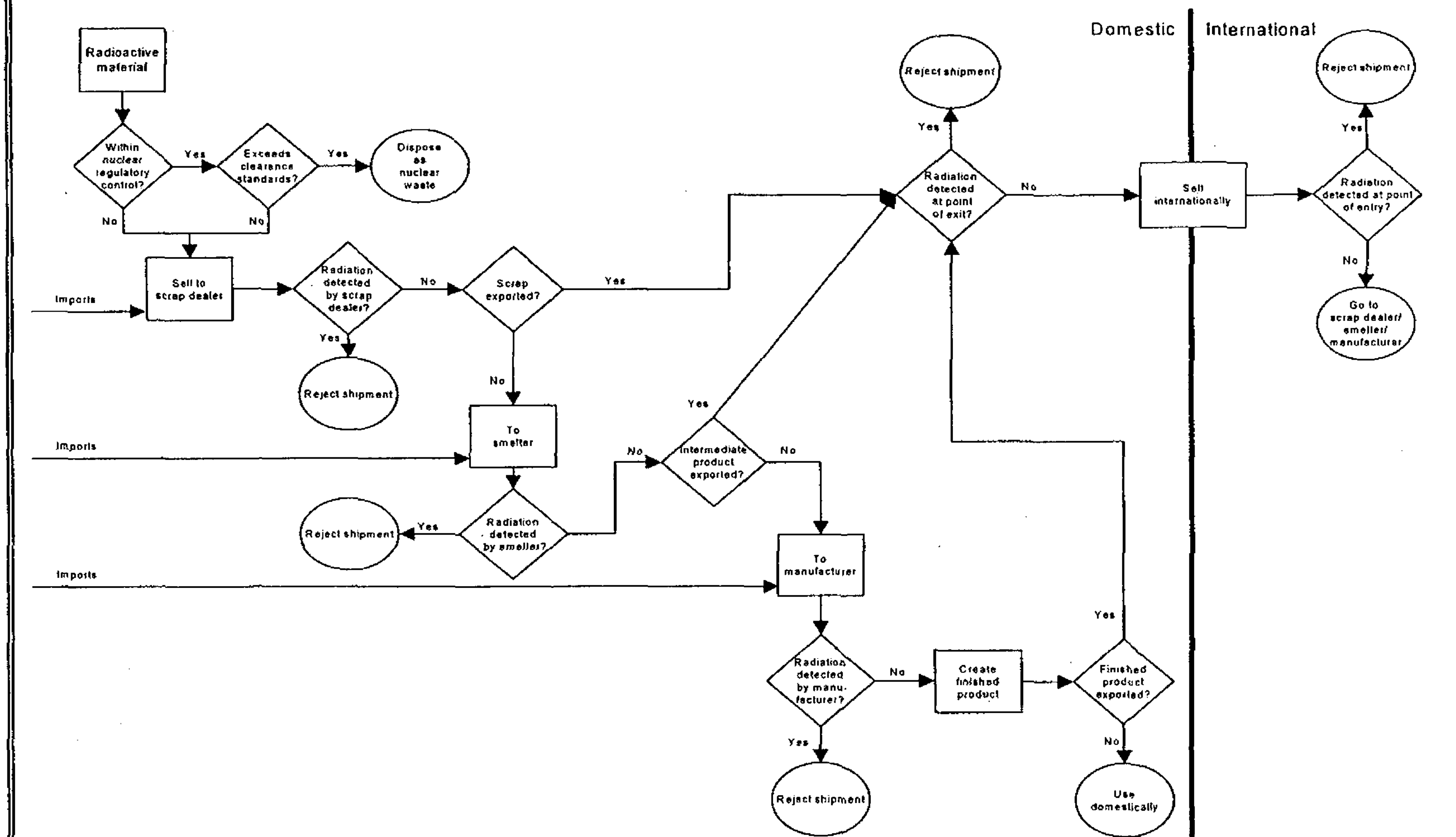
All of these metals, whether regulated or unregulated (or legally or illegally obtained), ultimately may be disposed or sold to a scrap dealer for re-use. Other options include recycling for re-use in a nuclear facility or decontaminating prior to sale as scrap. If the metal is sold to a scrap dealer, it may be smelted and developed into a finished product domestically, or may be exported as scrap or as an intermediate or finished product. Metals with elevated levels of radioactivity may also be imported as scrap, intermediate or finished products. These sources of metals, the extent to which they are regulated, and their domestic and international use, are explored in more detail in Chapters Two and Three of this report.

During this lifecycle, the level of radioactivity may be reduced intentionally by decontamination techniques or unintentionally as a result of metal processing (e.g., melting will cause certain radionuclides to partition to the slag or baghouse dust). Dilution (e.g., from mixing contaminated and uncontaminated metals during melting) also affects the levels of radioactivity in individual products (and hence individual exposure), although it may not reduce the total amount of radioactivity distributed across all metals.

Elevated levels of radioactivity may be detected at a variety of points in this lifecycle, as illustrated in Exhibit 1-2. In some cases, the radioactive content of scrap or finished products may not be detected either because it is below the detection limits of the monitoring equipment used or because it is never measured. Countries that enforce release standards are likely to monitor the radioactive content of metals before they leave the control of nuclear agencies. Other metals that are not subject to regulatory controls, either legally or due to illegal release, may be screened domestically at many points as the metal is processed by scrap dealers, smelters, and manufacturers of semi-finished and finished metal products.

Depending on the practices of the importing and exporting countries, metal may also be screened for elevated levels of radioactivity as it crosses international borders, either by customs officials or by the importing or exporting firm. However, the detection technologies and practices implemented at international borders are often weak, and several domestic and international agencies are working to improve them. At any point, if radioactivity levels of concern are detected, the metal may be rejected. The handling of rejected shipments depends both on the policies of the affected country and the circumstances and characteristics of the particular shipment. For example, shipments may be returned to the supplier for disposal if radioactivity is detected before the materials are mixed or melted with other metals. These issues are discussed in more detail in Chapters Three and Four.

Exhibit 1-2
OVERVIEW OF DETECTION OF RADIOACTIVE METAL



In addition to posing risks to human health and the environment, elevated levels of radiation impose costs on the firms and government agencies responsible for handling the metals. When shipments are rejected, the metal ultimately may be disposed, but first needs to be characterized and transported to the disposal site. The recipient may need to decontaminate the shipment before it is transported. There are also opportunity costs associated with rejected shipments because the individuals and resources involved are diverted from other, potentially more productive activities and commerce is disrupted.

If radiation from a shipment containing a sealed source or other radioactive materials is not detected, the materials may be melted accidentally, potentially contaminating an entire mill and causing it to shut-down while decontamination activities are undertaken. These types of firm-level economic impacts appear to be of greatest concern today because the quantities of radioactive metal may not be significant enough to affect overall market prices or to constrain the supply of uncontaminated metals. If the quantities of such metals (or associated levels of radioactivity) increase substantially, market-wide impacts may be of greater concern in the future. We discuss these economic impacts in more detail in Chapter Four.

POLICY OPTIONS

In response to concerns about increasing levels of radioactivity in the international metal supply, EPA has undertaken a number of efforts to develop better programs and standards for radiation protection, working with a number of U.S. and international agencies. EPA first became interested in these issues in the early 1990s, when it became involved in efforts to develop risk-based U.S. standards for release of metals from NRC licensees and DOE facilities. This work included economic analysis of alternative standards, as well as development of models that estimated the health risks associated with the release of these metals.[1] EPA has suspended its work on this initiative, but is supporting related NRC and DOE efforts.

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[1] Information on these efforts is available in: Industrial Economics, Incorporated, *Radiation Protection Standards for Scrap Metal: Preliminary Cost-Benefit Analysis*, prepared for the U.S. Environmental Protection Agency, June 1997; and, S. Cohen and Associates, *Technical Support Document: Potential Recycling of Scrap Metal from Nuclear Facilities*, prepared for the U.S. Environmental Protection Agency, September 30, 1999.

More recently, EPA broadened the scope of its work through the Clean Metals Program. The program currently includes two active initiatives, the Foreign Trade/Imports Initiative, which addresses contaminated metals imported from foreign sources, and the Orphan Sources Initiative, which addresses sources of radiation that are not under regulatory control (such as lost sealed sources).[2]

The Foreign Trade/Imports Initiative of the EPA Clean Metals Program encompasses EPA's efforts to develop consistent radiological standards for imports. EPA and the State Department have signed a Memorandum of Understanding which establishes an inter-agency protocol for coordinating activities and sharing information related to radioactivity in imported metals.[3] EPA has also been working with representatives from the IAEA and other countries to analyze and eventually establish radiological clearance levels and associated guidance.[4] For example, EPA has been participating in an IAEA committee that is working to define internationally consistent exposure scenarios for deriving clearance levels, based on expanding and refining the dose model initially developed for U.S. domestic standards. The IAEA's Model Projects also provide technical assistance to countries that lack adequate border controls to halt radiologically contaminated shipments.

The Orphan Sources Initiative is a joint effort of the EPA and Conference of Radiation Control Program Directors (CRCPD) to assist states in finding and disposing of lost radioactive sources. These are typically sealed sources that are found in specialized industrial machinery, such as wear detectors for industrial furnaces and radiation sources for medical devices. EPA is working with the CRCPD to conduct a state-by-state inventory of lost sources and to create a system for disposing of these sources. The agencies are also working to tighten accountability for radiation sources to prevent currently used sources from escaping regulatory control in the future.

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[2] Detailed descriptions of these EPA programs can be found on EPA's Internet site, http://www.epa.gov/radiation/cleanmetals/index.html, June 2, 2000.

[3] U.S. Environmental Protection Agency and U.S. Department of State, *Establishment of Radiological Screening Guidelines for Metal Products for Import to the United States,* 1998.

[4] In a separate initiative, EPA is studying NORM contamination of metals and other materials. Although much of this work focuses on characterizing NORM contamination resulting from domestic extractive industries, EPA is also conferring with the IAEA on the international evaluation and control of NORM-contaminated materials.

This report focuses primarily on issues related to the Foreign Trade/Imports Initiative, although it includes discussion of lost sources to the extent that they are likely to contaminate traded metals through accidental meltings. We consider the effects of current practices on the levels of radioactivity found in imports and exports, as well as the economic consequences of these practices. We also discuss the potential impacts of EPA's efforts on these practices.

IMPLEMENTATION ISSUES

The outcome of the efforts to develop standards for radioactivity in imports and exports will depend in part on the details of the specific policy decisions; e.g., the specific clearance levels selected. These levels are not yet known, and will result from the efforts of EPA and others that are now underway. However, the manner in which these policies are implemented will also determine their effectiveness. Dr. David Victor, a fellow at the Council on Foreign Relations, and other experts recently studied 14 international environmental agreements to determine the factors that influence their effectiveness.[5] We summarize some of the recommendations from the Victor study that may be most relevant to the development of standards for residual radioactivity in traded metals below. Appendix A of this report discusses two case studies which provide examples of these concerns.

Expand Participation

The Victor study recommends involving both target and non-governmental groups (e.g., citizen or industry associations) in the negotiations. For an international agreement to be effective, it must involve representatives of the groups whose behavior it is intended to affect (i.e., target groups), whether they are governments, industries, or other organizations. This participation is important for two reasons. First, target groups typically can provide information essential to evaluating the accord's policy options, technical feasibility, and costs and benefits. Such information is particularly important if the policy is complex or if there are numerous implementation options. Second, target group participation encourages implementation because it ensures that the accord is consistent with the interests of that group. That is, involvement of target groups does not appear to motivate implementation; rather, it is a prerequisite for it.

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[5] David Victor (ed.), *The Implementation and Effectiveness of International Environmental Commitments: Theory and Practice*, Cambridge, MA: MIT Press, 1998.

Involving non-governmental organizations is also important, particulary when developing implementation options. The non-governmental organizations addressed in the Victor study play a potential watchdog function in exposing implementation failures and suggesting alternative models. To the extent that non-governmental organizations are perceived as removed from the political realm, both target groups and those crafting the agreement view them as neutral monitors. Unfortunately, due to the expense involved in monitoring implementation progress, monitoring by non-governmental organizations is historically not as common as may be desired.

Create Flexible Implementation Instruments

Implementation instruments include the accord's enforcement and managerial provisions as well as the system for implementation review. Choices for managerial and enforcement provisions are somewhat determined by the accord's framework or prototype. There are two general types of international accords, binding and non-binding. Binding accords assume that the parties are not inclined to implement the provisions, and therefore the accord needs to have strict ("stick") enforcement provisions, including penalties for noncompliance, in order to be effective. In contrast, non-binding accords assume the opposite: that parties are inclined to implement the provisions and that compliance failures should be managed in a non-confrontational manner. Hence, non-binding accords use incentive-based ("carrot") provisions, such as generous funding and technical assistance, to encourage implementation.

Binding agreements are conventionally thought of as more effective, but the Victor study reports that non-binding agreements have a greater influence on behavior. This is because countries tend to adopt ambitious and clearly worded agreements only when they are in non-binding form. Clearly worded commitments tend to yield more incentives for behavioral change and for more specific actions. Binding commitments tend to be less ambitious and clear about implementation schedules and expectations, and were found to yield less impressive results overall. Thus, binding accords tend to be adhered to carefully but not ambitious in scope or flexible in nature. The diversity of countries or target groups that will participate in binding accords is limited mainly to industrialized, democratic nations. Changing the parameters of these accords over time is difficult, as indicated by the Basel Convention experience (discussed in Appendix A). Moreover, the Victor study found that enforcement provisions are rarely used in implementing accords; most cases of non-compliance were managed through negotiations and provisions for further funding or technical assistance.

Although non-binding accords tend to be ambitious in scope and flexible in nature, and therefore attract broader participation, they can be difficult to implement due to their voluntary nature and decentralized administration. Furthermore, the Victor study found that incorporating the threat of enforcement actions into agreements and occasionally using enforcement measures creates a deterrent effect for other would-be violators. In addition, non-binding accords have the potential to become binding over time if governments use them as models for domestic regulatory systems. Although non-binding agreements traditionally rely on managerial approaches and binding agreements rely on enforcement approaches, such parallel relationships do not have to be the rule. Since both types of accords have advantages and drawbacks, a successful effort combines features from each type in order to create a balanced, workable agreement.

Systems for implementation review allow for the adjustment of international commitments based on new information or unanticipated problems. As such, systems for implementation review provide a guarantee of flexibility. For example, these systems include the processes by which treaty monitors can mobilize technical assistance when an implementation problem occurs. International agreements require that many institutions take responsibility for verifying various aspects of implementation. Systems for implementation review provide coordination plans for the decentralized verification of progress.

The Victor study.recommends that parties developing international agreements should create systems that ensure a certain level of data quality. National reporting data are often not comparable, and their accuracy is often unknown. Systems for implementation review should include protocols for data quality that provide common metrics for reporting, verification mechanisms, and an infrastructure for analyzing and distributing results to all key players.

Address Needs of Developing Economies

Due to the level of resources and cooperation necessary to implement international accords, most participants tend to be industrialized democracies. This is problematic because many of the target groups of international accords, whether governments or industries, are located in developing countries. However, for developing countries to participate, they typically require funding for the incremental costs of implementation. Such costs include those for sending diplomats to meetings, transferring technologies necessary to implement the agreement, and staffing programs at implementing institutions. This funding requirement is often applicable to less liberal but somewhat developed countries as well.

Although they are not considered developing countries, countries with economies in transition, such as the states of the former USSR, are undergoing extensive political and economic changes that pose special challenges for implementing international accords. In these countries, the political and economic climate is at once becoming more open and more chaotic. This situation has led to economic instability, but also to greater information sharing and public discourse on social and environmental issues. As a result of these changes, the political systems of these countries have become decentralized and the ability of central governments to implement international accords has weakened. Jurisdiction among federal, state, and local authorities has also become blurred in the process.

The Victor study reveals that financial transfers for economies in transition are not as effective as they are for developing countries. Although funding may be a prerequisite for countries in transition to implement accords, it does not guarantee good results. The parties that craft agreements may have to negotiate more assistance with domestic coordination of practices, in addition to funding, to facilitate implementation in these countries in transition.

Summary

In summary, the key factors that may influence the successful implementation of international radiation protection standards for imported and exported metals include the following:

- Expand participation in the design and implementation of international accords: In addition to the official crafters of international agreements, participants should include representatives of the groups whose behavior is the target of the accord, as well as representatives of non-governmental organizations.

- Develop a broad set of implementation instruments that are strategically designed to fit the goals of the accord: The enforcement and management provisions of an accord should encourage both initial participation and good faith implementation. A system for implementation review is also needed to respond to new information while ensuring progress.

- Address the needs of developing economies: Past experience indicates that wealthier nations should consider paying the participatory costs of developing countries. Furthermore, countries in transition, such as those of the former USSR, may require extensive logistical as well as financial assistance to implement accords due to the nature of the political and economic changes they are experiencing.

The remainder of this report discusses information related to the economic impacts of current practices. Efforts to change these practices and increase protection from radioactive metals will, however, be more effective if they take into account these types of concerns.

ORGANIZATION OF THIS REPORT

The remainder of this report includes four chapters.

- **Chapter Two** provides information on the sources of radioactive metals and the regulatory programs that address the management of these materials.
- **Chapter Three** discusses the import and exports of metals and current practices for detecting elevated levels of radioactivity in these metals.
- **Chapter Four** describes the economic consequences of elevated levels of radioactivity in imports and exports, including the impacts of accidental meltings of sealed sources and of rejected shipments.
- **Chapter Five** summarizes our findings and discusses their implications.

More detailed information on these issues is contained in the appendices to this report.

Exhibit 2-1

ESTIMATED QUANTITIES OF RADIOACTIVE METAL GENERATED BY DECOMMISSIONING OF NUCLEAR POWER PLANTS

Country (number of plants)	Iron and Steel	Copper	Aluminum
Former Soviet Union (79 plants)	799,814 metric tons	7,312 metric tons	1,468 metric tons
U.S. (131 plants)	605,097 metric tons	9,691 metric tons	253 metric tons
South Korea (14 plants)	145,739 metric tons	1,245 metric tons	250 metric tons
Spain (10 plants)	95,169 metric tons	852 metric tons	173 metric tons
Brazil (5 plants)	61,703 metric tons	538 metric tons	107 metric tons
Italy (4 plants)	24,249 metric tons	260 metric tons	32 metric tons

Notes:
U.S. iron and steel quantities include potentially recyclable carbon and stainless steel, as well as galvanized iron; quantities for other countries include all radioactive iron and steel (including stainless steel).
U.S. estimates exclude metals that cannot be effectively decontaminated; estimates for other countries include all radioactive metals regardless of whether decontamination is feasible.
Actual releases are likely to be significantly less than these quantities due to regulatory controls and other factors, as discussed in the text.
Argonne estimates are for all the Republics of the former Soviet Union, not solely Russia.
Sources:
U.S. data: Sanford Cohen & Associates, Incorporated, *Technical Support Document: Potential Recycling of Scrap Metal from Nuclear Facilities,* prepared for the U.S. Environmental Protection Agency, September 30, 1999.
Data for other countries: Nieves, L.A., Chen, S.Y., Kohout, E.J., Nabelssi, B., Tilbrook, R.W., and S.E. Wilson, Argonne National Laboratory, *Evaluation of Radioactive Scrap Metal Recycling*, prepared for the U.S. Department of Energy, NAL/EAD/TM-50, December 1995.

As indicated by the exhibit, the majority of the radioactive metals resulting from decommissioning of these plants is iron and steel. Most of this metal is likely to be generated by the U.S. and the former Republics of the Soviet Union (including Russia), as existing nuclear power plants are decommissioned over the next several decades.[4] As noted earlier, the U.S. estimates are based on a different analytic approach than the other estimates, and focus more narrowly on potentially releasable metals. The other countries addressed by this study will generate smaller quantities of metals.

Information on the extent to which these materials may be released for unconditional use rather than disposed is available primarily for the U.S., based on a 1997 study completed for EPA by Industrial Economics, Incorporated.[5] This study estimates that between 62 and 73 percent of the potentially recyclable metal from U.S. facilities could be cost-effectively released (after any needed decontamination) under current U.S. standards (Regulatory Guide 1.86, discussed in the following section), over a 55 year time period.[6] If the standard was changed to a 1 mrem dose limit, 61 to 84 percent of the metals could be released. Actual releases may be significantly lower due to public concerns about these practices.

The Argonne study does not specifically address the quantities of metals that could be released under alternative standards. Given both the regulatory criteria applied in each country (discussed later in this chapter) and the relative costs of recycling (including any decontamination costs as well as the off-setting sales revenue) and disposal, only a small subset of these metals may be released.

However, the Argonne study provides some insights into the quantities that could be released, because it classifies metals according to the difficulty of removing the contamination. The researchers find that the majority of the metals reported in Exhibit 2-1 have surficial contamination

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[4] Argonne estimates that 50 power plants are located in Russia, 22 in the Ukraine, two in Armenia, two in Lithuania, and three in unidentified locations. More recent information, discussed below, indicates that Russia has only about 40 operating or closed plants.

[5] Industrial Economics, Incorporated, *Radiation Protection Standards for Scrap Metal: Preliminary Cost-Benefit Analysis*, prepared for the U.S. Environmental Protection Agency, June 1997.

[6] This study is based on 1997 SC&A estimates of metal quantities (Exhibit 2-1 includes updated 1999 estimates). Because the model used to convert dose to activity has also been refined, and the options for disposal of these metals are changing (two U.S. disposal sites, Barnwell and Envirocare, are now changing their acceptance policies and pricing significantly), we are uncertain about the extent to which these results would change based on more recent data.

that could be removed, including 90 percent of the metals from the former Soviet Union, and 65 to 68 percent of the metals from Italy, Spain, Brazil and South Korea. These percentages may provide an upper bound estimate of the amounts that potentially could be released in countries with regulatory controls; actual quantities are likely to be lower due to the relative costs of alternative disposition options as well as regulatory barriers and public pressures to limit these releases. The remaining ten to 35 percent of these metals have contamination that is either difficult or impossible to remove to achieve a reasonable release standard. These more highly contaminated metals may be released primarily in those countries lacking effective regulatory controls. More detailed information on the quantities of metal in each category is provided in Appendix B.

The Argonne estimates for the former USSR address metals from 79 power plants. Information from other sources (discussed in Appendix G) indicate that about 40 plants are operating or non-operating in Russia. In addition to metals from decommissioning, some sources suggest that, at least in Russia, significant quantities may be released from on-going operations. In contrast, the research conducted for EPA suggests that relatively small quantities are likely to be released from on-going operations in the U.S., due to regulatory controls, public pressures to limit release, and other factors.

Decommissioning of Nuclear Weapons Production Facilities

Use of nuclear materials in defense-related activities also generates contaminated scrap. The most significant source of scrap metal may result from the decommissioning of weapons production facilities. In addition, in some countries decommissioning of nuclear submarines may result in substantive quantities of scrap metal. As with nuclear power plants, a large portion of the metal at weapons facilities will have no radioactive content, however, metal used in processes such as fuel enrichment may become radioactive.[7] Other defense-related facilities (such as use of radioactive materials on military bases) are likely to generate significantly smaller quantities of potentially releasable metals.

The SC&A and Argonne reports cited above provide estimates of the quantities of potentially radioactive metals that may result from decommissioning of weapons facilities. The SC&A report is the most recent source of data for the U.S., and focuses on 11 major DOE facilities that are scheduled for decommissioning, including three fuel enrichment facilities. Due to the vast size of these facilities, they are likely to account for the majority of potentially recyclable metals from

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[7] The types and extent of radioactive contamination in these metals is highly uncertain. Radionuclides of concern include uranium-238, cesium-137, and plutonium-239, according to SC&A.

defense-related activities in the U.S. over the next several decades. The SC&A report focuses on metals that could potentially be released, given possible U.S. release standards and decontamination options. The sources of these data include several reports prepared for DOE as well as additional interviews and analysis performed by SC&A. Exhibit 2-2 summarizes the data on these facilities.

Exhibit 2-2

ESTIMATED QUANTITIES OF RADIOACTIVE METAL GENERATED BY DECOMMISSIONING OF MAJOR U.S. WEAPONS FACILITIES

Metal Type	Quantity
Carbon Steel	903,897 metric tons
Copper/Brass	53,990 metric tons
Nickel	44,818 metric tons
Aluminum	36,070 metric tons
Stainless Steel	26,960 metric tons
Lead, monel, and undefined metals	2,287 metric tons
Total	**1,068,022 metric tons**

Note:
Actual releases are likely to be significantly less than these quantities due to regulatory controls and other factors, as discussed in the text.
Source:
Sanford Cohen and Associates, Incorporated, *Technical Support Document: Potential Recycling of Scrap Metal from Nuclear Facilities, Volume 1,* prepared for the U.S. Environmental Protection Agency, September 30, 1999.

As indicated by the exhibit, over the next several decades, decontamination and decommissioning activities at these sites may generate an estimated 1,068,022 metric tons of scrap metal that could potentially be released or disposed. These quantities include only those metals whose disposition could be affected by future policies for unconditional clearance; they do not include non-radioactive metals or metals that cannot be effectively decontaminated. Carbon and stainless steel account for 88 percent of the potentially recyclable metal coming from these facilities.

As discussed earlier, the quantities of metals actually released from these facilities depends on several factors such as the applicable clearance standards, the costs of disposal compared to clearance, and public pressures to limit the release of these materials. DOE has also engaged in significant efforts to recycle metals for restricted use in nuclear facilities.

Industrial Economics' 1997 analysis, referenced earlier, assesses the impact of alternative release standards on the quantities of metals from these facilities that may be released for unconditional use. It finds that under current DOE standards (DOE Order 5400.5, as discussed later in this chapter), these facilities may release between five and 10 percent of these inventories, after any needed decontamination, over a 40-year period from 1998 to 2038. If the standard changes to a 1 mrem dose limit, these percentages will range from nine to 12 percent over the same time period. Actual releases may be substantially lower than these estimates due to public pressure to limit releases as well as changing DOE policies.

Little information is available on metals from Russian weapons facilities or other defense related activities, as discussed in Appendix G. As of 1995, Argonne also reports that Brazil was in the process of constructing one nuclear fuel enrichment plant in Resende. This plant will have a capacity of 10 kSWU/yr. No further information is available on this facility. The other countries included in this report (Italy, Spain, and South Korea) do not appear to have nuclear weapons production capabilities.

Both the U.S. and Russia also have fleets of nuclear submarines, which are an additional source of contaminated metals. However, the extent to which these countries are likely to release this metal for unrestricted use is unclear. According to Argonne, in 1990 the U.S. had approximately 160 naval propulsion reactors associated with submarines, which could result in 160,000 tons of radioactive stainless steel. The U.S. currently disposes of this metal as low-level radioactive waste. In Russia, it appears more likely that contaminated metal from submarines decommissioning could be released, as discussed in Appendix G.

NORM-Contaminated Equipment[8]

Radioactive scrap metal is also generated by the extraction sector, primarily petroleum and phosphate industries, as well as by geothermal energy production, uranium and metal mining and processing, drinking water treatment, and chemical manufacturing and processing industries.

[8] These materials are now often referred to as "TENORM" (technically enhanced NORM) to separate materials generated by human activity from materials present in undisturbed natural settings.

Drilling and processing operations related to extraction industries bring piping and equipment into contact with sub-surface sources of NORM; elevated concentrations of radioactivity may then be found in the resulting water, scale, and sludge, which may contaminate the equipment.[9]

The most significant sources of NORM-contaminated metal are tubulars and casings, injection piping, and surface equipment originating from activities associated with the operation and maintenance of oil and gas production facilities. There are two different kinds of NORM contamination; diffuse, characterized by large amounts of material containing low levels of radioactivity, and discrete, characterized by small volumes of material containing relatively higher levels of radioactivity. Whether used equipment ends up discarded or reused is determined based on cost and the properties of the scrap; such as its size and dimensions, bulk density, cleanliness, residual alloys and impurities.

Information on U.S. practices suggests that facility operators may often scan and clean these metals before releasing them, or store them in anticipation of eventual disposal. In many cases, the level of contamination may be relatively low, and may be removed by conventional cleaning techniques. However, if metals from these operations are sold as scrap without prior decontamination, the radioactivity they contain may then contaminate the resulting intermediate and finished products. In addition to contaminating the metal itself, excess scale and sludge may appear in loads of metal destined for resale. Depending on the extent to which these sources are regulated, the facility selling the equipment may not be obligated to determine or report the presence of radioactivity.

Only limited information is available on the quantities of contaminated scrap metal generated from these activities. Below, we first summarize available information on the quantities of NORM-contaminated scrap metal generated in the U.S by the oil and gas industries. We then present information on the size of the oil and gas industries in each of the six countries considered in this report, which provides a rough sense of the quantities of contaminated equipment that may result. Information on volumes of NORM-contaminated metal generated by other industry sectors is not available.

Two studies, one by SC&A and others, and the other by Argonne National Laboratory, provide information on the extent of NORM-contaminated metal generated in the U.S., although neither study considers the full range of activities that may generate these materials. According to

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[9] The primary radionuclides of concern in NORM waste streams are often radium-226 and radium-228, as well as other radionuclides in their decay series. Natural gas production and processing equipment may also be contaminated with a thin film of lead-210 plated onto interior surfaces.

SC&A, the U.S. had more than 852,000 oil and gas wells in 1991.[10] A typical 10-well production facility generates approximately 35,000 cubic feet of extraction components, and the researchers estimate that one-third of these wells may be contaminated with NORM. Based on a series of assumptions regarding the extent of contamination, the useful life of affected equipment, and the weight of the components, the researchers estimate that roughly 3.0 million metric tons of contaminated equipment are generated annually. The extent to which this equipment is repaired for reuse, stored for disposal, decontaminated and then sold as scrap, or sold without prior decontamination, is unknown.

In 1996, Argonne completed a separate study that focused solely on the petroleum industry.[11] The researchers assume that about 10 percent of all equipment is contaminated by NORM. Based on data on the number of wells abandoned annually, the researchers estimate that the quantity of NORM-contaminated equipment is approximately 173,000 tons per year.[12] Again, the disposition of this metal is uncertain, and we cannot predict the percentage of NORM-contaminated metal likely to enter the scrap market.

These sources do not provide information on the quantities of NORM-contaminated metal from other U.S. extractive industries, or from activities in Italy, Spain, Russia, Brazil and South Korea. However, each of these countries are likely to generate some of these metals given their involvement in these industries. To provide a sense of the relative magnitude of these industries and their potential for creating NORM-contaminated materials, in Exhibit 2-3 we present data in the size of two of the sectors that generate NORM-contaminated equipment: the petroleum and gas industries. Russia is the biggest producers of oil, and the U.S. output is almost 950 times that of the smallest producer, South Korea. Of the six subject countries, Russia is the biggest producer of

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[10] Dehmel, J.C. et al. *Scrap Metal Recycling of NORM Contaminated Petroleum Equipment,* prepared by Sanford Cohen & Associates, T.P. McNulty and Associates, and Hazen Research Incorporated, for the Petroleum Environmental Research Forum, September 1992.

[11] Smith, K.P., Blunt, D.L., Williams, G.P., and Tebes, C.L., Argonne National Laboratory, *Radiological Dose Assessment Related to Management of Naturally Occurring Radioactive Materials Generated by the Petroleum Industry,* prepared for the U.S. Department of Energy, September 1996.

[12] This estimate includes production equipment only. Another study, which has not been finalized, indicates that surface equipment may lead to an additional 30,000 to 300,000 metric tons of scrap metal annually, with a best estimate of 100,000 metric tons. S. Cohen and Associates, *NORM Waste Characterization Report (Final Draft),* prepared for the U.S. Environmental Protection Agency, 1997.

natural gas, closely followed by the United States, and Spain is the smallest. South Korea imports all of the natural gas it uses. As noted earlier, other industries (not addressed by this exhibit) may also generate NORM-contaminated equipment.

Exhibit 2-3

ANNUAL OIL AND GAS PRODUCTION
1998

Country	Oil Production	Gas Production
U.S.	367.9 million metric tons	489.4 million metric tons
Russia	304.3 million metric tons	496.2 million metric tons
Italy	5.9 million metric tons	16.8 million metric tons
Spain	0.5 million metric tons	0.1 million metric tons
Brazil	50.0 million metric tons	5.8 million metric tons
South Korea	0.4 million metric tons	----

Notes:
Data for oil production in U.S., Russia, Italy and Spain includes crude oil, shale oil, oil sands and natural gas liquids.
Data for oil production in Brazil and South Korea includes indigenous production of crude, natural gas liquids, and refinery feedstocks (including non-crude).
Data for natural gas production exclude gas flared or recycled.
Natural gas production is expressed as metric tons oil equivalent; data for Spain is converted from billions of cubic meters to millions of metric tons using a conversion factor of 0.9.
South Korea imports all of its natural gas.
Sources:
Data for U.S., Russia, Italy and Spain: BP Amoco, the *Statistical Review of World Energy*, June 1999.
Data for Brazil and South Korea: International Energy Agency, *Monthly Oil Survey*, November 1999 and International Energy Agency, *Monthly Gas Survey*, November 1999.

These data suggest that the quantities of NORM-contaminated metals may be relatively large; the annual quantities estimated for selected industries in the U.S. alone suggest that these quantities may be greater than the total quantities of metals that will become available from decommissioning of nuclear power plants and weapons facilities over several decades. It is unclear how much of this metal is sold as scrap or much may be disposed or re-used. In addition, as discussed in Appendix H, little data is available on the levels of contamination, which may be low in many cases. However, the available evidence suggests than at least some of these metals enter the scrap market.

Since 1983, James Yusko of the Pennsylvania Department of Environmental Protection has been maintaining a database of radioactive materials found in shipments of metal to recycling facilities in North America. Although this database is the most complete source of information available on the subject, it includes only reported incidents and therefore understates the total

These statistics suggest that the number of sealed sources is large, and that these sources can potentially escape nuclear controls even in countries (such as the U.S.) with active regulatory programs. Of the countries studied, Russia may have the greatest number of lost or stolen sources. However, the data on Italy and Spain suggest that sources containing significant amounts of radioactivity that are likely to remain in the metal melt (e.g., the cobalt-60 sources noted above) are a relatively small fraction of the total.

The lack of adequate controls over these sources in some countries, and the possibility of loss or theft, pose significant concerns regarding possible human exposure regardless of whether the source ultimately contaminates metal.[26] Their appearance in scrap metal loads may often result from simple negligence, or as a result of sources located in the retractory walls of electric arc furnaces accidentally falling into the melt. When equipment or structures are demolished and the resulting metal is sold as scrap, the source may remain with the metal through lack of knowledge of its presence or of associated risks. For example, Yusko cites the case of a brewery which purchased then demolished a production facility, not knowing that the facility contained a sealed source until the radiation was detected by a steel mill.[27]

In the U.S., the fear of the costly cleanups which result from the accidental melting of either sealed sources or radioactive scrap metal have caused many mills to take precautionary measures.[28] Several firms have installed radiation detectors at the portals of their mills to screen scrap as it enters the facility. These screening devices are not one hundred percent effective. Scrap which has been cut into smaller pieces and either crushed or baled can shield a radioactive source from the detectors.

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[26] A perhaps extreme example is an event in Goiânia City, Brazil, where a junk dealer dismantled a cesium-137 source. The contamination caused four deaths and wide-spread illness, and cesium-137 was also found in scrap metal. See: Oberhofer, M. and J.L. Bacelar Leão, *The Radiological Incident in Goiania,* prepared for the International Atomic Energy Agency, Vienna: STI/PUB/815, 1988.

[27] Yusko (1999).

[28] In addition, both the U.S. and IAEA have undertaken major projects to improve controls over these sources. In the U.S., EPA has launched the national Orphan Sources Initiative, a cooperative program with the CRCPD, to retrieve and dispose lost and stolen radioactive sources. The IAEA is also addressing orphan sources on the international level through a series of new initiatives to categorize sources according to health risk and pursue retrieval of those lost and stolen sources that pose significant risk. See: International Atomic Energy Agency, *Safety of Radiation Sources and Security of Radioactive Materials, Action Plan of the Agency*, 1999, pages 9-10.

As noted earlier, James Yusko, of the Pennsylvania Department of Environmental Resources, maintains a database of discoveries of radioactive material whether or not they are actually breached.[29] The database covers the U.S. and Canada. Since 1983, approximately 3,500 events have been recorded, of which 54 percent involved NORM and 30 percent involved unknown sources. The remaining events involve several different isotopes. About seven percent of the events involve radium, about two percent of the events involve cesium-137 sources, and less than one percent involve cobalt-60.

Yusko also tracks reports of accidental meltings of sealed sources worldwide in another database. The majority of the reported meltings between 1982 and 1999 (30 out of 65) were caused by cesium-137 sources. The next most commonly smelted source was cobalt-60 (17 events). Most of the meltings (48) involved steel; gold, aluminum, copper and zinc processors were also affected. Information on the activity level of the source is available for roughly half of the cases, and indicates that these levels range over several orders of magnitude (e.g., from less than 0.1 Gbq to over 15,000 Gbq).

In the countries addressed by this report, these meltings included the following:

- In the U.S., 31 accidental meltings were reported between 1982 and 1999.
- In Russia, four accidental meltings were reported in the same time period.
- Eight accidental meltings were reported in Italy, including a 1988 incident when the contaminated steel was exported to the U.S..
- One accidental melting was identified in steel in Spain. This event was detected when scientists found increased levels of cesium-137 in the atmosphere.
- Three accidental meltings were reported in Brazil. In all incidents, the contaminated steel was exported to the U.S.
- No meltings were reported in South Korea.

The prevalence of U.S. meltings in this database may be indicative of the sophisticated detection equipment used by the U.S. metals industry, as well as the size of this industry.

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[29] Yusko (1999).

While meltings of sealed sources can lead to acute, high hazard events that are eventually discovered and addressed, they may also escape detection and lead to increases in the radioactivity levels of the general metal supply. Undetected meltings may occur in cases where the source has a relatively low radioactive content, as well as in areas lacking detection capabilities. The extent to which such meltings are contributing to the overall level of radioactivity in the metal supply is difficult to determine due to the limited information available.

DOMESTIC RELEASE STANDARDS

This section analyzes the international and national clearance standards that affect the release of scrap from nuclear facilities in the six countries discussed in this report. We focus on the standards that are applicable to regulated nuclear facilities such as power plants. Industries generating NORM are generally subject to fewer regulatory controls. While a number of national and international efforts are underway to improve the tracking of sealed sources, these sources are not subject to the same types of release criteria as contaminated metals and related controls are not discussed in detail in this section.

First, we cover the international guidance on radiation protection and clearance standards developed by the International Atomic Energy Agency and the International Commission on Radiological Protection. Second, we summarize information on the national standards and policies of the six countries (including those of the European Union, hereinafter referred to as the EU). Finally, we discuss other issues that affect release decisions. The numeric release standards associated with these policies are provided in Appendix C.

International Guidance

The main sources of international guidance on radiation safety are the International Atomic Energy Agency (IAEA) and the International Commission on Radiological Protection (ICRP). The IAEA was founded in 1956 as an international forum for nuclear policy and technical information, and its members include countries from around the world. The ICRP was founded in 1928 as a professional association of radiologists, but expanded its mission in the 1950s to address all aspects of radiation protection. Its members are individuals with expertise in radiation protection. Both of these organizations play an advisory role in the creation of national nuclear and radiation protection policies. Although compliance with the recommendations of these groups is voluntary, policymakers often incorporate IAEA and ICRP recommendations into national law.

In addition, the United Nations Economic Commission for Europe (UNECE) has recently become active in addressing some of the problems that result from radioactive contamination in traded metals, such as uncertainty over clearance standards and a lack of protocols for transporting international shipments that are found to be contaminated. The UNECE committee that is investigating these issues eventually plans to submit resolutions on some of these issues to the UN International Trade Committee. The resolutions will likely contain text describing the problems brought about by current practices and propose ways to standardize practices. These resolutions may be treated as guidance, but will not have the effect of international law.[30]

IAEA Guidance

Currently, 130 countries belong to the IAEA, including the six countries addressed in this report. The IAEA membership includes many developing countries with limited resources for formulating radiation protection regulations. Therefore, several adopt IAEA guidance for regulatory and standard setting purposes. Furthermore, the IAEA and the EU have a historically close relationship, and many of IAEA's recommendations are incorporated into EU guidance as well.

IAEA's *Draft Safety Guide* seeks to clarify the threshold dividing regulated and non-regulated activities involving radioactivity.[31] To accomplish this goal, the *Guide* establishes an annual trivial dose of 10 μSv per year, which is equivalent to 1 mrem. This trivial dose corresponds to one percent of the annual dose limit of 100 mrem. Unlike former drafts of the *Guide*, which established the same standards for all materials, the most recent draft recommends a relaxed standard of 1 mSv/year for NORM contaminated materials while retaining a 10μSv/year standard for other materials.

The current IAEA numerical clearance standards (in terms of allowable activity levels for individual radionuclides) are found in *TECDOC 855*, and are replicated in Appendix C of this report. Although these standards are based upon the earlier *Safety Series No. 89*, the basic trivial dose of 1 mrem for materials other than NORM is consistent between both documents. These clearance standards are applicable to any solid material (including metal). *TECDOC 855* was released as an interim document, and is currently undergoing revision.

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[30] Information on UNECE activities is from: http://www.unece.org/meetings/00meet07.htm, August 2000.

[31] International Atomic Energy Agency, *Draft Safety Guide: Application of the Concepts of Exclusion, Exemption, and Clearance*, March 2, 2000.

ICRP Guidance

The ICRP's radiation protection recommendations are generally regarded as best practices and are widely used for reference where specific standards are not in place. *ICRP 60* provides recommendations on principles to guide radiation protection policies, based on a trivial dose of 1 mSv per year, which is equivalent to 100 mrem. These principles include justification of practices that release radiation and optimization of radiation protection efforts. Justification of practice is established when an action that causes radiation exposure has tangible benefits that justify the risk of exposure. Optimization of radiation protection entails the implementation of procedures to limit exposure, including monitoring radiation levels and planning for emergencies.[32]

Recently, the ICRP chairman publically discussed suggested changes to *ICRP 60*. One proposed change is to drop the concept of justification from ICRP guidance, and to focus more on optimization of protection efforts. The chairman also proposed changes to the dose system, including changing the trivial risk to 0.03 mSv, or 3 mrem, per year.[33]

<u>U.S. Standards</u>

Both the NRC (which regulates nuclear power plants and commercial uses of nuclear materials) and DOE (which is responsible for activities related to nuclear weapons production) are currently considering revisions to their policies for the release of metals and other materials. Historically, these agencies relied on NRC Regulatory Guide 1.86 and DOE Order 5400.5 (see Appendix C for nuclide-specific levels). These documents have similar release criteria, which were initially developed for license-termination purposes and have since been applied to release of metals. Both sources only provide guidance on surface contamination; no quantitative standards currently exist for volumetrically-contaminated materials.

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[32] International Commission on Radiological Protection, *Publication 60: 1990 Recommendations of the International Commission on Radiological Protection*, 1990.

[33] *Nuclear News*, "ICRP: Low and Very Low Radiation Doses," Vol. 42, No. 9, August 1999, pp. 102-103.

NRC Regulatory Guide 1.86

NRC is in the process of considering whether to proceed with a rulemaking that would replace current standards, (contained in Regulatory Guide 1.86) and update requirements for the release of solid materials.[34] However, NRC is facing heightened public opposition to policies that allow release of materials from nuclear facilities. These opponents include both citizen groups that are concerned about health risks, and representatives of the metals industry who fear detrimental economic impacts from free release standards.[35] Currently, NRC is deferring the rulemaking and asking the National Academy of Sciences to study alternative policies.

Regulatory Guide 1.86 establishes acceptable surface contamination limits based on the detection limits of the technology available at the time the guidance was issued.[36] NRC guidance also indicates that licensees must demonstrate that "reasonable effort has been made to reduce residual contamination to as low as practicable levels." Activity levels for volumetric contamination are not explicitly addressed. According to NRC personnel, this guidance is generally interpreted as meaning that material cannot be released if it contains detectable levels of radiation. Residual activity levels in released materials may be lower than those contained in Regulatory Guide 1.86 if the licensee employs more sensitive surveying techniques than those applied when the guidance was developed.

NRC applies somewhat different release criteria to commercial nuclear power plants than to decontamination and waste management firms. While power plants are prohibited from releasing materials with any detectable levels of radioactivity, waste management and decontamination firms can release materials at the limits specified in their individual licenses even if that limit is detectable. In general, these limits are similar to the Regulatory Guide 1.86 guidelines. Waste management and decontamination firms also may be subject to state requirements. In addition to specific release criteria, both materials (decontamination and waste management firms) and source (power plants)

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[34] For information on current practices and options now being considered by the NRC, see: U.S. Nuclear Regulatory Commission, *Control of Solid Materials: Results of Public Meetings, Status of Technical Analyses, and Recommendations for Proceeding*, SECY-00-700, March 23, 2000. NRC also regulates the use of sealed sources.

[35] U.S. Nuclear Regulatory Commission, "Commission Briefing on Controlling Release of Solid Materials," May 3, 2000.

[36] U.S. Atomic Energy Commission, *Regulatory Guide 1.86: Terminations of Operating Licenses for Nuclear Reactors,* Washington, D.C., June 1974.

licensees are required to use "procedures and engineering controls based upon sound radiation control principles to achieve occupational doses and doses to members of the public that are as low as reasonably achievable (ALARA)."[37]

DOE Order 5400.5

The extent to which DOE facilities release slightly contaminated metal appears to be limited, and currently has placed a moratorium on releases from its sites. Public concerns about the risks associated with release, as well as concerns about worker safety, have discouraged releases in recent years. In addition, DOE has encouraged the restricted recycling of metals for use within controlled nuclear settings as part of its Recycle 2000 initiative, as an alternative to unconditional clearance or disposal. DOE is in the process of reviewing its current requirements, contained in DOE Order 5400.5, and may revise or replace them depending on the outcome of NRC's rulemaking efforts and other considerations.

DOE Order 5400.5 describes the procedural and analytical requirements for releasing scrap metal as well as other materials from DOE control, and provides guidance on the surface activity levels allowable at the point of release.[38] The Order also states that the primary dose limit for the public from all exposures is 100 mrem per year and requires that any single release of material from DOE must account for only a fraction of this total. Furthermore, the order requires notification of DOE environmental health management if an individual release will result in a dose exceeding 10 mrem per year.

DOE Order 5400.5 prohibits the release of contaminated material unless sufficient analyses have been completed to ensure that the release will not result in harmful exposure. The analyses must document that the level of radioactivity is "as low as reasonably achievable" (ALARA). The

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[37] 10 CFR 20, "Standards for Protection Against Radiation," page 291.

[38] U.S. Department of Energy, *DOE Order 5400.5: Radiation Protection of the Public and the Environment,* Washington D.C., 1990; "Response to Questions and Clarifications of Requirements and Processes: DOE 54000.5, Section II.5 and Chapter IV Implementation (Requirements Relating to Residual Radioactive Material)," DOE Assistant Secretary for Environment, Safety and Health, Office of Environment (EH041), November 17, 1995; *Handbook for Controlling Release for Reuse and Recycle of Non-Real Property Containing Residual Radioactive Material (Draft)*, June 1997.

process for determining whether materials meet the ALARA goal is formally documented in DOE guidance documents and must be followed to minimize worker and general population exposure to radiation from all DOE activities, not only from the unconditional clearance of scrap metal.

State Regulations

While DOE is largely self-regulating, many NRC licensees may be regulated by the states in which they are located as well as by the Federal government. In addition, although EPA is currently analyzing policy options for NORM, most regulation of these materials is accomplished at the state level.[39] The Conference of Radiation Control Program Directors (CRCPD), which is the association of state radiation control programs, has issued draft standards for "technologically enhanced" NORM (TENORM), but states are not required to adopt these standards.[40]

Some states, however, have developed their own standards for NORM-contaminated materials. Specifically, the following states have regulations that specify exemption levels for NORM-contaminated equipment: Arkansas, Georgia, Louisiana, Mississippi, New Mexico, North Dakota, New Jersey, Oregon, South Carolina, and Texas. For these states, the exemption levels are 5 pCi/g, 25-50 μR/hr including background, and 100 cpm above background. (Colorado has proposed a standard of 5 pCi/g).[41] The states reserve the right to reject the importation of materials that exceed these standards.

The CRCPD has also been granted authority by the Federal government to issue exemptions for the return of shipments of materials found to be radioactive in the course of transit. The exemption only applies to very low level radioactive materials (under 0.50 mSv h^{-1}). In these cases, the state radiation control authority assumes responsibility for ensuring the safe return of the shipment, and sees it through to its point of origin, as long as the shipment originated in the U.S.,

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[39] "What EPA is Doing about NORM," on EPA's Internet site: http://www.epa.gov/rpdweb00/tenorm/whatare.htm, May 8, 2000.

[40] "TENORM" is the term EPA now uses to distinguish radionuclides that have been concentrated or exposed to the accessible environment as a result of human industrial activities, such as natural resource extraction, as opposed to concentrations of NORM unrelated to human industrial activities.

[41] Peter Gray and Associates, *The NORM Report*, Fall 99/Winter 00.

Canada, or Mexico. The CRCPD E23 Committee on Resource Recovery and Radioactivity, which develops guidance for states on the monitoring and management of scrap metal contaminated with radioactive material, is currently investigating the possibly expanding this exemption to the EU.[42]

European Standards

The EU has a taken a leadership role in providing guidance to member states concerning radiation protection, including the clearance of metals from the regulatory system. Italy and Spain are both EU members, and are thus bound by EU Directives, as are the other countries that make up the EU. As EU nations move towards a regional economy with free trade among member states, many European leaders believe that they need a uniform clearance standard. These leaders believe that the duplication of effort that arises from having different standards is economically undesirable and hinders the formation of a single European marketplace.

In 1996, the EU passed Council Directive 96/29, which contains radiation protection practices for all EU nations to follow.[43] These practices include sets of maximum doses for different subsets of the population, including children under 18, students and apprentices, workers, pregnant and nursing mothers, and members of the general public. The individual maximum dose for a member of the public is 1 mSv, or 100 mrem, per year. The Directive states that national regulatory bodies should develop clearance standards for materials based on this dose.

In 1998, the EU drafted *Radiation Protection 89*, which provides guidance to the EU members' national regulatory authorities on the subject of clearance standards and related policies for compliance with the radiation protection standards of the Directive. *Radiation Protection 89* cites previous IAEA recommendations that a dose of "some tens of microsieverts per year" is trivial and a basis for exemption. An EU study on exposure scenarios for metals yielded nuclide-specific clearance levels for scrap metal, which are provided in Appendix C.

Recently, the EU mandated that all member countries implement policies that conform to EU radiation protection rules, including the 1 mrem standard, by May 13, 2000. However, only a minority of the countries have fully implemented the standards. Mandatory radiation protection

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[42] Personal Communication with Ray Turner, Member of CRCPD Committee E-23, August 29, 2000. Conference for Radiation Control Program Directors committee descriptions are available at: http://www.crcpd.org/, September 2000.

[43] European Union, *Council Directive 96/29 EURATOM of May 13, 1996*, Official Journal No. L 159, 6/29/1996, pp. 0001-0114.

standards include: applying the 1 mrem dose limit for exemption and clearance, reporting and receiving prior authorization for releases exceeding 1 mrem, and adhering to worker safety practices.[44]

Although the majority of EU countries plan to use the 1 mrem standard, most EU members have not yet implemented related protocols and do not yet agree on the isotope-specific activity levels that correspond to a 1 mrem dose.[45] Also, while the EU will adopt a separate standard for NORM-contaminated materials in line with the IAEA's recent recommendation, the exact standard has not been determined. In Europe, high disposal costs may have historically provided an incentive for recycling, but France may be developing a capacity for more affordable disposal, which may undercut this incentive. Regardless of the outcome of these efforts, public opposition to release of nuclear materials may be growing in Europe and deterring release.[46] The situation in the EU is very similar to that in the U.S.; there is very little release of decontaminated metal from nuclear facilities due to public and interest group resistance.[47]

Italian Standards

Nuclear activities in Italy are regulated through a system of licensing and notifications. The National Agency for Nuclear Technologies, Energy and the Environment (EAEA) is charged with radiation protection, and the Italian environmental protection agency (ANPA) is responsible for control over radioactive materials. Italy has a somewhat automatic process for adopting EU legislation into its internal legislation. Italian legislative Decree No. 230 of 1995 specifically provides for the adoption of European Directives on radiation protection series.[48] Decree No. 230 is a broad piece of legislation and is supplemented by "implementation degrees," which are similar to U.S. federal regulations. Subsequently, EU Council Directive 96/29 was automatically adopted by the Italian legislature.

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[44] Personal communication with Vittorio Ciani, European Union, May 29, 2000.

[45] Ciani (2000).

[46] Personal communication with Augustin Janssens, European Union, April 26, 2000.

[47] Ciani (2000).

[48] Information on Decree No. 230 of 1995 from: OECD Nuclear Energy Agency, *Nuclear Legislation Analytical Study: Regulatory and Institutional Framework for Nuclear Activities,* 1996 update, Italy Chapter, pp. 1-11. Further information on Italy's radiation statutes is available at: http: //www.iss.it/leggi/radiazio.htm, June 2000.

SUMMARY

The information presented in this chapter indicates the following.

- Little information is available on the quantities of contaminated metal entering domestic metal supplies.

  — Of the four major sources of radioactive metals (decommissioning of nuclear power plants, decommissioning of weapons facilities, NORM-contaminated equipment, and accidental melting of sealed sources), only the metals available from nuclear power plant decommissioning have been subject to detailed study world-wide.

  — While estimates are also available for contaminated metals from decommissioning of U.S. weapons facilities, less information on release of metals from defense-related sources (including submarines) is available for Russia.

  — Very little information is available on NORM-contaminated equipment in any of these countries, and we are uncertain about the extent to which undetected meltings of sealed sources are contaminating the metals supply.

- Control of these materials appears strongest in the U.S. and Eastern European countries.

  — In the U.S. and E.U., nuclear facilities are subject to specific criteria for releasing metals and other materials from regulatory controls. While the detailed release standards as well as the enforcement mechanisms vary and are undergoing revision, these criteria generally target relatively low allowable dose levels (e.g., 1 mrem per year). In addition, due to public concerns about the risks associated with radioactive materials, facilities in these countries may not be releasing materials even in cases where it is cost-effective to do so under the existing standards. NORM-contaminated equipment is subject to fewer controls, and sealed sources may escape applicable controls in some cases.

  — In Russia, regulatory controls are weak or non-existent, and we are uncertain about the legal requirements in Brazil and South Korea.

- These findings suggest that metals from unregulated sources may be the most significant contributor to increasing levels of radioactivity in the metal supply.

  — Nuclear power plants and weapons facilities may not be a significant source of contamination of the metal supply in the U.S. or the E.U. countries. The role of NORM and sealed sources is more difficult to determine, and may be worthy of further study.

  — In the case of Russia, the lack of controls over potentially significant quantities of contaminated materials could lead to unrestricted release of highly radioactive metals; Russia and other countries from the former U.S.S.R. may be the greatest source of concern.

  — The lack of information about Brazil and South Korea makes it difficult to determine the extent to which they generate contaminated metals that may ultimately lead to elevated levels of radioactivity in the general metal supply.

In the next chapter, we explore the information available on the impacts of these domestic sources and release policies on international trade in the metals industry.

EXPORT AND IMPORT OF RADIOACTIVE METALS CHAPTER THREE

The available information on radioactivity levels in metal imports and exports tends to focus on acute, high hazard events. Less is known about the typical levels of radioactivity in these metals and the extent to which these levels are changing over time. The types of information available result in part from current detection practices at international borders as well as the detection capabilities of private industry.

In this chapter, we provide information on practices that influence the extent to which radioactivity is detected in imported or exported metals. These practices include both government efforts to detect radiation as metals cross international borders, and subsequent detection efforts by industry (which address both imports and domestically produced materials). In general, we find that current practices vary significantly across countries, and that many of the countries considered have inadequate protocols for detecting and addressing radiological contamination. In response to these problems, several international and national agencies are working to strengthen detection capabilities world-wide.

We find that existing data sources generally yield information on incidents that often involve materials with relatively high radioactivity levels. These events are serious problems that pose significant threats to human health, and the economic impacts of these events are discussed in Chapter Four. If these events are detected, the contaminated metals are often disposed rather than introduced into the general metal supply, avoiding further health risks and economic consequences. In this chapter, we focus on the contaminated metals that are not detected, and may make their way onto international scrap markets.

To provide further insights into the effects of radioactive metals on international trade, we compare the quantity of these metals to the total metal markets. We begin by providing background information on international trade in scrap metal, and then compare the limited available data on sources of radioactive metal to total domestic supplies. This comparison provides some indication of the extent to which radiation levels may be eventually diluted as contaminated scrap is melted with other scrap sources and manufactured into finished products. If metals with elevated radioactivity levels become a significant proportion of total metal supplies, the prices of uncontaminated metal may rise. These types of adverse market impacts are discussed in more detail in Chapter Four.

BORDER PRACTICES

Government and industry officials world-wide express growing concern about the frequency with which elevated levels of radioactivity are detected in metal exports and imports. In response, customs agencies in many countries, as well as an increasing number of firms in the metals industries, are bolstering their efforts to detect and address radiological contamination in imports and exports. In this section, we discuss current practices, detection technologies, the levels of radioactivity detected, and initiatives to strengthen detection practices.

Practices by Country

Many countries have implemented practices to detect and handle radioactivity in shipments that cross borders. The level of sophistication of these practices, however, varies greatly among countries. As described below, the information sources we have reviewed to date focus on practices in the U.S. and Italy; little information is available on border practices in the other countries we address.

Practices in the U.S.

The U.S. Customs Agency bears much of the responsibility for monitoring incoming shipments for radiation. We have limited information about specific protocols, but understand that the Agency has taken measures to identify and investigate shipments containing radioactive materials. However, the incidents of contaminated shipments that pass though U.S. Customs indicate that screening protocols are not fully effective in detecting radioactivity in metals.[1]

The U.S. is moving away from a comprehensive, "bottle-neck" style approach of radiation detection that involves scanning all shipments. With this approach, shipments pass through a fixed detector that sounds an alarm if radiation is detected. While fixed installation detectors are quite common at large ports of entry, they have been criticized both in terms of effectiveness and because they slow the movement of materials. At present, Customs officials are being issued Radiation

[1] Rejected shipments are discussed in detail in Chapter Four.

Pagers™ as a first line of defense against contaminated imports. Customs officials wear these pagers on their belts, allowing each agent to screen for radioactivity. These pagers are discussed in more detail in the Detection Capabilities section below.

Practices In Western Europe

Growing concern over the radioactive content of imported metal scrap has led to the implementation of radiation screening programs at border points in Western European countries. For the two Western European countries addressed in this report, we have more detailed information on Italy's border practices than on Spain's. As mentioned in Chapter Two, Italy requires that all imported scrap is accompanied by a declaration that it is free from radioactive contamination. To enforce this policy, Italy's monitoring program, in place since 1993, has screened more than 20,000 railway cars and several hundred trucks. On a monthly basis, between 0.5 percent and 2.5 percent of the screened railway containers are found to have radiation levels above the background level. While several shipments of high-level radioactivity have been identified, the monitoring program also found that the wagon doors on railcars (manufactured in Hungary between 1983 and 1990) were contaminated with low-levels of cobalt-60. Once the interference radiation from the railway car was taken into account, the percentage of containers exceeding background levels decreased significantly. Isolation of radioactive contaminants found at Italian borders has become difficult due to numerous shipments of mixed metal turnings, which are low-value scrap metals often transported by rail. Isolation is difficult because individual pieces of contaminated metal are often mixed in with large quantities of clean metal pieces.[2]

As part of the monitoring effort, Italy's Ministry of Finance has also taken steps to create a protocol for handling materials that are found to be radiologically contaminated. The policy goal is to return all contaminated shipments to the nation of origin. The policy has been effective in ensuring that shipments are rejected at some entry points; however, contaminated metals that enter through Italian sea ports can be more difficult to return. Presently, container ships unload their cargo and leave port before the transported material can be screened. Some Western European countries favor tightening law enforcement efforts to stop the flow of radioactive metals. For example, the French Atomic Energy Commission has called for tough criminal penalties and fines for illicit trafficking of radioactive materials.[3]

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[2] Fabretto, Mario, "Some Interesting Findings From the Radioactivity Control of Trucks and Wagons," presented at the *International Conference on Safety and Radioactive Sources*, September 14-18, 1998, Dijon, France, IAEA-CN-70/91.

[3] Gresalfi, Michael, Trip Report, Workshop on Radioactive Contaminated Metallurgical Scrap, Prague, Czech Republic, May 26-28, 1999.

Metals firms in Western Europe have also increased their detection capabilities. For example, steel smelting facilities in the United Kingdom (U.K.) began monitoring contamination in scrap in 1989, and by 1992, all facilities were equipped with radiation detectors. Imported metals have been the source the "worst finds" by UK steel manufacturers, and that the industry is especially concerned about NORM-contaminated metals. Like the UK, all smelters in Germany and Luxembourg are protected by radiation detection systems.[4]

Practices In Other Countries

Border practices in other, less industrialized countries are hampered by several factors, including a lack of enforcement capabilities, sophisticated radiation detection equipment, and qualified experts to train personnel in radiation safety and detection.[5] For the countries addressed by this report, we lack information on practices in Brazil and Korea, with the exception of the reported Korean policy to reject all shipments containing any residual level of radioactivity (discussed in Chapter Two). Some information is available regarding practices in Russia and the former Soviet Republics, which are areas of great concern due to the number of incidences of contaminated materials that have been exported from the region.

This information suggests that controls are weak in the former Soviet Union. While Russia has reportedly installed hundreds of radiation detectors at its Moscow airport, more work needs to be done to prevent radioactively contaminated metal from illegally leaving the country.[6] The U.S. government recognizes the threat of radioactive material leaving Russia undetected. In the Federal budget request for fiscal year 2001, the Clinton Administration proposed to fund an initiative called Export Control and Border Security Assistance, which is designed to facilitate implementation of several export control systems, enhance nuclear smuggling detection capabilities along Russia's borders, and improve the implementation of Russian dual-use export laws.[7]

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[4] Gresalfi, (1999).

[5] Shakshooki, S.K. and R.O. Al-Ahaimer, "Importance of the Awareness, Training, Exchange of Information and Co-operation Between Regulatory Authorities and Custs, Police and Other Law Enforcement Agencies," presented at the *International Conference on Safety and Radioactive Sources*, September 14-18, 1998, Dijon, France, IAEA-CN-70/68.

[6] *Increase of Illegal Traffic of Radioactive Scrap Metal*, WISE Amsterdam, September 1998.

[7] William Hoehn, *The Clinton Administration's Fiscal Year 2001 Budget Requests For Nuclear Security Cooperation with Russia*, March 13, 2000, p.6.

Representatives of the Ukraine government acknowledge that the Ukraine is the source of much of the contaminated metal scrap entering other European states. Although the Ukraine implemented an Environmental Control Program in 1998 to monitor the export of scrap metal for radioactivity, only 36 of the 157 border crossings in Ukraine had radiation detection equipment installed as of 1999. In a recent two year period, 835 radiation alarms have registered at Ukrainian borders.[8] Furthermore, none of Ukraine's airports or harbor ports have radiation detection equipment.

Detection Capabilities

Many countries and industry sites have installed radiation detection equipment in response to the threat of receiving contaminated metals. This section discusses the available information on detection technologies used by customs agencies, and then discusses detection capabilities at industry sites.

Detection Capabilities at International Borders

Radiation detection instruments are generally classified by their size and portability as pocket-sized, hand-held, or fixed installation devices. As might be expected, the sensitivity and analytic capabilities of an instrument are directly proportional to its size. However, pocket-sized or "pager" models provide non-specialized staff with a portable screening tool for radioactive materials. As mentioned previously, the most popular model of radiation detectors in this size class in the U.S. is the Radiation Pager™.

The Radiation Pager is a gamma-ray detector (about the size of a message pager) for use in the interdiction and location of nuclear materials.[9] It was specifically designed to be used by government agencies and in emergency responses, and is hundreds of times more sensitive than Geiger-Muller (GM) tube-type detectors in its size range. When x-rays or gamma rays are detected at levels significantly above natural background, the unit quickly alerts the operator by flashing a high intensity light and either sounding an audio alarm or triggering a vibrator. The unit provides an indication of the intensity of the detected radiation by displaying a number between zero and nine.

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[8] Kondratov, Sergiy, as quoted in Gresalfi, (1999); Associated Press, "Police Seize Radioactive Materials; Germany Warns Former Soviet Bloc About Smuggling," October 10, 1992.

[9] Information on radiation pagers was collected by Sanford Cohen and Associates during a visit with Douglas Smith of U.S. Customs in 1998.

Each number indicates a radiation intensity of twice the previous value. A level eight on the display occurs at a radiation intensity of about two mR/hr. Two mR/hr is a typical limit for public exposure set by U.S. regulatory agencies (including the Department of Transportation and IATA) for radioactive shipments. The operator can quickly localize the source of the alarm with a single digit LED display, a flashing LED, or an audio tone if selected.

The Radiation Pager will not detect contamination at a level that corresponds to a dose of less than about 30 mrem/yr of continuous exposure to a customs worker or 100 mrem/yr of continuous exposure to a member of the general public. The implication is that these detectors, though extremely useful in detecting lost sources and other sources of highly contaminated material, will not detect the very low levels of contamination associated with a dose of one mrem/yr above background.

The rationale behind using Radiation Pagers is that they allow each agent to screen for radioactivity, creating a "curtain of detection" instead of one fixed detector. Radiation Pagers allow agents to get closer to the radioactive source, theoretically preventing sources from passing undetected. In addition, the pagers provide customs agents with protection from exposed to undetected radiation sources.

However, there are limitations to the Radiation Pagers. In practice, lead shielding of sealed radioactive sources prevents detection, despite the decreased distance from the radioactive source that is gained by using the Radiation Pagers. Moreover, the maximum distance at which Radiation Pagers will detect contamination varies by isotope. For example, U.S. Customs has found that the maximum distance for detecting cobalt-60 is 283 inches between the pager and the metal, but the maximum distance for cesium-137 is only 79 inches.[10] Finally, since Radiation Pagers have been in use, 90 percent of all alert situations have actually been caused by passengers who have received radioisotopes for medical treatment.[11] This high level of alarms not attributed to contamination in metals mitigates some of the advantages of Radiation Pagers compared to portal monitoring.

Hand-held and mobile radiation detection instruments are generally more bulky than pocket-sized models, but are also used for identifying radioactive materials. The larger, hand-held instruments have more sensitive scintillators capable of analyzing a source's gamma-ray "fingerprint"

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[10] Warner, John L. and Kenneth G. Vadnais, *Radiation Pager, Safety of Radiation Sources and Security of Radioactive Materials Conference*, Dijon, France, September 14-18, 1998.

[11] Khan, Sirag M., "Test and Evaluation of Isotope Detectors," *Safety of Radiation Sources and Security of Radioactive Materials Conference*, Dijon, France, September 14-18, 1998.

to identify the element and isotope source of the radioactivity.[12] Hand-held instruments can also be mounted on helicopters or ground vehicles to scan larger areas for contamination. Hand-held models generally require more training to operate than the pocket-sized models.

Fixed installation instruments, originally designed for industry use, are now used for border control. However, the technology that was developed for use at scrap yards and smelters is not necessarily as effective when used to screen large quantities of materials at border points. Although fixed-installation detectors are the most sensitive radiation detectors, they suffer from reliability problems based on the distance from the source. Radiation intensity varies inversely with the square of the distance from the source. Thus, a fixed-installation detector, set up to scan large items, may not have the sensitivity to detect smaller items or shielded sources, which may be too far away to register with the detector unit.

Monitoring for radioactivity at borders is made difficult by the presence of background radiation levels and shielding. Background radiation from natural and anthropogenic sources is present at varying levels throughout the world. To monitor materials accurately, variations in background radiation levels due to environmental conditions need to be discernable from actual radioactive materials crossing the border. Furthermore, radioactive sources are often sealed in lead casing, which makes them difficult to detect in a shipment of scrap metal.

These two problems, background radiation and shielding, require conflicting solutions. To compensate for varying background radiation levels, a radiation detection limit needs to be set at a conservative level to avoid unnecessary false alarms. However, in order to detect trace levels of radiation from a sealed or shielded source, a more sensitive radiation detection limit is necessary to prevent dangerous sources of radioactivity from crossing between countries.

Detection Capabilities at Industry Sites

In the U.S., radioactivity has been detected in scrap from domestic origins as well as in imported scrap. Fear of costly cleanups associated with accidental meltings has caused most mills and scrap yards to take precautionary measures. Thus, if a shipment containing contaminated metal is not detected at a border, it may be detected at an industry site.

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[12] Duftschmid, Klaus E., "Preventing the Next Case; Radioactive Materials & Illicit Trafficking," *IAEA Bulletin*, April 13, 1999, page 39.

The metals industry uses both fixed and portable equipment to guard against radiation. Fixed monitors are installed at mill peripheries to scan truck or rail loads as they enter and exit. Fixed detectors used at industry sites contain sodium iodine (NaI) or plastic scintillators. Plastic scintillators are generally more expensive, as well as larger, more sensitive, and more durable. Large liquid scintillation detectors are used occasionally, but are more expensive and fragile. Portable detectors are used to scan smaller quantities of scrap or to locate a radioactive source within a larger batch. Portable detectors use sodium iodine or plastic scintillators for detection purposes.

As in the case of the detectors used by U.S. Customs, the detection limits of the detectors used by industry depend on a number of factors in addition to the sensitivity of the instrument itself: the background levels of radiation; the distance to the radioactive source; the scrap density; and the amount of time the scrap is exposed to the detector. As mentioned previously, detectors are not one hundred percent effective because sources of radiation may be shielded. Because the probability of detection depends in part on scrap density, detection limits will vary by type of metal and by the physical form of the scrap. To maximize the likelihood of detection, scrap yards may try to minimize the distance from the detector to the metal, increase the time the scrap is in view of detectors, and reduce scrap density to reveal sealed sources. As mentioned previously, detectors should be calibrated to account for the level of background radiation present.

A new detection technology system may overcome many of the limitations of the standard portal and portable monitors. This new system uses a very sensitive detector on the boom of the magnet that loads and unloads individual pieces of scrap metal. This system allows for maximum proximity between the metal and the detector, and typically obliterates the density problem because the magnet picks up individual pieces. David J. Joseph, one of the largest scrap brokers in the U.S., now recommends that mills install this technology.[13]

The Institute of Scrap Recycling Industries (ISRI) recommends standards for detection systems used at mills and scrap yards. Ideally, ISRI recommends that systems be able to detect a cesium-137 source in a shielded container with a volume of one cubic foot or greater, and a radiation output the equivalent of one mR/hr outside the container, which is buried in a load of randomly distributed demolition scrap at a distance between the source centerline and vehicle wall of 48 inches or less. In addition, ISRI recommends that scrap yards contact their state radiation control agency if they detection radiation above 2 mR/hr (or above the highest setting on a portable detector). If lower levels of radiation are detected, ISRI recommends that the scrap be more closely surveyed with a hand-held instrument.[14]

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[13] For more information on the new grapple detectors, see the case studies on a scrap broker, David J. Joseph (Appendix D) and on a steel mill (Appendix E).

[14] Institute of Scrap Recycling Industries, Incorporated, *Radiation in the Scrap Recycling Process, Recommended Practice and Procedure*, Washington D.C., 1993.

Detected Radiation Levels

As mentioned previously, radioactive metals can be incorporated into the metals stream via an accidental melting of highly radioactive materials (such as many sealed sources) or by smelting materials with lower levels of contamination (such as equipment with low levels of NORM contamination). Whether the radioactivity remains in the metal melt depends on the radionuclides present, and this radioactivity is likely to be diluted by mixing with uncontaminated materials. The release and recycling of metals with residual radiation, such as the inventories of metals from nuclear power plants, weapons facilities, or the extraction industry, (discussed in Chapter Two), could lead to gradual increases in background levels of radioactivity. The melting of a sealed source has a somewhat different impact. It is an example of an acute radiological event that could result in a temporary elevation in levels of radioactivity. These acute events would, however, only could raise general background levels of radiation if the contamination were not detected and the resulting material enters the metal market.

In this section, we first discuss background radioactivity in metals. Then, we discuss reported levels of radioactivity resulting from acute events such as melting of seal sources.

Typical Radioactivity Levels

Typical levels of radioactivity in metals that have been traded internationally are not well documented. Background levels in scrap iron and steel in the U.S. are discussed in greater detail in Appendix H of this report; information is lacking on background levels for other countries or metals. From information presented in Appendix H, it is apparent that background levels resulting from NORM-contamination in iron and steel are low compared to NORM activity in soils and rocks because levels of radiation are reduced during production processes. Similarly, we can infer that the levels of NORM in recycled metals should be even lower because many of the radionuclides of concern tend to accumulate in slag instead of alloying with metal during melting. In contrast, *radiation levels of cobalt-60 associated with meltings of sealed sources could be much higher,* exceeding a one mrem dose standard by six to 18 times if worst-case exposure assumptions are used. The levels of radioactivity in materials released from nuclear power plants and weapons facilities vary, as discussed in Chapter Two, and will depend on the release standards in place.

The Nordic Nuclear Safety Research agency is one organization outside of the U.S. that is currently examining the background levels of radiation in steel and aluminum products. The organization is collecting samples from steel manufacturers in Nordic countries and measuring background levels. The final report will not be public until mid-2001; however, preliminary findings suggest that steel and aluminum in Nordic countries may contain slightly elevated levels of radionuclides associated with NORM.[15] However, the origin of the metals tested is not known. Thus, it is not possible to tell whether the test metals are imports or originated in Nordic countries.

Radioactivity Levels from Acute Events

The available literature includes a few examples of elevated radioactivity levels resulting from acute events, such as accidental melting or breaching of sealed sources. In 1993, a shipment of ferrophosphorous alloy scrap was shipped from Kazakhstan, through Luxembourg and New Orleans, to Pittsburgh. From Pittsburgh, parts of the original shipment were sent to steelmakers in Michigan, Illinois, Ohio, and Ontario, Canada. It was not until the scrap reached Ohio that it was found to be contaminated with cobalt-60. The average rate of exposure was about 40 to 50 mrem/hour on contact and the maximum exposure rate was about 80 mrem/hour on contact. The low level cobalt-60 radiation believed to be from a source melted in the production of the material.[16]

A perhaps extreme example of levels of radioactivity resulting from an acute event is an incident that occurred in Goiânia City, Brazil. In September 1987, a radiotherapy source containing cesium-137 was stolen from an abandoned private hospital and taken apart by a junk dealer. The dealer dismantled it and distributed the cesium-137 to family and friends. Twenty people were hospitalized, at least 249 people were exposed, and four people died. Cesium-137 contamination was identified at the yards of three junk dealers in scrap materials, and in the trucks used to transport the material.[17]

[15] Interview with Karen Broden, Nordic Nuclear Safety Research, April 19, 2000.

[16] Dizard, Wilson III, "Cobalt-60 Found in Scrap from Kazakhstan; Some Call for More Security," *Inside NRC*, December 27, 1993.

[17] Oberhofer, M. and J.L. Bacelar Leão, *The Radiological Incident in Goiania,* prepared for the International Atomic Energy Agency, Vienna: STI/PUB/815, 1988.

Efforts to Strengthen Practices

In response to these threats, many international and national agencies, as well as individual metal firms, are undertaking efforts to the detection of radiological contamination in metals. This section first describes efforts to improve regulatory protocols; the second part of this section describes initiatives to evaluate and improve radiation detection technologies.

Improving Regulatory Protocols

In response to general concerns over the safety and security of nuclear materials, including the more specific concerns about radioactivity in imports and exports, NRC and DOE are taking actions to strengthen practices internationally, with support from EPA and other agencies. DOE 's Office of International Affairs is involved in a number of international agreements and other cooperative activities to improve control of radioactive materials, especially materials from weapons facilities.[18] NRC's international programs include efforts to bolster domestic systems to account for nuclear materials and formulate contingency plans for radiological incidents at U.S. borders, as well as to provide assistance to other countries interested in developing safeguards. For example, NRC is working with Russia, Kazakhstan, and Ukraine to update radiation regulations and implement better nuclear safety and control infrastructures in order to prevent further exportation of contaminated materials.[19]

The U.S. Congress has begun to address the problem of radioactivity in imported metals directly. An Amendment agreed to by the U.S. House of Representatives as part of the pending 2001 Appropriations Bill will provide $950,000 for a pilot project to check for radioactivity in imported scrap at U.S. border crossings.[20] The funding is likely to be used to buy more detection equipment and to train U.S. Customs personnel. Other legislation that is still being considered by a

[18] More information on DOE's international programs can be found on the agency's Internet site: http://www.osti.gov/international, June 2000.

[19] More information on NRC's international programs can be found on the agency's Internet site: http://www.nrc.gov/IP, June 2000.

[20] Amendment H.R. 1014 to the Treasury, Postal Service, and General Government Appropriations Bill, introduced by Representative Ron Klink and agreed to on July 20, 2000.

Congressional committee would require all exporters to certify and document the level of radioactivity in metals imported to the U.S.[21] This proposed legislation appears to be similar to the Italian declaration required for imports.

The IAEA is also taking a lead role in responding to these concerns. The agency has a high priority program for training border guards in Eastern and Central European regions. In conjunction with other security agencies, the IAEA has conducted at least two training courses for customs and police officers in Central and Eastern Europe on detecting radioactivity at borders .[22] After Germany raised concerns about contaminated metals originating in the former Soviet bloc, then passing through Poland into Germany, the Polish government increased its detection activities as part of its National Prevention System. Specifically, Poland has installed more than 100 radiation detectors at its land borders with Russia, Ukraine, and Lithuania, as well as at railway crossings and its seaports.[23]

Evaluating and Advancing Detection Technologies

In response to concerns regarding detection capabilities, both government agencies and metal firms are evaluating technologies currently available and investigating potential improvements. The IAEA is conducting a series of laboratory tests of fixed installation radiation detectors as part of the Illicit Trafficking Radiation Assessment Program (ITRAP). IAEA wants to determine a practical "investigation level;" a level of radioactivity above which a shipment would be stopped and investigated. IAEA staff, in the Division of Radiation and Waste Safety, proposed that the investigation level be set at 0.3 mSv/hr at one meter from the target vehicle.[24]

Another goal of IAEA's testing program is to determine the effectiveness of fixed-installation detectors currently available. In lab trials, the average failure rate (e.g., the frequency with which no alarm is triggered when a source is present) of the test fixed installation detectors is generally below 1 in 1,000 incidents, and the best system performance is below 1 missed alarm in 10,000

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[21] H.R. 4566, Steel Metal and Consumers Radioactivity Protection Act, introduced by Representative Ron Klink on May 25, 2000.

[22] Duftschmid, Klaus E. (1999), page 37.

[23] Smagala, Genowefa, as quoted in Gresalfi (1999).

[24] Duftschmid, Klaus E., as cited by Gresalfi (1999).

incidents. The average false alarm rate is 0.6 percent, and the best performers recorded no false alarms in 30,000 tests. The best performers in the lab tests will then be field tested at the Austrian-Hungarian border and the Vienna airport.[25]

The metal industries are also working to improve detection capabilities. Aside from the new grapple detectors, the industries are also working with manufacturers to develop detectors which can sense radioactive sources by looking at indicators such as metal density. If such equipment is also applied at borders, the result will be increased detection of sealed sources, decreasing the likelihood of accidental melting of these sources. However, it may be impractical to apply sensitive technologies at borders because of the costs of implementing a sophisticated detection program (e.g., equipment, staff training) and the time that it would take to scan shipments.

INTERNATIONAL TRADE

As indicated by the above discussion, most of the available information on radioactivity detected in metal imports and exports relates to acute events, and little is known about the typical levels of radioactivity in these metals. To provide some insights into related issues, in this section we provide background information on the total markets for scrap metal in the six countries addressed by this report, and compare them to the quantities of contaminated metals in each country to the extent possible.

We focus on those types of metals most likely to be affected by contamination from radioactive sources. The previous chapter suggests that most of these metals are likely to be carbon steel. For example, carbon steel accounts for about 76 percent (470,000 of 618,000 metric tons) of the metals potentially suitable for recycling from decommissioning of U.S. nuclear power plants, and 85 percent (904,000 of 1,068,000 metric tons) of the metals from decommissioning of major U.S. weapons facilities.[26] While a breakout of quantities by metal type is not available for NORM-contaminated equipment, descriptions of this equipment suggest that it largely consists of steel. The reports of accidental melting of sealed sources also primarily affect steel.

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[25] Beck, P., K.E. Duftschmid, C.H. Schmitzer, "ITRAP- The Illicit Trafficking Radiation Assessment Program," presented at presented at the *International Conference on Safety and Radioactive Sources*, September 14-18, 1998, Dijon, France, IAEA-CN-70/98.

[26] Sanford Cohen & Associates, Incorporated, *Technical Support Document: Potential Recycling of Scrap Metal from Nuclear Facilities, Volume 1,* prepared for the U.S. Environmental Protection Agency, September 30, 1999.

These sources of radioactive contamination also affect a number of other types of metals, but in comparatively smaller quantities. Review of the data suggests that contaminated stainless steel, aluminum, and copper are among the metals often contaminated by the sources discussed in Chapter Two.[27] In combination, these metal types account for about 21 percent of the potentially recyclable metals from U.S. power plants and about 11 percent of the metals from weapons facilities. Data on the use of these metals in NORM-contaminated equipment are not available, however, accidental meltings affecting aluminum and copper as well as steel have also been reported.

In the sections below, we first provide trade statistics on carbon and stainless steel (or total iron and steel when a more detailed breakout is not available) as well as aluminum and copper, since these are the most prevalent metals identified in this analysis.[28] Next, we provide more detailed information on iron and steel, since these metals dominate the total quantities likely to be contaminated by the sources discussed in Chapter Two. We then provide illustrative examples of the possible relationship between the total quantities of metals from nuclear sources and the domestic market for these metals.

Trade Statistics

Exhibit 3-1 summarizes 1996 quantities of scrap metal flows to and from the six countries addressed in this report. Analysis of metal flows shows that the U.S. imports and exports significant quantities of each of these types of metals, and is a net exporter of all metal types with the exception of aluminum scrap. Similarly, Russia is a net exporter of most metal types but has a smaller market presence than the U.S. The remaining four countries are net importers of most types of metal scrap. These data cover only metals sold as scrap; each country also trades intermediate and finished metal products.

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[27] The quantities of other types of radioactive metals may be significant in certain cases, for example, about 1,700 metric tons of inconel may result from decommissioning of U.S. power plants and significant quantities of nickel (45,000 metric tons) may result from decommissioning one U.S. weapons facility (Paducah).

[28] Note that other metals available in smaller quantities could potentially affect related markets. For example, releasing a small quantity into a very small market may have more of an impact than would releasing a larger quantity into a large market. In addition, release may be more likely if the metal is highly valued; e.g., scrap dealers may be more willing accept materials from nuclear facilities if they are rare metals such as nickel or gold.

The price of scrap varies by type of metal as well as by country. Of the metals discussed in this chapter, copper is more highly valued than aluminum, and steel generally sells for the lowest prices. (Stainless steel is more highly valued than carbon steel, but not always reported separately.) For example, in 1996, shredded iron and steel scrap sold for an average of $143 per ton, stainless steel scrap was $835 per ton, aluminum was $1,012 per ton, and copper was $1,850 per ton.[29] Prices may vary significantly from month-to-month as well as year-to-year, due to changing supply and demand conditions. Prices also may vary by geographic area as well as over time. For example, in 1995, Brazil paid an average of $43.00 per ton for iron and steel scrap imports, while the Republic of Korea paid $179 per ton.[30]

Because of the differences in metal values, countries may have negative trade balances in terms of quantity, but positive balances in terms of monetary value (or vice versa). Exhibit 3-2 summarizes international scrap flows in terms of total monetary value. It indicates, for example, that although Spain is a net importer of copper scrap in terms of quantity, it shows a positive trade balance in terms of monetary value.

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[29] American Metal Market, *Metals Statistics*, New York: Cahners Publishing, 1998, page 74, 76, and 322.

[30] These differences arise from supply and demand conditions in each country (including the mix of specific grades and types of scrap purchased). These factors can cause scrap prices to fluctuate significantly over time; for example, Brazil's average price paid was $146 per ton in 1993 and $19 per ton in 1994. Transport costs also affect the geographic variation in prices; for example, these costs can add $20 to $30 per ton to the price of U.S. iron and steel scrap exported to Asia. See: Economic Commission for Europe, *Iron and Steel Scrap*, New York: United Nations, 1997.

Exhibit 3-1

IMPORTS AND EXPORTS OF SELECT SCRAP METALS
(1996, metric tons in thousands)

Country	Trade	Iron and Steel	Aluminum	Copper
United States	Export	8,443.5	297.0	392.7
	Import	2,557.4	378.0	212.1
	Balance	**5,886.1**	**(81.0)**	**180.6**
Russian Federation	Export	2,735.2	59.7	214.1
	Import	125.4	0.4	2.2
	Balance	**2,609.8**	**59.3**	**211.9**
Spain	Export	21.4	5.1	39.8
	Import	4,479.6	41.8	59.3
	Balance	**(4,458.2)**	**(36.7)**	**(19.5)**
Italy	Export	20.0	11.8	46.5
	Import	4,935.4	266.2	228.1
	Balance	**(4,915.4)**	**(254.4)**	**(181.6)**
Brazil	Export	12.5	1.0	0.2
	Import	8.0	2.5	20.0
	Balance	**4.5**	**(1.5)**	**(19.8)**
Korea, Republic of	Export	12.2	2.5	13.2
	Import	5,209.9	66.6	111.6
	Balance	**(5,197.7)**	**(64.1)**	**(98.4)**

Parentheses indicate negative balance of trade.
Source: United Nations. *Handbook of World Mineral Trade Statistics, 1991-1996.* New York: United Nations, 1997.

Exhibit 3-2

VALUE OF IMPORTS AND EXPORTS OF SELECT SCRAP METALS
(1996, dollars in millions)

Country	Trade	Iron and Steel	Aluminum	Copper
United States	Export	$1,344.4	$322.0	$616.4
	Import	$360.6	$443.7	$373.2
	Balance	**$983.8**	**$(121.7)**	**$243.2**
Russian Federation	Export	$364.7	$43.3	$308.6
	Import	$10.8	$1.6	$2.1
	Balance	**$353.9**	**$41.7**	**$306.5**
Spain	Export	$8.5	$6.6	$63.3
	Import	$805.3	$41.4	$34.9
	Balance	**$(796.8)**	**$(34.8)**	**$28.4**
Italy	Export	$15.1	$15.4	$63.1
	Import	$721.8	$242.9	$381.7
	Balance	**$(706.7)**	**$(227.5)**	**$(318.6)**
Brazil	Export	$3.1	$1.3	$0.1
	Import	$1.2	$2.6	$47.0
	Balance	**$1.9**	**$(1.3)**	**$(46.9)**
Korea, Republic of	Export	$9.3	$2.7	$13.7
	Import	$940.1	$79.1	$256.6
	Balance	**$(930.8)**	**$(76.4)**	**$(242.9)**

Parentheses indicate negative balance of trade.
Source: United Nations. *Handbook of World Mineral Trade Statistics, 1991-1996.* New York: United Nations, 1997.

Iron and Steel

In the above exhibits, we focus on international trade in each type of scrap metal. Below, we provide more information on domestic supplies for iron and steel. World-wide, 47,394,000 metric tons of iron and steel scrap were imported in 1996; the largest importing countries were Turkey (7,042,000 tons) and Brazil (see below). There is some discrepancy between reported imports and exports; reported world-wide exports total 41,625,000 tons. The major exporters were the U.S. (see below) and Germany (6,684,000 tons); Russia is the third largest source. World-wide consumption of scrap totaled 351,676,000 tons; the largest consumers were the U.S. (see below) and Japan (43,931,000 tons). The other countries included in this report have smaller iron and steel industries, and vary in the extent to which they rely on imports for domestic consumption.

Exhibit 3-3

CONSUMPTION, IMPORTS AND EXPORTS OF IRON AND STEEL SCRAP
(1996, metric tons in thousands)

Country	Domestic Consumption	Imports	Exports	Apparent Domestic Supply
United States	68,700	2,604	8,443	74,539
Russia	27,003	160	2,827	29,670
Spain	9,597	4,479	18	5,136
Italy	15,982	4,935	20	11,067
Brazil	7,460	8	12	7,464
South Korea	18,927	5,115	15	13,827

Notes:
Estimates of imports and exports differ slightly from Exhibit 3.1 because of the different information sources used.
Apparent domestic supply = consumption - imports + exports.
Source: International Iron and Steel Institute, *Steel Statistical Yearbook: 1999*, January 2000.

The sources and destinations of the imports and exports listed above vary. For example, Exhibit 3-4 summarizes the available data on the quantities of iron and steel scrap traded between the U.S. and the other countries considered in this analysis.[31] Almost all U.S. imports of iron and steel scrap appear to originate in countries other than those listed in the exhibit; most steel scrap is imported from Canada. While a significant share of U.S. exports are sent to Korea, other major

[31] American Iron and Steel Institute, *Annual Statistical Report, 1997*, 1998.

recipients include Canada and Mexico. Note that these data represent the sending and receiving countries, not necessarily the countries of origin. For example, some scrap may go through an intermediate country before it arrives in the U.S., such as Russian metals as discussed in Appendix G.

Exhibit 3-4

U.S. TRADE PARTNERS, IRON AND STEEL SCRAP
(1997, metric tons in thousands)

Quantity imported by U.S. from:		**Quantity exported by U.S. to:**	
Russian Federation	<0.1	Russian Federation	N/A
Spain	<0.1	Spain	73.0
Italy	0.2	Italy	10.8
Brazil	19.8	Brazil	12.7
Korea, Republic of	<0.1	Korea, Republic of	3,872.6
Total U.S. Imports from All Countries	**3,481.9**	**Total U.S. Exports to All Countries**	**10,852.6**

Note:
Differences between these data and the data in the previous exhibits results largely from the different years for which data are available.
Data are converted from net tons (2,000 pounds per ton) to metric tons (2,204.6 pounds per ton).
Source: American Iron and Steel Institute, *Annual Statistical Report, 1997*, 1998.

Historically, scrap metals are imported into the U.S. primarily through Detroit, with Canada as the country of origin or the intermediary. Recently, however, the Canada/Detroit route has lost its dominance. Southern ports, such as New Orleans and Mobile on the Gulf of Mexico, and Southeastern ports such as Charlston and Berkeley, South Carolina and Hurtford, North Carolina, now are the point-of-entry for most scrap.[32]

[32] Hoeffer, El, "A Sea Change in the Metallics Market," *New Steel*, January 2000; and Personal communication with Ray Turner, David J. Joseph, August 29, 2000.

Part of the reason for this shift is the recent increase in pig-iron imports into the U.S. Pig-iron originates mainly in Brazil and to a lesser extent in Russia, and is imported through more accessible Southern ports.[33] Also new, large mills in the Southeastern U.S. appear to be utilizing more imported scrap than mills in other parts of the country. More generally, the shift in ports also reflects the diversification of the scrap trade. In contrast to the small number trade routes that previously dominated imports into the U.S., brokers such as David Joseph now import scrap from around the world, including the U.K., EU member nations, Scandinavia, and South American nations. As U.S. sources have diversified, so have the ports of call.

Some countries mostly export scrap that was produced domestically, such as the U.K. and Sweden, while other countries act as conduits for scrap produced in other countries. For example, much of the scrap from Russia travels through the European nations of Turkey, Greece, Italy, and Spain before being shipped to the U.S. Furthermore, most of the scrap that is exported through the Netherlands originates in Germany, while scrap exported from France typically originates in Belgium.[34]

Comparison to Quantities of Radioactive Scrap

The available data on quantities of radioactive scrap generated by domestic sources are not sufficient for us to determine, with certainty, their effect on domestic markets or international trade. The only source of metal for which we have quantity data for all six countries is the decommissioning of nuclear power plants; information on the quantities resulting from decommissioning of nuclear weapons facilities, NORM-contaminated equipment, or accidental meltings is incomplete or unavailable. However, for illustrative purposes, we compare the quantities of iron and steel generated from decommissioning of nuclear power plants to total domestic production of scrap iron and steel below.

For the purpose of this comparison, we assume that <u>all</u> radioactive scrap from decommissioning these facilities would be released rather than disposed. Furthermore, we assume that this release would occur <u>in a single year</u>, rather than over a 40 to 60 year period. We select the quantities from Chapter Two and Appendix B based on information on the regulatory controls in each country.

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[33] Hoeffer, El, "Questions Arise Over Pig-Iron Imports," *New Steel*, May 1999.

[34] For more information, see industry case studies in Appendices D and E.

- For the U.S., which regulates the release of these materials, we use the total amount of iron and steel identified as potentially recyclable.

- For Italy and Spain, which also regulate the release of these materials, we include iron and steel identified as having removable surface contamination.

- For Russia, we include all radioactive metals regardless of whether they can be decontaminated, due to the lack of regulatory controls.[35]

- For Brazil and Korea, we are unsure about the status of regulatory controls and hence report a range. The lower end of this range includes only metals with removable surficial contamination; the high end includes all radioactive metals.

As discussed in more detail in Chapter Two, this approach leads us to substantially overstate the total quantities of iron and steel that could be released in each country. The results of this comparison are provided in Exhibit 3-5.

[35] We use the Argonne data on Russia in this comparison for consistency, which includes plants in the other former Soviet Republics. Other data on Russian metals are reported in Chapter 2 and Appendix G.

Exhibit 3-5

COMPARISON OF POTENTIALLY RADIOACTIVE IRON AND STEEL FROM NUCLEAR POWER PLANTS AND ANNUAL DOMESTIC SUPPLY (metric tons in thousands)

Country	Total Potentially Releasable from Nuclear Power Plants (all years)	Apparent Domestic Supply (annual, 1996)	Nuclear Power Plant Scrap as a Percentage of Apparent Domestic Supply
United States	605	74,539	0.8 percent
Russia	800	29,670	2.7 percent
Italy	17	5,136	0.3 percent
Spain	63	11,067	0.6 percent
Brazil	41 - 62	7,464	0.5-0.8 percent
South Korea	95 - 146	13,827	0.7-1.0 percent

Notes:
Nuclear power plant iron and steel includes stainless steel and galvanized iron; see above text, Chapter Two, and Appendix B for more information.
Data listed for Russia includes metals from plants in all of the former Soviet Republics, whereas data on total apparent domestic supplies addresses Russia only.
Exhibit substantially overestimates quantities likely to be released from nuclear power plants, as discussed above and in Chapter Two.
Sources:
Data on scrap from nuclear facilities is derived from: Nieves, L.A., Chen, S.Y., Kohout, E.J., Nabelssi, B., Tilbrook, R.W., and S.E. Wilson, Argonne National Laboratory, *Evaluation of Radioactive Scrap Metal Recycling*, prepared for the U.S. Department of Energy. NAL/EAD/TM-50, December 1995; and, Sanford Cohen and Associates, Incorporated, *Technical Support Document: Potential Recycling of Scrap Metal from Nuclear Facilities, Volume 1*, prepared for the U.S. Environmental Protection Agency, September 30, 1999.
Data on apparent domestic supply is derived from: International Iron and Steel Institute, *Steel Statistical Yearbook: 1999*, January 2000.

This exhibit indicates that, even under assumptions that substantially overstate the amount of radioactive scrap likely to be released from these facilities, the total amount available is a relatively small percent of the domestic supply. With the exception of Russia, this scrap represents less than one percent of the annual supply in each country.

These calculations may overestimate the quantities of scrap from nuclear facilities by a factor of fifty or more, because the reported quantities are likely to be released over several decades as facilities are decommissioned. In addition, much of this scrap may be buried rather than released. Although data on specific quantities are not available for other sources (weapons facilities, NORM-contaminated equipment, or accidental meltings) we expect that they will not be a significant fraction of the domestic supply. The likelihood that these metals would be exported, rather than used domestically, cannot be determined from the available data.

Exhibit 3-6 compares the estimated total quantities of radioactive copper and aluminum from nuclear power plants to copper and aluminum supplies in the six countries addressed in this report. We make the same assumptions as in the analysis of iron and steel. We assume that the total quantity of radioactive metal will be released in one year, rather than over 40 to 60 year period. Again, the quantities of contaminated metals included in this comparison depend on the regulatory controls in each country: we include estimated recyclable quantities for the U.S., quantities with removable surface contamination for Italy and Spain, all contaminated metals for the former Soviet Republics, and a range for Brazil and Korea. This approach substantially overstates the total quantities likely to be released in the six subject countries.

This exhibit indicates that contaminated copper from nuclear power plants may be a somewhat larger proportion of the domestic scrap supplies than iron and steel, while contaminated aluminum is a very small proportion. The copper percentages are all less than 10 percent except in the case of Russia. These percentages would decrease if we considered the amount of contaminated scrap potentially released on an annual basis (rather than the total supply), e.g., over a fifty year period, and if we considered whether this metal is more likely to be disposed rather than released. In addition, the Russian percentage is overstated, because the Argonne data include plants in all of the Soviet Republics, whereas the data on production are for Russia only. Again, the available data do not allow us to predict how much, if any, of this metal could be exported.

Exhibit 3-6
COMPARISON OF POTENTIALLY RADIOACTIVE COPPER AND ALUMINUM FROM NUCLEAR POWER PLANTS AND ANNUAL DOMESTIC SUPPLY
(metric tons in thousands)

Country	Copper			Aluminum		
	Total Potentially Releasable from Nuclear Power Plants (all years)	**Secondary Refinery Production (annual, 1996)**	**Percentage of Total**	**Total Potentially Releasable from Nuclear Power Plants (all years)**	**Total Recovered from Old and New Scrap (annual, 1996)**	**Percentage of Total**
United States	9.7	332.9	2.9 percent	0.3	3,205.5	<0.1 percent
Russia	7.3	57.0	12.8 percent	1.5	N/A	N/A
Italy	0.2	60.8	0.3 percent	<0.1	376.6	<0.1 percent
Spain	0.7	54.0	1.3 percent	0.1	153.8	<0.1 percent
Brazil	0.4 - 0.5	N/A	N/A	0.1	145.6	<0.1 percent
South Korea	1.0 - 1.2	17.0	5.9-7.3 percent	0.2	50.0	<0.1 percent

Notes:
See above text, Chapter Two, and Appendix B for information on estimates of contaminated scrap quantities.
Russia data includes metals from power plants in all former Soviet Republics, while total production data are for Russia only.
Exhibit substantially overestimates quantities likely to be released from nuclear power plants, as discussed above and in Chapter Two.
Sources:
Data on copper and aluminum from nuclear facilities is derived from: Nieves, L.A., Chen, S.Y., Kohout, E.J., Nabelssi, B., Tilbrook, R.W., and S.E. Wilson, Argonne National Laboratory, *Evaluation of Radioactive Scrap Metal Recycling*, prepared for the U.S. Department of Energy. NAL/EAD/TM-50, December 1995; and, Sanford Cohen and Associates, Incorporated, *Technical Support Document: Potential Recycling of Scrap Metal from Nuclear Facilities, Volume 1*, prepared for the U.S. Environmental Protection Agency, September 30, 1999.
Data on secondary refinery production of copper is derived from: *International Copper Study Group Bulletin*, May 2000. These estimates may understate total copper scrap supplies.
Data on aluminum scrap recovery is derived from: *Metal Statistics, 1988-1998: Aluminium Scrap Recovery, 1998*, World Bureau of Statistics, Ware, England, 1999.

SUMMARY

This chapter discusses border and industry practices that address potential radiological contamination of metal imports and exports. It also presents information on the size of various metals markets, and the role of imports and exports. We compare estimated quantities of contaminated metals to domestic metal supplies to the extent possible. Our key findings include the following.

- Increasing concern about the prevalence of radioactivity in imported and exported materials has lead several countries to increase their efforts to detect radiation in imports. However, such detection presents several challenges.

    — Some of these challenges are technical. For example, it is difficult to calibrate equipment to detect low levels of radiation and sealed sources without registering a high percentage of false alarms.

    — Other challenges involve the need to develop clear thresholds for investigating sources of radiation and standardized protocols for handling contaminated materials.

    — In addition, detection efforts, especially those designed to find sealed sources, can slow the flow of material through international check-points, leading to the need to balance the desire for radiation protection with the desire to avoid lengthy delays.

    — Concerns about domestic and international sources of radioactive materials (especially sealed sources) have led to the widespread installation of radiation detection equipment at scrap yards and mills, especially in the U.S. These systems face technical and logistical challenges similar to those faced by customs officials (e.g., the apparent trade off between false alarms and the need to detect sealed sources). However, the new grapple systems appear promising in their ability to augment current technologies and overcome some of their limitations.

- The increased concern regarding radioactivity in metals appears to result largely from the inadequacy of nuclear controls in Russia and the former Soviet Republics, which may be a significant source of contaminated metals, sealed sources, and other radioactive materials.

- All six of the countries discussed in this chapter import and export some scrap metal, but the quantities involved vary significantly by country.

    — Exports from Russia may be of the greatest concern, due to the large quantities of radioactive materials available domestically as well as the potentially significant quantity exported.

    — Data on the U.S. suggest that only a negligible amount of iron and steel is imported directly from Russia. However, metals that originated in Russia may be sent to an intermediate country then imported into the U.S.

- Although the percentage of U.S. imports coming directly from Russia is small, the data on acute events (discussed in Chapter Four) indicate that many of the radiation sources originate in Russia or the former Soviet Republics.

- The comparison of domestic metal supplies to inventories of metals with residual radioactivity suggests that contaminated metals may represent only a small proportion of the total metal supplies. Hence the quantities of contaminated metals may not be large enough to cause broad impacts throughout the metal markets in the near-term. The more significant concern may be the acute impacts of the release of highly-radioactive metals or of radioactive materials that may be inadvertently melted with metal scrap.

In the following chapter, we discuss the economic impacts of these findings in more detail.

ECONOMIC CONSEQUENCES — CHAPTER FOUR

As discussed in the previous chapters, the extent to which metals with elevated levels of radioactivity are controlled domestically varies, depending both on the source of the metal and on the country under consideration. For example, in the U.S. and other developed countries, metals from nuclear facilities appear to be relatively well-controlled, while metals contaminated by NORM or accidental meltings are subject to comparatively fewer controls. These metals may be exported and imported without detection of the elevated radioactivity levels, unless radiation is detected by industry or other radiation monitors.

Under current conditions, the import and export of these contaminated metals can have a number of economic impacts in addition to posing potentially significant health risks. This chapter describes the types of economic impacts that could arise from radiological contamination of traded metals; it then discusses the potential for market-wide impacts on metal supplies and prices. Finally, we assess the costs associated with accidental melting incidents and rejected shipments of contaminated metal or sealed sources.

ECONOMIC IMPACTS OF CURRENT PRACTICES

Ineffective domestic controls over radioactive materials, inadequate detection practices at international borders, and a lack of agreement on radiation protection standards and practices all contribute to the possibility that metal imports or exports could contain elevated levels of radioactivity. This situation could result in a number of possible economic consequences, including impacts such as the following.

- If a high percent of the metal supply is contaminated, and the substitute sources of uncontaminated scrap or supplies of new metals are constrained, metal prices could rise.

- If a firm ships or receives contaminated metals, the firm may incur the costs associated with characterizing and remediating the contamination.

- If there is no target clearance or acceptance level, or standard practices for detecting and responding to elevated contamination levels, the resulting uncertainty can inhibit trade.

The presence of radioactivity in metal imports and exports could potentially result in broad economic impacts, such as impacts on prices and quantities of metals sold. If this radioactivity is uncontrolled, it could become prevalent throughout the metal supply. Depending on the availability (and costs) of substitutes for this metal, the quantities of uncontaminated metal available could become limited and cause prices to rise. In addition, some buyers may be willing to pay a premium for metals that they are confident have not been exposed to radioactivity, leading to greater differentiation in the marketplace between premium and non-premium scrap. Controlling the level of radioactivity could also have market impacts if the problems are pervasive and expensive to address. For example, if control costs are high, they may be passed on to consumers in the form of higher prices for metal products. For these broad effects to be realized, however, the proportion of metal supplies that are radioactively-contaminated would need to be considerable.

In Chapter Three, we compare the quantities of radioactive metals to domestic scrap markets to the extent possible given available information. These data suggest that these metals represent a relatively small fraction of the total market, indicating that radioactive metals may not significantly impact the overall supply of uncontaminated scrap nor scrap prices in the near-term. However, fear of acute events has caused metals firms to install detection equipment; we are uncertain about the extent to which installing and operating this equipment increases firm-level costs and whether these costs are passed onto consumers in the form of higher market prices.

Economic impacts on individual firms may be more significant than these market-wide effects. These impacts include costs for installing, maintaining, and operating radiation detection equipment. More significantly, individual firms (and, in some cases, government agencies) may incur substantial costs when radiation is detected in shipments, or when undetected sources are accidentally melted. These latter impacts could include a range of costs, including expert assessment of the incident, decontamination, shipping, and eventual disposal of contaminated metal or by-products. Other costs could include lost productivity and legal costs. Such costs may affect the profitability of a firm without having noticeable market impacts, in a competitive market that includes several similar firms. These possible impacts to firms are discussed in sections on accidental meltings and rejected shipments.

Other economic impacts resulting from radiological contamination are more difficult to quantify because they relate largely to the uncertainty associated with the lack of clear policies and standards. For example, firms have few standards for determining whether metals with low levels of residual contamination pose health risks and can be traded internationally. Information gained from the case studies in Appendix D and E suggests that mills base decisions to reject metals on the detection level of their equipment, which may detect levels of radiation too low to pose a health risk. As a result, they may refuse to accept metals that could be "safely" recycled. Such metal may be disposed despite its economic value.

Conversely, firms may accept metals that pose risks to human health under several scenarios. For example, they may not adequately monitor radioactivity in the metals they receive, "safe" levels of activity may be below the detection limits of their monitors, or they may incorrectly believe that the level of radioactivity detected is "safe" due to the lack of consensus on such levels. In these cases, the metal may be sold despite the fact that consideration of health risks would argue for decontamination or disposal. These impacts are difficult to measure, but the resulting uncertainties that could potentially impede metals transactions between potential buyers and sellers.

ACCIDENTAL MELTINGS

When detected, accidental meltings of sealed sources and radioactively contaminated metal comprise the highest costs associated with current practices. However, the likelihood of detection depends on where the incident occurs. Sophisticated technologies used by mills in the United States and Western Europe may detect melting incidents. However, meltings that result in low levels of contamination or that occur in non-industrialized countries may not be detected. In this latter scenario, economic costs are not realized but the health risks from introducing contaminated metal into the general metal supply may be high.

According to a database maintained by James Yusko at the Pennsylvania Department of Environmental Protection, the U.S. has reported 32 incidences of accidental meltings, Russia has reported four, Italy eight, Spain one, Brazil three, and Korea zero.[1] The total number of meltings reported worldwide is 65, for the time period from 1983 to 1999. The comparably large number of incidents in the U.S. may be related to several factors, including the size of the metal industry, the prevalence of detection equipment, and the fact that the data were collected by a U.S. resident. Relative to the total metal markets reported in Chapter Two, accidental meltings appear to be relatively rare events involving small amounts of contaminated materials. If detected, the

[1] Yusko, James G., "NORM and Metals Recycling in the United States, *Presentation at Natural Radiation and NORM International Conference*, London, September 30 - October 1, 1999.

contaminated metal may never leave the mill (except for disposal) or may be recalled. These incidences are very costly to metals industries despite their rarity, and are thus an important economic consequence of current practices.

This section first describes the effects of accidental meltings on imports and exports. The second part of the section describes the economic consequences of accidental meltings, including a discussion of specific meltings and a breakdown of the related costs.

Effects on Imports and Exports

In most cases, we are unable to determine whether meltings have result in the import or export of radioactive metal. The Yusko database, the main source of information on accidental meltings, only provides descriptions of consequences for some of the incidents listed. It is often impossible to trace the origin of a sealed source or contaminated scrap once it has been melted because scrap from various sources is continuously mixed and re-mixed with other shipments before smelting. Thus, we cannot estimate the total proportion of meltings that can be attributed to imported scrap or sealed sources.[2] Only the following events are known to have resulted in international trade of radioactive scrap metal.

Nine incidents of accidental meltings have been documented where contaminated metal was imported by the U.S. In addition, two incidents affected other products from the metals industry. In one such event, the U.S. imported flue dust from Canada for recycling which was contaminated, and, on another occasion, contaminated slag which originated in South Africa was imported by Italy. Several of these events are described in greater detail below.

In 1994, a cobalt-60 source was smelted in Bulgaria, contaminating steel plates which were exported to the U.S.. The contamination was discovered at a steel fabrication plant in Mississippi.[3] In 1995, cesium-137 was smelted in Canada and was detected in the furnace dust which was sent to a U.S. recycling facility. Lead-bismuth-tin slag contaminated with lead-210 and its progeny,

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[2] Ray Turner from David Joseph Co. knows of only one case where the mill was able to trace a sealed source, which was in an incident affecting Border Steel in El Paso, TX. Personal communication with Ray Turner, April 25, 2000.

[3] Lubenau, J.O. and J.G. Yusko, "Radioactive Materials in Recycled Materials - An Update." *Health Physics Society,* Vol. 74, No. 3, pp. 293-299, 1998.

bismuth-210 and polonium-210, was imported from a tin smelter in Brazil and used to make lead aprons which were exported from the U.S. The lead vinyl was also used in products such as additives for fuel and weights in golf clubs.

A notable example of an accidental melting which resulted in the importation of contaminated metal is the Ciudad Juarez, Mexico incident. A cancer therapy device was sold by an equipment company in Fort Worth, Texas to a medical facility in Juarez, Mexico. The facility never used the machine, and it was left in a warehouse until 1983 when it was stolen, dismantled, and sold to a junkyard. The source capsule was cut open in the bed of a pickup truck, spilling 6,010 metal pellets, each containing approximately 70 microcuries (mCi) of cobalt-60. These pellets spread around the scrap yard, stuck to the tires of trucks entering and exiting the yard, and were melted with steel at two foundries. The metal from these foundries was used to make reinforcing rods and metal table legs which were imported into the U.S.. In January, a truck carrying reinforcing bar from one of the foundries made a wrong turn while making a delivery and happened to pass over a radiation sensor at the Los Alamos National Laboratory in New Mexico, leading to the discovery of the accidental melting.[4]

Costs of Accidental Meltings

The costs associated with remediating acute events include decontaminating the scrap yard and mill, storing and disposing contaminated dust and metal, contracting with experts for assessment of the damage, and losing productivity during shutdown time. Estimates of the costs incurred by steel mills in the U.S. which have melted sealed sources are abundant, but are not well documented or detailed and are somewhat conflicting. For example:

- The analysis completed by James Yusko suggests that total cleanup costs average around $10 million, including costs for decontamination, waste disposal, and mill shutdown, with disposal and shutdown costs as high as $500,000 per day.[5]

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[4] Marshall, E., "Juarez: An Unprecedented Radiation Accident," *Science,* Vol. 22, pp. 1152 - 1154, 1984.

[5] Yusko (1999).

- The Steel Manufacturers Association (SMA) puts the total cost range at between $2 million and $24 million per incident, with an average cost exceeding $10 million. The SMA estimates disposal costs at between $3 million and $15 million, and shutdown costs at $5 million to $13 million in lost revenue.[6]

- The American Iron and Steel Institute reports that the costs of decontamination, disposal and losses due to shutdown reached $23 million in a single incident and average between $8 and $10 million at a steel mini-mill. The same source estimates that the cost of a radioactive melt at a large integrated steel mill can run as high as $100 million or more.[7]

- Furthermore, according to one expert, the $10 to $12 million figure may be an underestimate of today's average costs because it includes meltings that occurred 20 years ago.[8] He notes that costs today are much higher due to stricter environmental regulations for cleanup and disposal.

Exhibit 4-1 presents costs associated with specific U.S. accidental melting incidents. The available cost information is incomplete and not well documented, but nevertheless provides a range of estimates for various cost components, including:

- $2 - $10 million for decontamination, storage, and waste disposal,

- $1 - $20 million of lost productivity due to post-incident shutdowns, and

- $4.4 - $30 million in total costs per incident.

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[6] Steel Manufacturers Association, "Radioactive Scrap," on the SMA's Internet site, http://www.steelnet.org/sma/radscrap.html, April 24, 2000.

[7] Sharkey, Andrew G. for the American Iron and Steel Institute, testimony before the Nuclear Regulatory Commission, and *Recycling Today*, "Radioactive Scrap Threat Heats Up," May, 1998. The same cost figures are quoted by Greta Joy Dicus, Nuclear Regulatory Commissioner, in "USA Perspectives: Safety and Security of Radioactive Sources," *IAEA Bulletin*, Volume 41, Number 3, September 1999, pages 22-27.

[8] Personal Communication with Ray Turner, David Joseph Company, April 25, 2000.

The cost of the Acerinox melting in 1998, which is presented in Exhibit 4-1, is higher than the reported costs of other meltings -- and may indicate that related costs have risen over time. A significant information gap remains on the cost of expert assessments and on the cost of disposing of bag house dust following cleanup (which is a potentially significant cost for Newport Steel). In addition, the health hazards faced by workers exposed to these events have not been quantified.

Exhibit 4-1

EXAMPLES OF COSTS OF ACCIDENTAL MELTINGS

		Costs			
Mill	**Type of Source**	**Decontamination, Storage, and Waste Disposal**	**Lost Productivity**	**Expert Assessment**	**Total**
Acerinox (1998)	Cs-137	at least $6 million	at least $20 million	N/A	at least $26 million
Ameristeel (date unknown)	unknown	N/A	N/A	N/A	at least $30 million
Auburn Steel Company (1983)	Co-60	N/A	N/A	N/A	$4.4 million
Auburn Steel Company (1993)	Cs-137	N/A	N/A	N/A	$5 million
Chaparral Steel (1993)	Cs-137	$2 million	$ 1 million	$ 2 million	$ 5 million*
Florida Steel Corporation (1993)	Cs-137	$6.1 million	$8 million	N/A	at least $14.1 million
Newport Steel Corporation (1992)	Cs-137	$2.5 million	N/A	N/A	$5 million (not including bag house dust disposal)
Newport Steel Corporation (1993)	Cs-137	N/A	N/A	N/A	$5 million (not including bag house dust disposal)

Notes:
"N/A" indicates that data were not available.
Costs are given in U.S. dollars for the year in which they were reported.

Sources:
Acerinox- IAEA, *The Safety of Radiation Sources and the Security of Radioactive Materials*, August 17, 1999, and Yusko, James G.,"NORM and Metals Recycling in the United States," presented at *Natural Radiation and NORM* International Conference, September 30-October 1, 1999, London.
Ameristeel- Personal Communication with Ray Turner, David Joseph Company, April 25, 2000.
Auburn Steel (1983)- Lubenau, J. and J.G. Yusko. "Radioactive Materials in Recycled Metals," *Health Physics*, Vol. 68, pages 440-451.
Auburn Steel (1993)- Fitzgerald, Thomas J. and Jeff Pillets, "Hazards Spread Unnoticed," *The Record*, November 22, 1999.
Chaparral Steel- Personal Communication with John Brown, Chaparral Steel, May 9, 2000.
Florida Steel- Lubenau, J. and J.G. Yusko, "Radioactive Materials in Recycled Metals," *Health Physics*, Vol. 68, pages 440-451.
Newport Steel (1992)- Lubenau, J. and J.G. Yusko. "Radioactive Materials in Recycled Metals," *Health Physics*, Vol. 68, pages 440-451, and Fitzgerald, Thomas J. and Jeff Pillets, "Hazards Spread Unnoticed," *The Record*, November 22, 1999.
Newport Steel (1993)- Fitzgerald, Thomas J. and Jeff Pillets, "Hazards Spread Unnoticed," *The Record*, November 22, 1999.

The financial burden of an accidental melting typically lies with the mill, as opposed to the supplier of the contaminated metal. The SMA argues that the penalties for losing a sealed source are minuscule in comparison to the damage that the sources cause if melted (one or two thousand dollars as opposed to millions). Therefore, firms using radioactive devices have few incentives for controlling sealed sources, forcing mills to take responsibility for detection.[9]

REJECTED SHIPMENTS

Rejected shipments occur when the recipient refuses to accept (or tries to refuse to accept) metal found to be radioactively contaminated. For example, a steel mill may not allow a truck to enter its facility if the truck contains materials that cause the mill's detectors to alarm. Since we are primarily concerned with international incidents, we focus on shipments that cross international borders and are rejected by a recipient in another country. Rejection of contaminated shipments sometimes occurs at importing borders. If contamination is not detected at the border, the shipment then passes through to an industry site, where the contamination may be detected by more sensitive radiation detectors. In some cases, undetected contamination may end up in the final metal product.

The types of costs associated with rejected shipments are similar regardless of where the contamination is detected. Costs include expert assessment, decontamination and/or disposal, shipping, lost productivity, and, in some cases, litigation. However, the magnitude of costs associated with rejected shipments, as well as the party that assumes financial responsibility, is often dependent upon whether the shipment is rejected at a border or at an industry site. This section first presents information on rejected shipments discovered at international borders, then at industry sites, and finally in the marketplace.

Shipments Rejected at Borders

Radioactively contaminated shipments are sometimes discovered at international borders, either at their destinations or en route. Exhibit 4-2 presents five known incidences when shipments were rejected at borders for the six countries considered in this report. These incidences mainly involve Russia, former Soviet states, the United States, and Sweden. Japan and Italy were also involved in one incident each.

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[9] Steel Manufacturers Association, "Radioactive Scrap," available at: http://www.steelnet.org/sma/radscrap.html, April 24, 2000.

Exhibit 4-2

EXAMPLES OF SHIPMENTS REJECTED AT INTERNATIONAL BORDERS

From	To	Date	Source of Radiation	Disposition/Costs
Russia	Sweden, via Estonia	1992	77-ton scrap shipment containing Co-60, may have come from a Soviet submarine	Swedish agency assessed the shipment; costs not calculated. Cost approximately $1,000 to ship only contaminated metal back on a ferry. Radiation allowed to naturally decay; no decontamination costs. Half of the shipment was not contaminated, but no firm would buy the half, hence there were lost potential revenues from disposing of the uncontaminated scrap.
Russia	Sweden, via Estonia	N/A	scrap shipment from a Soviet submarine	Swedish agency assessed the shipment; costs not calculated. Entire ship was sent back 300 miles from Sweden to Estonia; shipping costs not available but were said to be significant.
United States	Italy	N/A	NORM-contaminated scrap metal	A third party has been assessing the shipment for approximately one year but disposition is still uncertain; costs not known.
United States	Japan	N/A	sealed americium source	Source is to be transported back to the U.S. via air carrier and disposed; NRC has agreed to repatriate the source.
Kazakstan	Uzbekistan (en route to Pakistan)	2000	1 ton, or 10 lead boxes containing contaminated scrap	Truck was sent back to Kazakstan; costs are not known at this time.

<u>Notes:</u>
"N/A" indicates that data were not available.
Costs are given in U.S. dollars for the year in which they were reported.
<u>Sources</u>:
Russia/Sweden 1992- Marley, M. Swedish Officials Turn Back Radioactive Scrap," *American Metal Market*, September 25, 1992, and personal communication with Michael Jensen, Swedish Radiation Protection Institute, May 22, 2000.
Russia/Sweden- personal communication with Michael Jensen, Swedish Radiation Protection Institute, May 22, 2000.
United States/Italy- personal communication with Mike Mattia, Institute of Scrap Metal Industries, September 23, 1999 and April 6, 2000.
United States/Japan - personal communication with Mike Mattia, Institute of Scrap Metal Industries, April 6, 2000.
Kazakstan/Uzbekistan 2000- Associated Press, "Nuclear Material seized from Truck," and Associated Press, "Kazakstan Denies Nuclear Material was Smuggled," April 7, 2000. (Articles quote different sources and conflict on the quantity of metal and description of the shipment.)

In four of the five cases, the rejected shipment was sent back to the country where it originated prior to decontamination. The one exception is a shipment of NORM-contaminated scrap metal from the U.S. that entered Italy, and was decontaminated domestically. Officials in Italy refused to accept the scrap, and wanted to identify the shipment as highly radioactive material. This classification meant that the ocean transport carrier was unwilling to handle the shipment. Instead, a third party decontaminated the metal in Italy.[10] The transport problems that arose in the Italian case do not appear to have arisen in the other cases we reviewed.

We were not able to locate cost information for most of these cases. The only quantitative cost information is a $1,000 shipping cost for the Russia/Sweden case in 1992. This incident involved a 77-ton shipload of scrap metal contaminated with radioactive material, which was sent back to Russia after Swedish customs officials identified levels of cobalt-60 and cesium-137 that were 10 to 15 times higher than allowable levels of metal that can be shipped from Swedish nuclear power plants. The source of the radioactive material is unknown, but Swedish officials suspect that it may have come from a Soviet submarine.[11]

In most cases where shipments are rejected at borders, it is unclear which government bore the financial responsibility for handling the contaminated material. The only exception is when a sealed source was shipped from the United States to Japan, and NRC agreed to pay to have it shipped back to the U.S.

<u>Shipments Rejected at Industry Sites</u>

Because detection technologies and radiation protection practices at international borders are limited, many radioactively contaminated shipments pass through borders and are detected at industrial sites, such as mills or industrial docks serving mill sites. Exhibit 4-3 presents information shipments rejected at industrial sites, again focusing on the six countries discussed in this report.

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[10] Personal communication with Mike Mattia, Institute of Scrap Recycling Industries, September 23, 1999.

[11] Marley, M., "Swedish Officials Turn Back Radioactive Russian Scrap," *American Metal Market*, September 25, 1992.

Exhibit 4-3

EXAMPLES OF SHIPMENTS REJECTED BY INDUSTRY

From	To	Date	Number of Known Rejected Shipments	Source(s) of Radiation	Disposition/Costs
various	Netherlands	1995-1998	200	various sources	Shipments were handled in the Netherlands. Receiving Dutch companies paid for the contaminated metal to be shipped to COVRA, the organization which stores radioactive waste in the Netherlands.
Russia and other former Soviet states	Great Britain	1998	4	various sources	Shipments were handled in Great Britain. Rejected shipments were decontaminated by a contractor of the British government.
Russia	South Korea	2000 (approx.)	2	NORM	Shipments were handled in South Korea. If this case had happened in the U.S., total cost for handling it would have been between $6-10 million, which includes assessment, decontamination, storage, and legal costs. Because this case happened in South Korea, the costs were somewhat less (exact costs not known).
Russia	United States	1998 (approx.)	1	700 pound ingot of mixed aluminum; source unknown	N/A
Kazakhstan	United States and Canada	1993	1	Co-60 sealed source	N/A
Netherlands	United States	1997 (approx.)	1	Co-60 sealed source	Shipment was handled in the U.S. Total costs equal $5-6 million, but much of these costs were unrelated to radioactivity and were due to other quality issues. Total costs that are attributed to radioactivity were $800,000.
Bulgaria	United States	after 1995	1	steel plates; Co-60	N/A
Canada	United States	1995	1	furnace dust; Cs-137 sealed source	Financial responsibility and costs N/A.
EU	United States	2000	1	oil pipe contaminated with NORM	Shipment was originally rejected at a U.S. mill that turned back 12 other barges from the same shipper because of the contamination on the one pipe. These other barges were sent to another U.S. mill that verified that they were not contaminated, and accepted them. The contaminated pipe was handled in the U.S. and the shipper was held financially responsible.

Notes:
"N/A" indicates that data were not available. Costs are given in U.S. dollars for the year in which they were reported.

Sources:
Various/Netherlands- "Increase of Illegal Traffic of Radioactive Scrap Metal," March 28, 2000.
Russia and former Soviet states/Great Britain- Reed, Camila "Europe acts on radioactive scrap imports," March 28, 2000.
Russia/South Korea- personal communication with Ray Turner, David Joseph Company, May 5, 2000 and August 29, 2000.
Russia/United States- personal communication with Cy Epstein, who was informed of the incident verbally by an Aluminum Association member, April 13, 2000 and August 29, 2000.
Kazakhstan/United States and Canada- Dizard, Wilson III; Cobalt-60 Found in Scrap from Kazakhstan; "Some Call for More Scrutiny," *Inside NRC*, December 27, 1993, page 4.
Netherlands/United States- personal communication with Ray Turner, David Joseph Company, April 25, 2000.
Bulgaria/United States- Lubenau, Joel O. and James G. Yusko, "Radioactive Materials in Recycled Metals- An Update," *Health Physics*, Volume 74, Number 3, March 1998, pages 293-299.
Canada/United States- Lubenau, Joel O. and James G. Yusko, "Radioactive Materials in Recycled Metals- An Update," *Health Physics*, Volume 74, Number 3, March 1998, pages 293-299.
EU/U.S.- personal communication with Ray Turner, David Joseph Company, August 29, 2000.

The exhibit suggests that these rejections are far more frequent than those at borders. For example, industrial sites in the Netherlands found and rejected 200 contaminated shipments in a three year period. We are uncertain why the number of reported rejected shipments is so high in the Netherlands. It may reflect the results of greater reporting or more widespread monitoring. In addition, Rotterdam is a major destination for the scrap metal trade.

In contrast to the diversity of rejected shipments at borders, the exhibit shows that there are a number of rejected shipments at industry sites that are similar, such as the four shipments from Russia and other former Soviet states to Great Britain, and the two NORM-contaminated shipments from Russia to South Korea.

When a shipment is rejected at an industry site, it is generally by a private party rather than a government agent. This distinction appears to affect the disposition of contaminated shipments. In all cases where we know the disposition of the material, shipments rejected at industry sites were handled in the receiving country instead of being sent back to the country of origin. Ray Turner, a radiation expert at the David J. Joseph metal brokerage, notes that this practice is common in the U.S.[12]

Despite the fact that shipments rejected in the U.S. are typically handled domestically, the shipper is usually held financially responsible as long as the metal was rejected upon entering the mill. If a shipment is rejected after it is inside the mill (and mixed with other scrap), the origin of the shipment may be difficult to trace or contested, and the mill may have to pay for handling the shipment[13] Some of these cases have led to litigation between the parties involved (such as the metal suppliers, brokers, and receiving mills) over the costs of handling the shipment. In the cases involving litigation, legal fees were also a significant cost. In contrast, we do not know of any shipments rejected at borders where litigation ensued.

We have quantitative cost figures for only three of the incidents presented in the exhibit. If we use these cases as a range, the total costs for a shipment rejected at an industry site appear to be between $800,000 and $10 million. Ray Turner of David Joseph Company notes that, in his experience, the most significant costs for these incidents are for assessment and disposal.[14] In

[12] Personal Communication with Ray Turner, David Joseph, August 29, 2000.

[13] See Appendix D on David Joseph for additional information.

[14] Personal communication with Ray Turner, David Joseph Company, April 25, 2000.

addition, Doug Jamieson of GTS Duratek, a company that decontaminates radioactive materials, notes that the cost of decontaminating metal rejected by mills ranges between pennies per pound to eight or nine dollars per pound, depending on the level of contamination and other factors.[15]

Other factors can also influence the costs of handling shipments rejected at industry sites. Ray Turner notes that the costs of rejected shipments can vary by country. For example, the Russia/South Korea rejected shipment presented in Exhibit 4-3 would have cost anywhere from $6-$10 million if it occurred in the U.S., but was less expensive because it was handled in South Korea. Furthermore, shipments rejected for radioactive contamination often have other quality-related problems. For example, the Netherlands/U.S. rejected shipment also presented in the exhibit cost $5 to $6 million to address, but only $800,000 was specific to handling the radioactive contamination. The additional costs were due to other problems with the quality of the materials and would have been incurred regardless of radiological contamination.[16]

<u>Shipments Rejected in the Marketplace</u>

In rare cases, radioactively contaminated shipments of finished or semi-finished products may evade detection at both international borders and industry sites, and may reach the general marketplace, e.g., in consumer products. We know of ten cases where radioactively contaminated products were imported into the U.S. The majority of the products were cobalt-60 contaminated steel; all were from different countries of origin except three shipments that came from Brazil.[17] One of these Brazilian shipments contained semi-finished steel parts that La-Z-Boy used to make recliners, which the company recalled once it discovered the problem.[18] This incident did not lead to significant public exposure.

In another incident, radioactively contaminated lead-bismuth-tin slag imported into the United States from Brazil was used to make a variety of products by manufacturers in the United States, including vinyl lead aprons, golf clubs, and fuel additives. The contamination was not

[15] Personal communication with Doug Jamieson, GTS Duratek, May 25, 2000.

[16] Personal Communication with Ray Turner, David Joseph, August 29, 2000.

[17] Greta Joy Dicus, Nuclear Regulatory Commissioner, "USA Perspectives: Safety and Security of Radioactive Sources," *IAEA Bulletin*, Volume 41, Number 3, September 1999, pages 22-27.

[18] Fitzgerald, Thomas J. and Jeff Pillets, "Hazards Spread Unnoticed," *The Record*, November 22, 1999, available at: http://www.bergen.com/news/scrap2tf199911221.htm.

discovered until a health physicist in a Georgia hospital conducted routine tests on one of the vinyl aprons and found the lead itself to be radioactive. At least three apron manufactures used the contaminated slag in their production processes, and contaminated products had been shipped worldwide by the time the contamination was discovered.[19]

Some releases of radioactive metal into consumer products have posed significant health risks. One example is the previously mentioned Juarez Mexico incident, where contaminated metal was unknowingly released by a foundry in Mexico. The metal ended up in reinforcing bars (rebar) and table legs that were shipped into the U.S., and had to be traced and recovered once the radioactive content of the metal became known.[20] The levels of radioactivity were very high and were ultimately detected. Lower levels that pose threats to human health may often go undetected.

In addition to posing health risks, sale of these metals may have financial consequences in cases where the radioactivity is ultimately detected. Costs could include the same categories as discussed in the sections on other types of rejected shipments, plus the cost of a recall and the potential for lost sales. We do not have any information on these potential costs.

We know of one additional rejected shipment that is not included in the exhibits because we do not know whether the materials were rejected at a border or at an industry site. Radioactivity was discovered in a shipment of vanadium that originated in South Africa and was en route to Austria. The contamination was discovered in Italy, and the was from a cesium-137 source that had been accidentally melted. We do not have any other information on this shipment.[21]

SUMMARY

This chapter has explored the economic consequences associated with radioactive contamination in metal imports and exports. Our key findings include:

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[19] Lubenau and Yusko (1998).

[20] U.S. Nuclear Regulatory Commission, *Contaminated Mexican Steel: Importation of Steel Into the United States That Had Been Inadvertently Contaminated With Cobalt-60 as a Result of Scrapping of a Teletherapy Unit*, NUREG-1103, January 1985.

[21] Lubenau and Yusko (1998).

- The comparison of radioactive scrap to total metal supplies suggests that the proportion of metal affected by contamination may be relatively small. Therefore, the release of contaminated metals may not have broad market impacts, such as effects on prices and quantities.

- The most significant economic effects from contaminated metals appear to be impact on firms. Accidental meltings and rejected shipments can cause millions of dollars worth of damage to individual firms for assessment, decontamination, shipping, disposal, lost productivity, and legal costs. Accidental meltings appear to have higher costs than rejected shipments, although we have less information on the costs of the latter types of incidents.

- The economic impacts resulting from rejected shipments differs according to whether shipments are rejected at borders or at industry sites. The majority of reported incidents involved shipments rejected at borders that were returned to the country of origin. In contrast, shipments that reach industry sites tend to be handled domestically, and may have higher associated costs.

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CONCLUSIONS AND IMPLICATIONS — CHAPTER FIVE

This report provides information on current practices affecting the presence of radioactivity in imported and exported metals and on the types of economic impacts that may result. The international standards currently under development may help to alleviate some of these impacts, but their effectiveness will depend on the standard selected and the extent of enforcement. In this chapter, we first present a summary of current practices and their limitations. Then, we discuss the possible implications of international standards, and discuss factors that will increase their effectiveness. Finally, we discuss options for future research.

SUMMARY OF CURRENT PRACTICES

Current practices can lead to the sale and potential export of metals with elevated levels of radioactivity. Some of the key problems with these practices include the following.

- The lack of international agreement on domestic clearance levels for radioactive metals from nuclear facilities (whether commercial or defense-related) as well as for metals contaminated with NORM.

- Ineffective controls over sealed sources in many countries.

- Limited detection and enforcement capabilities for the domestic control of nuclear materials (particularly in Russia and other former Soviet Republics), as well as limited monitoring at international borders.

- The lack of international agreement on intervention levels for imported and exported materials, as well as on protocols for handling radioactive materials once detected.

- The absence of mechanisms to force firms or countries to internalize the costs of their actions (e.g., to take into account the health effects of radiation on the general population when deciding whether to release, or accept, contaminated materials).

These problems are being addressed by a number of initiatives now underway within the U.S. and other countries, as well as those being undertaken by the IAEA and other international organizations. As described in Chapter Two, current practices and standards for releasing metal from nuclear regulatory controls vary domestically, and do not exist in some countries and for some types of materials. Existing standards are also undergoing revision, and experts disagree about both the appropriate dose level and the relationship of dose to allowable activity levels for individual radionuclides. Some nations, especially Russia, the former Soviet Republics, and developing nations, lack quantitative standards or protocols for addressing release of contaminated materials. Moreover, even in developed nations, regulation of NORM and tracking of sealed sources is limited.

The effects of disagreement regarding domestic clearance standards is counterbalanced to some extent in the developed countries by the strong public opposition to the release of materials with residual levels of radiation. Nuclear facilities in the U.S. and Western Europe release very limited amounts of these metals. The opposite may be true in less developed countries. The need for income (e.g., from the sale of scrap metal) may outweigh concerns about the health effects of radiation. For example, our research on Russia suggests that economic pressures may encourage both the legal and illicit sale of contaminated metals.

Addressing concerns related to the release of contaminated metals also requires efforts to improve detection technologies and practices. Monitoring practices that would allow government officials or firms to detect low levels of radiation (or shielded sources) are likely to be expensive and may often result in false alarms. However, new technologies are now being implemented that may more effectively address these problems. Effective monitoring also requires staff training as well as standard protocols for the disposition of contaminated materials once detected. While several organizations are working to address these problems, implementation of more effective procedures will require significant resources and time.

As a result of the lack of international standards and effective detection and enforcement, firms often develop their own procedures and criteria for radiation protection. In the U.S., this situation has led the metal industries to invest substantially in radiation protection equipment and to adopt a defacto "zero tolerance" position. If their detectors alarm, firms typically reject shipments. However, some radionuclides may pose health risks at levels below those that can be typically detected, whereas others may pose little risk even above detectable levels. As a result, firms may refuse to accept metals that could be safely re-used, and dispose these metals despite their economic value -- and vice-versa. As noted earlier, economic pressures may lead firms in other countries to ignore issues related to radiation protection.

Sealed sources present more complex problems than metals contaminated by use in nuclear facilities or from contact with NORM. The shielding on these sources makes them difficult to detect, and many countries do not track them effectively. Sealed sources may be unmarked and not easily recognized and therefore unknowingly combined with demolition or other materials. Once breached, the levels of radiation exposure from sealed sources can far exceed the levels typically associated with other sources of contamination in scrap metal.

The nature of the metals markets makes it very difficult to identify the original supplier of contaminated metals and to hold the supplier accountable if radiation is detected. For example, contaminated scrap metal from Russia may travel through intermediate countries before its arrival in the U.S.. If a firm then detects the radiation, it may be impossible to identify the original supplier of the metal and require it to reimburse the affected firm for related costs. If a source is not detected prior to melting, remediation costs are often borne by the mill, due to the difficulty in identifying the party responsible for the source once metals from difference suppliers are mixed and melted. Hence the original supplier may not be held liable for the costs associated with the release of contaminated metals or sealed sources, and may benefit from revenue received despite the health risks posed by the sale of the metals.

POTENTIAL IMPACTS OF AN INTERNATIONAL EFFORTS

As discussed in Chapter One, several organizations are involved in developing international radiation protection standards for both domestic release and international intervention. In addition, numerous efforts are underway to improve controls over sealed sources as well as detection and enforcement capabilities. Below, we discuss the potential impacts of these efforts on the types of baseline impacts discussed in this report.

<u>General Impacts</u>

As noted earlier, metals with elevated levels of radioactivity appear to have little impact on the overall metals markets, hence we expect that the market-level impacts of international standards will not be significant. The precise impact of numeric standards for the allowable levels of radioactivity in imports or exports will depend on the values selected. International trade could be affected if imports and exports routinely contain levels of radioactivity that exceed the standard, in which case the standard will discourage trade in these materials. Conversely, a standard that is above the levels typically found in metals may have limited effects on trade, but may prevent unusual, catastrophic events. The dose level likely to be selected, and the activity (or mass) limits associated with this level, are not known at this time. However, preliminary analysis (presented in Appendix H) as well as the experience of the U.S. metals industry suggests that the typical levels of radioactivity found in metals are below levels of concern for human health as well as often below detection limits. Hence it is most likely that international standards will affect the occurrence of potentially acute or catastrophic events associated with unusually high levels of radioactivity, without affecting the overall metals trade.

Some individuals countries with weak domestic controls, such as Russia, could find that fully enforced international standards will inhibit their export of metals (and encourage greater trade in materials from countries with tighter controls). However, although there are many instances of the (often illicit) export of radioactive materials from Russia, the levels of radiation in these materials may not be typical of most exported scrap. Some observers, as discussed in Appendix G, indicate that the Russian policy of releasing only uncontaminated metals from nuclear facilities is generally followed. Hence, even for Russia, the effects of international standards may be largely to avoid potentially catastrophic releases rather than inhibiting general trade.

Although we believe that international intervention standards may have minimal market-wide impacts on prices and on the quantities on uncontaminated metals available, a standard may cause markets to operate more efficiently by providing a common metric for determining whether metals can be imported and exported, thereby avoiding the costs associated with rejected shipments. Standards may also affect domestic decisions on whether to decontaminate and sell, or to dispose, metals with elevated levels of radioactivity. As a result, threats to human health will be reduced, including decreases in cancer and other risks associated with exposure to radiation. To the extent that a standard prevents accidental meltings or the shipment of highly radioactive materials, the acute exposures and high remediation costs of these events will also be avoided.

International standards would allow firms to determine whether metals with detectable levels of radioactivity actually pose risks to human health. If activity levels are detectable but below levels that are considered protective, industry may choose to accept the metal rather than reject it or send it to a disposal facility. However, we expect that this change in practices may be rare, at least in the U.S. and Western Europe, because the general public tends to be fearful of any detectable level of radioactivity regardless of the scientific evidence on the risks it poses. Hence, the metal industry may continue to reject any metal with measurable levels of radioactivity even if such levels are below domestic or international risk-based standards.

Numeric standards alone will not be sufficient, however, to alleviate the impacts of current practices on individual firms. Improved detection and enforcement efforts are also needed at international borders. Several domestic and international groups are now providing technical assistance and funding to strengthen these activities, but significant improvements are likely to be costly and require substantial time to implement effectively. In addition, these groups are working to improve domestic regulatory controls, particularly in Russia and the former Soviet Republics. Significant progress will need to be made in these areas for international clearance standards to become fully effective.

Impacts on Accidental Meltings

Currently, when an accidental melting occurs, metal may become contaminated and leave the mill without the knowledge of the mill operators. The metal can cross borders as semi-finished or finished products. As the metal is sold and subject to further processing, it becomes difficult to trace it back to the originating mill or scrap yard. Once some of the metal is discovered, locating the remainder of the contaminated material from the same incident can be expensive. The lack of border controls allows contaminated metal from these incidents disperse widely, creating large costs when the metal must be recovered. In addition, sealed sources may be exported without being breached and not detected due to its shielding, then accidently melted in the importing country. These meltings can impose high costs if detected and remediated; if not detected, contaminated metal may enter the general metal supply and pose more widespread risks to human health.

The extent to which international standards will avert accidental meltings will depend on whether they are accompanied by increased efforts to control sealed sources domestically and to detect them in exports or imports. While materials other than sealed sources (in particular NORM) may be melted accidently, sealed sources are often the materials of greatest concern because of the difficulty of detecting them and the relatively high levels of radiation involved. Systems to ensure tracking of sealed sources domestically may decrease the likelihood that they will be inadvertently included in demolition materials or otherwise escape regulatory controls. Improved detection capabilities at international borders may prevent the export or import of metal contaminated by accidental meltings. Whether sealed sources are detected will depend on the sensitivity of the detection practices followed. If contamination is detected earlier than currently, the spread of contaminated materials may be limited. The costs of recovering the material will be reduced, because the metal will not be as widely spread throughout semi-finished and finished products. Adverse human health effects will also be mitigated.

Impacts on Rejected Shipments

Currently, metals containing elevated levels of radioactivity may be shipped across international borders. If detected by government officials or industry, the shipments will often be rejected. If rejected at an international border, the materials are typically returned to the country of origin at some expense to governments involved. If contaminated shipments are not rejected at borders, they may be rejected at industry sites or in the general marketplace, at considerable expense to private parties.

International standards, if coupled with effective border controls and improved detection technologies, would decrease the likelihood that contaminated metal would be transported internationally by establishing agreement on protective levels of radiation, In addition, if international standards are used to establish domestic regulatory controls or as a defacto release limit by the metal industry, risks associated with domestic metal sales will also be reduced. The financial impacts of preventing the sale of such metal include some lost revenues for the sellers as well as the costs of implementing improved detection and enforcement capabilities, but would be counterbalanced by savings from avoiding the costs associated with rejected shipments. In addition, these lost revenues are counterbalanced by the social benefits of the accompanying risk reductions for workers and the general public.

Improved border practices would lead to detection of a larger proportion of contaminated shipments at international borders rather than at industry sites. Thus, the costs of handling these incidents may be transferred largely from private parties to governments or to the original source of the materials. To the extent that the costs are effectively transferred to the original supplier, they will provide a financial incentive for improved radiation protection practices.

Summary

In Exhibit 5-1 below, we summarize the potential economic impacts of an international standard that includes numeric intervention levels for acceptable levels of radiation in imported and exported metals, as well as improved methods for detection and enforcement.

Exhibit 5-1

SUMMARY OF POTENTIAL IMPACTS OF INTERNATIONAL STANDARDS
(assuming effective enforcement)

Issue	Current Practices	Leads to...	Potential Impact of International Standards
Lack of numeric standards	metal industry rejects metal which is "safe" or that could be cost-effectively decontaminated	loss of economic value due to disposal of metal	metal may be sold rather than disposed
	metal industry accepts metal that is "unsafe"	human health risks, costs of returning shipments or of remediation if ultimately detected	reduced health risks and costs
Lack of detection and enforcement	metal containing elevated levels of radioactivity is imported and exported	human health risks, costs of returning shipments or remediation if ultimately detected	increased costs of detection and enforcement, reduced human health risks and costs of returning shipments or remediation
Lack of control over sealed sources	sealed sources are included in scrap metal sold to industry and breached or metaled	human health risks, costs of remediation if detected	reduced health risks and costs
	metal contaminated by melting of sealed sources is sold and incorporated into semi-finished or finished products	human health risks, costs of returning shipments or of remediation if ultimately detected	reduced health risks and costs
Lack of standardized protocol for addressing radiological incidents	confusion over how to handle contaminated materials when detected	delays and inefficient efforts, leading to health risks and economic costs	greater response efficiency, reducing risks and costs
Lack of mechanisms to force firms to internalize the costs of their actions	firms may not carefully control the loss, theft, or sale of radioactive sources or material	human health risks, costs of contamination may be borne by recipient of material rather than source	incentives for improved controls, reducing risks and costs borne by others

FUTURE RESEARCH

This scoping analysis provides preliminary information on current practices and on the impacts of efforts to develop international radiation protection standards. Because this analysis suggests that the most significant impacts of international standards may be on individual firms, EPA may wish to focus on future research on these impacts. In particular, we suggest the following.

- **Additional, more detailed case studies of firm-level impacts:** The brief case studies included in the appendices of this report provide important insights into the problems associated with current practices and the potential effects of international standards. Additional, more detailed case studies would provide more in-depth information and insights, and would allow us to refine our understanding of associated costs. Expanding the number of case studies would also help to illustrate the potential impacts at a national (or international) level across a broader range of industries. These case studies could be focused on firms that have experienced problems (i.e., accidental meltings or rejected shipments) that could be potentially mitigated by international standards.

- **Collection of information on U.S. Customs practices:** Interviews with U.S. Customs officials as well as case studies of practices at individual U.S. ports could provide additional information on the extent to which elevated levels of radioactivity are found in imported scrap metal or metal products. In addition, this research could be used to develop better information on current and potential future monitoring practices, including the types of changes (and related costs) associated with effectively enforcing international intervention levels.

- **Analysis of incident databases:** This report relies largely on data collected by Yusko or provided by individual interviewees to assess the occurrence and costs associated with accidental meltings and rejected shipments. Databases maintained by IAEA and NRC contain additional data on these types of events, providing more information on their frequency and characteristics. While we understand that these databases provide little, if any, information on associated costs, we could use the additional references and information they provide to identify incidents for further research (e.g., for follow-up interviews or inclusion in the case studies listed above).

- **<u>Further review of information on NORM and sealed sources:</u>** Most of the problems identified by U.S. industry related to NORM or sealed sources. Further investigation of the quantities of NORM-contaminated equipment likely to be sold as scrap metal and their radiological characteristics could provide a better understanding of related issues. In the case of sealed sources, further research could focus on addressing the regulatory gaps that will not be fully addressed by current efforts to improve the tracking and disposal of these sources, and on assessing the effectiveness of different approaches for addressing these problems.

- **<u>Further analysis of Russian practices:</u>** The review of Russian practices included in this report provides a starting point for understanding the effects of these practices on the export of contaminated metals. More detailed research, including review of other data sources and additional interviews, may allow us to better understand the quantities of metals involved, their radiological characteristics, and their possible disposition both under current practices and under potential future international standards.

In addition, the analysis in this report focuses on baseline practices. As EPA and other organizations move towards establishing an international standard, future research could focus on defining different options for these standards (both for establishing numeric standards and for developing related detection and enforcement capabilities), and on assessing the effects of these options on the types of economic impacts described in this report.

Finally, this report provides little information on human health risks. Reductions of the risks associated with contaminated metals will have economic consequences, reducing the costs of medical care as well as the associated pain and suffering. Therefore, future research addressing the risks associated with the types of practices discussed in this report, and the changes in risks associated with establishing an international standard, may be desirable.

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Appendix A

EXAMPLES OF IMPLEMENTATION ISSUES

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Appendix A

EXAMPLES OF IMPLEMENTATION ISSUES

In Chapter One of this report, we discuss some of the issues that may affect implementation of radiation protection standards for imported and exported scrap metal and metal products. In this Appendix, we present two case studies to demonstrate the lessons learned from other international agreements, based on the framework developed by David Victor et al. and discussed in the main text of this report. The two case studies address:

- The Basel Convention, a binding agreement that regulates the flow of hazardous waste from developed to developing countries.

- The ISO 14000 standard series for Environmental Management Systems, a voluntary certification program for companies seeking to benchmark their environmental performance.

In each case study, we provide background information, discuss barriers to implementation, and describe lessons learned that may be applicable to other international agreements.

The Basel Convention

In 1989, representatives of the United Nations Environmental Program (UNEP) negotiated the Basel Convention on the Control and Transboundary Movement of Hazardous and Other Wastes to thwart the illegal dumping of toxic wastes in developing countries. The treaty went into effect in 1992. Developing countries are particularly at risk for illegal dumping because they lack the resources necessary to safely manage and treat hazardous wastes or to block shipments. In 1995, the Conference of the Parties (the group of country representatives to the Convention) passed the Basel Ban. The Ban forbids the transport of all hazardous waste from members of the Organization for the Economic Co-operation and Development (OECD), which are industrialized and developed countries, to non-OECD states, which are mainly developing countries.[1]

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[1] Radioactive waste is specifically excluded from the Basel Convention. See: United Nations Environmental Program, *Report of the Fourth Meeting of the Conference of the Parties to the Basel Convention*, March 18, 1998, page 16.

Implementation of the Basel Convention and the Ban in particular has faced numerous barriers. Most barriers to implementation involve controversy over economic issues. Below, we discuss some of the most significant barriers faced and lessons that can be drawn from the Basel experience. These barriers include: (1) ratification by parties; (2) classification of hazardous wastes; (3) free trade challenges by the World Trade Organization; and (4) controversy over a liability protocol.

Ratification by Parties: For the Basel Convention and Ban to be binding, the country's representative must sign the Convention and it must be ratified by the country's legislature. Signing is generally easier than convincing legislators to agree to implement the Convention through ratification. Although representatives of 123 countries originally signed the Convention, 22 out of the 123 had not ratified it as of September, 1999.[2] As of April, 2000, the U.S. still had not ratified it, and its failure to do so has greatly undermined Basel's effectiveness. Ratification has been held up by a number of factors, including national legislature concerns about the Convention's somewhat vague language as well as the other problems discussed below.

One of the lessons learned from the Basel experience is that vague wording, which is typical of binding agreements, may encourage signatures at conventions but invites ratification problems at the national level. There is a tension between making an agreement binding and making it ambitious. The Basel Convention tried to do both, and the difficulty of combining the two played out during the ratification process. Furthermore, many of the countries that signed but took years to ratify, or never ratified, are developing countries that may have pushed for ratification if the costs of their participation were supported by others.

Classification of Hazardous Wastes: The Convention's waste classification scheme evolved over time into an exceedingly complex system of four classification lists that are continuously changing. "A" list wastes are considered hazardous for the purposes of the Convention and fall under the Ban. Some "A" list wastes are described by vague characteristics such as "ecotoxic", and not by specific chemical compounds, which is confusing and difficult to use for classification. Theoretically, "B" list wastes are not considered hazardous by the Convention, but are the subject of much confusion when mixed with "A" list wastes. "C" list wastes are awaiting classification; they have no legal status. "D" list wastes are "wastes about which a particular concern is expressed," which also have no legal status and include substances such as asbestos, brake fluids,

[2] The Basel Convention ratification list can be found at: http://www.unecp.ch/basel/ratif/ratif.html#foot1. Signatories that have not ratified the convention are not listed.

and others. This complex classification scheme has impeded implementation efforts and sparked opposition from scrap and recycling industries, who assert that the Convention does not delineate between trade in hazardous wastes and trade in commodities destined for recycling.[3]

A lesson learned from Basel's waste characterization problem is that developing detailed requirements, such as classifying items as numerous as hazardous chemicals, has the potential to hold back an ambitious accord. When those creating the accord create "special" categories and set them aside indefinitely for further analysis, it can block implementation. Furthermore, failing to work with target groups, such as recycling industries, can also lead to potentially avoidable setbacks.

Free Trade Challenges: The wording of the Basel Convention sparked conflict among international business interests and the World Trade Organization, which implements the General Agreement on Tariffs and Trade (GATT). GATT has only weak provisions allowing trade bans for environmental issues. Generally, the World Trade Organization allows bans on *products* that are shown to pose a health or safety risk, but does not allow discrimination based on production processes.[4] Since hazardous wastes are neither products nor processes, it is unclear if GATT conflicts with the Basel Ban. This issue is still being debated among the World Trade Organization, national governments, and environmental groups.

Free trade challenges underscore the importance of involving environmental non-governmental organizations in accord implementation. The World Trade Organization refused to discuss these concerns before the 1990s, and only became involved after a series of "toxic ship" incidences were brought to media attention by environmental groups. Thus, non-governmental organizations put reconciling the World Trade Organization's position on Basel onto the public agenda, and helped to further implementation.

Liability and Compensation Protocol: The proposed Basel Convention Protocol on Liability and Compensation would provide compensation and penalties for damages incurred from the illegal shipment of hazardous wastes. The Protocol includes a "joint, strict, and several" system of liability, similar to the U.S. Comprehensive Environmental Response, Compensation, and

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[3] Classification information from Bureau of International Recycling, "EU moves towards imposition of trade ban on secondary materials to certain non-OECD countries," May 1998, http://www.bir.org/uk/keyissue.htm.

[4] Jonuiere, Guy de, "Trade and the Environment a Tough Balance," *Financial Post*, October 28, 1995.

Liability Act (CERCLA), and makes shipping insurance compulsory for hazards.[5] Negotiations on the Protocol took six years because OECD countries resisted the creation of a compensation fund, which developing countries view as the "teeth" of the Protocol.[6]

Controversy over the liability protocol demonstrates the difficulty of incorporating enforcement provisions. Since most OECD countries would accept the Protocol without the creation of a compensation fund, using other managerial tools and incentives instead may have encouraged ratification. The introduction of incentives as opposed to disincentives generally tends to de-polarize parties and helps to overcome these types of implementation impasses.

ISO 14000

The International Standards Organization (ISO) is a non-governmental organization established in 1947 to promote standardization to facilitate international trade and foster economic and scientific cooperation. The organization is comprised of national standard setting organizations, such as the American National Standards Institute. The ISO issues series of standards for industries to use to enhance quality control and international trading relationships.

The ISO developed the 14000 series on Environmental Management Systems in the early 1990s and countries began implementing it in 1996. The benefits of ISO certification include enhancing compliance with environmental regulations, facilitating financial and real estate transactions, increasing resource efficiency, promoting consumer perceptions of "greenness," and providing the ability to bid for contracts that require certification of environmental management. As of June 1999, 10,697 companies had received ISO 14001 certification, meaning that their environmental management systems meet ISO 14000 criteria as verified by an approved certification body.[7] Criteria include:

- demonstrated compliance with national environmental laws and regulations;

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[5] *German Package Proposal in order to finalize the Draft Protocol on Liability and Compensation for Damage Resulting from Transboundary Movements of Hazardous Waste and their Disposal*, May 6, 1999, http://www.unep.org/basel.

[6] Basel Action Network, "Rich Countries Run from Hazardous Waste Victims Compensation Accord," September 3, 1999, and "Liability Regime for Hazardous Wastes Accidents Opens for Signature in Bern," March 6, 2000.

[7] ISO 14001 certification data are available at http://www.ecology.or.jp/isoworld.

- a corporate environmental policy including concrete commitments to pollution prevention;
- a corporate strategic plan for minimizing environmental impacts with specific targets; and,
- an agreement to periodic implementation audits from a certified assessor.[8]

Implementation of ISO 14000 standards entails a very different set of challenges than implementation of the Basel Convention, which relies on the ratification of national governments to apply the Convention to private actors. Instead, ISO 14000 foregoes direct government involvement and deals directly with the target groups; i.e., private sector industries. This is one reason why ISO 14000 standards have quickly become popular among competitive companies. The challenges associated with implementing ISO 14000 relate to its decentralized nature, including: (1) decentralized verification, and (2) the uncertain role of government.

Decentralized Verification: The ISO formulates standards, but takes no responsibility for verifying that companies that claim to follow them actually do follow them in good faith. Companies can self-declare that they follow ISO 14000 standards, but to prove adherence, a company needs to be certified. Recently, a number of new industry certification groups have been created, and the American National Standards Institute and other traditional accreditation bodies cannot track them all. In turn, new national accreditation bodies have been established to provide some measure of control over the criteria that certification groups use to evaluate environmental management systems.[9] The evolving system of certification and accreditation for auditors has the potential to become unwieldy and compromise the validity of ISO 14000 certification claims.[10]

One lesson from the ISO 14000 verification problems is the need to weigh the advantages of a voluntary standard against the problems of verifying compliance with such a standard. Private, third party systems for implementation review can be so decentralized that they may not provide consistent interpretations of the standards. It is difficult to guarantee both the competency of the

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[8] Fredericks, Isis and McCallum, David, "International Standards for Environmental Management Systems: ISO 14000," *Canadian Environmental Protection*, 1995.

[9] ISO Press Release, "New directory reveals growth of ISO 9000 and ISO 14000 'certification industry'", June 17, 1999, http://www.iso.ch/presse/762.htm.

[10] Tibor, Tom and Feldman, Ira, *ISO 14000: A Guide to the New Environmental Management Standards*, Burr Ridge, IL: Irwin Professional Publishing, 1995.

auditors and their accrediting bodies, and there may be financial incentives to certify both incompetent auditors and non-compliant companies claiming adherence to standards. Furthermore, an option that allows self-declaration can be suspect, since there is little incentive for a self-declared party to implement an agreement if their progress is never monitored.

Finding a Role for Government: Government agencies, including EPA, are keeping a close eye on the ISO 14000 implementation process and investigating the role that these voluntary standards could play in regulatory strategy, enforcement, and procurement.[11] European Union leaders are looking to ISO 14000 as a possible supplement to the Eco-Management and Audit Scheme, which is a voluntary pollution prevention program for European industrial sites. Generally, developed countries with stringent environmental regulations see ISO 14000 as an opportunity to move past "command and control" strategies to encourage further environmental progress. Developing countries, on the other hand, see ISO 14000 standards as a way to enhance nascent or struggling regulatory systems.

Potential government involvement in ISO 14000, however, is of concern to international business interests. If some nations use the standards as a basis for regulation, further trade barriers could develop between those nations and other nations that do not incorporate the standards into their regulations. Moreover, the potential for government to incorporate ISO 14000 standards into regulatory systems may provide a perverse incentive: it may discourage companies from voluntarily adopting the standards if they see adoption as inviting further regulation.

An important lesson related to the role of government in promoting ISO 14000 and other voluntary standards is that the relationship must be carefully crafted not to alienate target groups; e.g., to retain the standards' voluntary, non-binding status. If some governments adopt standards into regulatory schemes while others do not, or if governments differ in the manner in which they adopt the standards, unanticipated trade barriers may result. Ironically, this defeats one of the main purposes of international standards: to encourage and simplify international trade.

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[11] Tibor, Tom and Feldman, Ira, *ISO 14000: A Guide to the New Environmental Management Standards*, Burr Ridge, IL: Irwin Professional Publishing, 1995.

Appendix B

METALS FROM NUCLEAR POWER PLANTS

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Appendix B

METALS FROM NUCLEAR POWER PLANTS

In Chapter Two, we provide summary information on the sources of radioactive scrap metal in each of the six countries discussed in this report. In this appendix, we provide more detailed information on scrap from the decommissioning of nuclear power plants. These data are taken from two documents: a 1995 report completed by the staff at Argonne National Laboratory, and a 1999 report completed by Sanford Cohen and Associates (SC&A) for the U.S. Environmental Protection Agency.[1] We summarize the methods used by these researchers in Chapter Two of this report.

The following sections discuss the quantities of the most common types of metal at the existing nuclear power plants (operating, inactive, or planned), that could potentially become available for release as these plants are decontaminated and decommissioned over the next sixty or more years. The data derived from the SC&A report addresses metals from U.S. facilities that could be affected by changes in the U.S. release standards. It includes potentially recyclable carbon and stainless steel quantities categorized as having high-level contamination (>1*10E7 dpm/cm^2), medium-level contamination (1*10E5 to 1*10E7 dpm/cm^2), or low-contamination (<1*10E5 dpm/cm^2). SC&A excludes activated metals (such as those comprising the reactor vessel and internal components) from its assessment because such metals cannot be effectively decontaminated to meet any reasonable release standard. Similar information is not available on the contamination levels for other metals; however, SC&A develops some general assumptions to estimate the quantities potentially available for recycling.

The Argonne report addresses nuclear power plants in the U.S. and other countries. It uses a different classification scheme, identifying components that are not radioactive (and hence not included in the quantities calculated for this report) as well as three other categories:

- **surface-contaminated (removable)** - components that may have significant levels of surface contamination that can be removed through decontamination;

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[1] Nieves, L.A., Chen, S.Y., Kohout, E.J., Nabelssi, B., Tilbrook, R.W., and S.E. Wilson, Argonne National Laboratory, *Evaluation of Radioactive Scrap Metal Recycling*, prepared for the U.S. Department of Energy. NAL/EAD/TM-50, December 1995; and, Sanford Cohen & Associates, Incorporated, *Technical Support Document: Potential Recycling of Scrap Metal from Nuclear Facilities, Volume I*, prepared for the U.S. Environmental Protection Agency, September 30, 1999.

- **surface-contaminated (fixed)** - components with significant levels of surface contamination that penetrates or is bound to the metal and may be difficult to remove; and,

- **activated** - components where decontamination alone is not expected to be sufficient to produce metal free of significant activity.

We include all three categories in the quantities reported below, although it may not be cost-effective to decontaminate some of these quantities in those countries that regulate release of these materials.

The following exhibits report the total potential inventory of these metals. We discuss each of the six countries included in this study, focusing on the types of metals likely to become available in the largest quantities: iron and steel, copper and aluminum. Much of this inventory will not become available for release or disposal until several years into the future, well after the facilities have ceased operations (operators generally wait 10 years or more after closure before dismantling the facility, to minimize health risks by allowing the relatively short-lived radionuclides to decay). In addition, much of this metal may be disposed rather than released, either because it is too costly to decontaminate or because of public pressures to minimize these releases.

United States

The Argonne report lists 124 nuclear power plants in the U.S., including both currently operating facilities and facilities which are no longer in operation. The SC&A report considers 104 operating reactors and 27 reactors formally licensed to operate. Metals from these facilities may become available for release or disposal over the next 60 or more years as the facilities are decommissioned. Both sources note that there are significant quantities of metal and metal alloys other than steel that may be suitable for recycling, including the quantities of aluminum and copper indicated in Exhibit B-1. However, according to SC&A, the published literature does not provide credible data on the extent of contamination of metals other than carbon and stainless steel, hence it is difficult to determine whether other metals could potentially be decontaminated to meet current or potential future clearance standards.

Exhibit B-1

POTENTIALLY RADIOACTIVE METAL FROM NUCLEAR POWER PLANTS
United States

Metal	Argonne 1995 Report[1]			SC&A 1999 Report[2]
	Surface contaminated - cleanable	Surface contaminated - non-cleanable	Activated	Potentially Recyclable Scrap[3]
Steel and Iron	774,676 metric tons	69 metric tons	356,316 metric tons	NA
Carbon Steel	NA	NA	NA	469,528 metric tons
Galvanized Iron	NA	NA	NA	18,258 metric tons
Stainless Steel	95,502 metric tons	23,770 metric tons	76,759 metric tons	117,311 metric tons
Copper	9,256 metric tons	0	2,318 metric tons	9,691 metric tons
Aluminum	1,729 metric tons	0	565 metric tons	253 metric tons

Notes:
[1]The Argonne report characterizes 124 operating and closed nuclear power plants, and also provides data on lead and zirconium. In addition, it reports quantities of non-radioactive scrap.
[2]The SC&A report characterizes 131 operating and closed nuclear power plants, and also provides data on nickel, inconel, lead, bronze, brass and silver.
[3]Includes potentially recyclable scrap categorized as low-level, medium level, and high level contamination.
Sources:
Nieves, L.A., Chen, S.Y., Kohout, E.J., Nabelssi, B., Tilbrook, R.W., and S.E. Wilson, Argonne National Laboratory, *Evaluation of Radioactive Scrap Metal Recycling*, prepared for the U.S. Department of Energy. NAL/EAD/TM-50, December 1995.
Sanford Cohen and Associates, Incorporated, *Technical Support Document: Potential Recycling of Scrap Metal from Nuclear Facilities, Volume 1*, prepared for the U.S. Environmental Protection Agency, September 30, 1999.

The predominant type of metal from nuclear power plants is carbon steel, accounting for the majority of the metals listed in Exhibit B-1. The Argonne report generally estimates larger metal inventories than the SC&A report, in part because the latter is based on more recent data. In addition, the SC&A report focuses more narrowly on metals that could potentially be cleared for unconditional use (after any needed decontamination), given current or potential future release criteria and decontamination costs.

The quantities of metals that actually will be released depend on a number of factors, include the clearance standards in place at the time the facility is decommissioned, the relative costs of disposal and clearance, and public pressures to limit the release of these materials. In 1997, Industrial Economics, Incorporated prepared a report for EPA which describes the impact of alternative release standards on the actual quantity of scrap metal that will be released from U.S. facilities, based on the information available at that time.[2] The analysis considers the effects of disposal and decontamination costs as well as scrap prices on decisions to dispose or release scrap. It assumes that facilities will consider only these costs and the applicable release standards in determining the disposition of these metals. The results of this analysis are presented in Exhibit B-2.

Exhibit B-2

PRELIMINARY ESTIMATES OF COMMERCIAL NUCLEAR POWER PLANT SCRAP QUANTITIES RELEASED BY OPTION

Option	Low Disposal Cost Scenario	High Disposal Cost Scenario
Current standards	0.40 million tons (62 percent)	0.47 million tons (73 percent)
0.1 mrem	0.07 million tons (11 percent)	0.20 million tons (31 percent)
1.0 mrem	0.39 million tons (61 percent)	0.54 million tons (84 percent)
15.0 mrem	0.47 million tons (73 percent)	0.54 million tons (84 percent)

Notes:
Based on 1997 scrap data and dose conversion model, which have since been refined.
Quantities would be released over a 55-year period from 1998 to 2053. Percentages are based on the approximately 0.64 million tons of scrap estimated to be available from the commercial nuclear power reactor inventory.
Source:
Industrial Economics, Incorporated, *Radiation Protection Standards for Scrap Metal: Preliminary Cost-Benefit Analysis,* prepared for the U.S. Environmental Protection Agency, June 1997.

As indicated by the exhibit, the majority of scrap from these facilities potentially could be cleared for unconditional use under all but the most stringent standards. Under the current NRC standards (Regulatory Guide 1.86, as discussed in Chapter Two), facilities could release between 62 and 73 percent of these inventories after any needed decontamination, over a 55-year period from 1998 to 2053. If the standards are changed to 1 mrem, these percentages will range from 61 to 84 percent for the same time period. In both cases, actual releases may be substantially lower than these estimates due to public opposition and other factors.

[2] Industrial Economics, Inc, *Radiation Protection Standards for Scrap Metal: Preliminary Cost-Benefit Analysis,* prepared for the U.S. Environmental Protection Agency, June 1997.

Russia

The Argonne report is the only source of data on the quantities of potentially recyclable metals available from nuclear power plants in countries other than the U.S. The Argonne report lists 84 nuclear power plants in the former Soviet Union. Metal information is unavailable for five of the power plants. The metal that could be released or disposed as the remaining 79 plants are decommissioned is listed in Exhibit B-3, focusing on the four major types of metal. As discussed in Appendix G, about 40 of these plants are located in Russia.

Exhibit B-3

POTENTIALLY RADIOACTIVE METAL FROM NUCLEAR POWER PLANTS
Former Soviet Union

Metal[1]	Surface contaminated - cleanable	Surface contaminated - non-cleanable	Activated
Steel and Iron	530,506 metric tons	5,129 metric tons	42,847 metric tons
Stainless Steel	191,386 metric tons	0 metric tons	29,946 metric tons
Copper	5,844 metric tons	0 metric tons	1,468 metric tons
Aluminum	1,101 metric tons	0 metric tons	367 metric tons

Notes:
1. The Argonne report also provides data on lead and zirconium, which are available in much smaller quantities. In addition, it reports quantities of non-radioactive scrap.
Source:
Nieves, L.A., Chen, S.Y., Kohout, E.J., Nabelssi, B., Tilbrook, R.W., and S.E. Wilson, Argonne National Laboratory, *Evaluation of Radioactive Scrap Metal Recycling*, prepared for the U.S. Department of Energy. NAL/EAD/TM-50, December 1995.

Based on Exhibit B-3, a total of 808,594 metric tons of potentially radioactive metal could become available as these facilities are decommissioned. Steel and iron accounts for approximately 72 percent of that total. No data are available on the extent to which these metals are likely to be disposed or sold as scrap; however, as discussed in Chapter Two, Russian nuclear regulatory controls are relatively weak.

Italy

The Argonne report lists four nuclear power plants in Italy. The metals that could become available for recycling or disposal as each plant is decommissioned are listed in Exhibit B-4. Again, the exhibit focuses on the major types of metals typically found at these plants.

Exhibit B-4

POTENTIALLY RADIOACTIVE METAL FROM NUCLEAR POWER PLANTS
Italy

Metal[1]	Surface contaminated - cleanable	Surface contaminated - non-cleanable	Activated
Steel and Iron	15,629 metric tons	0 metric tons	6,351 metric tons
Stainless Steel	1,079 metric tons	122 metric tons	1,068 metric tons
Copper	178 metric tons	0 metric tons	82 metric tons
Aluminum	24 metric tons	0 metric tons	8 metric tons

Note:
[1]The Argonne report also provides data on lead and zirconium, which are available in much smaller quantities. In addition, it reports quantities of non-radioactive scrap.
Source:
Nieves, L.A., Chen, S.Y., Kohout, E.J., Nabelssi, B., Tilbrook, R.W., and S.E. Wilson, Argonne National Laboratory, *Evaluation of Radioactive Scrap Metal Recycling*, prepared for the U.S. Department of Energy. NAL/EAD/TM-50, December 1995.

Based on Exhibit B-4, a total of 24,541 metric tons of potentially radioactive metal could become available as the facilities are decommissioned. Steel and iron account for approximately 90 percent of the total metal listed in the exhibit. The next largest percentage of metal is stainless steel, accounting for nine percent of the total. No data are available on the extent to which these metals are likely to be disposed or sold as scrap. However, Italy is affected by the European Union's efforts to establish a 1 mrem clearance standard, as well as public pressures to limit the release of these types of materials, as discussed in Chapter Two.

Spain

The Argonne report lists 10 nuclear power plants in Spain. The potentially radioactive metal that could become available as these facilities are decommissioned (for the four major metal types) is listed in Exhibit B-5.

Exhibit B-5

POTENTIALLY RADIOACTIVE METAL FROM NUCLEAR POWER PLANTS
Spain

Metal[1]	Surface contaminated - cleanable (tons)	Surface contaminated - non-cleanable (tons)	Activated (tons)
Steel and Iron	55,944 metric tons	0 metric tons	25,046 metric tons
Stainless Steel	7,193 metric tons	1,788 metric tons	5,198 metric tons
Copper	682 metric tons	0 metric tons	170 metric tons
Aluminum	129 metric tons	0 metric tons	44 metric tons

Note:
[1] The Argonne report also provides data on lead and zirconium, which are available in much smaller quantities. In addition, it reports quantities of non-radioactive scrap.
Source:
Nieves, L.A., Chen, S.Y., Kohout, E.J., Nabelssi, B., Tilbrook, R.W., and S.E. Wilson, Argonne National Laboratory, *Evaluation of Radioactive Scrap Metal Recycling*, prepared for the U.S. Department of Energy. NAL/EAD/TM-50, December 1995.

In Spain, steel and iron account for 84 percent of the total 96,194 metric tons of potentially radioactive metal could become available as these facilities close. The next largest percentage of metal is stainless steel, accounting for 15 percent of the metal listed in Exhibit B-5. Smaller amounts of copper and aluminum may also be available. No data are available on the extent to which these metals are likely to be disposed or sold as scrap. However, Spain is also affected by the European Union's efforts to establish a 1 mrem standard and by public pressure to limit release of these materials, as discussed in Chapter Two.

Brazil

The Argonne report lists five nuclear power plants in Brazil. The potentially radioactive metal that could become available as these facilities close is listed in Exhibit B-6.

Exhibit B-6

POTENTIALLY RADIOACTIVE METAL FROM NUCLEAR POWER PLANTS
Brazil

Metal[1]	Surface contaminated - cleanable (tons)	Surface contaminated - non-cleanable (tons)	Activated (tons)
Steel and Iron	35,919 metric tons	0 metric tons	15,759 metric tons
Stainless Steel	4,827 metric tons	1,608 metric tons	3,590 metric tons
Copper	431 metric tons	0 metric tons	107 metric tons
Aluminum	79 metric tons	0 metric tons	28 metric tons

Note:
[1] The Argonne report also provides data on lead and zirconium, which are available in much smaller quantities. In addition, it reports quantities of non-radioactive scrap.
Source:
Nieves, L.A., Chen, S.Y., Kohout, E.J., Nabelssi, B., Tilbrook, R.W., and S.E. Wilson, Argonne National Laboratory, *Evaluation of Radioactive Scrap Metal Recycling*, prepared for the U.S. Department of Energy. NAL/EAD/TM-50, December 1995.

Like the previous countries, the most abundant type of potentially radioactive metal is steel and iron, accounting for 51,678 tons, or 83 percent of 62,348 total tons. The next largest type of potentially radioactive metal which may be released is stainless steel, making up 16 percent if the total. Copper and aluminum may also become available as these facilities are decommissioned. As discussed in Chapter Two, no data are available Brazil's release policies, and we are uncertain about the extent to which these metals are likely to be disposed or sold as scrap.

South Korea

The Argonne report lists 14 nuclear power plants in South Korea. The potentially radioactive metal that may become available as the plants cease operation is listed in Exhibit B-7.

Exhibit B-7

POTENTIALLY RADIOACTIVE METAL FROM NUCLEAR POWER PLANTS
South Korea

Metal[1]	Surface contaminated - cleanable (tons)	Surface contaminated - non-cleanable (tons)	Activated (tons)
Steel and Iron[1]	82,109 metric tons	0 metric tons	36,519 metric tons
Stainless Steel	12,937 metric tons	3,568 metric tons	10,606 metric tons
Copper	995 metric tons	0 metric tons	250 metric tons
Aluminum	185 metric tons	0 metric tons	65 metric tons

Note:
[1] The Argonne report also provides data on lead and zirconium, which are available in much smaller quantities. In addition, it reports quantities of non-radioactive scrap.
Source:
Nieves, L.A., Chen, S.Y., Kohout, E.J., Nabelssi, B., Tilbrook, R.W., and S.E. Wilson, Argonne National Laboratory, *Evaluation of Radioactive Scrap Metal Recycling*, prepared for the U.S. Department of Energy. NAL/EAD/TM-50, December 1995.

In South Korea, approximately 147,234 metric tons of potentially radioactive metal may be available from these nuclear power plants as they are decommissioned. Steel and iron make up the bulk of this metal, accounting for 81 percent of the total. The next largest type of radioactive metal is stainless steel, accounting for 18 percent of the total. As discussed in Chapter Two, we are uncertain about Korea's release policies, and hence about the extent to which these metals are likely to be disposed or sold as scrap.

Summary

The total amount of surface contaminated-cleanable, surface contaminated-non-cleanable, and activated metal for each country is summarized in Exhibit B-8, based on the Argonne report. For the purpose of comparison only the Argonne data are included in the exhibit. However, the SC&A data reported above for the U.S. include smaller quantities, due largely to the focus on materials that could be decontaminated and released. For example, for the U.S., SC&A predicts that 487,786 metric tons of carbon steel and galvanized iron could become available for recycling as existing nuclear power plants are dismantled, compared with the 1,131,061 metric tons of steel and iron (excluding stainless steel) predicted by Argonne.

Exhibit B-8

POTENTIALLY RADIOACTIVE METAL FROM NUCLEAR POWER PLANTS SUMMARY

Country	Surface contaminated - cleanable	Surface contaminated - non-cleanable	Activated
U.S.	881,163 metric tons	23,839 metric tons	435,958 metric tons
Former Soviet Union	728,837 metric tons	5,129 metric tons	74,628 metric tons
Italy	16,910 metric tons	122 metric tons	7,509 metric tons
Spain	63,948 metric tons	1,788 metric tons	30,458 metric tons
Brazil	41,256 metric tons	1,608 metric tons	19,484 metric tons
South Korea	96,226 metric tons	3,568 metric tons	47,440 metric tons

Note:
Includes steel and iron, stainless steel, copper, and aluminum. Argonne reports quantities for other metals but the quantities are generally small.
Source:
Nieves, L.A., Chen, S.Y., Kohout, E.J., Nabelssi, B., Tilbrook, R.W., and S.E. Wilson, Argonne National Laboratory, *Evaluation of Radioactive Scrap Metal Recycling*, Prepared for the U.S. Department of Energy, NAL/EAD/TM-50, December 1995.

The U.S., with the largest number of nuclear power plants, is also the largest source of potentially radioactive metal. These numbers represent metal that could be released or disposed gradually over the several decades. Only some of this metal is likely to enter the scrap market, much may be disposed as waste as the plants are decommissioned.

Appendix C

NUMERIC CLEARANCE STANDARDS

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Appendix C

NUMERIC CLEARANCE STANDARDS

In Chapter Two of this report, we describe the standards for release of radioactive metals from regulatory controls. In some cases, these standards are expressed as allowable doses, which then must be translated into activity levels to determine whether particular items can be cleared for uncontrolled use. In other cases, the standards are expressed as activity levels that vary by radionuclide. In this appendix, we provide the detailed, radionuclide-specific clearance levels that have been developed to-date to implement the requirements discussed in Chapter Two. These standards are taken from: IAEA *TECDOC 855*, DOE Order 5400.5, *NRC Regulatory Guide 1.86*, and *EU Radiation Protection 89*, each of which is described in more detail in the main text of this report.

Exhibit C-1 presents the current IAEA standards from *TECDOC 855*, which are designed for use as standards for clearance (release from regulatory control) and exemption (materials never enter regulatory control).[1] IAEA is currently reformulating these standards to correspond to a clearance level of 100 mrem/year for applicability to NORM contaminated materials, but does not expect to change the standards for other types of materials. The exhibit presents a range of allowable activity levels for each category of radionuclides because IAEA believes that uncertainties in the data do not allow for individual radionuclide-specific standards. However, when a single value is required for regulatory purposes, the IAEA suggests using the log-mean values for radionuclides in each category, which are displayed in the far right column.

Exhibit C-2 displays surface activity levels for clearance under DOE Order 5400.5.[2] For each group of radionuclides, the allowable total residual surface activity is given. DOE 5400.5 does not address volumetrically contaminated materials, although DOE can consider release of these materials on a case-by-case basis. As noted in Chapter Two, DOE is now considering whether to revise its release policies, and has declined a moratorium on clearance.

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[1] IAEA, *TECDOC 855, Clearance Levels for Radionuclides in Solid Materials: Application of Exemption Principles,* Interim Report for Comment, January 1996.

[2] U.S. Department of Energy, DOE Order 5400.5: Radiation Protection of the Public and of the Environment, 1995 Addendum, page 9.

Exhibit C-1

IAEA DERIVED UNCONDITIONAL CLEARANCE LEVELS

Ranges of Activity Concentration (Bq/g)	Radionuclides[a]			Representative Single Values of Activity Concentration (Bq/g)
0.1 < 1.0	Na-22 Na-24 Mn-54 Co-60 Zn-65 Nb-94 Ag-110m Sb-124	Cs-134 Cs-137 Eu-152 Pb-210 Ra-226 Ra-228 Th-228 Th-230 Th-232	U-234 U-235 U-238 Np-237 Pu-239 Pu-240 Am-241 Cm-244	0.3
≥ 1.0 < 10	Co-58 Fe-59 Sr-90	Ru-106 In-111 I-131	Ir-192 Au-198 Po-210	3
≥ 10 < 100	Cr-51 Co-57 Tc-99m	I-123 I-125 I-129	Ce-144 Tl-201 Pu-241	30
≥ 100 < 1,000	C-14 P-32 Cl-36	Fe-55 Sr-89 Y-90	Tc-99 Cd-109	300
≥ 1,000 < 10,000	H-3 S-35	Ca-45 Ni-63	Pm-147	3,000

a. Radon-220 and radon-222 were not included in this classification.
Source: IAEA, *TECDOC 855: Clearance Levels for Radionuclides in Solid Materials: Application of Exemption Principles,* Interim Report for Comment, January 1996, Exhibit 2-2, page 11.

Exhibit C-2

DOE ORDER 5400.5 SURFACE CONTAMINATION GUIDELINES

Radionuclides[b]	**Allowable Total Residual Surface Activity (dpm/100 cm^2)**[a]		
	Average[c,d]	**Maximum**[d,e]	**Removable**[f]
Group 1 - Transuranics, I-125, I-129, Ac-227, Ra-226, Ra-228, Th-228, Th-230, Pa-231	100	300	20
Group 2 - Th-natural, Sr-90, I-126, I-131, I-133, Ra-223, Ra-224, U-232, Th-232	1000	3000	200
Group 3 - U-natural, U-235, U-238, and associated decay products, alpha emitters	5000	15000	1000
Group 4 - Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous[g] fission) except Sr-90 and others noted above	5000	15000	1000
Tritium (applicable to surface and subsurface)[h]	N/A	N/A	000

[a] As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by counts per minute measured by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.
[b] Where surface contamination by both alpha- and beta-gamma-emitting radionuclides exists, the limits established for alpha- and beta-gamma-emitting radionuclides should apply independently.
[c] Measurements of average contamination should not be derived over an area of more than 1 m^2. For objects of smaller surface area, the average should be derived for each such object.
[d] The average and maximum dose rates associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h and 1.0 mrad/h, respectively, at 1 cm.
[e] The maximum contamination level applies to an area of not more than 100 cm^2.
[f] The amount of removable material per 100 cm^2 of surface area should be determined by wiping an area of that size with dry filter or soft absorbent paper, applying moderate pressure, and measuring the amount of radioactive material on the wiping with an appropriate instrument of known efficiency. When removable contamination on objects of surface area less than 100 cm^2 is determined, the activity per unit area should be based on the actual area and the entire surface should be wiped. It is not necessary to use wiping techniques to measure removable contamination levels if direct scan surveys indicate that the total residual surface contamination levels are within the limits for removable contamination.
[g] This category of radionuclides includes mixed fission products, including the Sr-90 which is present in them. It does not apply to Sr-90 which has been separated from the other fission products or mixtures where the Sr-90 has been enriched.
[h] Property recently exposed or decontaminated should have measurements (smears) at regular time intervals to ensure that there is not a build-up of contamination over time. Because tritium typically penetrates material it contacts, the surface guidelines in group 4 are not applicable to tritium. The Department has reviewed the analysis conducted by the DOE Tritium Surface Contamination Limits Committee ("Recommended Tritium Surface Contamination Release Guides," February 1991), and has assessed potential doses associated with the release of property containing residual tritium. The Department recommends the use of the stated guideline as an interim value for removable tritium. Measurements demonstrating compliance of the removable fraction of tritium on surfaces with this guideline are acceptable to ensure that non-removable fractions and residual tritium in mass will not cause exposures that exceed DOE dose limits and constraints.

Source: Replicated from U.S. Department of Energy, DOE Order 5400, November 17, 1995, page 9.

Exhibit C-3 displays the surface contamination guidelines in NRC *Regulatory Guide 1.86.*[3] For each group of radionuclides, average, maximum, and removable activity limits are given. These guidelines are very similar to those in DOE Order 5400.5, because DOE's policy was based on the NRC guidance. *Regulatory Guide 1.86* does not address volumetrically contaminated materials. NRC is also in the process of considering changes to these standards.

Exhibit C-4 displays the EU clearance standards, as presented in *Radiation Protection 89.*[4] The EU clearance levels are very similar to the IAEA clearance levels, except that the EU uses the high end of the IAEA ranges (rather than the log mean) as the single value for clearance. Although clearance levels are not reported for volumetrically-contaminated materials, the standards for surficial contamination can be used for materials volumetrically contaminated with alpha, beta, or gamma emitters, as long as "all counts are attributed to surface activity even if in reality they are emitted from deeper layers." It is unclear whether the EU will follow the IAEA's precedent in setting less stringent clearance standards for NORM-contaminated materials; if so, *Radiation Protection 89* is likely to be revised.

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[3] U.S. Atomic Energy Commission, Regulatory Guide 1.86: Terminations of Operating Licenses for Nuclear Reactors, June 1974, page 5.

[4] European Commission, *Radiation Protection 89*: *Recommended radiological protection criteria for the recycling of metals from the dismantling of nuclear installations*, 1998, pages 3-10.

Exhibit C-3

NRC REGULATORY GUIDE 1.86 SURFACE CONTAMINATION GUIDELINES

Nuclide[a]	**Average**[b,c]	**Maximum**[b,d]	**Removable**[b,e]
U-nat, U-235, U-238, and associated decay products[a]	5,000 dpm α/100 cm^2	15,000 dpm α/100 cm^2	1000 dpm α/100 cm^2
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	100 dpm /100 cm^2	300 dpm /100 cm^2	20 dpm /100 cm^2
Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	1000 dpm /100 cm^2	3000 dpm /100 cm^2	200 dpm /100 cm^2
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above	5000 dpm $\beta\gamma$/100 cm^2	15,000 dpm $\beta\gamma$/100 cm^2	1000 dpm $\beta\gamma$/100 cm^2

[a] Where surface contamination by both alpha- and beta-gamma-emitting radionuclides exists, the limits established for alpha- and beta-gamma-emitting radionuclides should apply independently.
[b] As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute measured by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.
[c] Measurements of average contamination should not be derived over an area of more than 1 m^2. For objects of less surface area, the average should be derived for each such object.
[d] The maximum contamination level applies to an area of not more than 100 cm^2.
[e] The amount of removable material per 100 cm^2 of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of less surface area is determined, the pertinent levels should be reduced proportionately and the entire surface should be wiped.

Source: Replicated from U.S. Atomic Energy Commission. *Regulatory Guide 1.86*. June 1974, page 5.

Exhibit C-4
EU RADIATION PROTECTION 89
NUCLIDE SPECIFIC CLEARANCE LEVELS FOR DIRECT REUSE OF METAL ITEMS

Nuclides	Surface Specific(Bq/cm^2)	Nuclides	Surface Specific (Bq/cm^2)
H 3	10000	Tm 171	10000
C 14	1000	Ta 182	10
Na 22	1	W 181	100
S 35	1000	W 185	1000
Cl 36	100	Os 185	10
K 40	10	Ir 192	10
Ca 45	100	Tl 204	100
Sc 46	10	Pb 210	1
Mn 53	10000	Bi 207	1
Mn 54	10	Po 210	0.1
Fe 55	1000	Ra 226	0.1
Co 56	1	Ra 228	1
Co 57	10	Th 228	0.1
Co 58	10	Th 229	0.1
Co 60	1	Th 230	0.1
Ni 59	10000	Th 232	0.1
Ni 63	1000	Pa 231	0.1
Zn 65	10	U 232	0.1
As 73	1000	U 233	1
Se 75	10	U 234	1
Sr 85	10	U 235	1
Sr 90	10	U 236	1
Y 91	100	U 238	1
Zr 93	100	Np 237	0.1
Zr 95	10	Pu 236	0.1
Nb 93m	1000	Pu 238	0.1
Nb 94	1	Pu 239	0.1
Mo 93	1000	Pu 240	0.1
Tc 97	100	Pu 241	10
Tc 97m	1000	Pu 242	0.1
Tc 99	1000	Pu 244	0.1
Ru 106	10	Am 241	0.1
Ag 108m	1	Am 242m	0.1
Ag 110m	1	Am 243	0.1
Cd 109	100	Cm 242	1
Sn 113	10	Cm 243	0.1
Sb 124	10	Cm 244	0.1
Sb 125	10	Cm 245	0.1
Te 123m	100	Cm 246	0.1
Te 127m	100	Cm 247	0.1
I 125	100	Cm 248	0.1
I 129	10	Bk 249	100
Cs 134	1	Cf 248	1
Cs 135	100	Cf 249	0.1
Cs 137	10	Cf 250	0.1
Ce 139	10	Cf 251	0.1
Ce 144	10	Cf 252	0.1
Pm 147	1000	Cf 254	0.1
Sm 151	1000	Es 254	1
Eu 152	1		
Eu 154	1		
Eu 155	100		
Gd 153	10		
Tb 160	10		
Tm 170	1000		

Source: Replicated from European Commission *Radiation Protection 89*, page 10.

Appendix D

SCRAP BROKER CASE STUDY

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Appendix D

SCRAP BROKER CASE STUDY

This case study discusses the issues that David J. Joseph (DJJ) Company, a scrap metal broker, faces regarding radiological contamination of its imported shipments. In the first section, we provide background information on the firm and its affiliated companies. We next discuss DJJ's primary customers and suppliers of scrap metal. Then, we describe DJJ's brokerage operations, followed by a detailed discussion of the firm's concerns regarding radiological contamination of its scrap supply. Finally, we describe incidents of scrap metal contamination that the firm has experienced and the costs related to these incidents.

We gathered much of the background information for this case study from DJJ's Internet site: www.djj.com. We also conducted an interview on August 29, 2000 with Ray Turner, the firm's expert on radiological issues, and asked him to review and comment on a draft of this case study.

BACKGROUND INFORMATION

David J. Joseph (DJJ) Company is one of the largest scrap iron and steel scrap companies in North America. DJJ provides consumers and producers of iron and steel scrap with brokerage, processing, transportation, and scrap management services. DJJ is also a supplier of scrap substitutes such as pig iron, DRI (direct reduced iron), and HBI (hot briquetted iron) products. The company, headquartered in Cincinnati, Ohio, generates approximately $1.5 billion in sales each year. Including wholly-owned and joint-venture facilities, DJJ operates trading offices and processing plants in 20 states and Mexico, and employs approximately 1,200 people.

DJJ also provides related services through its four affiliated companies. Joseph Transportation, Incorporated buys, finances, and leases locomotives, railcars, and barges. SHV Holdings N.V. is involved in the trade and production of energy and raw materials, as well as the distribution of food and non-food consumer goods. Systems Alternatives International is a provider of advanced information systems and engineered solutions for the primary metals, steel, recycling, and glass industries. Thyssen Sonneberg Recycling, based in the Netherlands, is the largest metal recycling company in the European Union.

DJJ has three main operations: brokerage, processing, and service. The scrap metal processing operation is involved primarily in metal shredding and ferrous and non-ferrous metal processing. This case study focuses mainly on DJJ's brokerage business because it is the area most affected by problems involving radiological contamination of imported metals.

DJJ receives and ships scrap metal from all over the world. Origins and destinations include Turkey, the United Kingdom and the European Union -- in particular, countries such as Spain and Italy. DJJ also imports scrap metal from Scandinavian and South American countries. The company's network of suppliers includes small, family-owned scrap processors and large, worldwide industrial corporations, and DJJ's consumers range from small foundries to the large steel mills. DJJ maintains relations with almost every U.S. steel mill. DJJ also exports scrap metal to some consumers in Asia. The volume of DJJ's international trade fluctuates according to the strength of the dollar and world demand for scrap metal.

DJJ's brokerage business currently operates 13 domestic and international trading offices, and is in regular contact with approximately 5,000 producers and consumers of scrap and scrap substitutes. The firm employs over 40 traders who use a sophisticated communications network to provide customers with price quotes, scrap availability schedules, and over 300,000 freight rates through company's transportation database.

RADIOLOGICAL CONTAMINATION ISSUES

This section discusses DJJ's concerns about radiological contamination in the scrap supply. First, we describe the protocol that DJJ has established in the event of receiving a contaminated shipment. We then discuss DJJ's likely response to changes in residual radioactivity levels. Third, we describe DJJ's involvement in policy efforts to develop numerical and procedural standards for radioactivity in scrap metal. Finally, we discuss examples of rejected shipments.

Rejected Shipment Protocol

DJJ's main concerns regarding contaminated scrap shipments are the health and safety of employees, the potential contamination of the mills to which DJJ supplies scrap metal, and the costs of addressing rejected shipments. DJJ has established a general protocol to address the receipt of a contaminated shipment. For example, if a shipment arrives at a port on a vessel, and is found to be carrying a sealed source, DJJ attempts to isolate the specific radioactive component (rather than the whole vessel) to minimize lost production time. DJJ removes and shields the source with the help of radiation consultants, and then arranges to transport and dispose it. If DJJ receives a shipment where the metal itself is contaminated, DJJ would reject the shipment if the contamination was greater than normal background levels, or if it sets off their detectors. Again, DJJ would isolate the contaminated material from the rest of the shipment. Wherever possible, DJJ works with the international shipper to address disposal costs and options. If the contaminated shipment has already reached a mill, DJJ oversees the handling, transportation, and disposal of the contaminated material and works directly with the NRC and other federal and state authorities. DJJ attempts to ensure that the mill is not affected by the burdens of these activities.

Although DJJ would usually prefer to send contaminated shipments back to the country of origin, the contaminated material is almost always disposed in the U.S. In some cases, shipments cannot be repatriated because they contain weapons grade material or a highly contaminated source. In other cases, the country of origin may have a zero tolerance import policy for contaminated shipments and might not have a sufficient radiation protection program to handle the materials. In many cases, repatriating the shipment would result in negative publicity for the U.S. and unacceptable health and security risks. In addition, some countries do not have an agreement with the U.S. to dispose radioactive material in this country, which may impede its burial.

On occasion, DJJ has rejected specific shipments because there is a high probability of contamination. However, it is not their standard practice to reject shipments based on origin alone. For example, although DJJ is aware that a portion of the scrap metal from the United Kingdom and the European Union originates from Russia, it will not reject all shipments from Russia. Instead, DJJ advocates that ports and mills in European Union countries install grapple system detectors to protect against contaminated metal. In their own international shipping applications, DJJ has a pilot program where it works with mills to install these grapple detectors; however, DJJ cannot force customers and suppliers to install these systems.

Changes in Background Radiation Levels

Background levels of radiation, both in general and specifically in scrap metal, can affect the operation of detection equipment. For example, DJJ predicts that if the typical radioactivity levels in metal increase, and if the new level is three standard deviations away from the current level, detectors would alarm or malfunction. Some radiation detectors could be reconfigured to address higher background levels if desired (although that would tend to de-sensitize the systems), but others would need to be replaced. New detectors now have software than can be upgraded to correct for changes in general background levels, and DJJ would advise mills to upgrade their radiation detectors if background levels increased.

There would also be detector calibration problems if background radiation levels decreased. For instance, metals from DOE facilities and NRC licensees are sometimes cleaned so thoroughly that they fall below normal background radiation levels, and the discrepancy may set off a detector. If facilities regulated by these agencies were to release large quantities of such metals, the mills may have to recalibrate their equipment.

DJJ expects to continue to advocate installation of state-of-the-art systems at mills, regardless of government programs to detect contaminated imports. Mr. Turner does not recommend a particular radiation detector manufacturer; however, he does recommend that mills use plastic scintillator portal and wireless grapple systems. These systems are able to detect approximately more than 98 percent of radiation sources, according to manufacturers, and they generally perform better than sodium-iodide systems in detection of radionuclides in scrap metal. The wireless plastic scintillator systems are also able to detect americium and beryllium neutron radiation, whereas the sodium-iodide wired system are not able to do so.

DJJ's Involvement in Policy

DJJ is addressing the issue of rejected shipments through its involvement with the UN Economic Commission for Europe's (UNECE) Committee for Trade, Industry, and Enterprise Development, to which Mr. Turner is a delegate. The Committee met in July, and another meeting is scheduled in December in Geneva to discuss how to address problems related to rejected shipment, such as transportation, as well as the issue of establishing numeric clearance standards.

DJJ is advocating that the U.S. government install grapple radiation detectors at ports in the Gulf of Mexico and the East Coast. The Federal government has not yet purchased these new detection systems, but a bill in the House of Representatives sponsored by Representative Klink will earmark $950,000 for Customs and EPA to implement a pilot program to install detectors at ports in San Diego and Detroit. However, Mr. Turner points out that there is no longer a significant quantity of scrap metal entering the United States via San Diego or Detroit. Most international scrap metal shipments enter the United States through the Gulf of New Mexico and Atlantic ports in the Southeast, and DJJ would rather see the program implemented there.

Mr. Turner is also a member of the Conference for Radiation Control Program Director's (CRCPD) E23 Committee, which focuses on addressing domestic and international issues regarding resource recovery and radioactivity. Specifically, DJJ is also involved with the CRCPD in drafting an extension of the U.S. Department of Transportation's shipping exemption for contaminated shipments with low levels of radiation to the European Union. DJJ also works with the State Department, Customs, EPA, the Department of Commerce and the Coast Guard to issues related to contaminated shipments.

Finally, DJJ is working with steel mills and regulators on specific language regarding clearance. Mr. Turner thinks that a declaration from the shipper that confirms that the scrap material "contains no radioactivity above normal background levels" may be preferable to language such as "low level of residual radioactivity" because it acknowledges that there is a normal level of radioactivity in metals, as well as in many other materials. However, the issue of clearance remains highly controversial, despite expert opinion that it is largely an issue of perception as opposed to actual health risks when levels are low as one millirem per year. Thus, Mr. Turner believes that some mills would accept scrap material that comes from nuclear facilities with the declaration he recommends, while other mills may not.

Incidents and Costs

DJJ deals directly with rejected shipments. We describe examples of these incidents in Chapter Four, and find that the costs of rejected shipments vary greatly. DJJ's experience is that the major determinants of the expense include: (1) the country where a shipment is rejected, and, (2) whether the source of radiation can be isolated and handled separately from the rest of the shipment. Sometimes, there are other issues related to the quality of the metal that can raise the cost of handling the shipment.

In most cases, the shipper pays for the handling and disposal of a rejected shipment. Mills are seldom saddled with disposal costs when shipments are rejected before or upon entering the facility. However, sometimes the contaminated material is not detected when entering the mill and/or the mill loses track of source of the metal. In these situations, the contamination may be detected when the metal products are leaving the facility. Even if the mill has tracked the source of the contaminated metal, it is difficult to legally prove that the contamination came from a specific supplier after metals from numerous sources have been smelted together. In such cases, the mill may have to assume responsibility for the costs of handling the shipment or of cleaning up and decontaminating the facility.

For example, this year, an imported shipment of scrap metal, not supplied by DJJ, was rejected by a steel mill. The contaminated source was an oil pipe containing NORM, which arrived at the mill on a barge. As a result of the single contaminated source, the mill rejected 12 subsequent barges that contained a total of 1,250 tons of steel each. The shipper sent these shipments to another location with a better radioactive screening process so that the source could be isolated and all twelve barges would not have to be rejected. The exact costs that resulted from this incident are unknown to DJJ. The contaminated scrap was imported from Europe, but the shipper was not able to repatriate the contaminated material to its original country.

Appendix E

STEEL MILL CASE STUDY

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Appendix E

STEEL MILL CASE STUDY[1]

This case study discusses the issues facing the Titanic Steel Mill regarding possible radiological contamination of its scrap metal supply. In the first section, we provide background information on the mill, including the mill's main suppliers of scrap metal and their primary customers. We next describe the mill's sources of scrap metal and how the metal is used in the mill's operations. We then discuss the mill's concerns regarding radiological contamination of its metal supply. Finally, we describe previous incidents of contaminated scrap metal detected at the mill.

We gathered some background information for this case study from Titanic Steel's Internet site. We also conducted interviews with the mill's Materials Handling Manager and the Engineering Manager.

BACKGROUND INFORMATION

The Titanic Steel mill is located in the southeastern United States and has been in operation for approximately eight yours. The mill currently employs 500 workers and processes over two million tons of scrap steel each year. Titanic Steel produces a variety of intermediate steel products, including coils, sheets, and other industrial forms. Titanic Steel sells a majority of its production to outside customers. A small percentage of its output is used to supply other internal divisions within the main company, primarily for building systems. The mill's outside customers are in industries that use steel sheet coils, such as the automotive, construction, stamp steel, and oil tubing industry, and commercial and industrial appliance manufacturers.

David J. Joseph supplies approximately 95 percent of Titanic Steel's scrap metal. The remaining five percent is purchased directly by the mill. For pig iron, the mill purchases 15 percent of their supplies without a broker. Most of the scrap Titanic Steel uses is from domestic sources; however, it typically imports roughly one-third of its scrap. The proportion of domestic versus imported scrap depends on fluctuating commodity prices.

Most of Titanic Steel's imported scrap metal comes from the United Kingdom, France, the Netherlands, and Sweden. Material from the United Kingdom and Sweden typically originates in

[1] We have changed the name of the steel mill featured in this case study because the staff interviewed requested that we not identify them.

these respective countries. The material imported from other countries often comes from different points of origin; most of the scrap from the Netherlands originates in Germany, and scrap from France often originates in Belgium. The mill is usually aware of the scrap metal's country of origin, and maintains agreements with David J. Joseph that all metal shipments brokered through the importer should be free from contamination.

Titanic Steel produces a variety of intermediate steel products. The mill melts scrap and pours it into molds to produce coils, sheets, and other industrial forms. The mill produces hot rolled, cold rolled, and coated steel sheet. It is capable of producing hot band from 0.060-0.625 in thickness, with widths from 36 inches to 64 inches. With the addition of a cold mill last year, the mill also began producing other finishes of sheet metal, such as pickled and oiled, cold rolled, full hard and fully processed, and hot dipped galvanized materials. In addition to these sheet products, a significant portion of the mill's production is coils. The coils are shipped to other processors that manufacture automotive and construction equipment parts.

RADIOLOGICAL CONTAMINATION ISSUES

This section discusses concerns regarding radioactive contamination at the mill. First, we discuss general concerns and the detection equipment used. Then, we describe the training that Titanic Steel employees undergo to detect and address radioactive contamination. Finally, we discuss how the mill's management would respond if there were changes in the levels of residual radioactivity in its scrap metal supply.

Detection Equipment

Titanic Steel is concerned about radioactive contamination of incoming scrap metal because of the potential health risks to its employees as well as the possibility of losing customers. Moreover, Titanic fears the high cleanup costs associated with accidental meltings. The mill currently uses three types of detection equipment to safeguard against radiological contamination: portal detectors, hand-held portable devices, and detection equipment on magnet booms. Imported scrap often goes through an initial radioactivity screening by Customs at the port of entry into the U.S. The scrap is then brought to the mill by truck, railroad, or barge. Portal detectors installed at each unloading point and at all entry points to the facility continuously monitor incoming shipments. The mill currently has six portal systems, and each portal system costs approximately $250,000 when purchased from the Exploranium company of Canada. Employees check the portals once a week to ensure they are calibrated correctly, and replace or refurbish them every six to ten years. Two years ago, the mill upgraded all its fixed equipment, which cost approximately $200,000.

In the event of a portal alarm, employees scan the shipment with a hand-held portable radioactive detection device. Titanic Steel currently owns four hand-held devices that cost approximately $2,000 each. Employees check these devices annually or semi-annually to ensure that they are calibrated properly. If an employee identifies problems with the portable detectors, the mill replaces them with new models.

Titanic Steel is currently experimenting with a new system which uses a very sensitive radiation detector on the boom of the crane that moves individual pieces of scrap metal. Although mill staff are satisfied with the effectiveness of the system so far, they feel that the equipment may be particularly sensitive to wear and tear. Thus, they are still in the process of evaluating whether to purchase it. If purchased, the equipment will be installed at each of the mill's 10 grapples. The cost of installing this new equipment is approximately $300,000 ($30,000 per system multiplied by 10 grapples).

The experimental grapple system has been in use for four months and seems to be fairly effective. Usually, if there is a lot of refractory material in the shipment, the portal alarms are activated despite the very low levels of radiation, that are not significant enough for the mill to reject the shipment. In contrast, the detection equipment installed in the boom that moves the metal does not sound an alarm when it comes in contact with refractory material and other insignificant low-level radiation. Therefore, the new system has the potential to increase the effectiveness of radiation detection during the sorting and processing of scrap metal.

Staff Training

All employees at Titanic Steel are trained in procedures to detect and address radioactive contamination. The mill has established standard procedures to respond to radiation alarms. Employees isolate the radioactive material and check for the presence of a sealed source or other source of radiation with a hand-held radiation detector. If a high level source is found, employees call a radiation consultant. The radiation consultant assesses disposition alternatives appropriate given the source and level of contamination.

In addition, all employees receive yearly training on monitoring refractory wear devices to ensure that they are in proper working order and do not need to be replaced. While part of the training addresses procedures to follow in the event of an alarm due to an incoming contaminated shipment, the focus of this training is on wear detection.

Response to Changes In Radiation Levels

Mill staff noted that an increase in the levels of radiation in scrap metal would be a cause for concern. Titanic Steel currently has a zero threshold for residual radioactivity in carbon scrap, and rejects scrap that contains levels above the background level commonly found in metals. If there were any increases in radioactivity its scrap supply, the mill would change its suppliers. However, Titanic Steel appears unconcerned about the low levels of radiation associated with refractory material. Titanic staff also indicated that any new government efforts to detect radiation on imported scrap metal would not lead to any changes in the mill's current screening of scrap shipments. Titanic Steel is hesitant to trust any other entity with the responsibility for this screening. Furthermore, since much of the mill's scrap supply is from domestic sources, government efforts to improve border monitoring would only affect a portion of the mill's metal supply.

Incidents

Each year, Titanic Steel experiences a number of radiation alarms. Of these alarms, however, less than perhaps five per year are due to contaminated scrap metal shipments and are cause for concern. Most of the alarms are due to the detection of refractory material with radiation below levels of concern. The mill has never received a shipment containing a high-level radiation source, such as a sealed source. Nearly ten years ago, however, a sister mill located in Utah melted a Cesium-137 source that was contained in a shipment of scrap metal. The cleanup costs from this incident totaled several million dollars, which was a key factor in the decision of Titanic's parent company to install portal detectors at the company's mills.

An incident that occurred recently at Titanic Steel is typical of its experience with shipments containing contaminated scrap. Two years ago, the portal alarm sounded on an incoming scrap metal shipment, due to a pipe valve that was contaminated with NORM scale. The mill contacted the scrap broker, David J. Joseph, who in turn contacted the shipper to dispose the contaminated piece. The costs were borne by the original shipper and Titanic Steel did not experience any direct costs related to the disposal of this material, except for the staff time that was lost while addressing this shipment. (The mill does not track the number of personnel hours dedicated to responding to radiologically contaminated shipments.) Since this was a domestic incident, it was relatively easy for the mill to arrange for disposal of the material through David J. Joseph. However, if the contaminated material came from an international source, it may have been difficult to arrange for disposal.

Appendix F

SENSITIVE INDUSTRIES CASE STUDY

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Appendix F

SENSITIVE INDUSTRIES CASE STUDY

This case study discusses radiation issues faced by industries that have a manufacturing process or operation that is extremely sensitive to even slight changes in residual radiation levels. These industries include the manufacturers of radiation measurement and analytical instruments, the electronics and computer equipment industry, and the photographic industry.

The background information for this case study is taken from a draft 1998 EPA report prepared by Sanford Cohen & Associates (SC&A).[1] To collect additional information, we also conducted interviews with staff at trade associations representing the computer manufacturing and photographic industries.

INSTRUMENTATION INDUSTRY[2]

Radiation concerns in the instrumentation industry are focused on residual radioactivity levels in metals used to manufacture measuring equipment and detection devices. Low levels of contamination can have a significant impact, for example, on a device's calibration. Residual radioactivity could elevate background count-rates, resulting in reduced sensitivity and unacceptably high detection limits for some instruments such as scalers. For spectroscopy systems, radiation can lead to a possible loss of spectral resolution, such as the ability to discern specific alpha or gamma emissions. While the instrumentation industry has standards to address the presence of radioactivity in detectors and shielding materials, most of these standards are subjective. For example, the standards specify that materials used in the manufacturing process should be "low activity" metals or "radiation free;" there are no numerical criteria. However, some individual manufacturers impose specifications on their metal suppliers as an added measure to protect against contaminated metal.

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[1] Sanford Cohen and Associates, Incorporated, *Final Draft Report: Recycling of Scrap Metals from Nuclear Facilities, Subtask 2.3 - Sensitive Industries*, prepared for the U.S. Environmental Protection Agency, June 15, 1998.

[2] This section is based on SC&A (1998), primarily pp. 13-15.

The instrumentation industry has taken several steps to mitigate related problems. Manufactures of radiation measurement and detection equipment often use metal from sources that pre-date World War II; for example, steel from sunken ships. This ensures that the metal is free of radiation from weapons testing fallout during the Cold War era and from cobalt-60 liner wear indicators in steelmaking furnaces. In addition, components that could possibly contain elevated radioactivity levels are installed outside the counting shield, or are shielded to protect the detector from extraneous radiation. The industry is also now using lead that contains only low levels of naturally occurring radioactivity for some shielding components.

Some manufacturers audit their suppliers to ensure that raw material is free of radiological contamination, in addition to testing the materials for radiation upon receipt. Manufacturers also test the finished products before they are shipped to customers to verify background count-rates and instrument response to known amounts of radioactivity. All of the manufacturers surveyed in the SC&A report use in-house test facilities and have a quality assurance and quality control program to protect against radiological contamination.

ELECTRONICS AND COMPUTER MANUFACTURING INDUSTRIES

In the past, electronics and computer manufacturing firms were concerned about radiological contamination of the metal used in manufacturing components. In addition, these industries were concerned about elevated radioactivity levels in electronic grade water and phosphoric acid used in the manufacturing process, as well as the presence of NORM in ceramics used in packaging material. More recently, such firms have expressed concern about the effects of melting of radioactive scrap metal on equipment, and potential transfer of radioactivity to other components during the manufacturing process.[3]

The electronics and computer manufacturing industries use metal in very limited amounts to manufacture computer chips. For example, only 10 μg of aluminum is used to form a film around the electronic circuit of a chip that measures 0.25 x 0.25 inches. Metal is also used in very small quantities in electrical leads that connect the integrated circuit to the rest of a device, such as a computer circuit board. The diameters for lead wiring range from 0.013 mm to 0.8 mm thick, depending on the type of electrical contact. Estimates from the SC&A report indicate that the electronics industry uses about five percent of the world's total lead production annually, which is approximately 20,000 tons of lead.[4]

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[3] SC&A (1998), pp. 5-6.

[4] SC&A (1998), p. 3.

Metal impurities can result in lower production yields and can significantly decrease the reliability of a product. Concerns about the effects of radiation are fewer today than in past years, because older chips were less resistant to the effects of radiation. In the past, computer chips built with heavy metal interconnects, such as gold, typically exhibited elevated radioactivity levels after exposure to significant neutron radiation.[5] Overall, however, only very high radioactivity levels would typically affect the performance of these products. For example, a source from 1968 states that overlapping doses, ranging from a few thousand to about one giga-rad, could cause damage to semi-conductors, computers, integrated circuits and passive components.[6] For magnetic media storage, which includes hard drives and diskettes, damage could occur when the radiation sources contain heavy ions and particles, rather than just gamma rays. Such contamination alters the lattice structure of the magnetic media; for example, re-orienting magnetic domains.[7]

In previous years, the industry was also concerned about contamination of electronic grade water and phosphoric acid used to manufacture electronic and computer components. However, as with other industry standards, a 1992 standard for electronic grade water defies ultra pure water based on the weight of ions (a maximum impurity level of 0.1 ppb or less by weight is allowed) rather than activity levels.[8] Phosphoric acid is used in making semiconductors; specifically to etch silicon substrates during manufacturing. Phosphoric acid containing levels of Po-210 between 50 to 100 pCi/L can be problematic. To eliminate this problem, one company has established a limit for Po-210 of 1.9 pCi per liter of phosphoric acid.[9]

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[5] Personal communication with Ed Graham, Semiconductor Industry Suppliers Association, August 23, 2000, and September 28, 2000.

[6] Rittenhouse, J.B. and Singletary, J.B., Space Materials Handbook, Technical Report AFML-TR-68-205, July 1968, Air Force Materials Laboratory, Wright Patterson Air Force base, OH, as cited in SC &A (1998), p. 1.

[7] Cost, J.R., et al., Radiation Effects in Rare-Earth Permanent Magnets, *Mat. Res. Soc. Symp. Proc.,* Vol. 96, pp. 321-327, 1987 as cited in SC&A (1998), p. 1.

[8] Sematech Provisional Test Method for Determining Leachable Trace Inorganics in UPW Distribution System Components, Technology Transfer No. 92051107A-STD, Sematech, Austin, TX, July 1992, as cited in SC&A (1998), p. 4.

[9] Hasnain, Z. and Ditali, A. Building-In Reliability: Soft-Errors - A Case Study, International Reliability Physics Symposium, April 1991, San Diego, CA, as cited in SC&A (1998), pp. 4 and 6.

As of 1979, contamination of ceramic material was also a concern. NORM is sometimes found in ceramics such as zirconia and clay fillers which are used in packaging materials, for example to encase the integrated circuit. To solve the problems posed by radioactivity, buffer materials or shielding are inserted between the packaging materials and the sensitive portion of the integrated circuit. Contamination in ceramics, however, has been greatly reduced in recent years by improved manufacturing techniques, the use of new suppliers, and the substitution of materials such as plastic.[10] Hence, through technological advances, the industry has developed components that are more resistant to the effects of external radiation.

Emerging technological improvements in manufacturing mean that radioactive contamination is no longer a major issue for computer and semiconductor manufacturers.[11] Most computer and semiconductor chips are now made from aluminum and copper, which are more resistant to radiation due to processing that uses purer oxides and denser materials.[12] Thus, production processes have been altered to prevent problems associated with low levels of radiation and some chips are hardened to withstand the effects of radiation.

Today, the electronics and computer manufacturing industry is more concerned with regulating impurities and the composition of alloys than with the presence of radioactivity in metal. For example, radioactive elements such as uranium and thorium are treated like other impurities and are regulated by weight rather than by activity levels. The American Society for Testing and Materials has published standards for evaluating the effect of external radiation on components. However, there are no specific standards for the allowable levels of radioactivity in materials.

The SC&A report cites some recent sources that identify other areas of concern. Electronics and computer manufacturers are concerned that if scrap metal were recycled, the contaminated metal would become incorporated in fixed equipment such as diffusion furnaces, plasma etchers, ion implanters, and sputtering chambers. Radioactivity could then be transferred from this equipment to other materials used in the manufacturing process. For example, contamination can occur when unprotected semiconductor surfaces come into contact with contaminated equipment during processes such as wet etching, measurement, ion implantation, chemical vapor deposition, plasma etching, etc. The industry is also concerned that if material or equipment used in the manufacturing process is contaminated, any discharge from the process will also contain some radioactivity,

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[10] SC&A (1998), pp. 3-6.

[11] Personal communication with Henry Blazek, Components, Packaging & Manufacturing Technology (CPMT) Society, August, 24, 2000.

[12] Graham (2000).

generating new types of waste streams with increased waste disposal costs. Thus the SC&A report notes that the presence of radioactivity could possibly result in product liability claims and decrease the competitiveness of U.S. manufacturers.[13]

PHOTOGRAPHIC INDUSTRY

In the photographic industry, historically emulsion materials and metals that were used to manufacture 35 millimeter film cassettes were routinely monitored for radioactivity. Firms also monitor for airborne and waterborne radiation, as elevated levels could have negative impacts on the film development process.[14] A related issue is the radiation levels in airport x-ray units that scan luggage. If photographic film has prolonged exposure to elevated levels of radioactivity in these units, it could undermine the film quality.[15]

Metal is used to make 35 millimeter film cassettes and camera components. Metal is also used in camera and film manufacturing equipment and film processing equipment. Photographic film is extremely sensitive to residual radiation levels that fall within normally accepted standards. However, the current trend towards digital imaging may shrink the segment of the photographic industry that is affected by radiation.

In testing for radioactivity in metals, the industry focuses on material that could result in extended radiation exposure times during film manufacturing and storage. Radiation exposure in film processing and developing equipment is not a concern, as "the residence time is very brief, typically ranging from several seconds to a few minutes."[16]

The industry has also established procedures to monitor for airborne and waterborne radioactivity. These procedures were developed in previous years when there were high levels of

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[13] SC&A (1998), pp. 6-7.

[14] SC&A (1998), p. 11.

[15] Personal communication with Jim Peyton, Director of Standards and Technology, Photographic and Imaging Manufacturers Association, September 13, 2000.

[16] SC&A (1998), p. 11.

environmental radioactivity due to atmospheric testing of nuclear weapons.[17] The SC&A report provides radioactivity (gross beta) levels which might require some intervention to prevent damage to photographic products. These levels are as follows:

- Raw water (insoluble materials): 1.4 pCi/L
- Treated water (insoluble materials): 0.5 pCi/L
- Air particulates: 0.3pCi/m^3 [18]

Staff at the Photographic and Imaging Manufacturers Association (PIMA) indicate that international standards and efforts to screen for radioactive scrap metal would probably not have a significant impact on the photographic industry.[19] However, the industry is concerned about elevated levels of airborne radioactivity that resulted from weapons testing fallout and nuclear power plant incidents, such as the Chernobyl disaster in 1986 and the Three Mile Island incident in 1979. Airborne radioactivity can be absorbed by trees; when wood pulp from these trees is used to make paper, radioactivity can have a negative effect on photographic printing. Elevated levels of airborne radioactivity can also affect the general film manufacturing process and film in storage. PIMA maintains close ties with the Federal agencies, and is alerted if there is an incident that causes elevated levels of atmospheric radioactivity. PIMA in turn would alert its member companies.

Another concern is radioactivity levels in x-ray units that are used to scan luggage at airports. If film that is carried in luggage is exposed to high radiation levels in these machines, streaks in the photograph may appear when the film is developed. (The Federal Aviation Administration also allows film to be hand-examined as an alternative to x-ray scanning). The accepted dose rate in these x-ray machines is one millirem. The dose rate for U.S. machines is usually well below this level, and it is typically safe for commercial film to pass through the machine up to five times. Some of the newer x-ray units have a different configuration that may not be as safe for film. If the dose rate is above one millirem, airport authorities need to inform passengers. In some other countries, the dose rate in x-ray machines is sufficiently high to damage film.

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[17] United Nations, *Sources, Effects and Risks of Ionizing Radiation*, Report to the General Assembly, 1988, as cited in SC&A (1998), p. 11.

[18] SC&A, p. 11.

[19] Information in the rest of this section is based on Peyton (2000).

Appendix G

DETAILED REVIEW OF RUSSIAN PRACTICES

Appendix G

DETAILED REVIEW OF RUSSIAN PRACTICES

This Appendix provides more detailed information on Russian regulatory practices and export of contaminated metals, supplementing the information provided in Chapters Two, Three, and Four of this report. Because nuclear regulatory controls in Russia are generally weak and its border practices are relatively ineffective, contaminated metal can enter the domestic scrap metal flow and cross international borders.

Understanding the size of Russia's nuclear complex provides insights into the quantities of metal generated and provides information on the potential for export of these metals. However, very limited information is available on the quantities of radioactive scrap metal generated in Russia and released into general commerce. In this Appendix, we first describe the extent to which the release of materials in Russia is subject to regulatory controls. We then characterize the Russian radioactive scrap metal supply by describing each of the sources in as great detail as available information allows. In the second part of this Appendix, we turn to Russian exports of scrap metal and illegal trafficking in contaminated metal.

DOMESTIC SOURCES

Below, we provide information on domestic controls and sources of contaminated metals in Russia, supplementing the information provided in Chapter Two. We focus on nuclear power plants, weapons facilities, and submarines; little information is available on NORM or sealed sources.

Russian Regulatory Framework

The Ministry of Atomic Energy (Minatom), with its central staff of 850 people, is Russia's central agency governing nuclear policy and is responsible for overseeing the entire fuel cycle, including uranium mining and milling, fuel fabrication, operation of nuclear power plants, reprocessing, waste management, and disposal.[1] Minatom is the largest nuclear operating organization in Russia and comprises numerous departments and research institutes. In 1994, the

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[1] Don J. Bradley, *Behind the Nuclear Curtain: Radioactive Waste Management in the Former Soviet Union*, Battelle Press, 1997, p. 27-28.

Russian government appointed Minatom as the coordinator for radioactive waste management operations (Resolution No.805, July 6, 1994) and charged it with developing and implementing the federal program.

Separate from the Ministry of Atomic Energy is the State Committee for Nuclear and Radiation Safety (Gosatomnadzor, or GAN), which is responsible for supervision of Russian civilian nuclear power plants and is the chief regulatory body for nuclear safety.[2] GAN is entrusted with the task of defining safety principles and criteria, standards, rules, and other regulatory measures, and in particular, for establishing a licencing and inspection system for civilian nuclear activities. GAN is also responsible for ensuring the physical protection and non-proliferation of nuclear material.

The Russian bureaucracy authorized to deal with nuclear issues seems extensive; however, the shortage of funds makes it extremely difficult for the appointed authorities to exercise their responsibilities effectively. According to a 1995 GAO Report, GAN does not have the legal authority to provide strong and independent oversight, and has not been adequately funded to carry out its mission.[3] Inefficiency and lack of enforcement seem to be entrenched in the system of laws and authorities. For example, although a 1992 Russian presidential decree gave GAN the overall responsibility to inspect and license activities that involve handling radioactive material, its inspectors were not granted enforcement powers. Moreover, a 1994 Russia report noted that GAN had a skeletal staff supervising safety at nuclear weapons facilities; only 22 percent of the authorized slots were filled. The same report also stated that GAN was unable to carry out its responsibilities because the Russian Ministry of Defense had created obstacles to prevent inspections at nuclear defense facilities.

In one recent example of Russia's nuclear security lapses, a ton of radioactive stainless steel was stolen from an industrial site at Mayak, which works with radioactive materials, and was later dumped in a canal on outskirts of Ozersk, formerly known as Chelyabinsk-65.[4] The plant's spokesman said that dosimetric tests showed that the steel emanated radioactivity at a rate of 500 microroentgens an hour, which is 50 times the normal level. Reportedly, the level of radiation posed

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[2] OECD Nuclear Energy Agency, *Overview of Nuclear Legislation in Central and Eastern Europe and the NIS*, 1998.

[3] U.S. General Accounting Office, *Nuclear Safety: Concerns with Nuclear Facilities and Other Sources of Radiation in the Former Soviet Union,* November 7, 1995.

[4] Yevgeny Tkachenko, "Radioactive Steel Stolen From Russian Nuclear Factory," ITAR-TASS, December 17, 1999.

no lethal danger, but prolonged exposure posed health risks. One of the explanations offered for the reappearance of the steel is that the thieves realized that the metal was contaminated and dumped it after realizing that they could not sell it.

The information sources we reviewed suggest that, while Russia has no uniform clearance standards or release policies, its officials appear to be allowing the release of metals on a case-by-case basis. For example, Minatom has announced plans to sell scrap metal from decommissioned submarines.[5]

Because nuclear regulatory controls in Russia are generally weak, a number of U.S. and international agencies have launched programs to help strengthen them. The U.S. government, acting unilaterally and as part of broader international efforts, has implemented over a dozen programs in support of Russian nuclear disarmament and non-proliferation. These programs have made a positive contribution, but critics in both Russia and in the U.S. believe that the combined effect of the assistance programs is too small compared to the size of the problem. Furthermore, some Russian critics claim that the primary aim of U.S. assistance is to collect intelligence and undermine Russia's nuclear activities.[6]

Nuclear Power Plants

Information on the number of nuclear power plants in Russia is somewhat inconsistent. As discussed in Appendix B, in 1995 Argonne estimated that there were 84 plants in the former Soviet Union, and provided data on scrap quantities for 79 of these plants. Of this total, Argonne estimates 50 plants are in Russia.

A more recent report in *Nuclear News* lists 31 operating (both commercial and non-commercial) reactor units and 10 non-operating units in Russia alone as of the end of 1999.[7] The 31 operating units include all operable, under construction, or on order (30 MWe and over) plants.

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[5] Collier, Shannon, Rill and Scott, "Comments on NRC's Proposed Release of Solid Materials at Licensed Facilities," December 22, 1999.

[6] *Helping Russia Downsize its Nuclear Complex: A Focus on the Closed Nuclear Cities*, Report of an International Conference held at Princeton University, March 14-15, 2000, p. 17.

[7] "World List of Nuclear Power Plants," *Nuclear News*, March 2000, p. 42-58.

Of the nuclear power plants no longer in service, one was closed in 1983, one in 1988, three in 1989 and five in 1990. A slightly different estimate is provided by Bradley, who indicates that Russia has 32 operating reactors and five reactors taken off line for decommissioning.[8]

In Chapter Two, we discuss the quantities of metals that could become available from decommissioning of power plants in the former Soviet Union over the next 60 years or more based on the Argonne data, which includes plants outside of Russia. In addition, some sources suggest that significant quantities may be released from on-going operations. For example, in 1995, officials in Moscow stated that "hundreds of thousands of tons" of radioactive metal, primarily high-alloy steel, was scrapped as part of the normal nuclear production cycle.[9] The metal comes from the decommissioning of nuclear power plants and nuclear equipment on ships. Russian government officials said that most of the scrap is only superficially contaminated, and economics dictated that it should be recycled.

According to Don Bradley, Minatom (Russia's Ministry of Atomic Energy), oversees the decommissioning and regulates the release of decontaminated metals from decommissioned nuclear power plants.[10] Solid radioactive wastes from these sites are collected and sorted by type of contamination and treatment options, and then transported to a storage area or processing facility. Solid organic wastes are incinerated and the ash is mixed with cement for stabilization. Solid noncombustible wastes are compacted and then stored in a repository. Contaminated metals may be decontaminated, then compacted and packed in shielded carbon steel drums, reducing their volume by four to 100 times.

Metals that are below the standards for radioactive materials may be sold as scrap, according to Bradley. He is uncertain, however, whether disposition decisions are based on measurement of actual levels of contamination or more generally on how the metal was used in the plant (i.e., its proximity to radioactive sources). He believes Minatom's efforts to ensure that radioactively contaminated metals do not leave nuclear facilities are fairly successful.

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[8] Bradley (1997), pp. 587-590.

[9] Penson, S., "Russia Stockpiles Radioactive Scrap," *American Metal Market,* May 1, 1995.

[10] Personal communication with Don Bradley, August 22, 2000 and September 26, 2000.

Weapons Facilities

About 70 percent of the former Soviet Union's defense industries are located in the Russian Federation. According to a report published by the U.S. State Department, a large number of state owned weapons facilities are on the brink of collapse because of cuts in weapons orders and insufficient funding for transition to civilian production.[11] Weapons production has fallen dramatically over the past few years; between 1988 and 1993, it decreased by 50 percent for almost every major weapons system. If fewer weapons are produced, weapons facilities may not be utilized to their full capacity.

During the Cold War, the Soviet Union constructed and maintained a vast complex of facilities for production of plutonium and highly-enriched uranium, design of nuclear weapons, and their fabrication and assembly. The complex consists of 17 industrial enterprises and scientific research institutes and employs approximately 75,000 workers. The core comprising the most sensitive of these facilities is located in ten secret nuclear cities, known only by post-box numbers, with a combined population of about three-quarters of a million people. Today, the cities are more accessible, but still fenced and open only to persons cleared by Russia's security service. However, with the end of the Cold War, Russia does not need and is unable to finance such a vast weapons complex. Many initiatives exist to decrease its size and transition its workers to civilian activities. As a result, a number of major facilities are being closed and converted to other uses.

Given the size of Russia's weapons production complex, the effort required to downsize it is significant. In this Appendix, we do not attempt to provide an exhaustive summary of Russia's activities to reduce the size of its weapons complex and transition to civilian production, rather we discuss the implications for release of potentially contaminated scrap metals. According to *Helping Russia Downsize its Nuclear Complex*, the Russian Ministry of Atomic Energy wants to shut one of two fissile component production facilities, as well as shrink its remaining nuclear weapons facilities and their staffs. By 2005, Minatom hopes to reduce the current number of nuclear weapon workers by half. The extent to which these proposed reductions are underway remains unclear.

Minatom has already shut down or converted a number of major facilities. Production of new weapons has ended at two out of four warhead assembly/disassembly facilities in two of the nuclear cities, and nuclear materials and production equipment are being packaged and removed from the plants. Reportedly, environmental cleanup is under way, as one of the plants might be used for

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[11] *U.S. Department of State, Background Notes: Russia*, October 1998, http://www.state.gov/www/background_notes, p.11, as viewed in August 2000.

civilian production. At other facilities, weapons production is being concentrated at a smaller number of shops, which suggests that the sites no longer used by the weapons industry may be dismantled.

However, the lack of funds impedes this process.[12] Minatom estimates that relying only on Russian internal resources (without significant international financial assistance), the planned downsizing and conversion may not be completed for 10 to 12 years. With international assistance, the same plans could be implemented in five to seven years. Hence, for the next five to 12 years and possibly longer, scrap metal from dismantled facilities may be released or disposed. It appears that, as in the case of nuclear power plants, contaminated metal is disposed, while uncontaminated metal is released.[13]

In addition, according to the Argonne report (discussed in Chapter Two), the former Soviet Union operated one nuclear fuel enrichment plant in Siberia which is slightly smaller (in terms of production capacity) than the U.S. enrichment plant at Paducah. Argonne estimates that the Paducah plant has approximately 289,509 metric tons of potentially recyclable carbon steel, 258 metric tons of potentially recyclable stainless steel, 28,767 metric tons of potentially recyclable aluminum, 269 metric tons of potentially recyclable copper, and 60,911 metric tons of nickel. Other information is provided by the U.S. General Accounting Office, which states that 99 nuclear facilities are operating in Russia, not including civil nuclear power reactors.[14]

Nuclear Submarines[15]

Bellona, a Norwegian Environmental Group, monitors activities of the Russian submarine fleet. Over 130 Russian vessels were taken out of service as of 1996 and awaited decommissioning. Bellona projects that around 150 nuclear submarines will be taken out of service by the Russian Navy by 2007. While the lack of both qualified technical facilities and sufficient funding may slow decommissioning efforts, a recent press release confirms that Russian plans to scrap these submarines. Reportedly, 18 vessels are to be decommissioned in 2000 and the speed of

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[12] Unless otherwise cited, information in this subsection comes from *Helping Russia Downsize its Nuclear Complex: A Focus on the Closed Nuclear Cities* (as cited earlier), pp. 9-16.

[13] Bradley (2000).

[14] U.S. General Accounting Office (1995).

[15] Unless otherwise cited, information in this section is taken from: Bellona Group, *The Russian Northern Fleet: Decommissioning of Nuclear Submarines*, August 19, 1996.

decommissioning will increase each year.[16] As of 1995, retired Russian submarines were typically beached or disposed at sea.[17] However recent press reports confirm Russia's plans to sell scrap metal from decommissioned submarines.[18]

Decree No. 095-296, ratified by the Supreme Soviet and the Central Committee of the Communist Party in 1986, establishes formal procedures for decommissioning and dismantling inactive nuclear submarines. The decree orders that the vessels be decommissioned by cutting out their reactor compartments and re-using uncontaminated metal. The decree apparently does not specify the contamination levels acceptable for metal recycling nor address the disposition of contaminated metal.

According to Decree No. 514, ratified by the Russian government in July 1992, a number of submarines scheduled for dismantling and metal recycling were to be transferred from Navy jurisdiction to shipyards governed by the Ministry of Industry. This transfer would allow commercial enterprises to gain access to decommissioning work and the shipyards would receive the proceeds from the sale of scrap metal as payment for their decommissioning efforts.[19] However, despite the decrees and numerous discussions, as of 1996 the actual work was far behind schedule and no submarine had been decommissioned in compliance with the regulations.

There are several reasons why the decommissioning process is proceeding so slowly. One important factor is that the Navy, which bears the chief responsibility for dismantling submarines, does not want to relinquish control without reimbursement. The Navy finances scrapping the vessels in part through the revenue gained from the sale of scrap metal. (The removal of missile and reactor compartments is financed by the state.) According to the Bellona Group, Navy yards are permitted to co-operate with commercial institutions and foreign enterprises. They are also given the opportunity to sell the scrap metal on the international market. Until March 1995, tax exemptions were granted for Navy yards selling metals from dismantled submarines.

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[16] Bellona Group, "150 nuclear subs to be scrapped," May 22, 2000.

[17] U.S. General Accounting Office (1995).

[18] Hoffman, David, "Rotting Nuclear Subs Pose Threat in Russia; Moscow Lacks Funds for Disposal," *The Washington Post*, November 16, 1998.

[19] The Supreme Commander of the Northern Fleet, Admiral Oleg Yerofeev, expressed great displeasure over the decree and stated that Navy, not the shipyards, should benefit from the sale of scrap metal, especially since the submarines are the property of the Russian Navy. (Bellona (1996), p. 4.)

Although related official documents and decrees assume that decommissioning of nuclear submarines is self-financing and that participants in the decommissioning work will make a profit from sale of salvaged metals, participating Navy yards operate at a large loss. For example, the decommissioning of the Project 667A - Yankee Class K-241 at factory number 462 resulted in a loss of 311 million roubles (1993) for the Zvezdochka yard. Reportedly, 60 tons of copper, 100 tons of lead, and 20 tons of aluminum were salvaged from this one submarine and sold, failing to generate a profit.

It appears that only some of the metals that resulted from dismantling this submarine were sold. On average, the dismantling of a Yankee Class submarine of this type generates an estimated 3,300 tons of scrap metal, including 300 tons of stainless steel, 1,100 tons of low magnetic steel, 1,900 tons of steel, 50 tons of copper, 70 tons of brass, 70 tons of bronze, 30 tons of cuprous nickel and 5 tons of aluminum. The corresponding figures for a Project 667 B - Delta I class submarine are a total of 2,096 tons of scrap metal, including 554 tons of stainless steel, 220 tons of non-ferrous metals, 90 tons of titanium alloy, 95 tons of copper wiring, and 58 tons of lead.

In contrast, the Argonne report (discussed in Chapter 2) estimates that, as of 1990, Russia had 400 naval propulsion reactors. Argonne estimates that, if each reactor contains approximately 1,000 tons of radioactive stainless steel, about 400,000 tons of radioactive stainless steel may become available as these submarines are decommissioned. However, the basis for this estimate is unclear.

Export of this scrap may be appealing because of the revenue raised. Non-ferrous metals may be of the most interest to foreign buyers, because of the difficulty of smelting the tempered steel hulls of the submarines. However, as of 1996, Greece, Finland and China had bought ferrous scrap metal from the decommissioned submarines.

Waste Management

Russia has 16 regional disposal sites for the storage, treatment, and/or disposal of industrial, research and medical radioactive wastes. These facilities, commonly referred to as "Radons," were designed and constructed in the early 1960s. With some exceptions, the majority of sites do not meet modern safety requirements and the storage facilities have been filled or have limited remaining capacity. Solid wastes below 30 μr/hr are considered non-radioactive and do not require any special treatment or handling and are disposed at municipal landfills. Until 1990, the most common methods used for waste management at SIA Radon (in the Moscow oblast) were cementation (for low-salt liquid LLW), bituminization (for high-salt liquid LLW and ILW), incineration (for burnable waste), and burial (for spent radiation sources and contaminated metal).[20]

Some of these facilities may not provide adequate control over the storage and handling of radioactive material.[21] Radioactive materials have been stolen, in some cases by people who believed that it was harmless and could be sold as scrap. While accidental meltings of sealed sources are possible, they may be rare and hence not constitute a significant source of radioactively contaminated metal.

RUSSIAN EXPORTS OF SCRAP METAL

Recently, Eastern European countries have become some of the largest scrap metal exporters worldwide. Limited demand for scrap within these countries coupled with growing supply both contribute to the surplus of scrap and increasing exports. Russia, specifically, may export about 5.2 million tons of iron and steel scrap annually, according to estimates developed by the United Nations Economic Commission for Europe, IISI, and the United Nations Conference on Trade and Development. Based on this estimate, in 1997 Russia was the third largest exporter after the United States (8.9 million tons) and Germany (6.9 million tons). The Ukraine is also a major exporter of scrap metals. We are uncertain whether this trend will continue because domestic demand for scrap may increase as these nations rejuvenate their metallurgical industries. For example, the Russian steel industry intends to utilize more domestic scrap eventually, but currently is unable to pay for it in dollars, so export is more appealing to scrap dealers.

Presently, Russia has a large quantities of scrap for sale and can offer it for lower prices than its competitors from Western Europe.[22] Exhibit G-1 shows that Russia often is the single largest scrap exporter in the Commonwealth of Independent States (CIS), although estimated values for 1999 suggest that the past trend of increasing exports may be leveling off.

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[20] Bradley (1997), pp. 118-126.

[21] Bradley (2000).

[22] Information in this section is taken from: United Nations, *Iron and Steel Scrap, 1999*, Economic Commission for Europe, 1999, p.45-69.

Exhibit G-1

MAJOR SCRAP EXPORTS FROM THE CIS
(thousands of tonnes)

Country	1995	1996	1997	1998	1999
Russia to:	1,637	2,610	5,042	5,910	4,710
Europe	591		304		
Others	1,046		4,738		
Ukraine to:	636	800	845	3,255	3,000
Western Europe			212	638	
Eastern Europe			310	215	
Asia			313	2,350	
Others			10	62	
Other CIS	189	189	189	200 E	200 E
Baltic States	835	550	440	470	490 E
TOTAL	**5,147**	**6,111**	**8,930**	**12,385 E**	**10,800 E**

Source: *Iron and Steel Scrap, 1999*, United Nation, Economic Commission for Europe, 1999.
Note: E signifies an estimated value.

The ultimate destination of these exports is uncertain. According to the *American Metal Market*, members of the European Union typically import some 4 million tonnes of steel scrap from Russia and Ukraine annually.[23] Most of the scrap from Black Sea ports is destined for Turkey, Greece, Italy, and Spain. The rest goes to the Far East, Korea, Taiwan, Malaysia, Singapore, or Indonesia. Russian scrap also flows across the Baltic Sea, mostly to Sweden, Denmark, Germany, and even Spain. According to the same source, scrap metal merchants are occasionally offered scrap from Archangelsk or Murmansk, but often refuse to accept it due to fear of radioactivity. [24]

[23] Unless otherwise cited, information in this subsection comes from "Russian Ferrous Exports: Risk Seen of Involvement in Diplomatic Dispute," *American Metal Market Metals Recycling Supplement*, March 14, 2000.

[24] The Murmansk and Archangelsk regions operate naval yards and naval bases, and maintain naval nuclear reactors including submarines and icebreakers.

Illegal Trafficking[25]

Russian radioactive metal has been exported and intercepted in Europe and the United States, as discussed in Chapter Four and elsewhere in this report. The IAEA reports that this problem is worsening, and that contaminated metal (mostly from decommissioned nuclear power stations, radiation monitoring equipment, and waste containers) occasionally finds its way into metal products, including household items, in Europe.

Although it is impossible to piece together the extent of illicit trafficking from anecdotes and examples, it is clearly a growing concern. The IAEA's international working group convened in Dijon, France, in September of 1998 to discuss this problem and considered proposals to equip all border crossing points with automatic detectors. The available literature suggests that rail is the most popular transportation medium for contaminated scrap.

Recent incidents include one where a British scrap metal merchant in the north of England discovered part of a highly radioactive reactor vessel from a Russian nuclear power station in a shipment of steel. Officials admitted it was likely that other shipments of contaminated scrap might have passed through British customs undetected. Another recent incident took place at Czech-German border, where Russian radioactive scrap metal was intercepted and found to be 400 times above the accepted level of radiation.[26]

The situation is exacerbated by Russia's economic crisis and the ruble's continuing fall, the combination of which has increased the attraction of trafficking in contaminated metal to crime syndicates who are eager to acquire Western currencies. It comes as no surprise, then, that some of the material is stolen and those who initiate the sale are awaren of its contamination. But by the time any radioactivity is detected, the material has changed hands many times and it is impossible to trace it back to its original owner.

Some 100,000 radioactive sources are unaccounted for in the Ukraine alone, all of which may find their way into the scrap metal stream.[27] However, inspecting all metal crossing borders would be a very expensive and large-scale operation. Also, in the Netherlands and possibly elsewhere, merchants who detect contaminated material are obliged to send it to an organization

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[25] Unless otherwise cited, information in this section is from: Mike Leidig: "The East: Radioactive Scrap Creates Problems for Western Europe," Radio Free Europe, March 9, 1998.

[26] *IAEA Daily Press Review*, Number 216, November 16, 1996.

[27] "Increase of Illegal Traffic of Radioactive Scrap Metal," *WISE*, Amsterdam, http://www.antenna.nl/wise/498/4920.html, as viewed August 2000.

responsible for storage and are required to pay associated costs.[28] Hence it is possible that some dealers avoid officially "finding" any contaminated material on their premises.[29]

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[28] Rotterdam is the world's busiest port for scrap metal. See: Alfred Nijkerk, "Uncertainty Reigns as Markets Enjoy Mixed Fortunes," *Recycling International*, March, 2000.

[29] Nijkerk (2000).

Appendix H

ASSOCIATED RISKS

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Appendix H

ASSOCIATED RISKS

This Appendix provides information on the protectiveness of existing U.S. and international standards for clearance of metals from nuclear regulatory controls, the individual and collective risks associated with background radioactivity levels in imported and exported scrap, and the individual and collective risk related to accidental releases of radioactivity from metal recycling.[1] The approach for assessing these risks relies on work conducted by S. Cohen and Associates (SC&A) for EPA as well as on information provided in the main text of this report.[2]

Key findings include:

- The existing and proposed standards for release of metals from nuclear regulatory controls vary in protectiveness. However, most fall within the 10E-4 to 10E-6 risk range often used in EPA programs.

- Preliminary estimates of the total risk of fatal and nonfatal cancers from background levels of radionuclides in U.S. steel and iron are low, about one statistical cancer case annually.

- Estimates of risks from accidental meltings of contaminated scrap are much higher. Examples of these incidents show that cancer incidence would be around 200 additional cases, if the melting were undetected and the resulting materials were released.

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[1] Most of the material in this appendix was developed in 1999 by S. Cohen and Associates (SC&A) under Work Assignment 2-22 of Contract Number 69-D700-73. Since that time, SC&A has refined the model used to convert dose to activity levels for scrap metal, and more information has become available on some of these topics. Therefore, some of the material presented in this Appendix may be outdated.

[2] The approach used in this risk assessment is discussed in detail in: S. Cohen and Associates, Incorporated, *Analysis of the Potential Recycling of Department of Energy Radioactive Scrap Metal,* prepared for the U.S. Environmental Protection Agency, September 6, 1994; and *Technical Support Document: Evaluation of the Potential for Recycling of Scrap Metals From Nuclear Facilities (Review Draft),* prepared for the U.S. Environmental Protection Agency, July 15, 1997.

The following sections first discuss the protectiveness of the clearance standards presented in Chapter Two of this report. Next, we describe background levels of radiation in U.S. iron and steel and accidental meltings.

PROTECTIVENESS OF EXISTING AND PROPOSED STANDARDS

This section first discusses the protectiveness of current U.S. standards for release of materials from nuclear regulatory controls compared to alternative standards. It next discusses the adequacy of the existing international standards, including the current and/or proposed standards developed by the International Atomic Energy Agency (IAEA), International Commission on Radiological Protection (ICRP), and European Union (EU), which are described in Chapter Two of this report.

Protectiveness of U.S. Standards

As discussed in Chapter Two, NRC Regulatory Guide 1.86 and DOE Order 5400.5 have served as interim clearance standards for the release of materials from nuclear facilities.[3] The limits in Regulatory Guide 1.86 and DOE Order 5400.5 were established in the 1970s and were not specifically intended as clearance criteria for the release of metals.

Over the past several years, EPA has conducted extensive analysis of the dose levels and risks associated with existing and alternative U.S. standards.[4] In Exhibit H-1, we indicate the doses associated with the Regulatory Guide 1.86 levels for radionuclides commonly found in scrap from U.S. nuclear facilities, based on the dose model available in 1997. As indicated by the exhibit, the dose levels (and hence cancer risks) associated with the current standards vary by radionuclide. However, the doses are relatively small (less than 10 mrem per year) and the associated risks are all within the 10E-6 to 10E-4 risk range often used in EPA programs.

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[3] U.S. Atomic Energy Commission, *Regulatory Guide 1.86: Terminations of Operating Licenses for Nuclear Reactors*, June 1974, p. 5; and U.S. Department of Energy, *DOE Order 5400.5: Radiation Protection of the Public and the Environment*, 1995 Addendum, p. 9.

[4] Industrial Economics, Incorporated, *Radiation Protection Standards for Scrap Metal: Preliminary Cost-Benefit Analysis,* prepared for the U.S. Environmental Protection Agency, June 1997, p. 5-24. The dose conversion model applied in this report was developed for EPA by S. Cohen and Associates, and is described in detail in the report and companion documents. These results are based on the 1997 version of the model.

Exhibit H-1

DOSE ASSOCIATED WITH CURRENT U.S. STANDARDS FOR SELECTED RADIONUCLIDES (Regulatory Guide 1.86)

Nuclide	Dose (mrem per year)
Co-60	5.75E+00
Ru-106+D	1.65E-01
Cs-137+D	5.69E-01
U-238+D	1.84E+00
Pu-239	9.32E-02

Source:
Industrial Economics, Incorporated, *Radiation Protection Standards for Scrap Metal: Preliminary Cost-Benefit Analysis*, prepared for the U.S. Environmental Protection Agency, June 1997, Chapter 5. The dose conversion model applied in this report was developed for EPA by S. Cohen and Associates in 1997, and has since been refined.
Notes:
Totals may not sum due to rounding.

As part of this analysis, EPA also assessed the collective risks associated with alternative U.S. standards. In Exhibit H-2, we replicate the results of this analysis. The estimates in Exhibit H-2 reflect the risks associated with the domestic release of scrap from commercial nuclear power plants and major DOE sites over a 40 to 55 year period. These estimates take into account the effects of costs on decisions to release or dispose scrap, and assume that facilities will choose the least-cost option under each set of standards. (High and low disposal cost scenarios were used to address significant uncertainties related to the current and future costs of scrap disposal at commercial and DOE sites.) However, this analysis does not consider the impact of increasing public pressures to limit the release of scrap and actual releases are likely to be much lower, reducing these risks significantly. Collective impacts are expressed as the total number of statistical cancer cases (fatal and non-fatal) associated with exposure to scrap released under each clearance standard.

Exhibit H-2

PRELIMINARY ESTIMATES OF CANCER INCIDENCE ASSOCIATED WITH ALTERNATIVE U.S. STANDARDS (statistical cases)

Scrap Source	Current Standard	0.1 mrem Standard	1.0 mrem Standard	15 mrem Standard
DOE facilities	<0.1 cases	0 cases	<0.1 cases	1.3 cases
Commercial power plants	8.3 - 14.4 cases	<0.1 - 0.1 cases	1.9 - 4.4 cases	26.2 - 42.0 cases
Total	8.3 - 14.4 cases	<0.1- 0.1 cases	1.9 - 4.4 cases	27.5 - 43.2 cases

Source:
Industrial Economics, Incorporated, *Radiation Protection Standards for Scrap Metal: Preliminary Cost-Benefit Analysis*, prepared for the U.S. Environmental Protection Agency, June 1997. The dose conversion model applied in this report was developed for EPA by S. Cohen and Associates in 1997 and has since been refined.
Notes:
Details may not sum to totals due to rounding.
Range reflects results under "high" and "low" disposal cost scenarios (as disposal costs increase, they provide greater financial incentives for clearance rather than disposal of scrap, increasing the resulting risk estimates).
Results assume that generators will release the maximum amount of scrap possible given the release standards and economic costs. Actual quantities released are likely to be significantly lower.
Results assume initial activity levels at the logarithmic mid-point of the reported ranges.
Cancer incidence equals the total number of statistical cancer cases (i.e., the sum of small changes in the risks of incurring fatal and non-fatal cancers across all members of the exposed population) predicted to occur over 1,000 years as the result of scrap metal released over a 40 to 55 year period.

Exhibit H-2 demonstrates that the total number of cancer cases estimated by the 1997 collective impacts model varies greatly depending upon the release standard under consideration. The number of cancer cases associated with scrap released under the 0.1 mrem standard total 0.1 cases over the time period assessed; this figure rises to 43 cases under the 15 mrem standard. The current standards lead to risks above those attributable to a 1.0 mrem standard, but less than those under a 15.0 mrem standard.

These estimates may overstate the risks associated with each standard because they assume that activity levels in released scrap are equal to the relevant standard. In reality, released scrap may frequently have lower activity levels. In addition, given public concerns regarding the release of materials from nuclear facilities, the actual quantities released are likely to be much less than predicted in this analysis.

Protectiveness of International Standards

Exhibit H-3 presents the risk levels associated with the individual annual dose-based clearance standards of the IAEA, the ICRP, the EU, and Italy, which are discussed in detail in Chapter Two. The ICRP 60 standard (100 mrem/yr) is the radiation protection standard recommended for exposure to the general public from all sources of radiation excluding background radiation and medical treatment, while the ICRP's proposed standard of 3 mrem/yr is specifically for metal clearance. The IAEA and EU standards are specifically designed for release of solid materials or metals.[5]

Exhibit H-3

INDIVIDUAL DOSE AND LIFETIME INDIVIDUAL RISKS ASSOCIATED WITH INTERNATIONAL STANDARDS

Standard	Dose	Lifetime Cancer Incidence
ICRP 60 (1990)	1 mSv/yr (100 mrem/yr)	5.3 E-03
ICRP proposed	0.03 mSv/yr (3 mrem/yr)	1.6 E-04
IAEA TECDOC 855 (Interim, 1996); and EU Radiation Protection 89 (1998)	10 μSv/yr (1 mrem/yr)	5.3 E-05

Notes:
See Chapter Two for discussion of the international standards cited.
Lifetime cancer incidence was calculated assuming a 70 year lifetime.
Sources:
Risk conversion factors were taken from: U.S. Environmental Protection Agency, *Estimating Radiogenic Cancer Risk*, 1994,Table 6.
Lifetime cancer incidence was calculated using the normalized risk/mass activity concentration conversions found in: S. Cohen and Associates, Incorporated, *Technical Support Document: Evaluation of the Potential for Recycling of Scrap Metals From Nuclear Facilities (Review Draft)*, prepared for the U.S. Environmental Protection Agency, July 15, 1997, Exhibit 7-1.

Exhibit H-3 demonstrates that cancer risks vary from about 5E-03 to 5E-05. For comparison, EPA's acceptable individual lifetime cancer risk range for clean-up of Superfund sites is 1E-04 to 1E-06. Only the ICRP standard, which is for total exposures (not solely exposure to metals), falls outside this risk range.

[5] The IAEA standards assessed do not include the proposed 100 mrem standard for NORM.

RISKS ASSOCIATED WITH BACKGROUND LEVELS

Background levels of radioactivity in metals come from a number of sources, including contact with naturally occurring radioactive materials (NORM) and the melting of sealed sources. This section discusses sources of background radiation in iron and steel and associated health risks. We focus on iron and steel both because they are prevalent metals and because relevant information is available in the existing literature. While we rely on data from a variety of sources, the estimates of dose and risk consider only U.S. recycling of these metals, due to the limited data available for the other countries considered in this scoping analysis.

Background Levels from NORM

Naturally-occurring radioactive materials (NORM) are ever-present in the environment, and consists primarily of uranium and thorium, along with their decay products, and potassium. Radionuclide concentrations in nature vary significantly depending upon the types of soils and geological formations. Exhibit H-4 summarizes a typical range of concentrations observed in two types of rocks and in soils.

Exhibit H-4

RANGE OF CONCENTRATION LEVELS FOUND IN ROCKS AND SOILS

	Concentrations (pCi/g)		
Material	**U-238**	**Th-232**	**K-40**
Igneous rocks	0.2 - 1.6	0.2 - 2.2	2 - 40
Sedimentary rocks	0.3 - 1.0	0.2 - 1.3	2 - 22
Soils (average)	0.6	1.0	12

Source: National Council on Radiation Protection and Measurements, "Exposure of the Population of the United States and Canada from Natural Background Radiation," *NCRP Report No. 94*, Washington, D.C., December 1987.

NORM is found at higher concentrations in ores from which minerals are extracted.[6] Ores with elevated radioactivity include rare-earth elements, columbium, tantalum, tin, zirconium, bauxite, copper, iron, nickel, and lead, among others.

[6] S. Cohen and Associates, Incorporated, and RAE Corporation, *Diffuse NORM Wastes - Waste Characterization and Preliminary Risk Assessment*, prepared for the U.S. Environmental Protection Agency, 1993; and Eisenbud, M., *Environmental Radioactivity (2nd Edition)*, Academic Press: New York, 1973.

Because of their origin, refined ores or feedstocks used at smelters or steel mills could yield products containing residual amounts of NORM. Few studies address this possibility, although some address radioactivity in metals, alloys, and other products used to manufacture analytical equipment and radiation detectors. More recently, some studies assess the presence of radioactivity as an impurity in metals and other materials. Exhibits H-4 and H-5 summarize the results of these studies.

Exhibit H-5

VOLUME CONCENTRATIONS OF NATURALLY OCCURRING RADIONUCLIDES IN METALS AND ALLOYS

Materials	Concentrations (pCi/g)		
	U-238	Th-232	K-40
Aluminum Smelting:			
Bauxite ore (average)	3.4	5.4	1.6
Alumina product	0.3	<0.2	--
Finished Products:			
Aluminum (6061H)	0.018	0.19	<0.023
Aluminum (1100H)	<0.008	0.11	<0.027
Aluminum (1100A)	<0.012	0.036	<0.05
Aluminum (3003A)	<0.012	0.045	0.25
Stainless steel (304)	<0.003	<0.0027	<0.027
Stainless steel (304L)	<0.002	<0.0023	<0.009
Magnesium (PGT)	<0.0135	<0.023	<0.023
Magnesium (rod)	<0.0018	0.027	0.045
Magnesium (ingot)	<0.0009	<0.0045	<0.009
Magnesium (billet)	<0.0009	<0.0023	<0.009
Copper sheet	<0.027	<0.023	<0.09
Beryllium copper alloy	<0.027	<0.009	<0.09
Other Products:			
Alumina	0.83	0.066	--
Glass (4 types)	0.83 - 5.6	0.03 - 0.66	--
Ceramics (@):			
Bulk Sample	1.0 - 0.016	--	--
Package	0.43 - 0.46	--	--
Lid	0.18 - 0.14	--	--

Sources:
Camp, D.C. et al., Low-Background Ge(Li) Detector Systems for Radioenvironmental Studies, *Nuclear Instruments and Methods*, Vol. 117, 1974, pp. 189-211.
U.S. Environmental Protection Agency, *Emissions of Naturally Occurring Radioactivity from Aluminum and Copper Facilities*, Office of Radiation Programs, Las Vegas, NV, EPA 520/6-82-018, November 1982.
Adams, J.S., Richardson, K.A., "Thorium, Uranium, and Zirconium Concentrations in Bauxite," *Economic Geology*, Vol. 55, 1960, pp. 1653-1675.
May, T.C., and Woods, M.H., "Alpha Particle Induced Soft Errors in Dynamic Memories," *IEEE Transactions on Electron Devices*, Vol. ED-26, No. 1, January 1979.
Riley, J.E., Jr., "Determining Trace Uranium in Ceramic Memory Packages Using neutron Activation with Fission Track Counting," *Semiconductor International*, p. 109 - 120 May 1981.

Exhibit H-6

SURFACE ALPHA ACTIVITY LEVELS OF NATURALLY OCCURRING RADIONUCLIDES IN METALS AND ALLOYS

Metals/Alloys	Alpha Particles per 100 cm^2/hr.
Copper (machined)	9
Copper (exposed to air)	21
Copper (sandpapered)	8
Copper (CP)	11
Copper (electroplated - $BaCl_2$)	13
Copper (electroplated - $CuSO_4$)	160
Steel (commercial)	3
Brass (commercial)	5
Tin (commercial)	121
Tin (CP)	14
Solder (commercial)	2,800
Aluminum (commercial)	31
Aluminum	7

Sources:
Bearden, J.A., "Radioactive Contamination of Ionization Chamber Materials," *Rev. Sci. Inst.*, Vol. 4, May 1933, pp. 217-275.
Calculated assuming a total uranium and thorium concentration of 0.2 pCi/g (see Exhibit 2-2, Al, 6061H), 20 μm range in aluminum (applying Bragg-Kleeman Rule for 5 MeV alpha particles in Si), and an alpha particle energy of 5.0 MeV. From: Knoll, G.E., *Radiation Detection and Measures*, 2nd Ed., New York: John Riley & Sons, 1989.

Comparing Exhibits H-5 and H-6 to Exhibit H-4, we see that NORM activity levels in metals and finished products are significantly lower than in soils and rocks. Using aluminum for comparison, a reduction in radioactivity of about two orders of magnitude occurs from ore (bauxite) to a finished product. The processing and refining steps associated with the production of aluminum account for this reduction.

Apart from natural radioactivity in ores used to produce metals, oil and gas drilling equipment typically becomes contaminated with NORM during drilling operations, as discussed in Chapter Two. The subsequent recycling of such equipment causes radioactivity to be introduced into metals. NORM originates in subsurface oil and gas formations and is typically transported to the surface with produced water. Minerals then precipitate in well tubulars, production piping, and other equipment. These mineral scales grow into crystalline structures of various thicknesses. The primary radionuclides in the scales are decay products of uranium and thorium, such as radium-226. NORM contamination levels in scale, sludge and petroleum production equipment vary from background levels (≤2 pCi/g) to tens of thousands of pCi/g.[7]

An estimated 25,000 metric tons of NORM scale and 225,000 tons of NORM sludge are generated annually in the United States.[8] The scale contains estimated average concentrations of 360 pCi/g of radium-226 and 120 pCi/g of radium-228; the sludge contains estimated average concentrations of 56 pCi/g of radium-226 and 19 pCi/g of radium-228 (radium inventories are assumed to be in equilibrium with decay products). Most active equipment containing NORM contamination continues to be used for oil and gas production. Scrapped equipment is washed and stored, and eventually may enter commercial scrap recycling channels.

Little information is available on the level of NORM contamination present in metal end products as a result of recycling. As mentioned in Chapter Three, preliminary analysis by the Swedish Radiological Institutes indicates that levels of NORM in metal products are above background levels. However, during the melting of steel scrap, radium, uranium and other actinides tend to accumulate in slag rather than alloying with the metal. Thus, significant concentrations of these radionuclides would not be expected in recycled metals.[9]

Background Levels from Sealed Sources

Since the mid-1960s, cobalt-60 sources have been in widespread use as refractory wear indicators in blast furnaces of steel mills.[10] This method is employed because blast furnaces are completely enclosed structures, precluding visual inspection. In contrast, a simple visual inspection of electric arc furnaces that melt scrap metal exclusively eliminates the need for wear indicators at these facilities. According to NRC procedures, sealed sources typically containing about 50 mCi of cobalt-60 are mortared into a predrilled refractory brick and placed in the furnace. Furnace linings

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[7] Dehmel, J.C., S. Cohen & Associates, Incorporated, and Rogers, V., Vern, Rogers & Associates, *Diffuse NORM Waste: Waste Characterization and Preliminary Risk Assessment*, May 1993.

[8] Dehmel, J.C., S. Cohen & Associates, Incorporated, and Rogers, V., Vern Rogers & Associates, *Diffuse NORM Waste: Waste Characterization and Preliminary Risk Assessment*, May 1993.

[9] However, the radionuclide may contaminate pollution control systems or waste if it is retained in the slag or released as matallic fumes.

[10] Personal communication with A. LaMastra, Health Physics Associates, Incorporated, August 30, 1993.

typically contain a total of about 500 mCi.[11] Another source, LaMastra's *Radioactive Material in Steel Scrap,* indicates that cobalt-60 sources are typically between five and 10 mCi each, and that a total of 100 to 600 mCi are used in blast furnaces.[12] The locations of the sealed sources are recorded on the furnace shell, and mill staff conduct surveys periodically to measure the rate of loss of the sources into the steel and determine the rate of lining wear.

NRC indicates about 200 mCi of cobalt-60 is typically dissolved into tens of thousands of tons of steel (i.e., less than 20 pCi/g) in blast furnaces. Similarly, LaMastra suggests that it is unlikely that more than 20 to 30 mCi could be melted into a single iron heat of 250 to 800 tons. Hence, the worst-case concentration would be 25 to 120 μCi per ton of steel (i.e., about 30 to 110 pCi/g). NRC licenses the use of cobalt-60 in blast furnaces under 10 CFR 32.11 and 10 CFR 30.70, which limit the cobalt-60 concentration in product steel to 5E-4 μCi/g (500 pCi/g).

Cobalt-60 is used in steel mills in other countries as well. For example, a 1991 report published by Germany's Federal Environment Ministry (BMU) provides an overview of a study assessing cobalt-60 contamination levels in scrap steel and iron.[13] A total of 1,700 random samples were taken, representing about 300 million tons of scrap metal over a 10 year period. Samples ranged in weight from one to 1,000 grams with a collective weight of 73 kg. Researchers analyzed the samples for cobalt-60 contamination by means of an ORTEC high-resolution germanium detector. To ensure maximum sensitivity, researchers counted the samples in a low-background chamber consisting of 10 cm-thickness lead and lined with copper and cadmium. The lower limit of detection for this system was 10E-3 Bq/g (2.7E-2 pCi/g).[14] Researchers counted the samples for times ranging from 1,000 seconds to as long as 54,000 seconds. The activity concentrations for the 1,700 samples analyzed were distributed log-normally.

Researchers used the log-normal activity concentration distribution observed for the 1,700 random scrap metal samples as the basis for modeling the distribution of cobalt-60 activity for the 300 million tons of scrap metal derived from domestic and foreign sources. About 85 percent (255 million tons) of the total mass of scrap metal is projected to contain activity below 10E-4 Bq/g (2.7 x 10E-3 pCi/g); about 20 million tons have activities between 10E-4 and 10E-3 Bq/g (2.7 x 10E-3 pCi/g to 2.7 x 10E-2 pCi/g), nine million tons have activities between 10E-3 and 10E-2 Bq/g (2.7 x 10E-2 pCi/g to 2.7 x 10E-1 pCi/g) and two million tons have activities between 10E-2 and 10E-1

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[11] Correspondence from S. Baggett, U.S. Nuclear Regulatory Commission, April 14, 1993.

[12] LaMastra, A., *Radioactive Material in Steel Scrap: Its Occurrence, Consequences, and Detection*, Health Physics Associates, March 1989.

[13] Görtz, R. et al., Brenk Systemplanung, *Genehmigungsrelevante Aspekte der Nachbetriebsphase Kerntechnischer Anlagen*, BMU, 1991, Appendix F, pp. 2 - 3.

[14] 1 Becquerel = 27 pCi.

Bq/g (2.7 x 10E-1 pCi/g to 2.7 pCi/g). Researchers did not estimate quantities with activity concentrations greater than 1 Bq/g based on sample measurement data. Instead, they derived the quantities by conservatively assuming unusual, accidental, or inadvertent introduction of radioactive sources and/or contaminated metals in excess of the 1 Bq/g limit into scrap metal earmarked for recycling.

Japanese steel mills also use cobalt-60 sources as a wear indicators for blast furnace refractory material. The contamination level of the steel produced by these blast furnaces is no greater than 10E-6 μCi/g (1 pCi/g, or about 0.03 Bq/g).[15] Although the Japanese consider the resulting dose rates to be trivial from a public health perspective, the presence of cobalt-60 in generally available materials interferes with the detection of low radiation levels.

Since contaminated steel is widely distributed, it is exceedingly difficult to find "pure" steel. Retrieval of pieces from sunken battleships and other vessels is one technique for obtaining "clean" metal used for the manufacture of whole-body radiation counters, film canisters and other products.[16] In one case, metal was recovered from an old battleship for use as shielding material for a whole-body radiation counter with a low detection limit.[17] The practice avoids the inclusion of radionuclides from atmospheric weapons testing, as well as cobalt-60 wear indicators, in these products.

Background Levels from Other Origins

Some materials may contain radioactivity from other origins. These sources of radioactivity include long-lived radionuclides associated with weapons testing, the nuclear power fuel cycle, and materials inadvertently recycled with scrap metals.[18] Such radionuclides may include plutonium (Pu-

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[15] Tominaga, A. et al., "Measurement of Traveling Time of Blast Furnace Burden with Co-60," *Tetsu to Kon 45*, p. 689, 1959.

[16] Personal communication with A. LaMastra, Health Physics Associates, Incorporated, August 30, 1993.

[17] Kato, S., Yamamoto, H., Kumazawa, S. and Numakunai, T., "Effects of Residual Radioactivity in Recycled Materials on Scientific and Industrial Equipments," JAERI-USEPA Workshop on Residual Radioactivity and Recycling Criteria, St. Michaels, Maryland, September 27-28, 1989.

[18] National Council on Radiation Protection and Measurements, "Environmental Radiation Measurements," *NCRP Report No. 50,*, Washington, DC, December 1976; and Dehmel, J.C., S. Cohen & Associates, Incorporated, and Rogers, V., Vern Rogers & Associates, *Diffuse NORM Waste: Waste Characterization and Preliminary Risk Assessment*, May 1993.

238, Pu-239, Pu-240, Pu-241), cesium (Cs-134, Cs-137), cobalt (Co-60), iron (Fe-55), zinc (Zn-65), zirconium (Zr-95), and uranium and thorium from equipment contaminated with naturally occurring radioactivity. As previously discussed, this last category in particular may originate from obsolete equipment being recycled as metal scrap at steel mills. Due to a lack of data, it is not possible to characterize the presence of such radionuclides and their respective concentrations in metals.

Risk from Background Radiation in Iron and Steel

Background levels of radiation in iron and steel are displayed in Exhibit H-7, based on the above discussion. We present only levels from NORM and sealed sources because we lack data on other potential sources of background radiation.

Exhibit H-7

ASSUMED BACKGROUND RADIONUCLIDE CONCENTRATIONS IN IRON AND STEEL

Radionuclide	Concentration (pCi/g)
U-238	<0.003
Th-232	<0.0027
Co-60	0.0027 - Germany 1.0 - Japan 20 - U.S. NRC

Utilizing the radionuclide concentrations presented in Exhibit H-7, we calculate the maximum individual and collective doses and risks from typical levels of radionuclides in iron and steel based on work conducted for EPA in 1997. These estimates are presented in Exhibit H-8.

Exhibit H-8 demonstrates that virtually all the dose and risk comes from cobalt-60. The naturally occurring contamination (U-238 and Th-232) contributes very little to the overall dose and risk. The results show that maximum levels in iron and steel could exceed a one or three mrem standard by six to 18 times; however, these levels are based on NRC's worst case assumptions regrading cobalt-60 contamination in steel. If more typical levels were used for cobalt-60, the resulting individual doses would be well below the one or three mrem standards. The collective impact shows that about one cancer and cancer fatality would result from the typical levels of radioactivity in iron and steel.

Exhibit H-8

INDIVIDUAL AND COLLECTIVE DOSE AND RISK FROM BACKGROUND RADIOACTIVITY IN IRON AND STEEL (annual, U.S. only)

Nuclide	Maximum Individual Dose (Mrem/yr)	Maximum Individual Risk (Cancer Incidence/yr)	Collective Dose (Person-rem)	Collective Risk (Total Cancer Incidence)	Collective Risk (Fatal Cancers Only)
U-238	8.7 E-04	1.0 E-10	29	7.44 E-03	4.62 E-03
Th-232	7.7 E-03	9.0 E-11	235	1.53 E-01	1.03 E-01
Co-60	18[a]	1.4 E-05	1,680[b]	1.27	0.852
Total	18	1.0 E-05	1,940	1.43	0.960

Notes:
Analysis assumes that 68 million tons of iron and steel are recycled per year.
a. Based on maximum value of 20 pCi/g.
b. Based on 85 percentile value of 0.0027 pCi/g.
Source:
S. Cohen and Associates, Incorporated, *Technical Support Document - Evaluation of the Potential for Recycling of Scrap Metals From Nuclear Facilities (Review Draft)*, prepared for the U.S. Environmental Protection Agency, July 15, 1997. Normalized risk conversion factors for maximum individual dose and risk are found in Exhibit 7-1; normalized collective dose and risk conversion factors are found in Exhibit 9-15.

Note that these are annual estimates resulting from background levels, and should not be confused with the estimates of collective risks from scrap released from nuclear regulatory controls in Exhibits H-2 and H-3, respectively. These earlier exhibits cover only one of many sources of radioactivity in metals, and consider a substantially longer time period (40 to 55 years)

RISKS ASSOCIATED WITH INCIDENTS

Radioactive sources are used in a wide range of industrial applications. As discussed previously, abandoned, lost, or stolen sources create the potential for widespread contamination and exposure of the public. A serious accident, which involved an abandoned teletherapy unit, occurred in Juarez, Mexico in 1983 (this incident, and its connection to the U.S., is discussed in Chapter Four). Individuals received doses as high as 700 rem while several thousand people received elevated doses. Individuals that received the higher doses experienced mild symptoms of radiation exposure but no acute radiation exposure fatalities occurred, primarily because the exposures were protracted over a period of time.[19] The NRC estimates that maximum individual doses from steel table bases and construction rebar contaminated with cobalt-60 from the incident were no more than 96 mrem from the table bases and 100 mrem (0.01 rem) from the rebar. In a separate incident in Taiwan, rebar contaminated by a melted cobalt-60 source exposed apartment dwellers to 120 rem doses.[20] These doses are listed in Exhibit H-9 along with the maximum individual risk. Individual cancer incidence and fatalities are calculated using the risk/dose conversion factors developed by EPA in 1994.[21]

Exhibit H-9

INDIVIDUAL DOSE AND RISK TO THE GENERAL PUBLIC FROM SELECTED ACCIDENTAL RADIOACTIVE SOURCE MELTINGS

Nuclide	Maximum Individual Dose (Rem)	Maximum Individual Risk (Cancer Incidence per Exposure)	Maximum Individual Risk (Fatalities per Exposure)
Co-60	Table Base = 0.096 (Mexico)	7.3 E-05	4.9 E-05
	Rebar = 0.100 (Mexico)	7.6 E-05	5.1 E-05
	Rebar = 120 (Taiwan)	9.1 E-02	6.1 E-02

The population-wide health impacts of lost sources are unknown in many cases, but a few studies have estimated maximum individual doses. In general, the impacts of these incidents can be divided into acute or chronic effects. The acute effects are a result of the very high levels of exposure received by people who come into contact with the sources before they are diluted to relatively low levels during melt recycling. The acute effects are generally limited to a few people that receive exposure in excess of 25 rem. Below 25 rem, there are no immediately apparent clinical

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[19] U.S. Nuclear Regulatory Commission, *Contaminated Mexican Steel Incident: Importation of Steel into the U.S. that Had Been Inadvertently Contaminated With Cobalt-60 as a Result of Scrapping a Teletherapy Unit*, Washington, D.C., January 1985.

[20] Although the Taiwan incident does not involve one of the six subject countries of this analysis, it provides insights into the acute risks that may result from an accidental melting. Yusko, J. G. 1995, "Radiation in the Scrap Recycling Stream," published in the proceedings of *The Third Annual Conference on the Recycle and Reuse of Radioactive Scrap Metal, Beneficial Reuse '95*. July 31 - August 3, 1995, Knoxville, Tennessee; and, Lubenau, J.O., and J.G. Yusko, 1998, *Radioactive Materials in Recycled Metals- An Update*, Health Physics, Vol. 74, No. 3, pp. 293-299.

[21] U.S. Environmental Protection, *Estimating Radiogenic Cancer Risk*, EPA 402-R-93-076, June 1994.

effects. Above 25 rem, a person may experience a depressed blood count. As the exposures increase, an individual may develop the classic radiation exposure syndrome, including nausea and vomiting. If the doses are high enough (above several hundred rem), the syndrome may prove fatal.

The chronic exposures are associated with the dilution of the source during melting at steel mills. After melting, the source may be diluted in large volumes of steel, and relatively small amounts are distributed widely in a variety of steel products. In this case, we are concerned with the time integrated collective health burden on the population due to the dispersal of the radioactive materials in steel products.

We estimate the average amount of source activity using the data base supplied by James Yusko at the Pennsylvania Department of Natural Resources.[22] Many of the reported activity levels were from meltings of cobalt-60 and cesium-137 sources. Exhibit H-10 presents the activity levels calculated from the Yusko data base.

Exhibit H-10

RADIOACTIVITY LEVELS IN THE AVERAGE MELTED SOURCE
(based on Yusko Database)

Nuclide	No. Of Sources	Min (Bq)	Max (Bq)	Average (Bq)
C0-60	14	0.074 E+9	15,000 E+9	1.25 E+12 (33.8 Ci)
Cs-137	16	0.74 E+9	1,000 E+9	3.7 E+10 (3.3 Ci)

We estimate collective impact for a typical source melting using the conversion factors found in Exhibit 9-15 of SC&A's 1997 report and an average source activity. The estimates of collective impact are listed in Exhibit H-11.

[22] See Chapter Four for more detailed information on the Yusko database. The analysis presented in this Appendix is based on an older version of the database than the analysis presented in Chapter Four.

Exhibit H-11

ESTIMATED COLLECTIVE DOSE AND RISK TO THE GENERAL PUBLIC FROM ACCIDENTAL RADIOACTIVE SOURCE MELTING

Nuclide	Average Source Activity (Ci)[a]	Collective Dose (Person-rem)	Collective Risk (Cancers)	Collective Risk (Fatalities)
Co-60	33.8	3.41 E+05	259	173
Cs-137	3.3	3.1	2.1 E-03	1.4 E-03
Total		3.41 E+05	259	173

Average activity calculated by using data from 65 incidents discussed in the Yusko database.

These impacts are based on the assumption that an average source is melted and the entire amount of radioactivity in the source is released into products, byproducts, and environmental media. Since cobalt-60 remains with the melt while cesium-137 separates into the ash, impacts from cobalt-60 are greater. Exhibit H-11 demonstrates that about 260 cancers and 173 cancer fatalities would arise from a typical incident, assuming that the radioactivity is emitted into the environment unnoticed and unchecked.

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