

US EPA ARCHIVE DOCUMENT

## CHAPTER 7      Assessment of U.S. Balance of Trade And Strategic Metals Issues And Their Relationship To Metals Recovery Of Hazardous Waste

Metal recovery of secondary materials provides a number of important benefits to the United States. Metal recovery from secondary materials can offer a comparative advantage in energy savings over primary mining and mineral processing operations (though it may not do so in every situation). Metal recovery of secondary materials may also result in a lower generation of solid residuals when compared with primary mining and mineral processing operations. EPA has included examples of these benefits in the Inmetco case study in Chapter 6. This Chapter reviews two additional benefits provided by metal recovery of hazardous waste: 1) reduction in U.S. balance of trade deficits for metal commodities, and 2) alternative sources of supplies of strategic metals such as chromium.

As mentioned below, a 1980 GAO report completed in 1980 indicated that substantial quantities of metal values were being lost through the disposal of industrial wastes. The GAO estimate indicates that at least one third of our current balance of trade deficit for metals could be addressed through metal recovery of secondary materials, many of them hazardous wastes. Metal recovery of hazardous wastes may also be an important part of a strategy to minimize U.S. vulnerability to supply disruptions of strategic metals. Preliminary data indicates that land disposed hazardous wastes may contain a substantial quantity of chromium, a strategic metal used as an alloy in steel production.<sup>146</sup>

### 7.1. U.S. Mineral and Metal Commodity Balance of Trade

In authorizing RCRA, Congress recognized the importance of material recovery as one means of reducing the balance of trade deficit and dependence on foreign sources for materials:

"The Congress finds with respect to materials, that- 1) millions of tons of recoverable material which could be used are needlessly buried each year; 2) methods are available to separate usable materials from solid waste; and 3) the recovery and conservation of such materials can reduce the dependence of the United States on foreign resources and reduce the deficit in its balance of payments" 42 U.S.C. §6901(c) [RCRA §1002(c)].

Balance of trade is the net flow of goods (i.e., exports minus imports) between one country and other countries. It can be measured as the movement of a single good, a group of goods, or all goods between two countries (e.g., the U.S. and Japan) or as the flow of a specific good (e.g., copper) between the U.S. and all other countries. Considering trade balance from the latter perspective, a country is said to be running a surplus for a specific metal, say copper, when the value of its copper exports are greater than the value of its copper imports. Conversely, when the value of a country's copper imports exceed the value of its copper exports, the country is running a trade deficit for copper.

There are a number of problems with running a trade deficit. First, if the deficit is sufficiently large, the country running the deficit may be vulnerable to supply disruptions from the country running the surplus when the commodity in question is one of critical use and substitutes or alternate sources of supply are limited. An example is the Arab Oil Embargo of 1973. Oil from the Middle East was critical to the U.S. economy and petroleum prices in the United States skyrocketed when the supply of oil from the Middle East was disrupted. When either substitutes for the commodity are readily available or its value to the economy as a whole is minimal, there is little risk of significant economic impact. Trade deficits of metal commodities that are of critical use to the U.S. economy is discussed in Section 7.2 on strategic materials.

There are also some potential problems associated with running a prolonged balance of trade deficit in all goods with the rest of the world, as the United States has done over the last decade. When a country imports a greater value of goods than it exports, it must pay for its trade deficit by either selling assets, drawing down foreign reserves, or by borrowing the needed foreign currencies. All three methods have been used in recent years. Various U.S. assets have been sold to foreign buyers, including many very competitive corporations and large tracts of prime commercial and residential real estate. The profits and benefits generated from those assets are now being transferred to their foreign owners, as the United States continues to finance its trade deficit by selling portions of its wealth.

The U.S. has also financed its trade deficit by borrowing from foreign creditors. Since 1980, the United States has gone from being the world's largest creditor to the world's largest debtor. That is to say, in 1980 the United States was collectively owed more money by the rest of the world than any other nation, while currently it owes more money to the rest of the world than any other nation. The United States has had to pay substantial amounts of interest to its foreign creditors, and this trend will continue for the foreseeable future.

The significant amount of U.S. currency that is owed to foreign creditors makes the United States vulnerable to sudden shifts in demand for the dollar. If foreign creditors decide to shift their holdings to another foreign currency, such as one yielding higher interest rates, then the U.S. must respond by either raising interest rates and risking a recession or by allowing the value of the dollar to fall relative to other foreign currencies, this makes imports still more expensive. Either response would require painful economic adjustments.

Finally, one short term effect of running a sufficiently large balance of trade deficit is a loss of jobs domestically and decreased earnings of the domestic industry. Any significant reduction in U.S. balance of trade deficit will help to decrease our foreign debt and reduce the need to fund imports with the sale of productive assets or debt instruments.

The balance of trade issue then is really a series of problems stemming from a common source. The first problem mentioned above is excessive reliance on foreign sources of a specific commodity. The term "net import reliance" is generally applied when discussing the balance of trade for a single good. Net import reliance, as the name implies, refers to the level at which a country is dependent on other countries for its supply of a commodity. That is, it is the amount of a commodity that a country must import, minus any exports, and minus the amount of domestic production or stockpiling of the commodity, to meet the manufacturing and consumption needs of the country.

The U.S. presently has a net import reliance of 100 percent for three metals (arsenic, manganese, and columbium (a.k.a niobium)). The U.S. also runs high trade deficits for chromium, cobalt, nickel, platinum group metals (PGMs), tungsten, tantalum, and tin. As mentioned in the next section, the significance of this reliance varies from commodity to commodity.

The second problem stemming from balance of trade deficit is the amount of U.S. currency accumulating in foreign countries. The actual cost of U.S. trade deficits or the U.S. net import reliance for the first and second tier mineral and metal commodities, based on the difference between import and export values for each commodity, is estimated to be approximately \$9 billion.<sup>147</sup> This data is summarized in Table 7.1 on the next page. This estimate is based on primary mineral and metal commodities and excludes both imports and exports of manufactured goods containing the metal (manufactures), wrought metals and other forms that are secondary in nature such as pigments and chemicals. The five commodities with the highest net import reliance cost are iron and steel, platinum group metals, nickel, copper, and bauxite and alumina, respectively.

The value of U.S. exports exceeds that of imports for 6 of the 23 minerals included in this report. The U.S.'s most valuable metal export is aluminum; however, the U.S. imports a substantial quantity of alumina and bauxite to produce the aluminum. Aluminum is followed in net value by molybdenum, magnesium, lead, vanadium, and mercury.

U.S. manufacturing industries may be able to make greater use of metal recovery from hazardous waste streams to minimize both problems of overreliance on foreign metals and accumulation of U.S. currency by foreign entities. Although the U.S. does not have large domestic reserves for high net import reliance metal commodities such as chromium, cobalt, nickel and tungsten, there may well be recoverable levels of these metal in hazardous (and nonhazardous) waste streams. Further research would be required to assess the viability of this approach.

Table 7.1 Comparison of Value of U.S. Mineral and Metal Imports and Export 1991<sup>2</sup>

Metal or Mineral <sup>3</sup>	Value of Imports	Value of Exports	Estimated Cost of U.S. Net Import Reliance <sup>4</sup>
1. Iron and Steel	\$9,135,492,000	\$3,673,404,000	\$5,462,088,000
2. Aluminum	\$2,268,296,000	\$3,356,065,000	(+) \$1,087,769,000
3. Platinum	\$1,742,866,000	\$461,588,000	\$1,281,278,000
4. Copper	\$1,257,212,000	\$306,873,000	\$950,339,000
5. Bauxite/Alumina	\$1,127,206,000	\$417,515,000	\$709,691,000
6. Nickel	\$1,123,536,000	\$91,359,000	\$1,032,177,000
7. Zinc	\$726,959,000	\$281,229,756	\$445,729,244
8. Manganese	\$614,174,000	\$39,397,000	\$574,777,000
9. Chromium	\$293,860,000	\$18,439,000	\$275,421,000
10. Cobalt	\$181,650,000	\$30,683,000	\$150,967,000
11. Tin	\$163,637,000	\$5,455,000	\$158,182,000
12. Lead	\$74,100,000	\$95,141,000	(+) \$21,041,000
13. Magnesium	\$72,955,000	\$129,980,000	(+) \$57,025,000
14. Magnesium Compounds	\$67,815,000	\$58,250,000	\$9,565,000
15. Columbium	\$46,173,000	\$7,007,000	\$39,166,000
16. Tantalum	\$32,071,000	\$27,894,000	\$4,177,000
17. Silver	\$29,399,000	\$8,535,000	\$20,864,000
18. Arsenic	\$17,219,000	0	\$17,219,000
19. Molybdenum	\$16,388,000	\$136,521,000	(+) \$120,133,000
20. Selenium	\$15,630,000	\$1,939,000	\$13,691,000
21. Cadmium	\$7,928,000	\$218,000	\$7,710,000
22. Vanadium	\$6,310,000	\$17,755,000	(+) \$11,445,000
23. Mercury	\$301,000	\$3,144,000	(+) \$2,843,000
<b>Total</b>	<b>\$19,021,177,000</b>	<b>\$9,168,391,756</b>	<b>\$9,852,785,244</b>

<sup>2</sup> Manufactured and secondary materials are not included.

<sup>3</sup> Metal and mineral estimates have the following exclusions. Iron and steel includes steel mill products and pig iron. Aluminum estimates include crude and semicrude; excludes manufactured materials. Copper estimates include semifinished and unmanufactured, but not scrap. The value of bauxite and alumina imports listed does not include the value of crude and dried bauxite which accounts for 11,793,000 metric tons of total quantity. Estimates for the value of this material were not available. Nickel estimates exclude secondary and wrought products. Manganese estimates exclude chemicals. Chromium estimates exclude chemicals and pigments and preparation-based chromium. Cobalt estimates exclude wrought metals. Tin estimates exclude manufactures, tin plate and tin plate scrap. Lead estimates exclude pigments and compounds. Magnesium estimates exclude waste and scrap. Silver estimates exclude bullion (refined) and waste and scrap. Arsenic estimates include arsenic metal and trioxide. Molybdenum estimates exclude wrought material and wire. Vanadium estimates exclude vanadium-bearing materials.

<sup>4</sup> (+) indicates that there is a trade surplus for the commodity.

Metal recovery of hazardous wastes may also alleviate a substantial portion of the balance of trade deficit for metal commodities. Previous studies indicate that substantial quantities of metals are available in industrial wastes (hazardous and non-hazardous). In 1980, the General Accounting Office (GAO) reported that approximately 10 million tons of minerals with a market value of \$3 billion (1980 dollars) were lost in industrial waste streams<sup>148</sup>, mostly copper, iron and aluminum with smaller quantities of zinc, chromium, tin, lead, manganese and nickel. This represents about a third of the U.S. total balance of trade deficit attributable to metals.

Copper, iron, lead, and zinc tend to be the highest concentration metals found in hazardous waste streams. Often these metals are recovered through various pyrometallurgical processes. However, most metal-bearing hazardous waste streams will also contain significant concentrations of one or more of the following: arsenic, cadmium, chromium, magnesium, manganese, and nickel. According to some studies, these metals only need to be present at concentrations of 1 percent to make recovery economically feasible from slags, and recovery of much lower concentrations are technically and economically feasible from more dilute wastes such as plating waste effluent.<sup>149</sup>

Given the dramatic change in the manufacturing sector from high volume applications of metals to more refined, high technology applications, such as composites and specialty alloys, recovery and use of metals from metal-bearing waste streams is an increasingly realistic possibility and should be considered as a potential metal supply.

Currently, data limitations on characterizing metal-bearing hazardous wastes represent a significant barrier to providing technical assistance to industry about metal recovery alternatives. Significant quantities of metal-bearing secondary materials such as characteristic sludges and by-products being reclaimed are not subject to reporting requirements that would allow EPA to analyze their potential in ameliorating the metal trade deficit. The data that has been gathered needs to be validated, updated, and expanded so that it is possible to accurately match waste streams with available recovery technologies and provide technical assistance to generators of metal-bearing waste streams to assist these generators in identifying recovery alternatives.

Further research also needs to be pursued regarding the actual level of metals presently recovered from the metal-bearing hazardous waste streams. Reliable and consistent data on the quantities of metal-bearing waste streams that are sent to recovery versus treatment and disposal are sparse. The availability of this information would afford a better idea and increased confidence of the availability of recovered metals and would assist in expanding recovery technologies as alternatives to treating and disposing metal-bearing wastes.

In spite these data limitations, it appears on the basis of available information that metal recovery of hazardous wastes can play a useful role in maintaining the health and competitiveness of the U.S. economy.

## 7.2 Strategic Metals

In May 1985, the Congressional Office of Technology Assessment (OTA) issued a report entitled Strategic Materials: Technologies to Reduce U.S. Import Vulnerability. A strategic material is defined by OTA as:

"[a material] for which the quantity required for essential civilian and military uses exceeds the reasonably secure domestic and foreign supplies, and for which acceptable substitutes are not available within a reasonable period of time."<sup>150</sup>

Therefore, a strategic material is defined by both the critical nature of its use and the vulnerability of its supply. This report identified four strategic metals (chromium, cobalt, manganese, and platinum group metals) as critical to the U.S. industrial sector, based on each metal's importance to U.S. manufacturing industries, the level of domestic production, and the potential for disruptions in the supply of each metal to U.S. markets. These four metals will be referred to herein as "first tier" metals.

Currently, there is little or no domestic production of these metals and production during the period covered by the OTA report was centered in the Soviet Union, South Africa, and Zaire. Chromium, cobalt, manganese, and platinum are essential in the production of high-temperature alloys, steel and stainless steel, industrial and automotive catalysts, electronics, and various other applications critical to the U.S. economy and national defense.

The OTA report also identified eight "second tier" metals that are critical to U.S. manufacturing but are not as open to import vulnerability as first tier metals. These include bauxite/alumina, beryllium, columbium, futilite, tantalum, tin, titanium sponge and vanadium. Data for these metals will be presented where available, but only the first tier metals will be discussed in detail.

The OTA report identified potential approaches to decreasing import vulnerability for first tier metals. These approaches are centered on increasing the diversity of supply of strategic metals through the development of promising deposits throughout the world; decreasing the demand for strategic metals through improved manufacturing and recycling; and identifying and testing substitutes and new materials that could replace strategic metals in one or more of their primary uses. For a detailed discussion of these alternatives refer to the original OTA report.

Reclamation of the first tier metals from metal-bearing hazardous waste streams is a possibility and chromium and platinum group metals are routinely recovered from certain waste streams. However, treatment and disposal of metal-bearing waste streams is still the norm despite the high value of many of these metals and the potential for supply disruptions. Recovery opportunities may also exist for certain second tier metals such as beryllium and vanadium.

OTA also suggested that the U.S. establish an economic stockpile of critical metals. A National Defense Stockpile of strategic materials exists, but this is not available to industry when supply is disrupted by international events that do not threaten U.S. national security. The Pentagon is seeking to reduce this stockpile by selling approximately \$2 billion of materials; hence, it seems unlikely that government support is available for the creation of an economic stockpile of critical metals. This stockpile is discussed below.

The following section will provide an update of the information contained in the OTA report and discuss to what extent the recommendations of the OTA report have been met through 1) an analysis of U.S. apparent consumption of the metals, 2) U.S. net import reliance for the metals, and 3) a discussion of the National Defense Stockpile, its current status and how it may differ from strategic materials issues generally. Throughout the section, available information on metal-bearing waste streams containing strategic metals and possible opportunities of additional recovery are discussed.

### *7.2.1 U.S. Apparent Consumption Of Strategic Metals*

Apparent consumption is defined as total imports minus exports plus domestic production and increases in the quantity of domestic stocks and inventories. Apparent consumption is a useful indicator of the demand for a given metal by industry. Table 7.2<sup>151</sup> shows U.S. apparent consumption of the metals identified in the OTA report (bauxite, beryllium, chromium, columbium, cobalt, manganese, platinum group metals, rutile, tantalum, tin, titanium sponge, and vanadium).<sup>152</sup> This table shows the average apparent consumption in the U.S. for the periods 1978 to 1982 (the period covered by the OTA report) and 1988 to 1992, as well as the percent change in apparent consumption between those two periods. The averages provide a more accurate picture of U.S. change in consumption than any single-year figures because the averages help to ameliorate single-year anomalies.

As Table 7.2 shows, U.S. apparent consumption decreased for seven of the first and second tier metals since the period covered by the OTA report, and increased for the other six. Apparent consumption for manganese, one of the four first tier metals, has decreased substantially, with a decrease of nearly 50 percent. Chromium consumption has also decreased, although not so substantially. Apparent consumption of cobalt and platinum-group metals, the remaining first tier one metals, has increased 3 percent and 28 percent, respectively. Platinum-group metals showed the largest increase in apparent consumption of the first and second tier metals. The following paragraphs provide explanations for these changes with a discussion of developments in U.S. consumption patterns, use of substitute materials, and recycling.



**Table 7.2 U.S. Apparent Consumption of OTA Tier 1 and Tier 2 Metals--Selected Years (Metric Tonnes)**

Mineral or Metal	Annual Average Apparent Consumption (1978-1982)	Annual Average Apparent Consumption (1988-1992)	Percent Change
Platinum	79	110	28.0
Rutile	252,015	348,000	27.6
Columbium	3,262	3,425	4.8
Cobalt	7,252	7,522	3.6
Chromium	474,637	447,400	-6.1
Bauxite and Alumina	5,166,600	4,696,800	-10.0
Tin	56,428	49,488	-14.0
Beryllium	245	197	-24.4
Tantalum	550	387	-42.2
Manganese	969,050	649,000	-49.3
Vanadium <sup>1</sup>	7,773	4,129	NA
Titanium <sup>2</sup> Sponge	21,711	20,622	-5.3

<sup>1</sup> 88-92 figure is reported consumption, <sup>2</sup> reported consumption

### Chromium

Average apparent consumption of chromium decreased very little during the period. This is most likely due to the fact that, although there exist substitute materials for most uses of chromium, these substitutes are often less desirable. Chromium is used for many highly specialized and sensitive applications. Close substitutes for chromium are generally much more expensive than chromium and result in an inferior product. In other cases, the alternative may have more severe environmental repercussions, such as substituting creosote in wood preserving for chromium-copper-arsenic. There are a few areas, however, where decreases in chromium consumption will be seen and should be pursued to the greatest extent possible. Domestic use of chromium as a corrosion inhibitor may begin to decrease as the military budget is pared and the demand for corrosion resistant pigments for land and air military vehicles decreases.

Stainless steel must contain at least 10.5 percent chromium before it attains its corrosion resistant properties. After this point the chromium content is a function of the desired level of corrosion resistance. Chromium is the least expensive alloying element. Therefore, after the 10.5 percent chromium alloy is attained, other metals such as molybdenum or nickel can be added to stainless steel without diminishing the desired properties of the alloy. However, substituting other metals for chromium in stainless steel can be done only at a higher price. On the other hand, manufacturers of heat exchangers, chemical-storage tanks, reactors, boilers, and other process equipment made from stainless steel are turning to stainless steel alloys that can withstand higher temperatures and pressures. These superaustenitic stainless steels are alloys of nickel, chromium, iron, copper, and molybdenum, and may contain less chromium than conventional stainless steel.

Changes are occurring in the market for chromium in other areas as well that will cause future reductions in apparent consumption. Chrome yellow pigments used in paint and printing inks are facing increased environmental regulation because the toxic heavy metal chromium has the potential to leach from the paint or a landfill and accumulate in water supplies. Hence, various substitutes, such as a pigment blend of organic hansa and inorganic titanium dioxide, are coming into the market. Also, many state regulations have recently gone into effect banning the introduction of, among other things, hexavalent chromium in packaging. In 1989 EPA banned the use of chrome for inhibiting corrosion in comfort cooling towers, (e.g., commercial air conditioners and refrigeration systems). Thus, manufacturers have been forced to turn to substitute materials.

Recycling has decreased chromium consumption to some extent. Secondary chromium is recovered from stainless steel scrap and presently accounts for 26 percent of chromium demand. In 1982, recycling of purchased scrap (primarily prompt and obsolete scrap) accounted for 12 percent of domestic chromium demand. The potential for chromium recovery from metal-bearing hazardous waste streams is the highest of the four first tier metals. Chromium is found in high concentrations in wastes from chromium pigment and iron blue production, electroplating, ferroalloy production, and petroleum refining. Chromium is recovered from these wastes, but available data suggest that many chromium-bearing waste streams are still treated and disposed.

Given the importance of chromium as a corrosion inhibitor and given the fact that chromium is less expensive than other alloying agents, the most effective means of reducing chromium consumption will be 1) removing chromium from pigments when it is not absolutely necessary for corrosion resistance; 2) improving the efficiency of production processes, especially those in the electroplating industry; 3) promoting the use of alloys using a greater mix of metals; and 4) recovering chromium from all potential sources. These practices are clearly underway; however, many chromium-bearing resources, such as metal-bearing hazardous waste streams, remain comparatively underutilized.

## Cobalt

Table 7.3 shows a slight increase of approximately 3 percent in cobalt consumption since the 1985 OTA report. Superalloys account for the largest single use, about 40 percent, of cobalt consumption. Superalloys are high performance metals able to withstand high temperatures, high stress, and corrosion. The market for superalloys has been somewhat depressed by the recession of the early 1990s; however, consumption of cobalt in superalloy production has more than tripled since the 1960s.

Rapid increase in the price of cobalt in the early 1980s and again in the early 1990s due to political unrest in Zaire, the world's largest cobalt producer, helped to keep the consumption of cobalt from increasing more. Continued turmoil in Zaire caused many manufacturers to invest in research for identifying cobalt substitutes during the 1980s. During the early 1980s, some substitution did take place in the superalloy market with alternative alloys, such as Inco 718, coming into use.

The largest market for superalloys is jet engines. With the continuing decrease in military budgets, the slowdown in production of commercial airplanes, and the increased use of composite materials in aircraft design, demand for cobalt in the jet engine market should stay at approximately 1992 levels even as the U.S. manufacturing sector recovers from the recession. One report suggests that composite use in civil transport in the year 2000 will have grown from today's 7% to about 25% of structural weight per airplane.<sup>153</sup>

An historically large market for cobalt, accounting for about 10 percent of cobalt consumption, has been the production of cobalt-samarium magnets. Cheaper and stronger neodymium-boron-iron magnets, however, have been developed. Although not as corrosion-resistant as cobalt-samarium magnets, the neodymium-boron-iron magnets have rapidly replaced cobalt-samarium magnets in the production of office and telecommunications equipment.

Recovery of cobalt from secondary sources can play an important role in protecting U.S. industries from potential disruptions in the supply of cobalt. Cobalt can be recovered from a variety of sources, including superalloy production scrap, superalloy scrap (e.g., used jet engine parts and dismantled jet engines), spent petroleum catalysts, homogenous catalysts from the chemical processing industry, and used cemented carbide wear parts and tool inserts. Cobalt from scrap represents approximately 15 to 20 percent of U.S. consumption. Scrap cannot replace all uses of cobalt metals, particularly high-grade metal superalloys. Two metal reclaimers in the U.S. presently process spent petroleum catalysts to recover, among other constituents, cobalt as a mixed cobalt-nickel residue or alloy. Most metallurgical industries in the U.S. have well established cobalt recycling or recovery practices in place.

According to a report prepared by the U.S. Bureau of Mines, economic factors, such as metal prices, costs of scrap collection and processing, will continue to influence whether cobalt-bearing materials are recycled, downgraded, or landfilled. The report also states that other economic and environmental factors, such as the cost of landfilling, were the driving force behind the initiation of metals recovery from spent petroleum catalysts during the past two decades. With environmental regulations becoming even more stringent and treatment and disposal costs rising, this will continue to be a factor.

### **Manganese**

The U.S. average apparent consumption of manganese has declined nearly 50 percent since the 1985 OTA report. This is primarily for two reasons. First, approximately 90 percent of U.S. consumption of manganese is in steelmaking. The recession and international competition have served to lessen demand for American steel. Beyond this, steelmakers have decreased their unit consumption of manganese in steelmaking. That is, for every ton of steel produced, fewer pounds of manganese are required. This increased efficiency, largely the result of such improved techniques as bottom blowing, has decreased unit consumption of manganese in steel manufacturing by almost 25 percent over the past decade.

The amount of manganese used in ferroalloys has also declined as producers shift from ferromanganese to silicomanganese, an alloy with a high percentage of silicone. Silicomanganese is preferred in the production of steel from scrap in electric furnaces because it is less expensive for smaller operations and the metallurgy of the continuous casting process favors silicomanganese. Many of these "mini-mills" have now expanded to where they are competing with the large, integrated steel producers, thereby increasing the demand for silicomanganese and cutting into the market for medium-grade ferromanganese.

In general, it is difficult to find an economically feasible substitute for manganese that does not lead to other problems in the metal product. For example, aluminum could replace manganese in some steel production, decreasing oxygen content in steel, but then the alloying effects of manganese, which bind impurities such as sulfur, are lost. Similarly, titanium, zirconium, vanadium, or columbium could all be used as substitutes for manganese in some capacity. However, the cost per desired effect of such substitution is high, which makes all of these alternatives much less cost effective than manganese.

In another example, the electric power generating industry is interested in almost zero-impurity steel for generator rotors. In this case, the steel must be refined so that sulfur and carbon levels are greatly reduced. This is achieved at a significantly increased cost. When the sulfur and carbon levels are extremely low, however, chromium can be used as a substitute for manganese. Unfortunately, this is simply substituting one first tier strategic metal for another.

According to the U.S. Bureau of Mines, the amount of manganese recovered from scrap is insignificant.<sup>154</sup> Considerable amounts of manganese reenters production as a minor component of steel scrap, steel slag, and nonferrous scrap. Such recycling of manganese does not lead to a progressive buildup in steelmaking. Therefore, although research should proceed pertaining to recovery of manganese, especially from non-traditional sources such as metal-bearing hazardous waste streams, the most promising means of reducing manganese consumption is the continued improvement in steelmaking efficiency.

Manganese is found in certain metal-bearing hazardous waste streams such as zinc smelting process wastewater and titanium chloride reactor slurry. These concentrations are generally low and probably would only contribute marginally to the high volumes necessary for steelmaking.

### **Platinum Group Metals**

Platinum group metals (PGM) are one the two first tier metals for which average apparent consumptions increased between the two periods covered by Table 10. Demand actually exceeded supply of PGMs for most of the late 1980s and early 1990s. Platinum, endowed with strong catalytic qualities, is now used in the manufacture of one in five consumer products.

The primary market for PGMs is catalytic converters. Increasingly strict automobile emission requirements, promulgated as part of the new Clean Air Act, have spurred the development and employment of catalytic converters using platinum group metals as emission catalysts. Palladium, a PGM, has become the metal of choice in new catalytic converter development. Although weakness in the U.S. automobile market may affect PGM demand, this area should be one of strong growth, consuming substantial quantities of PGMs.

As research on catalytic converters continues, improved production efficiency may reduce the amount of PGMs consumed in the production process. However, at present, more platinum is being used in catalytic converters. Research has been conducted to make catalytic converters more efficient, and perhaps less reliant on PGMs, but it appears that no immediate reduction in domestic demand for platinum is forthcoming. Constant demand appears likely since new catalytic converter development, for the most part, has only shifted emphasis from one PGM to another.

Electrical applications are the next largest market for platinum group metals, using PGMs in capacitors and resistors. The petroleum refining industry also uses PGMs in reforming, cracking, and isomerization reactions.

Platinum group metals are presently recovered from certain hazardous waste streams resulting from PGM use as a catalyst in petroleum refining. Because of their high value, PGMs are also routinely recovered from chemical catalysts, automobile catalysts, glass fiber bushings, electronic scrap, laboratory equipment, and other sources. Catalysts and PGM-bearing solutions can be processed to increase their grade for resale. As an increasing number of automobile catalysts and electronics parts are retired, more PGM-bearing waste streams will be available for PGM recovery. In 1991, the U.S. Bureau of Mines released a publication tracing the flow of PGMs through their metallurgical, catalytic, and chemical applications. This document highlighted areas in which significant issues arise involving downgrading, export, or disposal. To exploit recoverable sources and minimize losses of PGMs, the recommendations of this publication should be considered and implemented.<sup>155</sup>

Platinum recovery from hazardous wastes in the United States is currently being encouraged through the precious metal exemption in RCRA Subtitle C regulations (40 CFR Part 266 Subpart F). The provision conditionally exempts precious metal recovery from full Subtitle C regulation while retaining notification and recordkeeping requirements for storage.

### *7.2.2 U.S. Net Import Reliance of Strategic Metals*

Net import reliance as a percent of apparent consumption was an important criterion in OTA's designation of first tier metals in the 1985 report. Net import reliance measures the U.S. balance of trade in metals and the extent to which the U.S. is reliant on other countries for its supply of a given metal. Table 7.3 shows the U.S. net import reliance for metals identified in the OTA report.<sup>156</sup> As Table 7.3 indicates, average U.S. net import reliance decreased for chromium and cobalt between the periods of 1978 to 1982 and 1988 to 1992. Average net import reliance for manganese and platinum group metals increased between these periods. The following discussion addresses the changes that have occurred in world production and U.S. import sources for each first tier metal since the 1985 OTA report was published as well as the political situation in key producer countries that may impact future trade in a given metal.

When the OTA report was published in 1985, the Soviet Union, South Africa, and Zaire accounted for 67 percent of the world's production of chromium, cobalt, manganese, and platinum group metals. In 1991, Russia (USSR), South Africa, and Zaire still produced 64 percent of the world's supply of first tier metals. However, various other countries have begun to increase their output and, more importantly, the U.S. has begun the important process of reducing its reliance on these three countries for its supply of first tier metals.

Since publication of the 1985 OTA report, the U.S. has decreased its average net import reliance on chromium by over 14 percent. During the 1980s the U.S. was able to eliminate its reliance on Soviet (Russian) supplies of chromium and reduce its reliance on supplies from South Africa. Despite these efforts, however, the U.S. must continue diversifying its sources of chromium imports. Decreasing U.S. reliance on unstable supplies of chromium will be difficult given the limited number of countries producing chromium. To the extent it is possible, then, the U.S. must continue investigating chromium substitutes and new sources of recovered chromium.

**Table 7.3 U.S. Net Import Reliance for OTA Tier and Tier 2 Metals --Selected Years**

Metal	Annual Average Net Import Reliance (1978-1982) <sup>1</sup>	Annual Average Net Import Reliance (1988-1993)	Percent Change
Manganese	98.0	100.0	2.04
Bauxite	94.2	98.2	4.24
Cobalt	93.0	82.0	-11.82
Chromium	90.0	76.8	-14.66
Platinum	87.0	90.4	3.90
Tin	77.4	74.6	-3.61
Tantalum	93.0	86.0	-7.52
Columbium	100.0	100.0	0.00

<sup>1</sup>Expressed as a percent of apparent consumption

U.S. average net import reliance on cobalt decreased by almost 12 percent since publication of the OTA report, and as discussed earlier, consumption of cobalt has also decreased markedly. The U.S. decreased its reliance on Zaire for cobalt imports by 27 percent, due in part to greatly reduced Zairian output, while increasing the share of imports from Canada by 150 percent, from Zambia by 77 percent and from Norway by 57 percent. At present, the demand for cobalt has not revived from the recession and supply of cobalt, while important, isn't as critical as at other times. There is still a large supply of Russian cobalt that has been dumped on the market and the U.S. government is beginning to sell much of the cobalt in the national defense stockpile. Despite these supplies, the situation is critical enough in the primary cobalt-producing countries that the U.S. should work towards a sustained recycling program and further investigation of substitutes in alloying.

The United States is totally reliant on foreign sources of manganese. However, over the past decade the U.S. has radically altered the structure of import sources. Imports of manganese ore from South Africa were eliminated for the 1988-1991 period, reducing U.S. reliance on South Africa for manganese ore and ferromanganese by more than 50 percent since the early 1980s. This is quite significant, considering that South Africa increased their output of manganese between 1981 and 1991.

Perhaps as a result of expectations over the North American Free Trade Agreement, the U.S. increased manganese imports from Mexico by 80 percent. Manganese imports from Brazil also increased by 68 percent and imports from Gabon were up 55 percent. Although U.S. average apparent consumption of manganese has decreased significantly, the decrease in reliance on South African imports and increase in imports from Gabon, France, Mexico and Brazil seem to constitute positive steps toward smoothing potential supply disruptions, and may also contribute to improved relations between the U.S. and its trading partners in the Americas.

Platinum Group Metals represent a somewhat different case than the other three first tier metals. Because of their use as a catalyst in catalytic converters and increasingly stringent air emission regulations applicable to automobiles, PGM apparent consumption and net import reliance have both increased. Further, production of PGMs is almost exclusively centered in South Africa and the former-Soviet Union. At the end of 1992, Russian platinum output was running at 68% the 1991 rate. Recession in South Africa, low metal prices, and labor strife may disrupt PGM production in South Africa.

The U.S. decreased imports from the former-Soviet Union and South Africa by 19 percent and 11 percent, respectively, since publication of the OTA report, while imports from the United Kingdom increased by 45 percent. U.K. production of PGMs, however, is from ores originating in South Africa and Canada.

Given the extreme reliance on PGMs across the U.S. manufacturing sector and the tenuous nature of their supply, the U.S. must work toward fostering the recovery of secondary PGMs, increasing the use of substitutes, and investigating the alteration of production processes so that they are less reliant on PGMs. At present the U.S. accounts for almost 3 percent of world PGM production. The possibility of increasing domestic production and tailoring domestic manufacturing processes to use the PGMs produced domestically should also be investigated further.

The supply situation for chromium, cobalt, manganese, and PGMs has deteriorated since the 1985 OTA report with the deterioration of conditions in South Africa, the former-Soviet Union, and Zaire. Substitute materials are being pursued to reduce reliance on these metals but development is progressing at a slow pace and it may be a long time before such substitutes as composite materials have reached a level of uniformity where they are available for widespread use.



The most obvious track the U.S. should follow, then, to reduce its overall reliance on imported metal supplies is that which decreases demand for the metals. This can be accomplished through applying measures to increase U.S. production efficiency, recycling scrap material and recovering metals from alternative sources such as metal-bearing hazardous waste streams when such sources are available.

### *7.2.3 National Defense Stockpile*

In addition to the basic commercial need for strategic materials to the U.S. economy, these materials have specific application to the Nation's defense. Its importance has declined somewhat with the end of the Cold War. However, conservation of these materials in hazardous and nonhazardous waste streams may be one strategy to ensure our national security in the event that need arises.

Under the Strategic and Critical Materials Stock Piling Act of 1946, the Department of Defense (DOD) has maintained a stockpile of strategic and critical materials to sustain military, industrial and essential civilian needs during a 3-year conventional global war. At the end of 1992, the stockpile contained 99 strategic and critical materials worth approximately \$9 billion. This Act was amended by the Defense Authorization Act of 1993 (hereafter referred to as the Act), and DOD is currently in the process of downsizing the stockpile to reflect the changes caused by the dissolution of the Soviet Union, although the value of the stockpile will still contain many metals which have been discussed as candidates for recovery from hazardous waste streams. Increasing our domestic supply of strategic and critical materials, and thus mitigating the reliance on potentially instable import sources, is a major objective of the Act.

The Act defines strategic and critical material to include materials that would be needed to supply the military, industrial, and essential civilian needs of the United States during a national emergency and are not found or produced in the United States in sufficient quantities to meet such needs. A national emergency means a general declaration of emergency with respect to the national defense made by the President or by the Congress.

A 1992 report by the General Accounting Office (GAO) determined that the disposal of six materials from the stockpile could be considered a high risk from a national security perspective based on a sensitivity analysis of the reliability of the source country. These metals were antimony, refractory grade chromite, iridium, palladium, platinum and tungsten. Furthermore, the GAO considered the sensitivity analysis of country reliability to be the most influential factor in yielding high stockpile requirements for a material. Therefore, increasing the domestic supply of all strategic and critical materials would be the most beneficial towards increasing national security.

Section 8 of the Act recognizes the need for increasing the domestic supply of materials, and supports the rationale for the increased recovery of metals from hazardous waste streams. The section states that the President shall make scientific, technological, and economic investigations concerning the development, mining, preparation, treatment, and utilization of ores and other mineral substances that are found in the United States in inadequate quantities or grades, and are strategic material. Such investigations shall be carried out in order to determine and develop new domestic sources of supply of such ores and mineral substances and develop substitutes for such essential ores and mineral products

#### ***7.2.4 Conclusion: Strategies To Increase Opportunities For Strategic Metal Recovery From Hazardous Wastes***

For the United States to take advantage of additional supplies of strategic metals in hazardous wastes, several steps may be necessary. First, hazardous waste streams that contain recoverable levels of strategic metals should be identified. To date, comprehensive analysis has not been completed on which hazardous waste streams contain recoverable levels of strategic metals. Second, technical, economic and regulatory barriers to recovery of these materials must be determined and analyzed to develop strategies to remove these barriers. Third, cost-effective incentives that are environmentally protective would need to be implemented. Generator concerns of compliance cost and long term liability would need to be addressed in the development of these incentives. Finally, end markets for secondary strategic metals would need to be developed and encouraged by the Federal government through procurement, subsidies, grants or other means. The opportunity for strategic metal recovery of hazardous waste may depend largely on the specific metal being recovered.

Chromium recovery has the greatest potential for strategic metal recovery due to its prevalence in hazardous waste streams. And while Inmetco (the case study respondent in Chapter 6) is recovering ferrochrome alloy from chromium-bearing K061, there are probably substantial quantities of other chromium-bearing wastes that are amenable to recovery. Data presented in Chapter 3 indicates that characteristic chromium waste, D007, accounts for over 3 million tons, by far the leading quantity of any single metal-bearing hazardous waste stream. While only a portion D007 contains recoverable levels of chromium, the total mass of recoverable chromium in these wastes may be substantial. Chromium may also be available in plating wastes such as F006, the second largest metal-bearing waste stream identified in Chapter 3. Further research on chromium recovery of hazardous waste is warranted.

As mentioned above, platinum recovery from hazardous waste streams is already being encouraged through the precious metal exemption in RCRA Subtitle C. However, precious metal industry representatives remain concerned that RCRA Subtitle C may be discouraging precious metal recovery by subjecting precious metal recovery operations to hazardous waste manifesting requirements.

Less is known about the potential for cobalt and manganese recovery in hazardous waste streams. Scrap and non-hazardous waste streams may be the most likely source of these metals. Cobalt is believed to exist in recoverable levels in spent petroleum catalysts which may be nonhazardous. As with chromium, additional research may be warranted.

## Chapter 8 Encouraging Environmentally Sound Metal Recovery

The second issue Congress asked EPA to study is how metal recovery can be encouraged. The regulated community has provided a series of proposals reviewed above in Chapter 5. The case studies in Chapter 6 provide insight about specific RCRA Subtitle C regulatory provisions that might be modified to facilitate metal recovery in the United States. This Chapter reviews current EPA activities that may encourage environmentally sound metal recovery of hazardous waste including the Hazardous Waste Identification Program and the Definition of Solid Waste Task Force. This Chapter also reviews a series of non-regulatory alternatives such as waste exchanges and incentive-based alternatives to traditional command and control regulation such as pollution taxes and marketable permits.

### 8.1 Current EPA Activities Encouraging Environmentally Sound Metal Recovery of Hazardous Waste

EPA is currently conducting three activities (one initiative and two rulemakings) that will affect metal recovery of hazardous waste: the Definition of Solid Waste Task Force (Task Force), the proposed Part 273 Special Collection System regulations, the proposed universal treatment standards for metal constituents in hazardous wastes. While none of these activities was established solely to promote metal recovery of hazardous waste, each initiative will play an important role in modifications to Subtitle C regulation affecting metal recovery.

#### 8.1.1 *Definition of Solid Waste Task Force*

On October 1, 1992, EPA's Office of Solid Waste (OSW) established the Definition of Solid Waste Task Force (Task Force). The Task Force was created to develop a comprehensive strategy to modify Subtitle C regulation to simplify the current regulatory scheme, to reduce disincentives to safe recycling and innovative technologies and to address concerns about increased risk from expanded use of products derived from hazardous wastes.

The Task Force has been established to conduct followup to prior definition of solid waste activities including the RCRA Implementation Study (July 1990), RCRA Forums (November/December 1990) and the RCRA Implementation Study Update (July 1992). Since its inception, the Task Force has conducted important public outreach with various stakeholders on Subtitle C regulatory issues includes industry, environmental groups and state governments.

In completing this outreach, the Task Force has built upon the previous EPA initiative mentioned above through the consideration of options to modify the definition of solid waste in order to encourage environmentally sound recycling. These options have included modifications to RCRA jurisdiction and regulatory requirements over secondary materials, including metal-bearing secondary materials, to better optimize RCRA's dual objective of resource recovery and environmental protection.

One option currently under consideration include establishing a new recycling system that tailors management requirements to the type of recycling, e.g., dividing recycling into categories based on the source of the recyclable materials and the recycling location. In evaluating all of the options, the Task Force has relied on several key operating principles for recycling under RCRA jurisdiction:

- Safe recycling operations use equipment designed to prevent releases of hazardous constituents to the environment, especially groundwater.
- Recyclers must quickly and effectively respond to releases of hazardous constituents that occur despite these prevention measures.
- Government regulators must know the identity of recycling facilities and basic recycling data to enforce compliance with the appropriate management standards.
- An effective regulatory system must assure safe transportation and tracking of secondary materials from "cradle to grave."
- Waste-derived products must pose no more threat to human health and the environment than the virgin products they replace or compete with.
- The community surrounding a recycling facility should be notified if the facility will be receiving and recycling hazardous waste generated at another facility.

### ***8.1.2 Part 273 Special Collection System Regulations***

Recently, EPA proposed a rulemaking (58 FR 8102, February 11, 1993) to establish a streamlined set of regulatory requirements for collection of certain hazardous wastes such as batteries and certain recalled pesticides that may be widely distributed in commerce, generated by a large number of users, and problematic in municipal solid waste streams. These proposed requirements known as Part 273 or Special Collection System regulations are designed to facilitate collection of batteries, certain recalled pesticides and possibly other "universal" hazardous wastes to ensure proper management prior to recycling or treatment/disposal. Part 273 would facilitate collection in part by simplifying requirements (such as reduced recordkeeping and reporting requirements) for generators, transporters and owner/operators of interim storage facilities known as "consolidation points"). Part 273 would also facilitate collection through lower compliance costs (e.g., use of a non-hazardous waste hauler for some shipments; operation of a consolidation point without a storage permit).

Although Part 273 was not specifically proposed to encourage metal recovery in particular, when final it may facilitate metal recovery of certain metal-bearing hazardous waste such as hazardous waste batteries and other mercury-containing wastes such as thermostats by removing disincentives to collection and consolidation. For many of these wastes (cadmium-containing batteries, lead-acid batteries, high category mercury containing batteries and mercury-containing thermostats), thermal recovery is already required under the Land Disposal Restriction program. Part 273 would improve the efficiency of collecting these wastes prior to recovery. Potentially, in the future Part 273 could be applied to other metal-bearing hazardous waste streams that may be appropriate for recovery.

### *8.1.3 Universal Treatment Standards for Metal Hazardous Constituents*

On September 14, 1993 (58 FR 48092) EPA has proposed a rulemaking that would establish uniform performance-based treatment standards, called "universal treatment standards" under the Land Disposal Restriction (LDR) program for 14 metals: antimony, arsenic, barium, beryllium, cadmium, chromium, lead, mercury, nickel, selenium, silver, thallium, vanadium and zinc. Currently, metal constituents present in different hazardous wastes may be required to be treated to different levels depending upon what type of hazardous waste the constituent is part of.

For example, cadmium present in D006 nonwastewaters, waste which exhibits the toxicity characteristic for cadmium, must be treated to the characteristic level of 1 ppm prior to being land disposed while cadmium present in F006 nonwastewaters, wastewater treatment sludge from electroplating operations, must be treated to 0.066 ppm prior to land disposal. Under proposed universal treatment standards, cadmium present in either D006 or F006 nonwastewaters would need to be treated to 0.19 ppm prior to land disposal thus simplifying the LDR program. The proposed universal treatment standards would not modify treatment standards where a technology has been specified as the treatment standard for a particular waste stream.

Because the proposed universal treatment standards would be performance-based rather than technology-based, they would not encourage metal recovery of hazardous through mandating recovery. However, the proposed universal treatments standards for 13 of the 14 metal hazardous constituents are based upon either high temperature metal recovery or stabilization (the proposed arsenic standard is based upon slag vitrification). This may be an incentive for generators to chose high temperature metal recovery as a preferred management choice for their waste since this technology is the basis for achieving performance levels required prior to land disposal. It may also preclude generators from using other non-recovery management treatment options than do not meet the levels required by the proposed universal treatment standards.

## 8.2. Non-regulatory and Incentive-based Approaches To Encouraging Metal Recovery From Hazardous Waste

In addition to traditional regulatory approaches to managing hazardous waste, non-regulatory approaches such as technical or financial assistance and incentive-based approaches may play an important role in facilitating metal recovery of hazardous waste in the United States. EPA has reviewed one non-regulatory approach (waste exchanges) and several incentive-based approaches (pollution taxes/fees, marketable permits/recycling credits, deposit/refund systems, and removal of federal subsidies for primary metals) that have been used in other countries and may have value in facilitating metal recovery in the United States.

### 8.2.1 *Non-regulatory Approaches To Encouraging Metal Recovery From Hazardous Waste/ Waste Exchanges*

Historically, non-regulatory approaches such as financial and technical assistance to encouraging metal recovery of hazardous waste have been used by countries such as Japan as a compliment to strict regulation of industry. In 1980, the GAO reported that the Japanese government was providing financial assistance to the private sector to invest in metal recovery equipment.<sup>157</sup> The GAO found that comparatively little such assistance was being provided by the U.S. government to the private sector.

In addition to financial assistance to encourage investment in metal recovery, waste exchanges are another type of non-regulatory alternative designed to encourage metal recovery and reduce disposal of metal-bearing hazardous waste.<sup>158</sup> Waste exchanges are public or private institutions that are dedicated to promoting the reuse and recovery of hazardous and non-hazardous wastes.

The history of waste exchanges dates back to World War II, when waste exchanges were established by the British in 1942. When World War II ended, most exchanges had met their original goals consequently ceased to exist.

In 1972, the concept of promoting transfers of industrial waste was reborn in the Netherlands. This first modern-day exchange was known as the VNCI Waste Exchange. Shortly after the VNCI Waste Exchange began, other European nations began to recognize the environmental benefits of promoting the reuse of industrial wastes and established their own exchanges. From 1972 to 1976, approximately 12 exchanges were established in Europe.

At the same time, other nations outside of Europe also began to focus on programs that helped to protect the Earth's resources. During the early to mid-1970's waste exchanges were set up in New Zealand. The government of Australia in 1977 set up an Industrial Waste Exchange which still operates today as part of the government. The first North American Waste Exchanges were established in 1973.

Waste exchanges in the United States are comparatively new to those in Europe. European waste exchanges successfully exchange about 30 to 40 percent of wastes listed compared with 10 percent for U.S. exchanges. In 1978, Canada established a National Waste Materials Exchange. The GAO reports that the Canadian national waste exchange was relatively successful its first year in operation.

Most of the early waste exchanges served strictly as information exchanges and did not provide for actively pursuing matches of industrial waste generators and users. While some of the early exchanges operated for-profit, most were not-for-profit. The for-profit exchanges tended to deal solely with surplus inventories, while the not-for-profit exchanges dealt surplus inventories, off specification products, and waste products.

Hazardous wastes were included on many of the waste exchanges and, in fact, some exchanges dealt primarily with hazardous wastes. Waste exchanges were generally limited to trades on a regional basis and not on a national basis. Funding for early exchanges came from several sources: government (federal, state and local), private donations, listing fees, and subscription fees.

In recent years, computers and telecommunications technology has greatly facilitated the ease with which waste exchanges can be set up and managed. For instance, a national computerized bulletin board is linking together regional markets. States and municipalities are starting more localized exchanges, and some exchanges are actively seeking wastes and markets for waste as opposed to serving only as informational exchanges, as in the past.

Throughout their history, waste exchanges worldwide have faced similar problems as they attempt to expand and grow. As the waste exchange concept grows and becomes part of the standard business operating procedure, operational problems that exist today (e.g., funding, marketing, liability concerns) will need to be addressed in order for exchanges to succeed.

High purity, steady supply and high disposal costs avoided are primary factors contributing to success of materials successfully matched at waste exchanges. Data from California indicates that solvents, oils and aqueous metal solutions are the materials most commonly recycled off-site. Additional materials that are technically and economically feasible to recycle through waste exchanges include alkalis, acids, metals and metallic compounds and catalysts. Specific data on which metal-bearing hazardous wastes were listed on exchanges has not been available.



Recently, EPA awarded a contract for \$350,000 to Pacific Materials Exchange (PME) to develop a computerized National Material Exchange Network (NMEN). NMEN became operational in January 1993. Although it is too early to tell what effect NMEN will have on waste exchanges in the United States, the hope is that greater access to materials and markets on a national basis will improve the probability of matching buyers and sellers of secondary materials. With the help of state and local waste reduction requirements, NMEN facilitated the development of new waste exchanges by reducing start up costs for new exchanges. As of May 1993, 22 exchanges are being developed in 19 states.

Waste exchanges may provide additional opportunities to encourage metal recovery of hazardous wastes. Financial and technical assistance to regional and local waste exchanges could compliment NMEN to encourage metal recovery.

Studying which metal-bearing hazardous wastes are currently amenable to recovery but not being listed at waste exchanges is another opportunity. The objective of all alternatives would be to facilitate establishing end markets for partially recovered metals from metal recovery operations as well as encouraging generators to manage metal-bearing hazardous waste for recovery.

### *8.2.2 Incentive-Based Approaches To Encouraging Metal Recovery of Hazardous Wastes*

Today, economists and environmental policy analysts speak of a dichotomy between "command and control regulation" and "incentive-based approaches" to environmental protection. This dichotomy is based on how government influences or directs changes in a polluter's behavior.

Command and control regulation is the traditional means that government uses to achieve environmental protection. Command and control regulation directs polluters **how** to reduce or manage pollution as well as prescribing **what level** of pollution is permissible. Command and control regulation is a characterization which includes traditional permitting (non-transferable, location specific); performance, design or technology-based standards, and traditional compliance monitoring/enforcement procedures (e.g., issuance of orders, civil penalties). RCRA Subtitle C is an example of a command and control system. Examples of modifications to command and control regulation include proposed modifications to Subtitle C regulation presented by the regulated community in Chapter 5 and those currently under deliberation by the Definition of Solid Waste Task Force.

Incentive-based approaches rely on market behavior of polluters to achieve a reduction in levels of pollution or to improve pollutant management. Incentive-based approaches usually do not direct a polluter how to reduce pollution. Rather, these approaches set performance levels (based on quantity) or charges (based on price). In contrast to command and control regulation, incentives-based approaches influence rather than dictate the behavior of polluters. Pollution taxes or fees, transferable permits and deposit/refund systems are examples of incentive-based approaches.

Economists have traditionally been critical of command and control approaches to environmental protection, preferring incentive-based approaches instead. They assert that command and control approaches are economically inefficient because they do not take into account the varying cost of reducing pollution from facility to facility. Environmental groups have traditionally favored command and control approaches believing that they provide a greater level of certainty and uniformity than incentive-based approaches and that compliance can be enforced.

The use of incentive-based approaches is gaining in popularity across the globe. According to a review by the Organization of Economic Cooperation and Development (OECD), there are 150 different applications of economic instruments in 14 countries.<sup>159</sup> For example, Green Taxes have been adopted across Europe - though more as a revenue raiser than as a tool for behavior modification.

In the United States, some forms of incentives (such as tradeable permits) have been studied for several years. Through the Clean Air Act Amendments of 1990 and elsewhere, the Agency is expanding the use of incentive-based approaches such as fees, charges and marketable permits. For example, incentive-based approaches are now a major part of EPA's approach to the problem of acid rain. The Clean Air Act Amendments include provisions for the use of tradeable emission allowances to more cost-effectively reduce sulfur dioxide emissions from utility plants that contribute to acid rain.

On a local level, waste management officials in many communities are working to send a stronger market signal directly to consumers of disposal services. Through "unit pricing programs," homeowners and commercial entities are charged a fee per unit (volume or weight) of waste disposed. Generators of waste may then decide (independent of any kind of mandate) whether or not to change their disposal practices, increase their source reduction/re-use behavior or step up their recycling efforts. EPA is evaluating the effectiveness of unit based programs across the country.

This section on incentive-based approaches is presented to provide a full range of alternatives to encourage metal recovery of hazardous wastes. This section includes discussion of several categories of incentive-based programs that could be considered for managing the metals reclamation industry along with questions a policy-maker or analyst would ask in deciding which among them might be most effective. Finally, the chapter concludes with a brief discussion of some of the limitations of an incentive based system and barriers to their acceptance.

EPA is beginning to analyze the use of several types of incentive-based programs that may be relevant to the metals reclamation industry.<sup>160</sup> Typically, these programs fall into four categories:

1. Pollution Charges (Both Fees and Taxes) (Section 8.2.2.1);
2. Tradeable Waste Generation Permits and Recycling Credits (8.2.2.2);
3. Deposit/Refund Programs (8.2.2.3);
4. Removal of Federal Subsidies (those that support the use of virgin products) (8.2.2.4).

Because further evaluation is needed on a case-by-case basis, neither this chapter nor this report endorses any of the incentives described. Rather, this report provides a starting point for discussions with legislators, industry and environmentalists.

#### *8.2.2.1 Pollution Charges (Both Fees and Taxes)<sup>161</sup>*

Pollution fees and taxes impose a charge per unit of pollution or per unit of production or activity. Pollution charges tend to be effective when the policy question is how much (as opposed to whether) waste generation is acceptable.<sup>162</sup> Government levies a fee or tax on the inputs or outputs of manufacturing, recycling or reclaiming metals. Pollution charges create an incentive for industry to reduce pollution up to the point where the incremental cost of controlling pollution equals the pollution fee or tax rate.

Two approaches can be used in setting fee or tax levels. First, fees could be set to approximate the harm imposed by pollutants forcing the cost to be paid by the polluter rather than the public. In this approach, industry would determine total waste generation levels. The second approach hybridizes an incentive-based system and a performance-based system. Waste generation targets are calculated using economic and scientific assessments. Via this approach, charges are computed as a tool for reaching those targets.

The effectiveness of a pollution charge is directly tied to: 1) the calculation of the fee or tax rate; and, 2) enforcement and oversight of industry. According to environmental economics, if environmental goals are to be achieved, the policy maker must calculate the "correct" charge. The "correct" charge is that which results in the generation of an "optimal" amount of pollution - the amount of pollution at which the incremental cost of controlling pollution equals the value of damage avoided by reducing pollution.

In order to calculate the correct charge, the policy-maker must know the private costs of pollution control and the costs to society of pollution damages (i.e., the benefits to society of reducing pollution). The cost to society is typically viewed as the cost of health and environmental damage - often very contentious issues. Because private costs of control are heavily guarded and damages occur to essentially public goods (on a local - not a national - level), this is an especially difficult task.

Failure to calculate the "correct" charge and/or provide adequate enforcement can have severe and far-reaching implications. For example, a tax on an inelastic input will yield no reduction in waste generation and only increase regulatory burden. If the charge is too high, industry may employ pollution controls that are excessive and economically inefficient (i.e., environmental control costs exceed their environmental benefit). If the charges are too low, goals for reduced waste generation will not be achieved.

The calculation of pollution charges may ultimately be an iterative process with the charges rising and falling until the "correct" charge is found. This volatility is, perhaps, the most significant obstacle to a successful program. Investments in pollution control may make sense when pollution charges are high but not when charges are low. To industry, it may be optimal to wait for charges to stabilize (itself, distorting the economics by adding bias to the supply and demand curves) before investing in pollution control.

For these reasons, policy-makers generally take a conservative approach in the early stages of a pollution charge system.<sup>163</sup> Adjusting the charge upward over time toward "optimal" levels serves to reduce economic impacts at the early stages of the program (as firms evaluate methods for increased waste reduction) while still encouraging some reductions so as in waste generation. However, it would be important to make future increases predictable to ensure that industry could anticipate the economics of future reductions in waste generation rates.

Pollution charges and taxes give industry two incentives: to reduce waste generation and also the incentive to misrepresent waste generation. This latter distortionary effect is one which adds a significant cost to the system: the costs of enforcement and oversight. Currently, though some of the wastes are captured by RCRA's various reporting requirements, many are not. Though random monitoring of facilities may discourage under-reporting, it does so only at some cost.

Some state governments have tried pollution charges on hazardous waste generation. As mentioned above in Chapter 6 in the U.S. Filter Recovery Services (USFRS) case study, the State of Minnesota has levied a tax on releases tied to the Federal definition under the Emergency Planning and Community Right-To-Know Act (EPCRA). Unfortunately, USFRS reports that the tax creates no distinction between off-site recycling and traditional treatment or disposal. This is likely due to the fact that the Federal definition of release under EPCRA made no such distinction. Recent revisions to Form R used to report EPCRA release now contain additional data elements distinguishing between off-site treatment or disposal and recycling.

In 1985, Noll et. al. reported several variations on state hazardous waste taxes.<sup>164</sup> Some state government structure higher hazardous waste taxes on treatment and disposal than for recovery. Other states provide lower permit application fees for recovery facilities. Noll reports that in 1985 both Kansas and Tennessee had authorized their regulatory agencies to impose a tax based upon risk of the material and the cost of treatment and disposal. Indiana imposed a \$1.50 per ton tax on waste disposal but not recovery. The state of Kentucky structured its fee system in a manner that assess hazardous waste fees for on-site treatment and disposal at one-half the fee for off-site treatment and disposal. On-site treatment and recovery is exempt from assessment unless there is landfilling of process residuals.

What is not made clear in the review of state regulations is whether the fees are simply used as revenue sources, or as a mechanism to reduce hazardous waste generation. If it is the latter, the administrative costs of such a system would be greater due to economic adjustments required to set fees at levels to reduce waste generation rates. The review also does not make clear how revenue raised from pollution charges is to be allocated. It may be added to general revenue to reduce any deficit. Alternatively, revenue may be used to subsidize metal recovery operations, research and development grants for innovative technologies or loans for pollution prevention projects.

In summary, if the charge is calculated correctly and if properly administered and enforced, a pollution charge system will yield four significant benefits. First, the incentive system minimizes the aggregate costs of pollution control. Second, pollution fees and taxes give generators continuing incentives to develop and adopt more efficient and effective pollution control technologies. Third, pollution fees and taxes tend to be a comparatively progressive form of taxation - the per entity fraction of tax paid increases in direct proportion to income.<sup>165</sup> Fourth, pollution fees are revenue raisers which will serve to reduce the federal or state deficit (or reduce the need for other, more regressive taxes), albeit for a short time only. Nevertheless, the policy-maker must recognize that the costs of administering and monitoring such a system could place a heavy incremental burden on government.

#### 8.2.2.2 *Tradeable Waste Generation Permits and Recycling Credits*<sup>166</sup>

Tradeable waste generation permits and recycling credits are collectively referred to as "marketable permits." Tradeable waste generation permits are used when the environmental goal is to minimize waste generation rates and to achieve a national waste generation target. These permits are entitlements to emit or generate specified amounts of a pollutant during a specified time in a specified location. Locations may be defined in terms of facilities, bubbles,<sup>167</sup> ecosystems<sup>168</sup> or nations. Every generator of waste must have a permit in order to operate.

As with traditional command and control regulations (i.e., performance standards), tradeable waste generation permits ration the total amount of pollution that the control authority is willing to allow. Just as when performance standards are applied, those entities with permits can only generate the amounts of pollutants specified in the permits that they own. Unlike performance standards, however, these permits are not entity specific: they can be purchased, sold, leased or bartered across entities. They are freely transferable.

Recycling credits, in contrast, are devices used when the environmental goal is to either maximize recycling of certain waste streams or to realize pre-determined national recycling rates (or content standard). Through the use of recycling credits, entities could do their part to satisfy the environmental goal by either diverting wastes to recyclers (or by using the required percentage of secondary materials) or by purchasing "credits" from other entities which have exceeded their recycling requirements. An entity must achieve a total "use" of secondary materials either in practice or through some combination of waste diversion (or use of secondary materials) and credit purchase. Ultimately, the same amount of recycling should occur as under a uniform standard, but the total costs of compliance are less since those entities best suited for recycling (or using recycled materials) would essentially be paid by other entities to undertake the bulk of the recycling (or recycled material usage) burden.

This transferability of either mechanism provides industry with much more flexibility than traditional command and control regulations.<sup>169</sup> For instance, if the Agency were to develop a marketable permit program, waste generators with low pollution control costs and/or low reformulation costs would have the incentive (assuming the entity is a profit-maximizer) to alter their processes and market their excess waste generation capacity. Less flexible entities would be required to purchase marketable permits in order to continue operating in instances where they exceed their original allotment. Generators who wish to increase their levels of waste generation could also go out on the market and acquire permits for waste generation greater than their individual allotment. Finally, environmental organizations which hope to reduce aggregate generation beyond the government allowance could purchase permits.

Historically, marketable permit schemes have been applied to air and water quality management. More recently the concept of "Debt for Nature" swaps has gained in popularity. In the future, marketable permits may be used to manage waste, phase out the use of certain materials<sup>170</sup> or foster recycling.<sup>171</sup>

The establishment and implementation of any marketable permit scheme involve several discrete policy decisions: 1) specifying a policy objective; 2) selecting a target; 3) allocating permits; and 4) monitoring and enforcing the system. Each is described briefly below.<sup>172</sup>

The economics literature tends to focus on two objectives with regard to marketable permits: efficiency and cost-effectiveness.<sup>173</sup> When efficiency is the objective, the regulator "balances... the damage cost incurred from remaining uncontrolled pollution with the costs of avoiding this damage." In other words, the regulator seeks an allocation which minimizes the sum of damage costs and avoidance costs. In contrast, cost effectiveness, "suggests that the 'best' allocation is the one which achieves a specified policy target at a minimum cost."

Creating an efficiency-based program, like a pollution charge program, requires knowledge of both control and damage costs: a resource intensive endeavor. Thus, because the costs of developing an efficient policy are often prohibitive, the cost effectiveness criterion is more readily adopted. Cost effectiveness, in contrast, separates the two components integral to a marketable permit program: the selection of a policy target and the adoption of a system to meet that target. Cost effectiveness always addresses the latter component and, only occasionally, the former. Economic efficiency addresses both.

Target selection tends to fall into one of two categories: aggregate emissions cost effectiveness (ECE) or performance standards. Tietenberg writes that the, "ECE criterion envisions the establishment of some standard - a legal ceiling - on the allowable weight of [waste generation] and then allocates the responsibility for meeting that standard among the [generators] in such a way as to minimize the resources committed to pollution control." The cost is that the individual generator will select a waste output level based on economic criterion and not on individual risk and that the resulting distribution of waste generation will not minimize risk (given a particular compliance cost). The benefit of the ECE is that it is comparatively simple to administer. In contrast, the performance standard, "represents target waste generation levels measured at specific regions at specified average times." The performance standard is more closely related, from a risk perspective, to environmental degradation than is the ECE. Unfortunately, the relationship of the waste generator to that standard is less clear.

The initial allocation of permits is, perhaps, the most difficult of the four key decisions regarding marketable permits.<sup>174</sup> The government specifies an acceptable level of pollution. The total acceptable level is divided among polluting firms and then allotted in the form of permits. Should the permits then be allocated by auction or endowment? Should they be allocated free of charge? If they are allocated free of charge, what should be the criteria? What about new entities that enter the market after the original distribution? How should importers be addressed?

Depending upon the allocation method selected, the cost burden for pollution control may be borne by the government (if the entitlements are considered held by the generator), consumers, potential new entrants or the polluter itself (if the entitlements are considered vested in the state).<sup>175</sup> Currently, there is no preferred method of allocation. Like the details of any market-based program, the selection of an allocation method is case specific and dependent upon the environmental goals and industries involved.

Finally, like a pollution charge system, a marketable permit system will only be as good as the enforcement function and its ability to detect violations. Oversight is so crucial, because without the ability to detect non-compliance, entities need not acquire permits. All of the properties of an incentive system are lost in an environment where non-compliance exists. Those entities that are non-compliant must be subject to sufficiently large fines or penalties so as to make non-compliance an extremely unattractive option. Moreover, violations must be broadcast to the broader regulated community.

Despite the fact that marketable permit systems are in their infancy, several conditions have been identified which will assist in the development of efficient markets:<sup>176</sup>

- a. Compliance: Entities must accurately report waste generation (or use of materials) and acquire the number of permits needed to conform to usage.
- b. Transaction Costs: Effectiveness and efficiency of marketable permit systems are achieved only if transaction costs (including the costs of finding buyers and sellers and trade approval) are sufficiently low.
- c. Competitive Market Conditions for Permits: Sufficient quantities of buyers and sellers are needed to avoid conditions where a single entity can influence the price of the permit. Economic efficiency will only be realized if ample buyers and sellers participate in the market.
- d. Certainty in the Permit Market: Trading will only occur if the rights of permits are clearly defined and there is little or no question concerning the legitimacy of transactions. If accountability is placed with permit sellers (not buyers) and permits are registered with the government, the certainty issue is minimized.

Marketable permit systems offer real potential for achieving environmental goals at private costs equal to or lower than conventional command and control alternatives.<sup>177</sup> There are, however, numerous issues that must be addressed as these systems evolve. Like pollution charges, the cost of control is not known in advance. Thus, economic efficiency is an iterative process.

Also like pollution charges, success is in large part dependent upon the enforcement function; detection of violations and the legal ability to deal with violations once detected. The costs of enforcement and oversight can be high if the regulated universe is large or if imports are involved.



The use of marketable permit trading has not been extensive either in the United States or abroad. Isolated cases, (controlling the use of chlorofluorocarbons and reducing lead in gasoline) have yielded promising results. Research concerning the further development of marketable permit systems should continue. Specifically, research must be conducted on the short- and long-run elasticities of supply and demand of potential targets. Analysis concerning the distributional effects of these systems should also be conducted. Finally, with regard to certain metals, foreign trade issues (sales and subsequent enforcement of permits overseas and balance of trade issues) must be more closely examined.

### *8.2.2.3 Deposit/Refund Programs<sup>178</sup>*

Deposit/Refund programs are designed to accomplish several goals. First, the refund provides an incentive to follow the rules for proper disposal by raising the costs of illegal disposal. Second, deposit/refund programs that encourage proper disposal produce a desired composition of demand.<sup>179</sup> Third, deposit/refund program foster the conservation of raw materials. Deposit/Refund programs often promote the least-cost means for collecting waste.<sup>180</sup>

Deposit/refund programs are probably the easiest economic incentive program to develop, implement, understand and enforce. Essentially, a deposit/refund program is a front end tax on waste precursors. For example, a deposit/refund program might be used to control the disposal of sealed lead-acid batteries. A surcharge could be applied at any point along the production chain: from the acquisition of raw materials, through the manufacturing process or at the point of wholesale or retail purchase. The "taxed" party pays a surcharge which is refunded to them when either the battery is sold (by the subsequent purchaser who then bears the responsibility for proper disposal) or the product is sent on for recycling or proper disposal.

In principle, the size of the deposit equals the social cost of illegal disposal. Ideally, as the product moves through the sales chain (from manufacturer → wholesaler → retailer → consumer) the purchaser of the battery repays a deposit to the seller - mirroring the shift in responsibility for disposal from one party to another. This continues until the ultimate consumer returns the battery to a certified collection center responsible for recycling or disposal.

Refunds are paid from tax revenues that are paid out to collection centers upon verification of proper disposal. The certified recycling center repays the taxed party. Refund monies that are not repaid to consumers might be split between the government and the private sector.

Like other economic incentives, there are problems which limit the utility and effectiveness of deposit/refund programs. First, they are successful only where the targeted product or material is easily identifiable. Sealed lead-acid batteries are easily identifiable (except that it may be difficult for the consumer to distinguish between sealed lead-acid batteries and other types of rechargeable batteries such as Ni-Cds) and their sources are fairly limited. Clearly, deposit/refund programs create the incentive to turn toward imitations, substitutes and counterfeit products. If the targeted product is not identifiable, fraud will be prevalent, revenues will be insufficient to repay depositors and environmental goals will not be achieved.

Second, the transportation costs associated with proper disposal vary by location and may exceed the cost of the refund. Thus, not all waste may be properly disposed.

Third, collection facilities may face the significant incremental costs of handling hazardous waste subject to RCRA Subtitle C simply by virtue of the volumes of waste managed.

Finally, the policy-maker must look at the reaction/distortion chain: How will impacted manufacturers and consumers react? What substitutions will occur in the marketplace? Will there be shifts toward riskier (but not addressed) materials? Will the programs yield increases in the theft of recyclable goods? Will it undermine the viability of more or marginally successful waste management programs?

According to the Project 88 Report, deposit/refund programs are most appropriate when the incidence and consequences (to human health and the environment) of illegal waste disposal are great. There are three reasons:

- i. Relative to command and control regulation, enforcement costs are lowered dramatically;
- ii. Industry has a far greater incentive to conserve in process materials relative to virtually every other regulatory and incentive-based program; and,
- iii. Because materials are always lost in process, industry has a greater incentive to look for materials that are "safer" (i.e., that are not subject to the deposit/refund system).

For these reasons, deposit/refund systems hold the greatest potential for containerizable hazardous wastes, batteries and other recognizable and verifiable goods.

#### 8.2.2.4 Removal of Federal Subsidies<sup>181</sup>

For more than 100 years, the federal government has granted subsidies for the extraction and refining of certain natural resources - minerals, timber and energy stocks. These programs were originally implemented to encourage and maintain the development of mineral and other natural resources during periods of national economic difficulty. Though many were conceived to be temporary, many of the subsidies have remained in place over time. These programs endure, in large part, because of claims that they are important to national security and that they foster local stability. Federal subsidy programs generally fall into one of two categories: federal tax code provisions or federal programs.

It is generally held that a potential disincentive to recycling exists where a federal tax policy increases the cost of using recycled materials (where they are practical substitutes) relative to the cost of the virgin material. A disincentive is, thus, created by increasing the price of a recycled material or by decreasing the price of a virgin material. A recent EPA draft report examined four tax disincentives that impact the metals reclamation industry:

- i. Percentage/Cost Depletion Allowances: Available to primary minerals and oil/gas extraction companies. In fiscal year 1988, beneficiaries received a tax break of greater than \$1 billion.<sup>182</sup>
- ii. Tax Provisions for the Development of Energy: Via expending (rather than capitalizing) costs associated with exploration and development.
- iii. Financing Provisions: The investment tax credit (rescinded in 1986) was the most popular of these provisions. Private activity bonds and industrial development bonds now serve to provide low cost capital for capital intensive endeavors.
- iv. Other Tax Considerations: Pollution control equipment expenditures are subject to a five year (not a seven year) amortization schedule, thereby providing a tax benefit for dirtier industries.

The same report also examined federal programs which impact the mining industries. Historically, among the most vital programs to this industry has been the below-cost leasing program.

The extraction of hardrock minerals is governed by the Mining Law of 1872. Essentially, federal lands are relinquished as the government leases the lands below cost. Provisions of this law allow a miner or company to stake a claim on federal lands which contain potentially valuable minerals. Once the claim is staked, the miner need only spend \$100 per year on exploration and development to retain the claim. The miner is entitled to any revenues extracted from the claim. Revenues for any other extracted commodity require the claimant to pay royalties to the government. The Mining Law of 1872 makes this unnecessary.

Moreover, the Mining Law's patent provision allows the claim holder to transfer property rights (surface and sub-surface) to private ownership for between \$2.50 and \$5.50 per acre. Between 1872 and 1989, 3.2 million acres (nearly the size of Connecticut) have been sold under this provision.<sup>183</sup> Over time, the scope of the Mining Law has been narrowed. Today, several "fuel minerals" (oil, gas and coal) and "common variety minerals" (including sand, gravel stone and cinders) are excluded. Additionally, several million acres are now protected against mining. Nevertheless, the low cost of mining federal lands creates a market inefficiency with regard to virgin metals. This inefficiency virtually eliminates one of the most crucial components of social costs: the public value of land and the cost of resource depletion. Relative to recycled or reclaimed metals, the Mining Law of 1872 serves to lower the cost basis of raw materials.

Subsidies create market inefficiencies for several reasons. First, they support extraction and refining industries and businesses that are known to generate large volumes of waste and consume large volumes of water and energy: actions that hold the greatest potential to result in environmental degradation. By subsidizing these industries, the federal government prevents the market from properly valuing the social and private costs of these industries. Subsidies create a second inefficiency: they work against conservation goals by reducing the relative competitiveness of secondary (recycled) materials vis-a-vis virgin materials. Subsidies create other inefficiencies like excessive consumption of virgin materials and excessive waste.

In general, federal subsidies like those described above were intended to spur economic development. The impacts on the environment, on waste management and on recycling markets and industries were an unintended adverse side effect. Removing or reducing these subsidies could have dramatic positive and negative consequences. The range of responses could span a fairly large continuum and include:

- a. No change in recycling rates;
- b. Substitution of foreign materials in place of domestic raw materials (and a subsequent increase in the balance of trade deficit);
- c. Substitution of recycled materials in place of domestic raw materials;
- d. Substitution of other subsidized materials in place of domestic raw materials;
- e. Reduced consumption.

Regardless of the response, the effect of a reduction or elimination of subsidies could reverberate throughout the economy. Thus, it is important for the policy-maker to make every effort to anticipate reactions in all sectors. In certain instances, where responses can not be anticipated, resolving the imbalance posed by preferential subsidies might be better answered by extending similar subsidies to recycling industries. In other instances, the existing subsidies could be phased out over a five or ten year period.

### 8.2.2.5 Evaluation Criteria: Questions for the Policy-maker

Economic incentives are not a panacea for waste policy. Clearly, there are circumstances where they hold the potential to be more effective and efficient than traditional command and control mechanisms. Sometimes, however, the command and control approach better protects human health and the environment. In order for the policy-maker to better assess which paradigm is likely to be more effective, we suggest that a good point of departure is presented by the answers to the questions below:

- a. What is the problem that the policy is supposed to address?
- b. Is the environmental problem the result of some externality?
- c. How significant is the resulting environmental problem?
- d. What jurisdiction can most effectively address the problem?
- e. Is an incentive-based approach feasible?
- f. Will an incentive-based approach help to maximize net social benefits?
- g. Which particular incentive-based policy be effective?
- h. What are the risk/benefit tradeoffs?
- i. Will this encourage pollution prevention?
- j. What distortions are likely to occur (e.g., fraud, illegal dumping)?

Clearly, this forces the policy-maker to look at the spectrum of regulatory and non-regulatory alternatives on a case-by-case basis. This has, historically, been perhaps the greatest challenge to waste policy in the United States: overcoming the minor differences in industries, products and processes that yield dramatic distinctions in risk, economics and the effectiveness of regulation.

### 8.2.2.6 Conclusion

There are philosophical barriers that must be overcome before economic incentives become more widely accepted. Author Charles Davis suggests that there are four philosophical barriers to the acceptance of economic incentives as a tool for regulating hazardous waste: administrative resistance to change; existing gaps and/or deficiencies in policy design; media attention focused on the perceived dangers of hazardous wastes and the presence or absence of selected policy and institutional characteristics on the state level.<sup>184</sup> In the four years since the printing of that article, the Agency has made progress in overcoming these barriers. The new Administration is looking for new and better ways to achieve environmental goals. EPA is now working more closely with industry, environmentalists, state and local government. Today, economic incentives are playing a greater part than ever before in the protection of human health and the environment. They will continue to provide an effective alternative to command and control in the future.

## Chapter 9 Findings

Based on information collected and analyzed in completion of this report, EPA finds the following with respect to metal recovery of hazardous waste and its relationship to RCRA Subtitle C regulation:

1. RCRA Subtitle C regulation includes both incentives and disincentives to metal recovery of hazardous waste. Overall, RCRA Subtitle C regulation has been a substantial contributing factor to the increase in metal recovery of hazardous waste over 1980 levels. Currently, EPA estimates that between 2.6 and 2.8 million tons of hazardous waste are managed for metal recovery. In 1980, the GAO reported that fewer than 15,000 tons of metal were being recovered from industrial sludges, by-products and spent materials. Increases in world metal demand in the mid-1980 were also a major contributing factor. Major RCRA Subtitle C incentives include Land Disposal Restriction treatment standards and general requirements for Subtitle C management. These requirements encourage metal recovery by raising treatment and disposal costs thereby influencing generators to look for alternative forms of management such as metal recovery.
2. RCRA Subtitle C regulation is also apparently constraining metal recovery from reaching its potential in the United States. Compliance costs and liability concerns with RCRA Subtitle C regulation may limit waste generators selection of metal recovery as an option. These costs and concerns also limit the ability of metal recovery operations to expand their capacity and invest in new projects. Major RCRA Subtitle C disincentives to metal recovery include the derived-from rule, storage permit requirements, facility-wide corrective action and hazardous waste shipping costs. These requirements are the most costly and cumbersome for metal recovery operations to comply with.
3. RCRA Subtitle C regulation may inhibit innovative metal recovery technologies. The Molten Metal Technology case study in this report indicates that several RCRA Subtitle C provisions including research, demonstration and development permits and mass limits on regulatory exemptions for treatability studies may not be adequate for encouraging innovative metal recovery to develop at a faster rate. The case study also shows that innovative technologies may face a more difficult burden than established technologies in overcoming regulatory impediments to operation.
4. Notwithstanding the disincentives posed by RCRA Subtitle C regulation, damage incidents (including Superfund sites) involving metal recovery operations indicate that mismanagement of these materials can pose a significant risk to human health and the environment. Therefore, proposals to modify RCRA Subtitle C statutory or regulatory authority must assess the potential environmental/economic benefits against the potential for increased risk to human health and the environment. EPA has created the Definition of Solid Waste Task Force to assess these types of proposals.

5. Recovery of metals from metal-bearing hazardous waste has the potential to ameliorate the current U.S. balance of trade deficit. It may also become an important source of supply of strategic metals, particularly chromium.
6. Available data shows that metal recovery of hazardous waste should continue to increase in the 1990's as landfill capacity decreases and alternative forms of management are increasingly need to support the U.S. hazardous waste management system.

## NOTES

1. PPA §6603(5), 42 U.S.C. §13102(5).
2. Source Reduction Opportunities in the Plating Industry, Terry Foecke, Minnesota technical Assistance Program (MnTAP), Presented at the 1989 Symposium on Metal Waste Management Alternatives: Minimizing, Recycling, and Treating Hazardous Metal Wastes.
3. For a more detailed discussion of metal recovery technologies that are available for hazardous wastes, please consult PEI Associates, Inc. Cincinnati, OH, "Overview of Metals Recovery Technologies for Hazardous Wastes", Prepared for Environmental Protection Agency, Cincinnati, OH, NTIS # PB91-176792, December 1990. Also see James W. Patterson, "Metals Separation and Recovery" in Metal Speciation, Separation and Recovery, (Chelsea, MI: Lewis Publishers, 1987), pp.63-93 and ICF Inc., "Profiles of Metal Recovery Technologies For Mineral Processing Wastes And Other Metal-Bearing Hazardous Wastes" prepared for U.S. Environmental Protection Agency, Office of Solid Waste, Waste Treatment Branch, Draft August 31, 1992.
4. American Society of Metals, Metals Handbook, Desk Edition, (Metals Park, OH: American Society of Metals, 1985), p. 1-30. **Winning** (a type of extractive metallurgy) refers to recovering metal from an ore or chemical compound. In contrast, **refining** refers to the purification of crude or impure metals. Both winning and refining are types of **process metallurgy**, the science of separating metals from their ores and purifying metals.
5. ICF, p.i.
6. ASM, p. 21-8.
7. ASM, p. 1-21.
8. ICF, p.ii.
9. Recall from Chapter 1 that the term "related secondary materials" refers to metal-bearing secondary materials such as sludges and by-products that exhibit a characteristic of a hazardous waste but are nonetheless not within the definition of solid waste when reclaimed. These materials would be regulated as hazardous wastes if discarded in manner other than reclamation.
10. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, National Biennial RCRA Hazardous Waste Report (Based on 1989 data), February 1993.
11. Between January and April 1993, EPA received information from five trade associations representing generators of metal-bearing hazardous wastes and metal reclaimers of these wastes. The trade associations included the National Association of Metal Finishers, the Steel Manufacturers Association, the American Iron and Steel Institute, the Metal Recovery Coalition, and the Association of Battery Recyclers.
12. Each source of data has limitations on its utility for this study. First, the BRS data are now over three years old. A number of new metal recovery operations have become commercial or expanded capacity. Second, certain metal-bearing secondary materials such as sludges or by-products of an industrial process which exhibit a characteristic for toxicity, reactivity, corrosivity or ignitability are not solid wastes and therefore hazardous wastes when reclaimed (40 CFR §261.2(c)(3)). Therefore, these materials would ordinarily be exempt from BRS reporting requirements (40 CFR §262.41). These same materials would be hazardous waste under the federal rules if land disposed or applied to the land. Based on the information



reviewed in completion of this study, it is probable the BRS data underestimates the total quantity of metal-bearing hazardous wastes being managed for metal recovery and the United States. Although more current than the BRS data, the trade association information submitted to the EPA was completed in a limited time frame and represents only a portion of the regulated community subject to RCRA regulation.

13. Note: EPA has proposed a rule, (Part 273, Special Collection System, for encouraging the efficient collection and transport of nickel-cadmium batteries. 58 FR 8102, February 11, 1993. Although the proposed rule does not specify management in metal recovery operation, land disposal restriction treatment standards specify that these batteries must be managed for reclamation prior to land disposal 40 CFR §268.42. EPA believes that the proposed Part 273 regulations would increase the recovery rate for nickel-cadmium batteries.

14. National Research Council, Environmental Epidemiology: Public Health and Hazardous Wastes, (Washington D.C.: National Academy Press, 1991).

15. NRC identified substances that were present at more than 100 Superfund sites and are either animal or human carcinogens and also classified as group 1 substances of the Agency for Toxic Substances and Disease Registry (ATSDR)/EPA list of the 100 most hazardous substances, National Research Council, p 104.

16. Ibid., p.106.

17. Ibid., p. 105.

18. EPA, RCRA Implementation Study Update: The Definition of Solid Waste, July 1992. Appendices C and D. (hereafter RIS update).

19. Robert A. Goyer, M.D., Chapter 19 "Toxic Effects of Metals" in Mary O. Amdur, Ph.D., John Doull, Ph.D, M.D., Curtis D. Klaassen, Ph. D. eds, Casarett and Doull's Toxicology: The Basic Science of Poisons, 4th ed., (United States of America: McGraw-Hill Inc. 1993. Lars Friberg, Gunnar F. Nordberg, Velimir B. Vouk, Handbook on The Toxicology of Metals, Vols. 1 & 2, (Amsterdam, New York, Oxford: Elsevier Science Publishers, 1986); Pradyot Patnaik, A Comprehensive Guide to the Hazardous Properties of Chemical Substances, (New York, New York: Van Nostrand Reinhold, 1992); John Harte, Cheryl Holdren, Richard Schneider, Christine Shirley, Toxics A to Z: A guide to everyday pollution hazards, (Berkeley and Los Angeles, CA: University of California Press, 1991).

20. United States Environmental Protection Agency, Office of Pollution Prevention and Toxics, 1991 Toxics Release Inventory: Public Data Release, EPA 745-R-93-003, May 1993.

21. Ibid., p.19.

22. Note that precious metals recovery is subject to a reduced set of requirements. Persons recovering precious metals must comply with RCRA §3010 notification requirements and must maintain records to document that they are not accumulating materials speculatively (as defined in 40 CFR §261.1(c)). In addition, generators, transporters and TSDs must comply with manifest requirements. Precious metals include economically significant amounts of gold, silver, platinum, palladium, iridium, osmium, rhodium, ruthenium, or any combination of these.

23. The term "land disposal" means placement in or on the land except in a corrective action management unit, and includes, but is not limited to, placement in a landfill, surface impoundment, waste pile, land treatment facility, salt dome formation, salt bed formation, underground mine or cave, or concrete vault or bunker intended for disposal.

24. Limited exceptions exist. See 40 CFR §268.1, §268.5, and §268.6.
25. Because the metal-bearing wastes are generally listed sludges that will be reclaimed, they are defined as solid wastes under 40 CFR §261.2. Given that these solid wastes are listed hazardous wastes under 40 CFR §261.31 and §261.32, they are subject to all applicable RCRA regulations. Such hazardous wastes include F006-F009 (electroplating), F010-F012 (metal heat treating), and F019 (sludges from aluminum coating). They also include K-listed wastes from iron and steel plants, secondary lead smelters, and inorganic pigment production.
26. 40 CFR §261.3(c).
27. 54 FR 41176; 8/19/91.
28. Rotary kilns, flame reactors, electric furnaces, plasma arc furnaces, slag reactors, rotary hearth furnace/electric furnace combinations, or industrial furnaces. In addition, the rule imposes testing and notification requirements.
29. 40 CFR §261.4(d)(1). Note that recent litigation may affect both the derived-from rule and the applicability of the LDR requirements. See, Shell Oil Co. v. EPA, U.S. Court of Appeals for the District of Columbia Circuit, No. 80-1532 et al. (12/6/91); and Chemical Waste Management, Inc. v. EPA, U.S. Court of Appeals for the District of Columbia Circuit, No. 90-1230 et al., (9/25/92).
30. 40 CFR §261.1(c)(7).
31. Tank storage facilities and some piles and surface impoundments that intend to clean close are not required to provide post-closure financial assurance. (See 40 CFR §264.140(b)). Also, State and Federal facilities are not subject to closure and post-closure financial assurance requirements (40 CFR §264.140(c) and §265.140(c)).
32. 40 CFR §266, Subpart H.
33. On-site furnaces, exempt under small quantity generator provisions, burning their own hazardous waste are exempt from regulation under Parts 264/265 and 270 with respect to the storage of mixtures of hazardous waste and fuel in tanks that feed directly to the furnace.
34. Ore or mineral furnaces subject to §261.4(b)(7) must process at least 50 percent by weight normal, non-hazardous raw materials.
35. EPA has exempted selected mining wastes from the definition of hazardous waste including slags from primary copper and lead production, as well as from iron blast furnaces and open hearth/basic oxygen furnace carbon steel production. 40 CFR §261.4(b)(7).
36. DPRA Inc., Comparative Analysis of RCRA Treatment and Disposal Costs and Recycling Costs With and Without Regulatory Modifications. Final Report ( St. Paul, MN: DPRA Incorporated, March 1991) Prepared for Regulatory Analysis Branch, Office of Solid Waste, U.S. Environmental Protection Agency.
37. Spent-lead acid batteries are actually subject to reduced RCRA regulatory requirements for collection and transport under 40 CFR §266.80. Person reclaiming these materials are subject to full Subtitle C regulation including storage permit requirements prior to reclamation.
38. Personal communication between Paul Borst, U.S.E.P.A./Office of Solid Waste and Lyle Salsbury, National Steel Corp./Great Lakes Division, May 26, 1993.

39. Disposal costs for untreated K061 were approximately \$200 per ton. Shipping the same material to Palmerton, PA for metal recovery was estimated at approximately \$400 per ton including both shipping cost and user fees. Metal recovery was considered at least as cost effective as treatment and disposal costs at a Subtitle C facility.
40. Spent lead-acid batteries are typically sawed or shredded prior to being smelted to remove lead plates and groups. LDR requirements prohibits the storage of a restricted waste (e.g., the shredded battery material) through placement on the land (40 CFR §268.50). In 1992, EPA promulgated a final rule which allows owners/operators of hazardous waste treatment, storage or disposal facilities to place restricted wastes in **containment buildings** without considering the placement of the restricted waste to constitute land disposal as defined in §3004(k) of RCRA (57 FR 37211, August 18, 1992). Containment building standards are stated in Subpart DD of 40 CFR Parts 264 and 265.
41. Under RCRA, hazardous wastes being reclaimed remain hazardous wastes until the reclamation process is complete. 50 FR 633,634,655, January 4, 1985. Because the Agency recognized that some secondary materials that are partially-reclaimed are more commodity-like than waste-like, it has promulgated a variance from the definition of solid waste for materials that are partially-reclaimed. 40 CFR §260.30(c). The appropriate regulatory agency will grant or deny this variance based upon a series of criteria promulgated by EPA. 40 CFR §260.31(c).
42. This exclusion exempt materials that are returned to the original process from which they are generated without first being reclaimed. The material must substitute for raw material feedstock and the process must use raw materials as the principal feedstocks.
43. The concern is that producers of waste-derived products may become potentially responsible parties (PRPs) under Superfund remedial actions if metal recovery residuals used to produce their products remain hazardous waste because of the derived-from rule. CERCLA §107 defines covered persons for purposes of liability as any person who arranged for the treatment or disposal of a hazardous substance. Because the CERCLA definition of hazardous substance includes RCRA Subtitle C hazardous wastes, some people believe that the risk of PRP liability is greater if materials are designated as a hazardous waste.
44. DPRA Inc., Comparative Analysis of RCRA Treatment and Disposal Costs and Recycling Costs With and Without Regulatory Modifications, Final Report, ( St. Paul, MN: DPRA Incorporated, March 1991) Prepared for Regulatory Analysis Branch, Office of Solid Waste, U.S. Environmental Protection Agency.
45. The DPRA analysis also included other wastes such as K048-52 petroleum wastes, F003-5 solvents, and K088 spent aluminum potliners. However, because these wastes do not involve metal recovery, the DPRA results for these wastes have not been included in this report.
46. Ibid., p.6
47. For example, the study assumes that electroplating rinsewaters may be evaporated in smaller facilities and have the metal concentrate reused in the plating bath. Based on the Agency's experience, electroplating rinsewaters typically commingle several types of metals from several different plating baths. This being the case, one could not reuse metal concentrates in a single plating bath without contaminating the plating bath with other metals. Evaporation might be used successfully if either the plating shop used only one kind of metal or if rinsewaters were kept segregated with only one type of metal.
48. For low zinc (5 percent) K061, electric arc furnace dust, treatment and disposal is less expensive than metal recovery at a large commercial metal recovery facility. This is true for recycling under current regulations or with regulatory modifications.

49. DPRA, p. 40.
50. See Chapter 3, p.20
51. DPRA, p.42
52. EPA is not commenting in this report on the extent of Subtitle C regulatory disincentives identified by the regulated community in this section since the Agency has not had the opportunity to verify the claims of the regulated community on the significance of the disincentives. In theory, any type of RCRA Subtitle C regulatory compliance cost for metal reclaimers is a disincentive to the extent that it displaces capital that could otherwise be used for investment for additional metal recovery capacity. The more relevant question is not whether RCRA Subtitle C regulatory requirements are disincentives, but rather what is the extent of the disincentives relative to incentives provided by the regulation.
53. Roy O. Ball, Gregory P. Verret, Philip L. Buckingham, Stephen Mahfood, "Economic Feasibility of a State-Wide Hydrometallurgical Recovery Facility", Metal Speciation, Separation and Recovery, James W. Patterson and Roberto Passino Eds., (Chelsea, MI: Lewis Publishers, 1986), pp. 690-711.
54. Leading Edge Reports, A Competitive Analysis of Hazardous Waste Management, (Cleveland Heights, OH: Leading Edge Reports, 1990), p.140.
55. ICF Inc., 1990 Survey of Selected Firms In The Hazardous Waste Management Industry: Final Report, Prepared for the United States Environmental Protection Agency, Office of Policy Analysis, July 1992 (Fairfax, VA: ICF Inc, July 1992), p.2-6
56. Ibid., 2-24, 3-1.
57. Ibid., p. 2-27.
58. U.S. Environmental Protection Agency, Office of Policy, , Environmental Investments: The Cost Of A Clean Environment: A Summary, EPA-230-12-90-084 , December 1990, p.3-4. According to the executive summary of this report, historic data are based on surveys conducted by the Department of Commerce. Projected costs are extrapolations of spending trends and EPA estimates of the costs of new regulations.
59. ICF. Inc., 1990 Commercial Survey..., p.2-33.
60. Ibid., p. 3-2.
61. Ibid., p. 5-2.
62. Part of U.S. Filter Recovery Service's success is that the firm is able to keep rinsewaters from electroplating operations segregated so that cross-contamination of metals does not occur. This produces a purer product than would occur if the rinsewaters were commingled and the processed to separate the metal using conventional leaching and precipitation techniques.
63. Putnam, Hayes & Bartlett, The Impacts of Lead Industry Economics and Hazardous Waste Regulations On Lead-Acid Battery Recycling: Revision and Update, Prepared for Office of Policy Analysis, September 1987, pp. 22-30.
64. John E. Tilton (ed.)World Metal Demand: Trends and Prospects, (Washington D.C.: Resources For The Future, 1990), pp.1-11.

65. Tilton, p.7.
66. National Research Council, Competitiveness of The U.S. Minerals and Metal Industry, (Washington D.C.: National Academy Press, 1990), pp. 11-13.
67. National Research Council, p. 19.
68. U.S. Bureau of Mines, Mineral Yearbooks 1984 to 1989.
69. U.S. Bureau of Mines, Metal Prices In The United States Through 1991, 1991.
70. Price information is adjusted for inflation using 1987 dollars.
71. Putnam, Hayes, & Bartlett, pp. 1, 27.
72. Data in Table 5.2 were taken from data submitted to EPA by Weinberg, Bergeson and Neuman on behalf of Battery Council International, May 25, 1993.
73. 1993 Data From Battery Council International.
74. Ibid., p.46.
75. See Section 5.1.1.4. supra.
76. Letter from Robert N. Steinwurtzel, Counsel to the Association of Battery Recyclers, to William K. Reilly, Administrator, Environmental Protection Agency, March 10, 1992., p.4.
77. Note: alternative treatments that can achieve the same degree of performance may be submitted via an application to the EPA administrator who may at his or her discretion approve the use of the alternative treatment standard. 40 CFR §268.42(b).
78. N.R.C., p.16.
79. Ibid., pp. 34-35.
80. General Accounting Office, Industrial Wastes: An Unexplored Source of Valuable Minerals, (Washington D.C.: GAO, May 15, 1980), p.51.
81. Ibid., p. 51.
82. Refer to the Inmetco case study below in Chapter 6.
83. Ibid., p.13.
84. Please note that this estimate has been developed from data of metals recovered between 1989 and 1993.
85. Environmental Protection Agency, Office of Pollution Prevention and Toxics, 1991 Toxics Release Inventory: Public Data Release, EPA 745-R-93-003, May 1993, pp. 60-63. TRI data are estimates of the manufacturing sector (SIC codes 20-39) on quantities of toxic and hazardous chemicals released to the environment. The data estimates release of materials that would be **hazardous constituents of hazardous waste**. Thus, for example, the data includes release of lead or cadmium as opposed to quantities of materials

that contain lead or cadmium. In contrast, Biennial Reporting Systems data that EPA uses to evaluate hazardous waste management reports quantities of materials (wastes) that contain hazardous constituents. While TRI data does not allow direct comparison with BRS or other hazardous waste data, it is a useful proxy especially for estimating metal totals being reclaimed that may originate from related secondary materials such as characteristic sludges and by-products being reclaimed that are not normally estimated in BRS data.

86. Ibid. p.63.

87. The reader should note however that large quantities of industrial D wastes such as mining wastes are not included in the TRI data base since they do not fall within the 20-39 SIC code manufacturing sector range.

88. These include P015, beryllium dust; P087, osmium trioxide; P092 phenyl mercury acetate, U151 mercury.

89. U.S. Bureau of Mines, Mineral Yearbooks 1984 to 1989.

90. U.S. Bureau of Mines, Metal Prices In The United States Through 1991, 1991.

91. Research Triangle Institute, Center For Economics Research, Characterization of Recycled Wastes by SIC Code, Waste Source Code, Waste Description Code and Metals Present, Prepared for Office of Policy, Planning and Evaluation, U.S. Environmental Protection Agency, July 1991, Chart 1-Characterization of Recycled Wastes: Summary Data.

92. Please note that this data was analyzed from National Survey of Hazardous Waste Generators conducted in 1987 for calendar year 1986. Data limitations preclude using this data set to conduct trend analysis with the other EPA estimates of metal recovery of hazardous waste cited in this report.

93. For example, the National Association of Metal Finishers estimates that 15 to 20 percent of F006 was recovered in 1992. There are no reported quantities of F006 being managed for metal recovery in 1989 BRS data (although EPA is aware that some F006 recovery did occur at operations exempt from BRS reporting requirements such as Cyprus Mines in Arizona). Also, K061 recovery remains high in 1992 with 90 percent (500,000 tons) recovered. In addition, the K061 market appears to be becoming increasingly competitive with a number of new firms entering the market such as Metal Recovery Technologies, Zia Technologies of Texas, Glassification International Limited (vitrifies K061 for use in glass frit) at a time when the price of zinc has declined over the last three years.

94. For purposes of this report, a central recovery facility can be considered to be an off site metal recovery operation that reclaims metals from hazardous waste. As mentioned later in this case study, U.S. Filter representatives believe that a central recovery facility can be distinguished from other off site recovery facilities by the degree of involvement in customer operations and greater likelihood of generator compliance.

95. From 1980 to 1986, private parties in Cleveland and New York City tried unsuccessfully to initiate central recovery facilities despite the fact that each operation was believed to be economically viable. The Cleveland initiative failed when the federally mandated compliance date for categorical pretreatment standards of April 27, 1984 for plating facilities forced several major platers to install on-site pretreatment systems to achieve faster compliance. As a result the market for the proposed central recovery facility, collapsed. Illinois Department of Energy and Natural Resources, ILENR/RE-WR-86/12, Feasibility of a Central Recovery Facility For The Metal Finishing Industry In Cook County, November 1986, p.47.

The New York initiative suffered a similar setback when 20 plating firms backed out to avoid civil

penalties for noncompliance with federal pretreatment regulations. The time required to obtain a RCRA Part B permit for the proposed central recovery facility contributed to this result by extending the time of noncompliance for the plating firms. *Ibid.* p.50. The New York initiative to cite a central recovery facility ultimately failed when remaining platers backed out after paying civil penalties for noncompliance with federal pretreatment regulations. Personal communication between Paul Borst, EPA/Office of Solid Waste and representatives of U.S. Filter Recovery Services Inc., Roseville, MN, February 12, 1993. Personal communication between Paul Borst, EPA and David Norwine, VP Haward Corp, May 17, 1993.

96. Illinois Department of Energy and Natural Resources, *Ibid.*; Roy O. Ball, Gregory P. Verret, Philip L. Buckingham, Stephen Mahfood, "Economic Feasibility of a State-Wide Hydrometallurgical Recovery Facility", Metal Speciation, Separation and Recovery, James W. Patterson and Roberto Passino Eds., (Chelsea, MI: Lewis Publishers, 1986), pp. 690-711. The Illinois study concludes that a CRF would probably not be cost-effective in Cook Co. because civil penalties would drive metal finishers to install on-site pretreatment units and eliminate the market for CRF services. In contrast, Ball, *et. al.* conclude that a CRF in Missouri would not be cost-effective because treatment and disposal cost of plating sludges in a hazardous waste landfill would be considerably cheaper than recovery at a CRF.

97. Personal communication between Paul Borst, EPA Office of Solid Waste and representatives of U.S. Filter Recovery Services Inc., Roseville, MN, February 12, 1993.

98. On the other hand, EPA regulations favor pyrometallurgical metal recovery operations in two ways. First, Land Disposal Restriction (LDR) treatment standards that specify a recovery technology (40 CFR §268.42) only specify pyrometallurgical technologies. So, if a metal-bearing hazardous waste such as high category mercury waste or nickel-cadmium batteries was amenable to recovery hydrometallurgically, it would still need to be recovered from a high temperature (pyrometallurgical) process to meet LDR treatment standards prior to land disposal. Second, generic exclusion levels for residues generated from high temperature metal recovery operations (HTMR) disposed in Subtitle D facilities (e.g., a nonhazardous landfill) by definition do not apply to residues from hydrometallurgical operations. These RCRA Subtitle C provisions may favor pyrometallurgical recovery by creating markets and reducing compliance costs for metal-bearing hazardous wastes. BIF permit requirements cut the other way favoring hydrometallurgical operations.

99. Ibid. note 1.

100. Jim Bishop and Mary Melody, "Inorganics treatment and recovery", Hazmat World, February 1993, p.24.

101. Inco Limited Annual Report, 1991, p.26.

102. Inmetco- Best Demonstrated Available Technology Project, Volumes 1 and 2 (October 18, 1991).

103. EPA representatives from the Office of Solid Waste visited Inmetco's Ellwood City facility on December 18, 1993. The company provided a paper to EPA, dated December 17, 1993, entitled "Some Observations on Regulatory Costs Associated with Operation of a Metals Reclamation Facility Under the Provision of Subtitle C of RCRA".

The company also submitted a separate response to EPA's Metal Reclamation Study Survey which the Agency had distributed in January 1993 to the Metal Recovery Coalition and the Association of Battery Recyclers to solicit the input of these trade associations. Letter From Richard H. Hanewald, President of Inmetco to Paul Borst, EPA Office of Solid Waste dated February 17, 1993. Inmetco is a member of the Metal Recovery Coalition.

104. Paper submitted by Inmetco to EPA entitled "Proposed Structure for Regulating the Recycling of Hazardous Secondary Materials Through Metals Recovery", dated January 28, 1993 and attached with a letter from Richard H. Hanewald, President of Inmetco to James R. Berlow, EPA, Office of Solid Waste, dated January 28, 1993.

105. Paper submitted to EPA by Inmetco dated January 28, 1993 and entitled "The Risks and Benefits of Recycling Compared to the Risks and Benefits of Primary Manufacturing and the Use of Virgin Materials" and attached with a letter from Richard H. Hanewald, President of Inmetco to James R. Berlow, EPA, Office of Solid Waste, dated January 28, 1993.

106. Inmetco, "Some Observations on Regulatory Costs Associated with Operation of a Metals Reclamation Facility Under the Provisions of Subtitle C of RCRA", December 17, 1992, p.6. Although it is possible that some of this cost could be passed on to Inmetco's customers, stainless steel producers could choose to export their waste or manage it in an alternative manner.

107. Personal communication between Paul Borst, EPA/Office of Solid Waste and Sigma Toth, PADER, Meadville Region, March 25, 1993.

108. Infra Note 4., January 28, 1993 letter from Richard H. Hanewald to Jim Berlow. Inmetco believes based on their current customers or publicly available information that most of these materials are currently being landfilled or exported for reclamation or disposal.

109. A strategic material is defined by OTA as:

"[a material] for which the quantity required for essential civilian and military uses exceeds the reasonably secure domestic and foreign supplies, and for which acceptable substitutes are not available within a reasonable period of time"

Therefore, a strategic material is defined by both the critical nature of its use and the vulnerability of its supply. Office of Technology Assessment, Strategic Materials: Technologies to Reduce U.S. Import Vulnerability, 1985, p.11. Chromium is one of four first tier strategic materials identified by OTA along with manganese, cobalt and platinum group metals.

110. Inmetco, "Proposed Structure for Regulating the Recycling of Hazardous Secondary Materials Through Metal Recovery", January 28, 1993.

111. Jeffrey D. Smith, "Molten Metal Technology, Technology Destroys Waste and Recovers Salable Products", EI Digest, July 1991, p.8.

112. Molten Metal Technology, Prospectus, 1993, p. F-7.

113. Jim Bishop and Mary Melody, "Inorganics treatment and recovery", Hazmat World, February 1993, p.28.

114. David Stamps, "Molten Metal Technology, Soon-to-Open R&D Center Will Test Company's Claims of Turning Hazardous Waste into Useful Materials", EI Digest, November 1992, p. 13.

115. Smith, p.11.

116. Stamps, p. 13.

117. Stamps. p.13.



118. Stamps, p.13.
119. Letter from Eugene Berman, Vice-President For Regulatory Affairs, MMT to Paul A. Borst, EPA Office of Solid Waste, February 17, 1993.
120. Personal communication between Paul Borst, EPA Office of Solid Waste and Eugene Berman, MMT, Vice-President for Regulatory Affairs, January 26, 1993. See also, Stamps. p.14.
121. This assumes that the CEP unit either is not subject to the Boiler and Industrial Furnace requirements at 40 CFR Part 266, Subpart or that the unit is subject to Subpart H requirements and is conditionally exempt as metal recovery operation burning solely for metal recovery.
122. September 23, 1992 letter from Ed Kunce, Deputy Commissioner, MADEP to Merrill S. Homan, Director, Office of Waste Management, U.S. Environmental Protection Agency, Region 1 on MMT. Personal communication between Paul Borst, EPA, Office of Solid Waste and Eugene Berman, Vice-President For Regulatory Affairs, MMT, January 26, 1993.
123. Stamps, p.14.
124. April 26, 1989 Memorandum from Sylvia K. Lowrance to Hazardous Waste Management Division Directors on F006 Recycling. The attachment of this memorandum recognizes the economics of the recycling process as a relevant factor although it looks more at the disparity of revenue derived from recovered materials versus user fees rather than the value of recovered materials versus their cost of processing. EPA does not consider this to be a test or requirement.
125. April 26, 1989 Lowrance Memorandum, p.1.
126. EPA, Office of Solid Waste and Emergency Response, "The Nation's Hazardous Waste Management Program at a Crossroads, The RCRA Implementation Study", EPA/530-SW-90-069, July 1990, p.111.
127. Final Rule on Land Disposal Restrictions for Electric Arc Furnace Dust, 56 FR 41164 (August 19, 1991).
128. The information presented in the Horsehead Resource Development Company, Inc. case study not otherwise noted was obtained from personal conversations between Charlotte Mooney, EPA Office of Solid Waste, and Bruce Conrad, Director of External Relations, Horsehead Resource Development Company, Inc. and from company personnel during a site visit at the Palmerton, Pennsylvania facility conducted by EPA staff on May 7, 1993.
129. In comments on this case study and in the context of enforcement proceedings, HRD has argued that their operations are not reclamation of hazardous waste and that the term reclamation should not be used to describe the operations. HRD thus argues that they are not actually subject to RCRA at all. In this case study the Agency uses the word recovery to describe HRD's operations, because recovery is a specific form of reclamation and HRD's operations constitute recovery of metal from hazardous waste. See section 1.3 of this study for a general discussion of these terms.
130. October 14, 1993 letter from William L Miller, Chief, Division of Policy Analysis, Bureau of Mines, U.S. Department of the Interior to Paul Borst, U.S. Environmental Protection Agency, Office of Solid Waste, and personal communication between Paul Borst, U.S. EPA, and James F. Collins, Steel Manufacturers Association, October 21, 1993.
131. Derby, James V., Recycling of Zinc-Bearing Materials, Zinc Corporation of America, undated, p. 5.

132. Under the federal hazardous waste regulations, recycling units are exempt from RCRA permitting unless they are boilers or industrial furnaces (40 CFR 261.6(c)(2)). Industrial furnaces conducting metal recovery are also exempt from permitting (40 CFR 266.100(c)). However, units that store hazardous wastes prior to recycling generally do require permits (40 CFR 261.6(c)(1)).

133. The information presented in this section was obtained from the following sources:

-- Derby, James V., Recycling of Zinc-Bearing Materials, Zinc Corporation of America, undated.

-- Horsehead Resource Development Company, Inc., HRD Flame Reactor Flash Smelter, Eliminating Waste and Landfill Liability Through High-Temperature Processing, marketing materials, undated.

-- Horsehead Resource Development Company, Inc., HRD Metals Recovery Services, Eliminating Wastes and Liability Through Recycling Technology, marketing materials, undated.

-- ICF Inc., Profiles of Metal Recovery Technologies for Mineral Processing Wastes and Other Metal-Bearing Hazardous Wastes, prepared for U.S. Environmental Protection Agency, Office of Solid Waste, Draft, August 31, 1992.

-- James, S.E. and Bounds, C.O., Recycling Lead and Cadmium, As Well As Zinc, From EAF Dust, Proceedings of Lead-Zinc '90, The Minerals, Metals, and Materials Society, 1990.

-- Smith, Jeffrey D., Horsehead Resources Development, EAF Recycling Stalwart Expands Within and Beyond its Core Business, EI Digest, Environmental Information Ltd., May 1991.

134. Letter from Metals Recovery Coalition to EPA, Office of Solid Waste., March 1, 1993.

135. Under 40 CFR 266.20(b), zinc-containing fertilizers using EAF dust that are produced for the general public's use are not presently subject to RCRA regulation.

136. EPA has determined that use of EAF dust to produce "glass frit" that is used in roofing shingles, abrasive blast, glass ceramic, and ceramic glazes is direct reuse of EAF dust as a product rather than reclamation of a waste and thus is not subject to RCRA regulation.

137. EPA has promulgated "generic delisting" concentrations for slag from high temperature metal recovery (40 CFR 261.3(c)(2)(ii)(C)). To meet the generic delisting criteria the slag must not exceed concentrations specified for 13 constituents. Once these criteria are met, the slag may be managed in a Subtitle D (non-hazardous waste) unit.

138. In addition, some wastes from primary metal production are excluded from hazardous waste regulations based on the statutory "Bevill" exclusion (40 CFR 261.4(b)(7)). The excluded wastes are generated in high volumes and are of relatively low toxicity, and include, for example, slag from primary zinc processing (40 CFR 261.4(b)(7)(xx)).

139. There is a case-by-case variance available by petitioning the EPA and demonstrating that a partially-reclaimed material is more commodity-like than waste-like (40 CFR 260.30(c)). This variance has been used infrequently.

140. The majority of the information in the East Penn Manufacturing Company, Inc. case study was obtained from company marketing materials and from personal conversations between Charlotte Mooney, EPA Office of Solid Waste, and Richard Leiby, Vice President of Metals Operations, East Penn

Manufacturing Company, Inc.

141. Smith, Bucklin & Associates, Inc., 1990 National Recycling Rate Study, prepared for Battery Council International, May 1992, p. 1.

142. Personal communication between Charlotte Mooney, EPA Office of Solid Waste and Ann Noll of the Battery Council International.

143. Smith, Bucklin & Associates, Inc., 1991 National Recycling Rate Study, prepared for Battery Council International, April 1993, p. 7.

144. 50 FR 6649, January 4, 1985, and 48 FR 14498 - 499.

145. It is difficult to tell, however, how much other variables may also be affecting the recycling rate of do-it-yourselfers and conditionally exempt small quantity generators. These variables might include state laws mandating recycling and banning landfilling, landfills' unwillingness to accept batteries (which are relatively large and thus easy to identify), and people's natural disinclination to store batteries or manage them improperly because the acid electrolyte makes the hazards posed by batteries relatively obvious.

146. According to the U.S. Bureau of Mines, Mineral Commodity Summaries, in 1992, total U.S. chromium usage was estimated at 288 thousand metric tons. Although it is not possible with current data limitations to directly estimate the amount of chromium discarded in hazardous waste, 1991 Toxic Release Inventory (TRI) data indicates that the manufacturing sector discarded 21,000 tons of chromium through releases to the land or transfers for disposal. This represents 7.3 percent of total chromium use in the United States. Most of this discarded material included industrial wastewaters (chromium used as a corrosion inhibitor) and chromium-bearing sludges and by-products of manufacturing. Many of these materials are likely to be hazardous wastes under RCRA Subtitle C.

147. Based on the difference between imports and exports of each commodity as reported in McClaskey, Jacqueline A. and Smith, Stephen D., "Survey Methods and Statistical Summary of Nonfuel Minerals," U.S. Department of the Interior, Bureau of Mines, 1991.

148. GAO, Industrial Wastes: An Unexplored Source of Valuable Minerals, Washington D.C.: GAO, 1980), pp. 10-13.

149. See Shamsuddin, M. "Metal Recovery from Scrap and Waste," *Journal of Metals*, February, 1986; and Brooks, Clyde S., "Metal Recovery from Industrial Wastes," *Journal of Metals*, July, 1986.

150. OTA, p.11.

151. (1978-1982) U.S. Bureau of Mines, "Mineral Commodity Summaries", 1983 and 1984 (as reported in OTA...1985), (1988-1992) U.S. Bureau of Mines, "Mineral Commodity Summaries", 1993.

152. Rutile, a mineral precursor to the production of Titanium, has been excluded because of insufficient data.

153. Purchasing Vol: 107 Iss: 2 Date: Jul 20, 1989

154. U.S. Bureau of Mines, Mineral Commodity Summaries, 1993.

155. Gabler, R.C., Jr., "A Platinum-Group Metals Consumption and Recycling Flow Model," U.S. Bureau of Mines, IC 9303, 1991.

156. Comprehensive data are only available for the first tier metals and a few others, so this table is limited to the first tier metals.

157. General Accounting Office, Industrial Wastes: An Unexplored Source of Valuable Minerals, (Washington D.C.: GAO, May 15, 1980), pp. 33-34. The GAO mentioned three Japanese government agencies providing such assistance: the Environmental Pollution Control Service Corporation (EPCSC), the Japan Development Bank (JDB) and the Small Business Finance Corporation (SBFC). The EPCSC financed pollution prevention and metal recovery projects and sells them on a long term, low interest basis. It also extended loans to finance the installation of pollution prevention projects at various facilities. The JDB and SBFC provided loans for pollution prevention and metal recovery projects for large and small businesses.

158. Support for this section was developed from the following sources. Bill Quan, "Waste Exchanges" in Standard Handbook of Hazardous Waste Treatment and Disposal, Harry M. Freeman ed., (New York: McGraw-Hill Book Company, 1989), pp. 5-29 to 5-37.; Kenneth E. Noll, Charles N. Haas, Carol Schmidt, Prasad Kodukula, Industrial Waste Management, James Patterson ed., Chelsea MI: Lewis Publishers, Inc, 1985), pp. 61-63., GAO, supra, pp. 35-36.

159. See Economic Instruments for Environmental Protection, OECD, Paris, 1989.

160. Note that the discussions that follow and each of the economic hypotheses assume a profit maximizing motive on the part of regulated entities.

161. See U.S. Environmental Protection Agency, Economic Incentives: Options for Environmental Protection, Office of Policy, Planning and Evaluation, March 1991, 2IP-2001; and, Tietenberg, Tom, Environmental and Natural Resource Economics Scott Foresman and Company, 1984 for a further discussion of pollution charges.

162. Marshall, Will and Schram, Martin, Mandate for Change, The Progressive Policy Institute, Berkley Books, January, 1993.

163. Such an approach would involve first setting the pollution charge below the incremental cost of controlling pollution in order to encourage firms with relatively low control costs to reduce their generation of waste.

164. Noll, et. al., supra, Note 138., p.56-60.

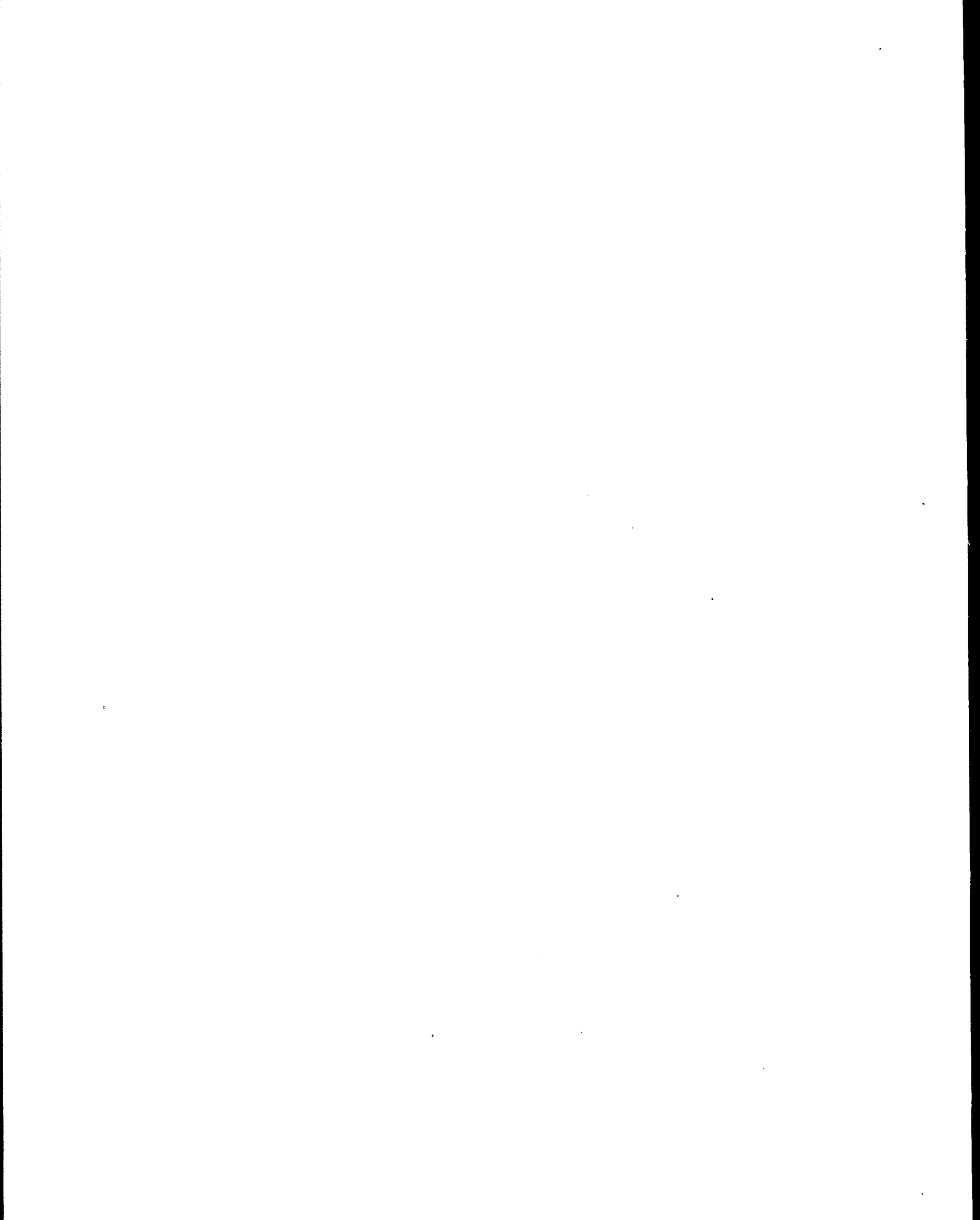
165. This assumes that those entities which generate the greatest amount of waste also generate the greatest amount of taxable income.

166. See U.S. Environmental Protection Agency, Economic Incentives: Options for Environmental Protection, Office of Policy, Planning and Evaluation, March 1991, 2IP-2001; and, Tietenberg, Tom, Environmental and Natural Resource Economics Scott Foresman and Company, 1984 for a further discussion of marketable permit systems.

167. There have been numerous interpretations of "bubble" by the courts and by EPA. In general, the term is used when describing some unit of area which may encompass contiguous or non-contiguous stacks, pipes or other outlets for the disposition of waste. The limits of a "bubble" may span all or part of a facility or region.

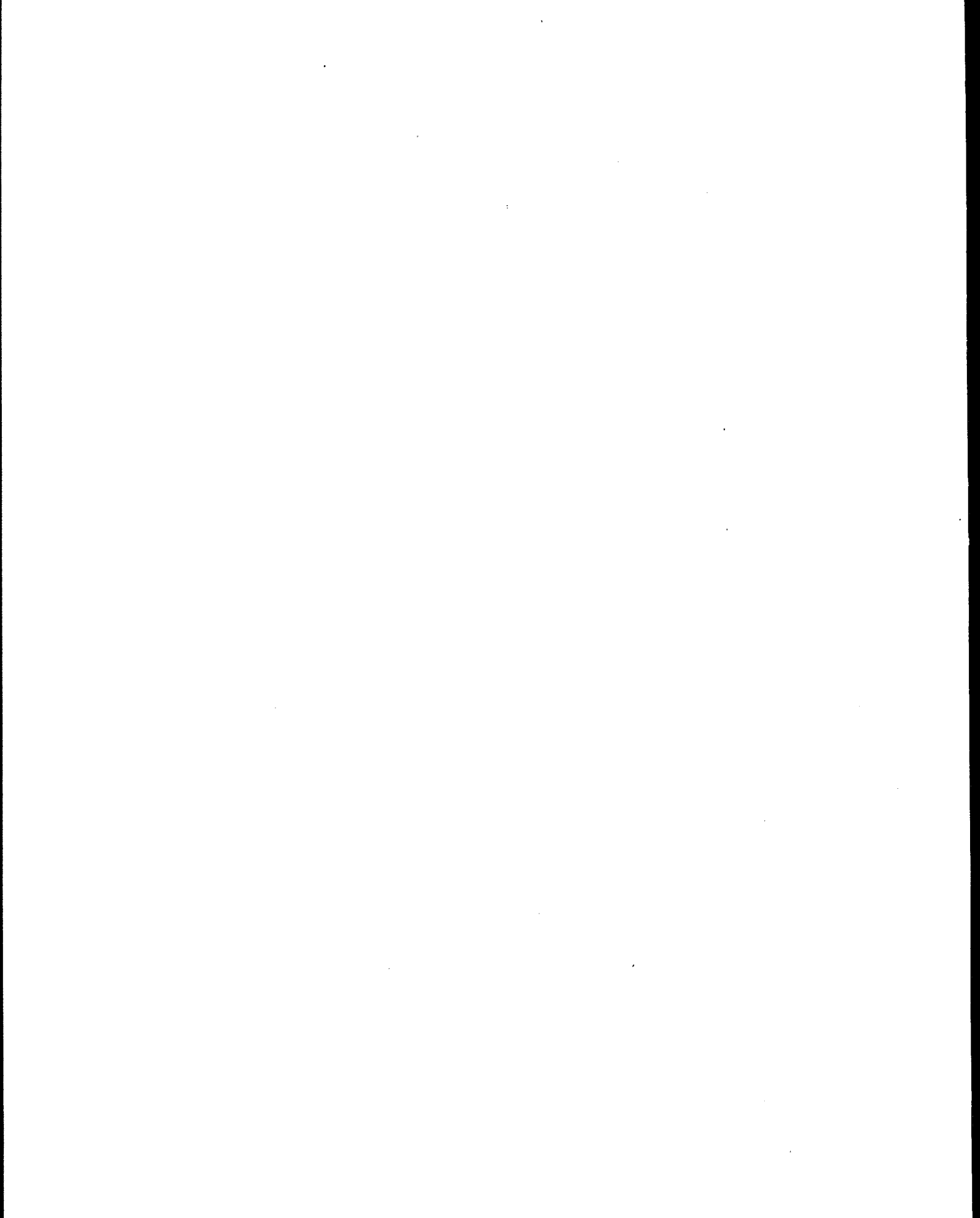
168. Regional efforts include, for example the Great Lakes Initiative.
169. See Anderson, Terry L. and Leal, Donald R. Free Market Environmentalism Pacific Research Institute for Public Policy, Westview Press, Inc., 1991, Chapter 10.
170. See Macauley, Molly K., Bowes, Michael D and Palmer, Karen L., Using Economic Incentives to Regulate Toxic Substances, Resources for the Future, 1992. Chapter 4.
171. Marshall and Schram. In order to develop a tradeable permit for recycling, the federal government would set a minimum recycled content standard which entities would satisfy in one of two ways: either they would meet the standard or they would, like other programs, acquire permits to satisfy the difference.
172. See Tietenberg, Thomas H. "Transferable Discharge Permits and the Control of Stationary Source Air Pollution, from Land Economics, v.5 (1980) pp 391-416.
173. Tom Tietenberg, Environmental and Natural Resource Economics, (U.S.A.: Harper Collins Publishers, 1988).
174. Note that the ultimate allocation of permits will be driven by the market.
175. See Tietenberg (1980).
176. See Project 88 - Round II Incentives for Action: Designing Market-Based Environmental Strategies, A public policy study sponsored by Senator Tim Wirth and Senator John Heinz, Washington D.C. May 1991, Chapter 3.
177. Public costs are likely to approximate the costs of conventional command and control regulations. See U.S. Environmental Protection Agency, Economic Incentives: Options for Environmental Protection, Office of Policy, Planning and Evaluation, March 1991, 2IP-2001.
178. See U.S. Environmental Protection Agency, Economic Incentives: Options for Environmental Protection, Office of Policy, Planning and Evaluation, March 1991, 2IP-2001; and, Project 88 - Round II Incentives for Action: Designing Market-Based Environmental Strategies, A public policy study sponsored by Senator Tim Worth and Senator John Heinz, Washington D.C. May 1991, Chapter 3. for a further discussion of Deposit/Refund Systems.
179. See Tietenberg (1984) pages 164 and 174. Composition of demand is an incentive whereby consumers have a tendency to switch to products made with cheaper, recycled raw materials. Deposit/refund systems lower the costs of collection to recyclers thereby lowering the cost of processing. Theoretically, via a deposit/refund system, recycled materials may present industry with a more efficient alternative than virgin materials.
180. Also see Bohm, Peter. Deposit-Refund Systems: Theory and Application to Environmental Conservation and Consumer Policy (Baltimore, Maryland: Johns Hopkins University Press for Resources for the Future), 1981.
181. See U.S. Environmental Protection Agency, Economic Incentives: Options for Environmental Protection, Office of Policy, Planning and Evaluation, March 1991, 2IP-2001; and, Federal Disincentives to Recycling, Office of Policy, Planning and Evaluation, Office of Policy Analysis, **Draft Report**: November, 1991.

182. As cited in the Federal Disincentives Report, U.S. EPA, and the Center for Economic Policy Analysis, Economic Incentives and Disincentives for Recycling of Municipal Solid Waste, Draft, December, 1988. Prepared for the Office of Technology Assessment.
183. As cited in the Federal Disincentives Report: Alice Rivlin, Chair of the Governing Council of the Wilderness Society and Senior Fellow in the Economic Studies Program of the Brookings Institute, Statement before the Senate Budget Committee, March 15, 1989, p.9.
184. Davis, Charles, Approaches to the Regulation of Hazardous Wastes Environmental Law, Volume 18, pp. 505-535.



APPENDIX A





The following examples illustrate opportunities for source reduction in industries that generate metal-bearing hazardous waste.

**1. Change from Chromic Acid to Sulfuric Acid in an Aluminum Anodizing Operation (Material Substitution, Process Modification)<sup>1</sup>**

An armament manufacturer (General Dynamics) in Pomona, CA reduced the volume and metal (chromium) content of an acid wastestream that presumably was classified as a hazardous waste.<sup>2</sup> The plant

used chromic acid in the original aluminum anodizing process due to military contract specifications....This process, in spite of its higher operating costs, is used by the aerospace industry, the military, and military contractors.

General Dynamic's motivation for converting to a sulfuric acid anodizing system was that its original chromic acid system could not be modified cost-effectively to meet production requirements and maintain compliance with current and anticipated air and water regulatory requirements. Besides the chemical substitution to eliminate chromium releases, the addition of automated hoists and the on-demand water bath rinse system helped to reduce wastewater treatment requirements....from approximately 15-20 gallons per minute...to approximately 6-8 gallons per minute.<sup>3</sup>

Assuming that during the substitution, the metals present in the wastestream as a result of the anodizing operation [if any] remained constant during the switch to sulfuric acid, then the company would have achieved a reduction in chromium present in the wastestream through the technique of materials substitution.

**2. Removal of Cyanide from Plating Operations (Material Substitution)**

Prior to 1986, a California electronic instrument manufacturer (Hewlett Packard, or HP) used zinc cyanide in its precision plating operations, and generated waste zinc cyanide when replacing the plating baths.<sup>4</sup> The company

"attempted to treat this waste in the wastewater treatment plant. However, this wastestream caused significant operational difficulties for HP's treatment plant and the environmental manager chose to send the waste off-site for treatment and disposal. Because the zinc cyanide caused similar problems for the commercial treatment facility, this alternative was very expensive.

For these reasons, HP staff committed themselves to developing a plating process that did not use cyanide. Since processing protocols require complex engineering to develop, HP had to overcome the inertia of established protocols and dedicate staff resources to find an appropriate alternative zinc compound that excluded cyanide.

The HP process engineers were successful in their efforts. The new zinc compound is an effective plating medium with a much longer lifespan. Although the plating bath is periodically replenished, HP has not had to replace it since it implemented the process over a year ago. Moreover, HP believes that waste from this plating solution could easily be treated in its wastewater treatment plant. Therefore, the cost of off-site treatment/disposal has been eliminated. A total of 16,650 pounds of waste were disposed in 1986 at a total cost of \$6,862. The cost of off-site treatment/disposal has increased to \$0.82 per pound in 1987, creating an effective savings of \$13,653...<sup>5</sup>

### 3. Process Modifications at a Circuit Board Manufacturing Plant<sup>6</sup>

Also documented at the General Dynamics Pomona Division printed circuit board manufacturing plant are two process changes: eliminating process rinse tanks reduced rinsewaters from 60 gallons per minute to 10 gallons per minute, and initiating a copper-recovery technique for the process waste streams which consisted of ion exchange columns and "electrowinning" (generally, running electric current through a metal-bearing solution to capture the metal ions in a usable form); these changes resulted in cost savings with a payback period of 8.3 years.<sup>7</sup> For the purposes of this study, EPA is assuming that the wastewater treatment sludge that would have resulted from the higher rinsewater volume and from the copper that was recovered was classified as a hazardous waste.

### 4. Product Reformulation of Sealers in Automotive Body Repair Firm

KD Auto Body in Washington State won the Governor's Award for Outstanding Achievement in Pollution Prevention. One of the wastestreams that KD Auto Body reduced at the source was their sealers - their "yellow-based sealers" contained high levels of lead and chromium; they instead began using "gray-based sealers" which had lower lead and chromium concentrations, thus reducing their disposal costs.<sup>8</sup>

#### NOTES

1. Kathryn Barwick, et al. Economic Implications of Waste Reduction, Recycling, Treatment and Disposal of Hazardous Wastes: The Fourth Biennial Report, p. 24. California Department of Health Services, Toxic Substances Control Division, Alternative Technology Section, 1988; Johnny Springer, Pollution Prevention Case Studies Compendium, pp. 8 & 9. U.S. Environmental Protection Agency, Office of Research and Development, Risk Reduction Engineering Laboratory, Cincinnati, OH, EPA/600/R-92/046, 1992.

2. Either the waste met a listing in 40 CFR 261.31, or the waste was hazardous because of corrosivity (40 CFR 261.22) and/or toxicity (40 CFR 261.24).

3. Springer, Johnny. Pollution Prevention Case Studies Compendium, p. 8. U.S. Environmental Protection Agency, Office of Research and Development, Risk Reduction Engineering Laboratory, Cincinnati, OH, EPA/600/R-92/046, 1992.

4. Which possibly would be classified as F007 under the federal hazardous waste regulations at 40 CFR 261.31.

5. Barwick, pp. 17-18.

6. Springer, p.5.

7. It is unclear whether the process change described in this paragraph is the same process change documented in the California Department of Health Services Economic Implications... report.

8. Turning Point Newsletter (Volume 3, No. 1, p.2), published by EPA Region 10 in Seattle, WA.

## APPENDIX B

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This Appendix provides more specific information regarding the hazards associated with selected metals found in metal-bearing hazardous waste. These summaries were developed from sources cited in Section 3.3.2.

### Lead

Lead is a silver-gray metal that is used in the production of storage batteries, solder, ammunition, ceramics and crystal glass, radiation shielding and other uses. Lead is an acute and chronic toxin. Acute toxic symptoms include headaches, convulsion, tremors and coma. Chronic exposure symptoms include affects to the central nervous system (restlessness, irritability, memory loss), kidney dysfunction, and changes to the liver (resulting from inhalation of lead dusts). Permanent brain damage in children has been observed from lead poisoning. Carcinogenicity in humans resulting from lead exposure has not been established. Exposure routes for lead include food, air and water. These routes are believed to account for 60 percent, 30 percent and 10 percent of blood lead levels in humans respectively. Lead behaves like calcium in the human body and bioaccumulates in the bones and teeth.

Blood lead levels (ug per 100 MI) in people are reported in the following ranges: rural children, 7-11; urban children, 9-33; adults, 15-22; children living near a smelter 35-68. The following health effects have been observed at varying blood lead levels (ug per 100 mL) in humans: level of concern for fetal effects, 10-15; blood enzyme changes, 15-20; IQ deficiencies in children, <25; clinical anemia, children, 40; clinical anemia, adults, 80; reproductive effects in adults, 60; mental losses (writing and speech problems, mental retardation), 50-60; irreversible brain damage, 100.

### Cadmium

Cadmium is a silver or bluish-white metal that is malleable and resistant to corrosion. It is used for the production of nickel-cadmium batteries, pigments, coating and painting, plastics and synthetic products, and alloys. It is both an acute and chronic toxin. Acute cadmium toxicity has been linked with chemical pneumonitis causing fatality. Additional symptoms of acute cadmium poisoning include nausea, vomiting and abdominal pain. The oral LD<sup>50</sup> (lethal dose required to kill 50 percent of the mass of specimens) of cadmium for rats is 250 mg/kg.

Chronic exposures of cadmium are linked in humans to emphysema, chronic bronchitis, heart disease, anemia, kidney and liver disease. Cadmium caused kidney disease is the most well studied of these effects and is irreversible. Cadmium is classified as a probable human carcinogen and is linked with lung cancer in occupational studies. Evidence linking cadmium exposure to prostate cancer is less certain. Airborne cadmium may be attach to fly ash, dust, soil particles or sediments and stay in the atmosphere for a week or more. Cadmium deposition becomes absorbed in soils and water bodies where it enters the food chain. Food accounts for about 80 to 90 percent of the dose received by most people. Smoking is an additional source of exposure.

Cadmium is a trace contaminant in fertilizers that is slowly building up in agricultural soils. Literature reviewed in completion of this report states that might be one of the most important sources of cadmium exposure in the future. One of the main end uses proposed for cadmium-bearing hazardous wastes is either direct use as a fertilizer or reclamation for zinc to be used in a micronutrient in fertilizer.

### Arsenic

Arsenic varies in form from a shiny gray metal to a white powder. It main uses are wood preservatives, hardening metals such as copper and lead, a doping agent in solid-state products of silicon and germanium. Arsenic salts are used in making herbicides, rodenticides, semiconductors and pyrotechnics.

Arsenic is both an acute and chronic toxic as well as a carcinogen. Arsenic is much more toxic in the inorganic form than the organic form. Ingestion of doses between 70 to 180 mg of arsenic may be fatal. Acute arsenic toxicity causes severe gastrointestinal damage causing shock, coma and death. Several hundred deaths from arsenic poisoning in food have been reported, but none in the United States. Chronic exposure to arsenic may lead to noncancerous lesions, peripheral nerve effects.

Arsenic is classified by both the International Agency for Research on Cancer (IARC) and the Cancer Assessment Group of EPA in the highest category of carcinogens. Arsenic is associated with a higher incidence of lung cancer through inhalation and liver, blood, skin and lung cancer through ingestion. Confirming the carcinogenicity of arsenic in animal experiments has been difficult.

Exposure to arsenic occurs mainly through food (70 percent), however most of this is in the organic, inert form of the metal. Drinking water and air contribute smaller total amounts but a much higher proportion of the toxic inorganic form. High risk groups for arsenic exposure include children, smelter workers, farm workers and carpenters who work with wood preservatives.

### Chromium

Chromium is a grayish, hard, lustrous metal. It is used in the production of steel alloys, metal plating, wood preservatives.

Chromium occurs in three forms: metal, trivalent (chromium III) and hexavalent (chromium VI). Hazards caused by chromium to human health and the environment come primarily from the hexavalent form. Hexavalent chromium is rapidly transformed in nature by organic matter to the trivalent form. Some of the literature reviewed reports that significant quantities of hexavalent chromium in nature are most likely to be the result from human sources. In addition to being the most toxic, hexavalent chromium is much more mobile in groundwater than trivalent chromium.

Acute chromium toxicity is rare. Only six cases have been reported since 1935, but most were fatal. Chronic chromium toxicity results in perforated and ulcerated nasal septa, inflammation of the nasal passages, nose bleeds, and skin ulcers and dermatitis. Chromium VI is believed to cause lung cancer. EPA classifies hexavalent chromium as Class A carcinogen indicating there is sufficient evidence to show it causes cancer in humans. Hexavalent chromium is also very toxic to plants and aquatic life. Water quality standards to protect aquatic life have been promulgated by EPA.

Steel production, fossil fuel combustion and chemical production account for most of chromium released to the air. Electroplating operations, textile manufacturing and leather tanneries are the main source of water release. Chromium chemical plants and chromite ore refineries are the largest source of chromium-bearing solid wastes (not necessarily subject to Subtitle C regulation).

### Mercury

Mercury is a silvery-white metal that is liquid at room temperature. Mercury is used for electrical uses (thermostats, mercury switches), the manufacture of chlorine and caustic soda, dental amalgam, thermometers, batteries and light bulbs.

Mercury is a neurotoxin. Inorganic mercury such as metal mercury is less toxic than methylmercury. Symptoms of mild mercury exposure include memory loss, tremors, insomnia and a loss of appetite. At higher levels, mental disorders and motor disturbances and kidney damage result. High short term exposure leads to lung damage and death. High risk populations include workers exposed to mercury vapors (especially women), pregnant women, young children and people who consume large quantities of seafood products. Risk of cancer in humans from mercury has not been established.

Mercury evaporates readily once it is exposed to air. This is problematic because of the risk of inhalation of mercury vapors and absorbed into the bloodstream. Mercury is also an ecotoxin to aquatic species including, fish, invertebrates and algae.

### Nickel

Nickel is a white-silver lustrous hard metal used in the production of steel alloys, nickel-cadmium battery production, electroplating, petroleum catalysts, and household products. Inhalation of nickel dust may cause cancer of the lung, nasal passages and possibly the larynx, primarily through occupational exposure. Acute nickel toxicity is limited to exposure that is several thousand times the average daily dose or linked with nickel carbonyl (a highly toxic nickel compound limited mainly to nickel refineries since it easily degrades to less toxic forms in the environment).

High risk groups for nickel include workers in nickel refining, stainless steel makers, welders, electroplaters, battery makers, jewelers, spray painters, paintmakers and varnish makers. It has been reported that 250,000 workers are exposed to nickel on the job. Although generally nickel has not been identified as causing a problem in the environment, it has been reported to biomagnify in aquatic flora and fauna.

### Selenium

Selenium varies in physical form from a dark red to bluish-black amorphous solid to a dark red or grey crystal. Selenium is used in the manufacture of colored glass, photocells, semiconductors and rubber manufacture.

Although selenium is both an acute and chronic toxin, recorded cases of selenium poisoning in humans are rare. Acute selenium poisoning in Venezuela caused illness in natives ingesting selenium-rich nuts. Symptoms included vomiting, nausea and diarrhea. All patients recovered. Chronic selenium poisoning in China reports villagers had loss of hair and fingernails, disorders of the skin, nervous system and teeth. There are no recorded cases of selenium poisoning in the United States.

Selenium is an ecotoxin. There are reports of selenium rich irrigation water in California killing and causing birth defects in ducks and other waterfowl in the Kesterson Wildlife Preserve. Selenium intoxication of farm animals from grazing on plants grown in selenium rich soils has been recorded.

### Zinc

Zinc metal is a bluish-white with a luster. It is mainly used as an alloy with copper and tin to make brass and bronze and as a galvanizing agent in metal plating. Although acute exposure through ingestion to zinc can cause nausea in humans, there is little risk of buildup over chronic exposures because the body efficiently excretes the metal. In contrast to ingestion, workers who inhale zinc oxide fumes may develop symptoms known as "metal fume fever". Short term effects include rapid breathing and chest pain usually lasting 2 to 3 days. Long term effects from such exposure are not known. Zinc is not associated with cancer in humans.

Zinc is an ecotoxin. Depressed plant growth, impaired aquatic life and waterfowl, and fish kills are associated with zinc releases from smelters and mine runoff. Zinc is also an essential mineral for human health and a micronutrient for plant and animal life. Zinc is used in micronutrient fertilizer formulations for agricultural commodities.



### Barium

Barium is a silvery-white to a yellowish-white shiny, malleable metal. It is used in electric tubes and as a carrier for radium. Barium salts are used in paints, ceramics, lubricating oils, analytical work. Barium sulfate is the most common form of the metal in nature. Barium chloride is the most toxic form of the metal.

Barium is an acute toxin. Fatal doses in human are about 1 to 15 grams depending upon the compound. Barium ion is toxic to muscle. Absorption of barium causes sustained and prolonged contractions of muscles including the heart. Muscular weakness and paralysis of the limbs follow. No relationship between barium and cancer in humans has been established.

### Beryllium

Beryllium is a gray metal. It is used for developing a copper alloy which goes into instruments, aircraft parts, and other components. Some beryllium is used in ceramics for high heat conductivity. Small quantities of pure beryllium metal are used in missile and rocket parts, aircraft, heat shields and nuclear weapons.

Beryllium is both an acute and chronic toxin; it mainly affects the lungs. Acute beryllium poisoning in humans causes pneumonitis, a chemically induced inflammation of the respiratory tract. Chronic beryllium exposure in humans cause berylliosis, an inflammatory lesion of the lungs. After a 25 year latency period, victims can develop fibrosis of the lungs, emphysema and death. Beryllium is known to cause cancer in animals. Although evidence is insufficient to establish the beryllium causes cancer in humans, it is suspected of causing lung cancer in humans. EPA classifies beryllium as a probable human carcinogen. Exposure routes of beryllium in humans are estimated at 70 percent drinking water, 30 percent from food with very little from air or dust.

### Thallium

Thallium is a bluish-white, soft, fusible metal. Thallium is used in superconductor formulations, pharmaceuticals, photoelectric cells and low grade thermometers. Thallium salts are used as rodent poisons. Thallium is a by-product of zinc, copper and lead smelting. Thallium is highly toxic. Fatal doses of thallium in humans is about 500 mg. Chronic toxicity can cause liver and kidney damage. Patnaik reports that ingestion of thallium salts in children has caused neurological abnormalities, mental retardation and psychoses.

### NOTES