# ⊕EPA Regulatory Impact Analyses: Phase IV Land Disposal Restrictions - Toxicity Characteristic [TC] Metals

# Regulatory Impact Analyses:

## Phase IV Land Disposal
## Restrictions - TC Metals

Prepared for

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§3004(m) of the Resource Conservation and Recovery Act directs the EPA Administrator to promulgate treatment standards for hazardous wastes prohibited from land disposal in order to minimize long term threats to human health and the environment.[1] In 1990 as part of the Third Third LDR rule EPA developed treatment standards for Extraction Procedure (EP) metals wastes that require the wastes meet characteristic levels before land disposal. In 1994 the Phase II LDR rule established Universal Treatment Standards (UTS) for 216 organic, metal, and cyanide constituents in hazardous waste. In 1995, EPA proposed to revise treatment standards for eight toxicity characteristic (TC) metal wastes: arsenic, barium, cadmium, chromium, lead, mercury, selenium and silver.[2] In the RIA for the proposed rule, EPA stated that the achievement of the proposed universal treatment standards (UTS) for TC metal wastewaters and nonwastewaters could be achieved through existing technology at a minimal cost.[3]

Public commenters have raised concern over their technical ability to meet the standards and the costs associated with the previously proposed treatment standards. EPA has carefully considered this information and, as discussed in Section 4.0 below, EPA believes that there will not be significant costs to the majority of the TC metals universe affected by the standards. However, nonferrous foundries may incur additional costs, especially for the management of lead and cadmium nonwastewaters. This RIA examines the potential costs and the economic impacts of those costs for nonferrous foundries. It also provides a qualitative assessment of the potential environmental benefits of the standards.

## 1.0 Nonferrous Foundries

The United States nonferrous foundry industry (SIC codes 3366, 3369, also some nonferrous foundries in the fabricated metal SIC codes, principally 3491, 3492, and 3494, valves and fittings) includes some 2,000 nonferrous foundries (3,000 total) producing fabricated metal products. All foundries produce spent sand from molds used to form metal castings. Approximately, 791 nonferrous foundries (either brass & bronze or brass, bronze & aluminum) would be directly impacted by the rule.[4]

It is generally believed that all nonferrous foundries are small businesses according to the Small Business Administration definition of small business as firms with fewer than 500 employees. A 1989 survey by the American Foundrymen's Society (AFS) indicated that the average foundry size was 69 employees. The survey was biased towards larger foundries because foundries with 10 or fewer employees were not included. A 1995 AFS survey indicates that 345 of 614 surveyed copper-based foundries had fewer than 50 employees. An extrapolation from data from the 1992 Census of

[1] 42 U.S.C. §6924(m), Solid Waste Disposal Act 3004(m).

[2] Developed from a telecon between Gary Mosher, American Foundrymen's Society, and James H. Turner, RTI. September 24, 1996.

[3] Regulatory Impact Analysis of the Phase IV Land Disposal Restriction Rule, August 18, 1995, pp. 1-11, 1-14.

[4] Data provided in a letter from Collier, Shannon, Rill, and Scott, November 27, 1995 to EPA RCRA Information Center.

Manufactures indicates that 1992 annual revenues for this group of nonferrous foundries were approximately $2.094 billion.[5]

## 2.0 Waste Generation and Management

Sand is used in the production of nonferrous castings to provide physical support of the mold and to serve as a heat sink. While much of this sand is recycled, some is degraded and must be discarded. Of the estimated seven million tons of foundry sand disposed of annually about 300,000 tons exhibit the toxicity characteristic for lead and cadmium. This estimate is based on the assumption that each of the 650 brass and bronze foundries and each of the 386 brass, bronze and aluminum foundries generate 375 tons of waste sand annually. Further, it is estimated that 98 percent of the former group and 40 percent of the latter generate sand wastes that exhibit the TC for lead and cadmium.[6] Thus,

$$375[(650 * 0.98) + (386 * 0.40)] = 300,000$$

Assuming all facilities that generate TC wastes requiring treatment require treatment for all their waste sand, about 791 facilities would be directly impacted by the requirement to meet UTS requirements. About 89 percent of these facilities (704) treat on site. Of that treated on site about 75 percent is treated with iron filings. The remainder is stabilized with other chemicals typically trisodium phosphate (TSP)[7] -- see Table 1.

Table 1. Estimated Number of Foundries Employing Each Stabilization Reagent for On-Site Treatment in the Baseline

| Stabilization Reagent | Number of Facilities |
|---|---|
| Iron fillings | 528 |
| Trisodium phosphate | 176 |
| Total | 704 |

## 3.0 Current Treatment Practices

The treatment practices used to reduce the mobility of metal concentrations in TC wastes consist of a series of unit operations that can be combined in different ways depending on the waste to be treated and its form. These operations are described below for treatment of nonwastewaters. These operations

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5. Data from the 1992 Census of Manufactures indicates that 437 nonferrous foundries (including copper, brass, bronze foundries) each generated receipts of $2.647 million. This would extrapolate to an aggregate value of $2.094 billion (791 x 2.647 = 2.094 billion) for 791 nonferrous foundries that AFS believes are affected by today's rule.

6. Data provided in a letter from Collier, Shannon, Rill, and Scott, November 27, 1995 to EPA RCRA Information Center.

7. Letter from the American Foundrymen's Society, Inc. to Michael Petruska, USEPA, Office of Solid Waste, August 2, 1996.

are current practices and can be used to meet the proposed standards. Practices will vary across facilities depending on the specific conditions of each manager.

While similar to mineral processing waste treatment, quantities and specific treatment practices may be different. For example, cement is a typical stabilizing agent used in the treatment of metal wastes. However, as noted above, information suggests that foundry wastes are typically treated with iron filings or trisodium phosphate (TSP).

The current LDR treatment standard for hazardous lead nonwastewaters is 5.0 mg/L TCLP. After the concentration of lead is reduced below its characteristic level, the waste is no longer hazardous and may be disposed of in a Subtitle D landfill. A typical waste treatment train used to reduce concentrations of solid toxic metals includes storage, stabilization of solids with cementitious materials, and disposal of stabilized wastes in Subtitle D (nonhazardous) landfills. The treatment methods and subsidiary operations are summarized below.

## Storage

Wastes are typically stored in drums, tanks, roll-off containers, or buildings. Small quantities of solids are usually stored in drums. Each storage method has its own requirements for moving the waste into and out of the storage area. Where leaching or leaking can take place, monitoring must be used to detect such occurrences. As long as the material is defined as hazardous waste, storage facilities must meet Subtitle C design and operating requirements.

## Stabilization

Metal-bearing solids and dewatered sludges that exhibit a characteristic and are, therefore, hazardous can be treated with cement and/or other materials that form a hard substance with low leaching characteristics. Stabilization adds significantly to the mass of material that must be landfilled.

## Disposal

After treatment, residues must be given a final disposal place. Either Subtitle C or Subtitle D landfills are generally used.

**Subtitle C Landfill Disposal** Subtitle C landfills are required for disposal of hazardous wastes. Stringent monitoring, closure, and post-closure requirements must be met to ensure that toxic materials do not migrate from the site. Construction must be such that leaching or migration is kept to a minimum. Highly impermeable underlying soils and landfill liners are required. In some cases, because of logistics, it may be less costly to dispose of Subtitle D wastes in a Subtitle C landfill.

**Subtitle D Landfill Disposal of Treated Wastes** For characteristic wastes that have been treated to a concentration below the required treatment level, disposal may be made in a Subtitle D landfill. Some of these landfills do not have the special requirements for construction, monitoring, and closure that are found at the Subtitle C landfills.

## 4.0  Revised UTS Levels for TC Nonwastewaters

Public commenters including a commercial hazardous waste treatment firm and trade associations representing generators of lead-bearing hazardous waste D008 (primarily secondary lead slags from lead-acid batter smelters and foundry sands from nonferrous foundries) stated in their response that either the proposed treatment standards for certain constituents could not be met or alternatively that they could only be met at an additional cost.[8] These comments focused mostly on the proposed treatment standards for lead, chromium and selenium. For lead and chromium nonwastewaters, one commercial hazardous waste treatment firm, Chemical Waste Management, suggested that additional costs could result from additional treatment reagent when the total lead and chromium content of these wastes exceeded one percent.[9] Another commercial hazardous waste treatment firm, Rollins Environmental, has suggested that it would have been able to meet treatment standards for lead and chromium nonwastewaters at the 0.37 and 0.86 ppm level without modifying its treatment process.[10] Only the foundry industry identified cadmium as a constituent of potential concern in terms of treatability using treatment reagents, trisodium phosphate and iron filings, currently utilized within the foundry industry. EPA has carefully considered this information in developing revised treatment standards levels.

For lead, chromium, and selenium TC metal nonwastewaters, EPA had previously proposed UTS of 0.37, 0.86 and 0.16 ppm respectively. For today's reproposal, EPA is proposing UTS standards for lead of 0.75 ppm, chromium of 0.85 ppm, and selenium at 5.7 ppm (its current treatment standard) for TC metal wastes. Most of the wastes identified by the commercial hazardous wastes treaters as not amenable to the proposed UTS relate to selenium bearing wastes. Since EPA has reproposed to retain its treatment standard for selenium at its current level, it does not believe that today's rule will incur incremental costs for any selenium-bearing D010 hazardous waste as a result of the reproposed selenium UTS.

Regarding lead, public commenters for the secondary lead smelter industry and nonferrous foundry industry indicate that the secondary lead slags and nonferrous foundry sands are either not amenable to the proposed UTS nonwastewater level of 0.37 ppm[11] or cannot achieve this level without

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[8]   Letter to RCRA Docket from Kevin Igli, Vice-President, Chemical Waste Management, November 20, 1995; Letter to Anita Cummings, USEPA, Office of Solid Waste from Kevin Igli, Vice-President, Chemical Waste Management, June 17, 1996 (non-CBI portion); Letter to RCRA Docket from John L. Wittenborn, William M. Guerry, Jr., Peter G. McHugh, of Collier, Shannon, Rill & Scott on behalf of the American Foundrymen's Society, November 20, 1995; Letter to Mike Petruska, USEPA, Office of Solid Waste from Gary Mosher, Director of Environmental Affairs, American Foundrymen's Society, August 2, 1996; Letter to Paul A. Borst, USEPA, Office of Solid Waste from Susan Panzik of Swindler & Berlin, on behalf of the Association of Battery Recyclers, November 12, 1996.

[9]   Personal communication between Paul A. Borst, USEPA, Office of Solid Waste and Mitch Hahn, Chemical Waste Management Inc., June 21, 1996.

[10]   December 19, 1996 letter to Anita Cummings, USEPA, Office of Solid Waste from Michael G. Fusco, director of Regulatory Analysis, Rollins Environmental Inc., p.4 of edited draft EPA trip report letter to Rollins Highway 36 facility in Colorado.

[11]   The secondary lead smelter industry has been the principal commenter that secondary lead slags could not meet the proposed UTS for lead.

incurring additional costs.[12] However, it is possible that secondary lead smelters may be able to modify their processes to generate nonhazardous secondary lead slags. Some secondary lead smelters have been able to render slags generated as nonhazardous by processing them through an electric arc furnace.[13] Other secondary lead-smelters have been able to render slags nonhazardous as generated through reprocessing them through blast furnaces onsite a second time, though this has proven unsuccessful commercially.[14] Finally, it is possible for slags containing hazardous constituents such as lead, cadmium and arsenic to be cooled in such a way either through ambient cooling or quenching to significantly reduce the leachability of these constituents in the slag matrix.[15]

Moreover, EPA has data suggesting that secondary lead slags have been successfully treated to the proposed UTS level for lead by both secondary lead smelters and commercial hazardous waste treaters.[16] In contrast to comments from Chemical Waste Management, the data from Rollins Environmental (as well as the slag data from BCI/ABR) also seem to suggest that when portland cement is used as the primary stabilization reagent, it is possible to treat a wide variety of TC metal wastes including high lead and chromium wastes (i.e., those with greater than one percent total concentrations of lead and chromium) to the previously proposed UTS levels including 0.37 ppm for lead and 0.86 for chromium without incurring additional treatment cost or modifying existing treatment processes. Because these results apply to the more conservative previously proposed treatment standards for TC metal wastes, EPA believes that for the higher revised UTS standard for lead of 0.75 ppm that it will be even easier to meet these treatment standards using portland cement-based stabilization without incurring additional treatment costs.

However, when less expensive, less effective treatment reagents other than portland cement are used to treat TC metal waste, existing data indicates more of these reagents must be used at a higher cost (principally for additional treatment reagent) to achieve the reproposed UTS standards in today's rule. Although most commercial hazardous waste treatment facilities and many industries use portland cement as the treatment reagent of choice, other industries such as the foundry industry principally use other treatment reagents such as iron filings or phosphate-based treatment reagents.

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[12]    The American Foundrymen's Society main contention in its public comments has been that existing management practices of treating lead-bearing foundry sands to the current treatment standards of 5 ppm leachable lead cannot be maintained without additional cost. However, in contrast to the Association of Battery Recyclers, AFS has not made the claim that hazardous foundry sands were not treatable to the proposed UTS for lead.

[13]    Personal Communication between Paul Borst, USEPA, Office of Solid Waste and Gerald Dumas, Vice-President for Environmental Services, RSR Corporation, September 23, 1996.

[14]    R.A. Leiby, Jr. Secondary Lead Smelting at East Penn Manufacturing Co. Inc., EP Congress 1993 as cited in Paul Queneau, et al., Recycling Heavy Metals in Solid Waste, Sponsored by Office of Special Programs and Continuing Education, Colorado School of Mines, June 28-30, 1994.

[15]    Paul Queneau, Lawrence D. May, and Douglas E. Cregar, application of slag Technology to Recycling of Solid Wastes, Incineration Conference, Knoxville, TN, May 1991, as cited in Queneau, supra, Note 9.

[16]    Supra, Note 11, See also October 9, 1996 letter to Anita Cummings, USEPA, Office of Solid Waste from Steve Emmons, Battery Council International Environmental Committee chair and Earl Cornette, Chairman, Association of Battery Recyclers, Inc.

Although these reagents are typically less expensive than portland cement,[17] the range of TC metal constituents and long-term effectiveness of some of these reagents is questionable.[18] Based on existing data on iron and phosphate based treatment reagents, EPA believes that phosphate-based treatment reagents (usually trisodium phosphate or calcium phosphate) with or without ph buffers represent the least costly management reagent that could be considered effective treatment for a range of TC metal wastes that are not TC simply for lead. EPA is not commenting on the long term effectiveness of phosphate-based treatment reagents in this analysis. Rather, because: 1) the American Foundrymen's Society only provided bench scale data on phosphate-based reagent performance for both lead and cadmium in foundry wastes and did not provide comparable data on iron filings for TC lead and cadmium wastes and 2) some industry data indicate that iron filings are ineffective treatment agents for hazardous EP (extraction procedure) cadmium wastes, EPA does not believe that it is appropriate to estimate compliance costs from today's rule using iron filings as a baseline management method. Rather, EPA has modeled phosphate-based reagents as the least expensive reagent that has been demonstrated in bench scale trials to treat both lead and cadmium in foundry wastes. EPA solicits comment on the effectiveness of metallic iron in stabilizing cadmium in TC hazardous cadmium-bearing nonwastewaters.

## 5.0    Cost Analysis

Treatment costs are estimated for lead nonwastewater generated by nonferrous foundries at the facility and industry level.

### 5.1    Unit Costs

Functions used for estimating existing and future costs due to regulation of TC metal wastes are based on the same functions used for mineral processing wastes. The modification of these functions for TC wastes is given in Appendix A, and is included because the functions used for foundry wastes proceed directly from the TC waste functions. The equation sets listed below are numbered in sequence from those listed in Appendix A. The equations below are based on changing from cement to TSP as the stabilizing agent. A set of cost functions based on changing from iron filings to TSP is given in Appendix B.

Equations used for the analysis of lead wastes from foundries are listed below. Storage, stabilization, and disposal in a Subtitle D (nonhazardous) landfill are the operations required for the solid waste treatment and disposal.

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[17]    Supra, Note 9, August 2, letter from Gary Mosher, American Foundrymen's Society to Mike Petruska, USEPA, Office of Solid Waste. AFS data indicate that to treat foundry sands, the reagent cost of portland cement in foundry sand stabilization averages $55 per ton compared with $26 to $31 per ton for trisodium phosphate or $11 per ton for iron filings.

[18]    EPA has previously proposed to prohibit the use of iron filings as treatment reagent as impermissible dilution because the Agency believes that iron filings do not provide effective long term stabilization of lead in hazardous wastes such as foundry sands. 60 FR 11702, 11731 (Thursday, March 2, 1995). The Agency also noted that iron filings or iron material may result in false negatives for the Toxicity Characteristic Leaching Procedure (TCLP).

<u>Current Regulations Using 15 Percent Stabilizing Agent</u>

<u>Storage—Equation Set 9</u>

$$cost = 24.589\,Q + 132.23 \qquad \text{for Q to 200 mt/yr}$$

$$= -0.0022\,Q^2 + 29.272\,Q + 4,840.9 \qquad \text{for } 50 < Q < 7,500 \text{ mt/yr}$$

These equations, as described above, are taken directly from the February 12, 1997 draft RIA, Exhibit D-21. They apply to solids in drums and roll-off containers, respectively. Conditions used to develop equations in the February 12 draft are also used for the equations given here. However, on the basis of equivalent costs, the drum storage equation could be used to about $Q = 2,900$ mt/yr.

<u>Stabilization—Equation Set 10</u>

$$cost = (207.93\,Q^{0.78} \times 0.9) \times 0.09439 \qquad \text{(annualized capital cost)}$$

$$+ (87,839 + 52.16\,Q)(1 - (0.1113\ln(Q) - 0.3429) \qquad \text{(O\&M cost minus cement cost)}$$

$$+ (0.1113\ln(Q) - 0.3429)(260/67.00)(10/70)) \qquad \text{(TSP cost)}$$

$$+ ((9,806 + 0.19\,Q)/(1.07^{21})) \times 0.09439 \qquad \text{(closure cost)}$$

$$\text{for } Q < 100,000 \text{ mt/yr}$$

$$= (207.93\,Q^{0.78} \times 0.9) \times 0.09439$$

$$+ (87,839 + 52.16\,Q)((1-0.98) + (0.98)(260/67.00)$$

$$\times (10/70)) + ((9,806 + 0.19\,Q)/(1.07^{21})) \times 0.09439$$

$$\text{for } Q > 100,000 \text{ mt/yr}$$

These equations are taken from the February 12 draft RIA, but are modified by terms that adjust for different stabilizing agents, different ratios of stabilizing agent to waste quantity, and different ratios of stabilizing agent cost to total operation and maintenance cost. Each term in the equations is discussed below.

The term $207.93\,Q^{0.78}$ is taken directly from the February 12 draft RIA, p. D-7. It represents the capital cost required to build a stabilization facility capable of treating Q mt/yr of waste. Because the quantity of TSP used for stabilization of foundry wastes is significantly lower than the amount of cement assumed to be used for mineral processing wastes, the capital costs for the foundry facility are expected to be lower. This decreased cost, attributable to slightly smaller storage bins and treatment tanks, is obtained by multiplying the capital cost equation by a factor of 0.9. A factor of 0.09439 is then applied to obtain an annualization of the capital cost.

The term $(87,839 + 52.16\,Q)$ is taken directly from the February 12 draft RIA, p. D-7. It represents the operation and maintenance (O&M) costs associated with stabilizing wastes.

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The term $(0.1113 \ln (Q) - 0.3429)$ is developed from data generated from plant size *vs* cost of cement as a fraction of total O&M cost.[19] The data set is:

| Plant size, mt/yr | Cement cost, % of O&M cost |
|---|---|
| 426 | 21.0 |
| 4,265 | 71.5 |
| 42,648 | 94.9 |
| 426,477 | 98.6 |

This term estimates stabilizing agent cost as a fraction of total O&M cost for any size plant within the range of sizes given in the February 12 draft RIA (the data points were developed from the mineral processing waste cost functions). When the mineral processing RIA O&M cost equation is multiplied by one minus this term (as above), an O&M cost without the stabilizing agent is estimated based on plant size. To account for the cost of TSP as a stabilizing agent, this term is added back into the equation after modification for different reagent costs and application fractions as shown for the next two terms.

The term $(260/67.00)$ is the ratio of TSP cost[20] to cement cost[21] (both in dollars per ton).

The term $(10/70)$ is the ratio of stabilizing agent used for foundry wastes[22] to the amount used for mineral processing wastes (as given in the February 12 draft RIA).

The term $(9,806 + 0.19 \, Q)$ is taken directly from the February 12 draft RIA, p. D-7. It represents closure costs for the stabilization facility. Because this cost is not incurred until after the 20-year life, but is spread over that life, it must be divided by the terms that follow $(1.07^{21}$ and $0.09439)$ to obtain a uniform annual reserve as explained under equation set 2.

For $Q > 100,000$ mt, the term $(0.1113 \ln (Q) - 0.3429)$ is replaced by 0.98 to prevent obtaining factors greater than 1. Examination of the data suggests that an asymptote exists near this value.

Dispose—Equation Set 11

$$\text{cost} = ((25.485 \, Q) + 294,701) \times 1.20$$

This equation (for metric quantities) is developed from data for on-site nonhazardous waste landfill costs.[23] The data set is:

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[19] Telecon between Caroline Peterson, DPRA and Jim Turner, RTI. September 25, 1996.

[20] Supra, Note 9, August 2. Letter from Gary Mosher, American Foundrymen's Society to Mike Petruska, USEPA, Office of Solid Waste. Exhibits 4 and 7 provide dosage and cost data.

[21] Supra, Note 20, Value reported as $0.0335/lb taken from R.S. Means Construction Cost Data for 1995.

[22] Supra, Note 21.

[23] Letter from Carol Sarnat, DPRA, to Paul Borst, U.S. Environmental Protection Agency. March 4, 1993.

| Landfill size, short tons/yr | Capital cost, $ | Annual O&M cost, $/yr | Closure cost, $ | Annual post-closure cost, $ |
|---|---|---|---|---|
| 5,000 | 2,632,000 | 114,000 | 434,000 | 5,000 |
| 25,000 | 7,034,000 | 236,000 | 1,547,000 | 9,000 |
| 50,000 | 10,899,000 | 328,000 | 2,675,000 | 12,000 |

The equation is multiplied by a factor of 1.20 to account for the difference between added stabilizing agent quantities in lead wastes and in other TC metals wastes. For small quantities, it is likely that offsite disposal would be used as in equation set 6.

Proposed Regulations Using an Additional 5 Percent TSP

For this case, stabilization costs are increased by 5 percent for additional reagent, and also for the extra capital associated with a small increase in storage space, increased O&M costs, and increased closure costs. Reagent cost is a direct increase of 5 percent, but the other added costs are judged to increase by 2.5 percent. These changes to equation set 10 (for Q < 100,000 mt/yr) are shown as:

$$\text{cost} = (207.93Q^{0.78} \times 0.9 \times 1.025) \times 0.09439$$

$$+ (87,839 + 52.16\,Q) \times 1.025 \times (1 - (0.1113\ \ln(Q) - 0.3429)$$

$$+ (0.1113\ \ln(Q) - 0.3429)(260/67)\,((15/70))$$

$$+ ((9,806 + 0.19\,Q) \times 1.025 / (1.07^{21})) \times 0.09439$$

The changes are factors of 1.025 applied to capital and closure costs and an increase applied to the ratio (15/70) for quantity of reagent.

Storage costs are increased using equation set 9, but with Q equal to 34.02 mt/yr for the baseline case and to 51.03 for the proposed regulation. These values represent reagent usage of 10 percent of the waste for baseline and 15 percent for the proposed rule.

Disposal costs are increased using equation set 6 because of the small quantities involved. The amount disposed of is increased to 375 x 1.10 tpy (340.2 x 1.10 mt/yr) at baseline and 375 x 1.15 tpy (340.2 x 1.15 mt/yr) for the proposed regulation.

The capital costs and annual incremental cost (which includes the annualized capital cost) per foundry for the revised UTS level is provided in Table 2. These values are found by solving appropriate equations above at baseline and with the stricter levels for lead for Q = 340.2 (the metric equivalent of 375 tpy), the average value per foundry. The methodology for obtaining these costs assumes that the increased quantity of TSP required to meet the proposed UTS standard also requires slightly increased capital and O & M costs for all aspects of the treatment facility: more storage and treatment capacity, higher treatment and disposal labor costs, and higher closure costs.

## Table 2. Incremental Cost Per Nonferrous Foundry

| Activity | Capital Cost | Annual Cost |
|----------|--------------|-------------|
| Storage | a | 418 |
| Stabilization | 441 | 11,504 |
| Disposal | a | 736 |
| **Total Incremental Cost** | **$441** | **$12,658** |

a Included in stabilization costs

### 5.2 Aggregate Costs

The aggregate costs of the UTSs are the sum of the costs for all effected entities. Because of the existence of economies of scale in metals wastes management some small generators ship their TC metals wastes to off-site managers. Presumably these generators have compared the cost of on-site treatment to the cost of transporting wastes to off-site managers and paying the price charged by these commercial firms and found commercial management cheaper. It is possible that changes in cost and pricing of commercial waste management services will change some generators' waste management choice. However, given the small unit cost changes involved, this seems unlikely in this case.

Of more importance regarding the on-site:off-site issue is whether all the current on-site managers of lead-containing wastes will be able to treat to the UTSs on-site. If some find it technically infeasible to meet these standards they will have to switch to off-site treatment. This will increase their costs from those projected here and, perhaps, place pressure on the capacity of commercial managers. In time any capacity constraints are likely to be overcome with new investment but in the short-run capacity limitations could result in price increases for commercial treatment.

The incremental costs for nonferrous foundries of meeting the lead UTSs for nonwastewaters are provided in Table 3. They are estimated by multiplying the per facility costs from Table 2 by the number of nonferrous foundries: 791.

## Table 3. Total Incremental Cost to Nonferrous Foundries

| Activity | Capital Cost | Annual Cost |
|----------|--------------|-------------|
| Storage | a | $330,638 |
| Stabilization | 348,831 | $9,099,664 |
| Disposal | a | $582,176 |
| **Total Incremental Cost** | **$348,831** | **$10,012,478** |

a Included in stabilization costs

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## 6.0    Economic Impacts

Based on the foregoing analysis, EPA believes that most generators of TC metal wastes using portland cement as the main reagent of stabilization will not incur cost resulting from today's rule. However, nonferrous foundries will collectively incur estimated incremental costs of $10.0 million annually resulting from today's rule. Because economic impact analysis indicates that this costs will represent less than 1 percent of nonferrous foundry revenues and about 3 percent of nonferrous foundry profits, EPA does not believe that today's rule will impose a significant economic impact on a substantial number of nonferrous foundries -- see Table 4.

### Table 4.   Economic Impact of UTS on Nonferrous Foundry Industry for Facilities that Generate Hazardous Wastes

| Estimated Phase IV UTS/TC Metal Compliance Costs for Nonferrous Foundries | Estimated Revenues[a] | Compliance Cost as Percentage of Revenues | Estimated Profits[a] | Compliance Costs as a Percentage of Profits |
|---|---|---|---|---|
| $10.0 million | $2.094 million | 0.48 | $316 million | 3 |

[a]Based on per facility averages for SIC 3366 and 3369 from the 1992 Census of Manufactures scaled by 791.

The standard view of the facility closure decision is that profit-maximizing managers will elect to exit a market when the value of the productive assets in their best alternative use exceeds the expected present value of remaining in the market. This view requires that managers of nonferrous foundries assess the current and future market for the commodity produced at the facility to evaluate the revenue implications of keeping the facility open and remaining in the market. It also requires that they assess the current and future markets for the inputs used to make foundry products to evaluate the cost implications of keeping the facility open and remaining in the market. Finally, managers must evaluate the market for the land and the plant and equipment used to produce the foundry products. Presumably, if only informally, managers of the 791 foundries in this analysis have completed that evaluation and found that staying in the market is the profit maximizing choice.

Compliance with the revised standards for lead will raise the costs of production at each affected nonferrous foundry about $13,000 annually. Depending on market conditions some or all of this amount may be passed downstream to consumers in the form of higher prices for foundry products or upstream to input suppliers to in the form of lower input prices. In the long run these costs are likely to be passed on entirely to consumers of foundry products as new facilities will not be constructed unless investors can expect to cover all their costs. However, in the short run when there is specificity in the fixed capital (e.g., the plant and equipment used in making castings may have no value except that of scrap metal outside the foundry industry), the costs will be shared across foundry owners, consumers of foundry products, and suppliers of inputs to nonferrous foundries.

It seems unlikely that even if foundry owners are forced to absorb the entire cost of meeting the revised standards that an additional $13,000 annually would cause a nonferrous foundry to prematurely close. Most of these costs are variable thus, owners would not be required to make large up front

expenditures for additional plant and equipment which are inherently more risky than operating and maintenance costs since the latter can be readily avoided if continued facility operation becomes unprofitable. Further, there is considerable randomness to all prices rendering both costs and revenues for nonferrous foundries subject to fluctuation. It seems likely that much of the costs of meeting the revised standards would be largely lost in the normal profit fluctuations.

## 7.0    Impacts on Small Entities

The Small Business Regulatory Enforcement Fairness Act of 1996 (SBREFA) requires that agencies consider the impact of new regulations potential impacts on small businesses, amending and strengthening the requirements of the Regulatory Flexibility Act (FRA). Agencies must either certify that a rule will not have "significant impacts on a substantial number of small entities" (with a factual justification) or must comply with additional requirements.

Virtually all nonferrous foundries are small businesses by the SBA definition (less than 500 employees). According to current EPA draft guidance on completing small business initial assessment, there is a rebuttable presumption that significant economic impacts result to a substantial number of small entities (firms) when the estimated compliance cost of the rulemaking equals or exceeds 3 percent of firm sales/revenues. When firm-specific data is unavailable, industry sales/revenues may be used as a proxy for estimating impacts.

Using this guidance, EPA does not believe that there is a significant impact to a substantial number of small entities resulting from the part of today's reproposal pertaining to the revision of UTS for TC metal wastes. Table 4 indicates that the estimated compliance costs are less than one percent nonferrous foundry revenues. AFS previously indicated to EPA that it does not have accurate number on :rofit percentages for nonferrous foundries.[24] However, using data from the 1992 Census of Manufactures, Table 4 indicates that estimated compliance costs associated with today's rule are about 3 percent of profits.

## 8.0    Benefits

The revised standards for TC metals are designed to reduce the release of hazardous materials into the environment thereby increasing the quality of environmental services and, indirectly, human welfare. Human welfare changes form the basis for valuing environmental quality changes expected with the
regulations. To relate human welfare to changes in the quality of environmental and natural resources it is necessary, among other things, to identify the ways in which individuals interact with economic and environmental systems and the ways these two systems interact. Economic systems, including market and household systems, operate in conjunction with environmental systems to contribute to human welfare.

A conceptual framework is developed immediately below to structure this benefits evaluation of the regulation. This framework: (1) identifies the ways environmental quality affects human welfare, (2) distinguishes between economic and environmental system responses to changes in environmental quality, and (3) illustrates how benefits from the regulation can be inferred. This is followed by a tracing of the linkage between the regulation and its benefits.

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[24]    Personal communication between Gary E. Mosher, Director of Environmental Affairs, American Foundrymen's Society and Paul A. Borst, USEPA, Office of Solid Waste, September 23, 1996.

## 8.1 The Circular System

Pearce and Turner (1990) identify three key economic functions of the environment that can be used to guide this analysis:

resource supply-the extraction or in-situ use of environmental and natural resources in the production of goods and services ("commodities") by governments, firms, and households (e.g., use of ground water for drinking water supply or for process water).[25]

waste assimilation-the provision of a sink for disposal of waste products produced by economic and natural systems (e.g., use of land for disposal of wastes).[26]

aesthetic and spiritual services-the direct, incidental exposure to the environment (e.g., enjoyment provided when people observe the environment).

Integrating these three functions we arrive at Boulding's (1966) metaphor of the earth as a spaceship with a closed economic and environmental system except for solar energy. This system recognizes the limits that exist at any point in time in our resource base, environmental quality, capital and labor stock, technical methods, and institutions for creating utility flows (Figure 1). Utility is the term used to describe individual's subjective sense of economic well-being. It is conditioned by people's values and preferences. Economic systems are designed to promote improvements in utility.

If the assimilative capacity of the groundwater is exceeded by the release of TC metals to the environment then the resource supply function of the environment will be threatened. Faced with the threats posed by contaminated groundwater decisionmakers in government, industry, and in households may take averting or preventative actions to avoid or reduce these risks. They may also undertake mitigating or repair actions once the event has been registered.

Both averting and mitigating behaviors require the diversion of resources away from their alternative uses reducing the utility provided by those uses. Also, mitigating actions may only incompletely restore the services provided by the affected natural, physical or human capital. The benefits of the controls are the avoided losses in utility to the US population from the release of TC metals to the environment.

In addition to these "use" benefits people may also enjoy "nonuse" benefits from the protection of the three functions of the environment. Nonuse benefits may derive from altruistic preferences. Nonuse services may also contribute to an individual's welfare through a sense of stewardship for the

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[25] Labor services, capital services (e.g., plant and equipment, infrastructure created from past production), intermediate production (e.g., materials, energy), and environmental and natural resource services are combined in the economic system where public, market, and household systems use the appropriate techniques or receipts to convert these inputs into more desired public and household commodities.

[26] Economic systems generate unwanted byproducts or residuals in the form of heat, scrap, combustion byproducts, etc. As Kneese, Ayres, and d'Arge (1970) point out, the First Law of Thermodynamics requires that "...the amount (i.e., mass) of residuals inserted into the environment must be approximately equal to the weight of basic fuels, food, and raw materials entering the processing and production system, plus oxygen taken from the atmosphere."

environment. That is, individuals not directly impacted by the controls may experience a utility gain when they learn that the quality of the environment has been protected.

## 8.2 The Economic Benefits of Groundwater Protection

The key threat to the environment from TC metals is from their potential to leach into groundwater resources. Bergstrom et al. (1996) have developed a framework to assess the economic benefits of groundwater that, with some modifications, forms the basis of this evaluation of the benefits of protecting groundwater resources from TC metals wastes. The framework consists of (1) assessing the changes in the quality of the resource stock with the rule, (2) identifying groundwater service flows that may be effected by the quality changes, (3) evaluating how market and household production may be impacted by the change in service flows, and (4) valuing the effect on human welfare of the production impacts and of the passive linkages between human welfare and environmental quality.

Developing quantitative estimates of the economic benefits of protecting groundwater entails two challenging requirements. First, formal linkages between groundwater protection policies and changes in the biophysical condition of groundwater must be established. Second, these linkages must be developed in a manner that allows for the estimation of policy-relevant economic values. The framework in Figure 1 is used to identify and characterize the potential benefits of the proposed regulation. However, only a qualitative assessment of the expected benefits are provided due to the multitude of impacted locations and the complexity of the linkages between releases of TC metals to the environment and any changes in human welfare.

### 8.2.1 With Policy Groundwater Quality Changes

The first step in developing estimates of the impact of the regulation on groundwater is to measure or estimate current groundwater conditions in quantity and quality terms. Since the proposed rule affects the quality of groundwater, rather than the quantity, further discussion will focus primarily on quality. Step two is to assess how baseline quality will change with and without the proposed regulation. This step provides estimates of the reference (without-policy) quality and the subsequent (with-policy) quality.

No explicit effort is made here to estimate the water quality changes of the rule. The potential sources of pollution, disposal sites of the treated sands, are likely to be numerous and diffuse. Further, the expected improvements in groundwater quality, while positive, are nevertheless likely to be small.

### 8.2.2 Groundwater Service Flow Changes

Groundwater has two broad functions that may be positively impacted by the regulation. The first function is storage of a water resource. Groundwater stored in an aquifer provides a reserve of water with given quantity and quality dimensions. The second function is discharge to surface waters. Again, this discharge supply has quantity and quality dimensions. Through this function, groundwater indirectly contributes to services generated by surface waters. As Figure 2 indicates, surface waters may also recharge groundwaters. Table 5 is adapted from the Bergstrom et al. (1996) framework and presents the groundwater service flows associated with each of the two broad groundwater functions that could be threatened by TC metals wastes. Of these services, provision of drinking water and nonuse services appear to be most threatened by the release of TC metals into groundwater.
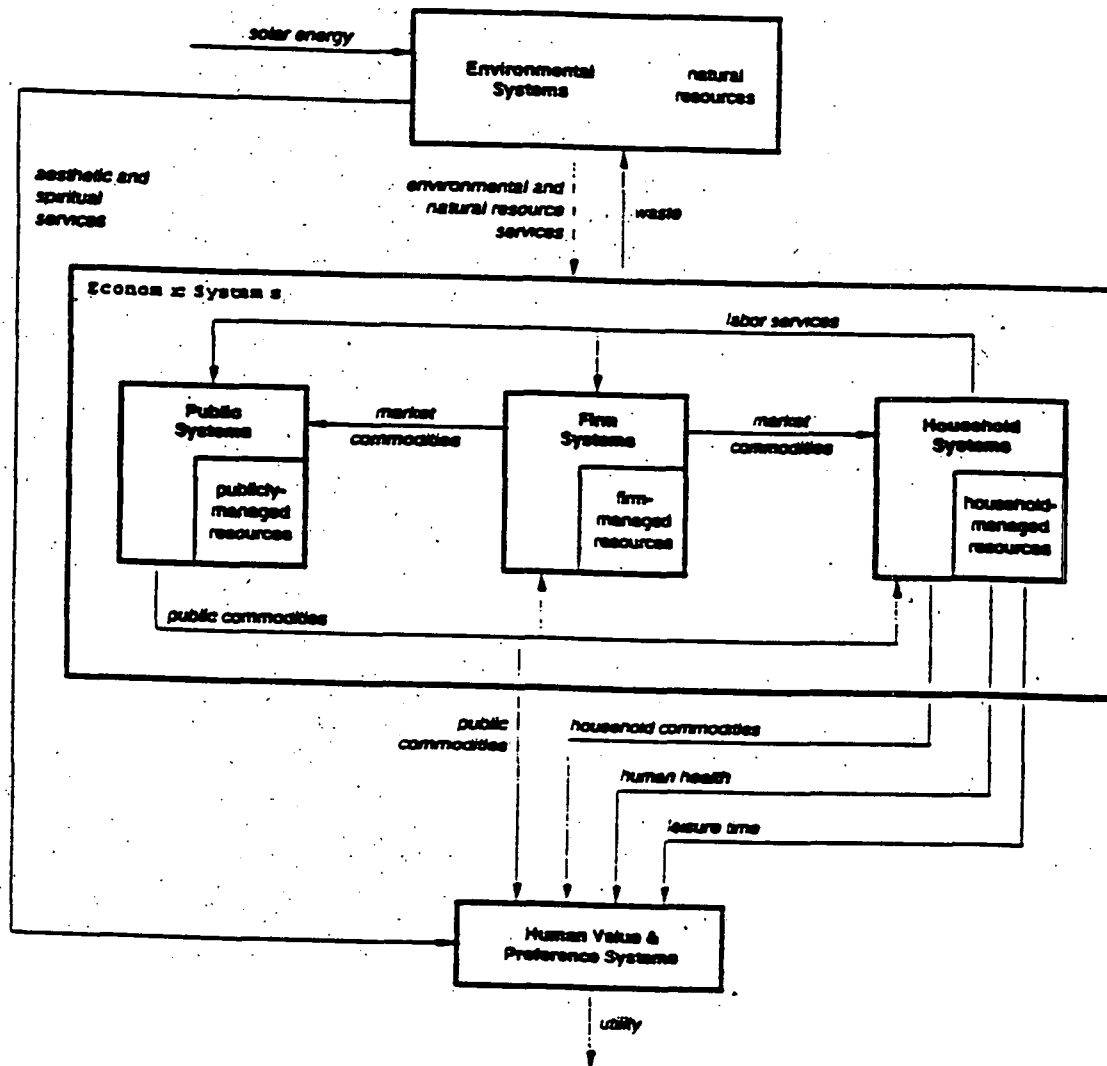
Figure 1. The Circular System

### 8.2.3 Resource Allocation Changes

Changes in the quality of services provided by groundwater may directly change some market and household activities. In Figure 1, this phenomenon is depicted by the arrows flowing from environmental systems to the economic stocks and production processes (market and household). Two types of productive behaviors are particularly important—averting and mitigating.
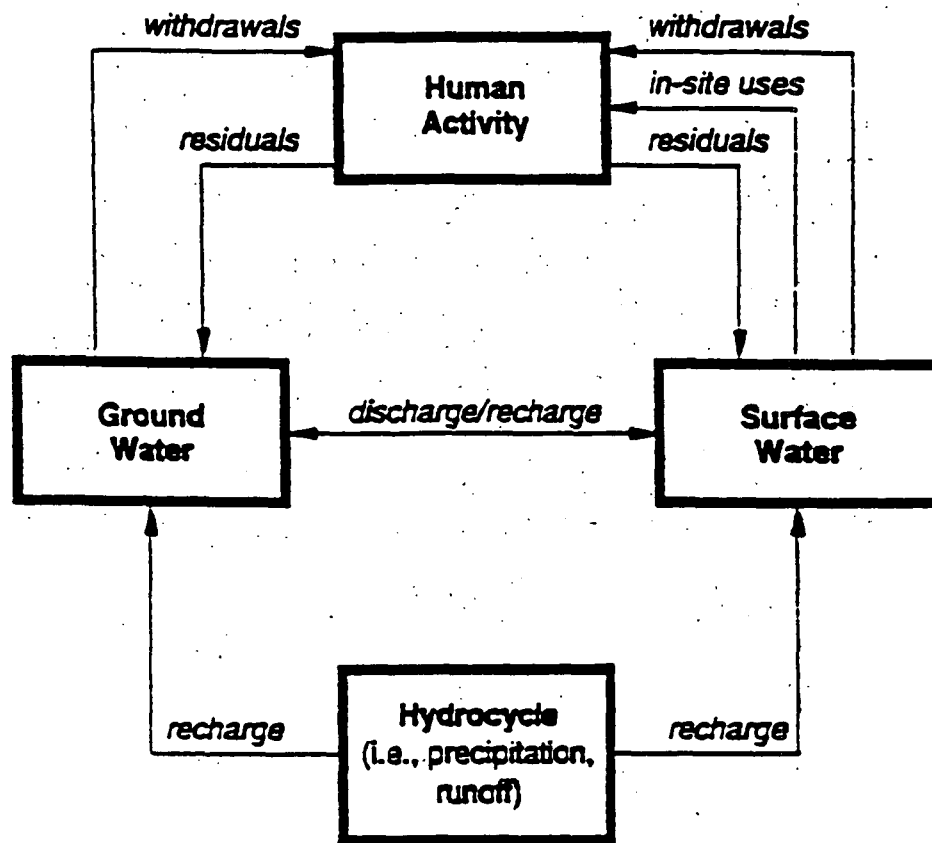
**Figure 2. Groundwater Function**

Averting behaviors are those taken to avoid or to reduce the impact of service quality reductions. For example, polluted irrigation water may induce farmers to change cropping patterns or practices. Households may purchase bottled water in lieu of consuming well water. Governments may install alternative municipal water supply systems to avoid contaminated water supplies. The result of health-related averting activities is a lower level of realized (or ex post) exposure to environmental contaminants. This will effect one's actual health state. The relationship between realized exposures and the ex ante health state is determined through the human biological system.

TC metals are very toxic causing a variety of human health effects even at low doses and especially to children. Brain, kidney, and nervous system functions may all be impaired by exposures to these metals leading to excess illness and even premature death. Knowledge of these effects and of the potential for exposure is likely to lead to averting activities by households.

**Table 5. Storage and Service Functions of Water Resources Potentially Impacted by TC Metals Wastes**

| | Services | Effects |
|---|---|---|
| 1 | Provision of Drinking Water | Change in Quality of Drinking Water |
| | | Change in Human Health or Health Risks |
| 2 | Provision of Water for Crop Irrigation | Change in Value of Crops or Production Costs |
| | | Change in Human Health or Health Risks |
| 3 | Provision of Water for Livestock | Change in Value of Livestock Products or Production Costs |
| | | Change in Human Health or Health Risks |
| 4 | Provision of Water for Food Processing | Change in Value of Food Products or Production Costs |
| | | Change in Human Health or Health Risks |
| 5 | Provision of Water for Other Manufacturing Processes | Change in Value of Manufactured Goods or Production Costs |
| 6 | Provision of Clean Water Through Support of Living Organisms | Change in Human Health or Health Risks |
| | | Change in Animal Health or Health Risks |
| | | Change in Value of Economic Output or Production Costs |
| 7 | Support of Recreational Swimming, Boating, Fishing, Hunting, Trapping, and Plant Gathering | Change in Value or Costs of Recreational Activities |
| | | Change in Human Health or Health Risks |
| 8 | Support of Commercial Fishing, Hunting, Trapping, and Plant Gathering | Change in Value or Costs of Commercial Harvest or Costs |
| 9 | Support of On-Site Observation or Study of Fish, Wildlife, and Plants for Leisure, Educational, or Scientific Purposes | Change in Value or Costs of On-Site Observation or Study Activities |
| 10 | Provision of Passive or Non-Use Services (e.g., Existence or Bequest Motivations) | Change in Personal Utility |
| 11 | Provision of Non-Use Services (e.g., Existence Services) Associated with Surface Water Body or Wetlands Environments or Ecosystems by Ground Water | Change in Personal Utility |

Source: Bergstrom, J.C., K.J. Boyle, C.A. Job, and M.J. Kealy, "Assessing the Economic Benefits of Ground Water for Environmental Policy Decisions." Paper No. 95041 of the *Water Resources Bulletin with some modifications.*

Conditional upon contracting an environmentally-related illness, the individual's realized health state may differs from the ex ante health state because of mitigating behaviors. The key resources needed to treat the ill individuals are the labor, materials, and capital from the medical services sector.

Since averting behaviors are taken to avoid some or all of the anticipated effects of a reduction in service quality, the role of information is critical to those choices. Further, averting and mitigating behaviors are substitutes. Indeed, costless irreversibility is a perfect substitute for averting behaviors.

Health related pathways groundwater quality could affect human welfare. In this framework, household time is an endowment and must be allocated among multiple uses. In Figure 2, time is divided between labor and leisure (leisure makes up part of the flow from household production to utility). In the health model, this is expanded to include averting activities, mitigating activities, and sick time.

The issue of information and uncertainty is particularly applicable to the health model. While the health model in Figure 1 implicitly treats the relationship between exposures, averting, and mitigating behaviors, and health state as certain, the reality is individuals face considerable uncertainty and must make decisions based on expected health outcomes.

### 8.2.4 Human Welfare Changes

In Figure 1, the rule may positively impact human welfare by

- reducing the amount of resources allocated to averting and mitigating activities by producers and households thereby leaving more resources for consumption goods and services,

- increasing health, and

- increasing the passive or nonuse services of the environment.

The conceptual measure of the change in human welfare in economic analysis is the change in an individual's utility due to the above-listed changes. However, utility is unobservable, thus the need for a surrogate. The surrogate used in most analyses is money. Two monetary measures of individual welfare change are employed—willingness to pay (WTP) and willingness to accept (WTA). WTP is the maximum amount an individual is willing to pay for utility-augmenting changes and is taken as the individual's value (benefits) of the change. WTA is the minimum compensation the individual would be willing to accept to forgo the welfare improvement. It is also accepted as the individual's the value (benefits) of the improvement.

Prices formed in competitive markets provide a basis for developing WTP/WTA values for averting and mitigating activities. WTP/WTA is simply the avoided expenditures (i.e., price times quantity). For household time spent on averting or mitigating activities or sick, the price of labor services (i.e., the wage rate) may be used to develop estimates of foregone income.

In addition to these direct costs any utility loss associated with the inability of averting activities to completely protect or mitigating activities to completely restore the individual's utility stream must also be valued. For example, individuals who purchase bottled water to avoid exposures to lead in drinking

water may still be exposed through purchased meals prepared with contaminated water. Or, individuals who do experience an environmentally-related illness my not have immediate or complete recovery.

Nonuse or passive use represents final benefit category to consider. Nonuse values are said to arise from a variety of motives, including knowledge of existence, a desire to bequeath natural resources to future generations, a sense of stewardship or responsibility for preserving features of ecosystems and/or natural resources, and a desire to preserve options for futures use (Freeman, 1993). One cannot rely on observable behavior such as expenditures or price differences for evidence of nonuse values because they arise without an individual taking any action. They enter the utility function directly and are not related to other processes within the household production framework. For example, individuals may gain utility from the knowledge that a healthy ecosystem exists, or simply that a stock of groundwater is protected by regulation of waste streams. The only way to determine these values is to ask people to directly provide them in response to a contingent outcome question.

While there are no specific studies on the WTP/WTA for this regulation the economic literature does offer evidence that individuals do value groundwater resources and have positive WTP for their protection. Specifically, Table 6, reproduced from Crutchfield et al. (1995) shows that households value groundwater protection in the range of several hundred dollars annually. This regulation would contribute to such protection. However, the values reported in Table 6 would not apply to the very small changes in groundwater quality expected with this rule. The values for this rule would be some fraction of those for complete protection since contaminants other than TC metals from sources regulated under this rule also contribute to reductions in groundwater quality.

## 9.0 Benefit-Cost Comparison

The potential benefits of the regulation may accrue to direct users of the affected water resources and to nonusers who would benefit to the extent that they hold altruistic values for the affected individuals or a sense of environmental stewardship for the impacted resources. The potential key gains to users are the reduced averting and mitigating expenditures, increased incomes, and improved health states. Individuals proximate to the several thousand sites where these wastes are managed would benefit through direct use of the environment. The rest of the U.S. population would benefit through nonuse linkages.

Juxtaposed against these potential benefits are the annual costs of the regulation. These costs are cents per household annually for the entire U.S. population. EPA believes that the typical U.S. household would value the benefits from this regulation more than its costs.

## Table 6. Empirical Estimates of Ground Water Protection Benefits

| Study | "Good" being valued | Estimated willingness to pay (WTP) |
|---|---|---|
| Caudill, 1992, and Caudill and Hoehn, 1992 | Protection of ground water subject to pesticides and nitrates. | Rural: $43-$46/household (hh)/year. Urban: $34-$69/hh/yr. |
| Powell, 1991 | Ground water subject to contamination by toxic chemicals and diesel fuel. | All data: $61.55/hr/year. Respondents with a history of contamination: $81.66/hh/year. Respondents with no contamination: $55.79/hh/year. |
| McClelland and others, 1992 | Ground water, type of contaminant not specified | Complete sample: $84/hh/year. |
| Shultz, 1989, and Shultz and Lindsay, 1990 | Ground water, type of contaminant not specified | Mean WTP: $129/hh/year. |
| Jordan and Elnagheeb, 1992 | Drinking water subject by contamination by nitrates. | Public water system: $146/hh/year. Private wells: $169/hh/year. |
| Poe, 1993, and Poe and Bishop, 1992 | Drinking water subject to contamination by nitrates. | $168-$708/hh/year. |
| Edwards, 1988 | Ground water subject to contamination by nitrates and pesticides. | $286-$1,130/hh/year. |
| Sun, 1990, and Sun, Bergstrom, and Dorfman. 1992 | Ground water subject to contamination by agricultural fertilizers, nitrates and pesticides. | Mean WTP: $641/hh/year, ranges from $165-$1,452/hh/year. |

Source: Crutchfield, S.R., P.M. Feather, D.R. Hellerstein. "The Benefits of Protecting Rural Water Quality: an Empirical Analysis." Report No. 701 Economic Research Service, U.S. Department of Agriculture.

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# APPENDIX A

## DEVELOPMENT OF COST FUNCTIONS FOR METAL WASTES

This appendix describes the basic cost functions used for estimating storage, treatment, and disposal of TC metal wastes. Most of the equations are taken directly from functions developed for mineral processing wastes or developed from information associated with those functions. Sets of typical treatment practices, which form the basis for the cost functions given here, are shown in Figure A-1 for liquids, sludges, and solids.

Quantities shown in Figure A-1 begin with 100 tons of waste entering the treatment system. In the treatment of solids, for example, mass in the form of treatment chemical is added to the entering stream. The amount of cement required for stabilization of solids from storage increases by 75 percent from the original 100 tons.
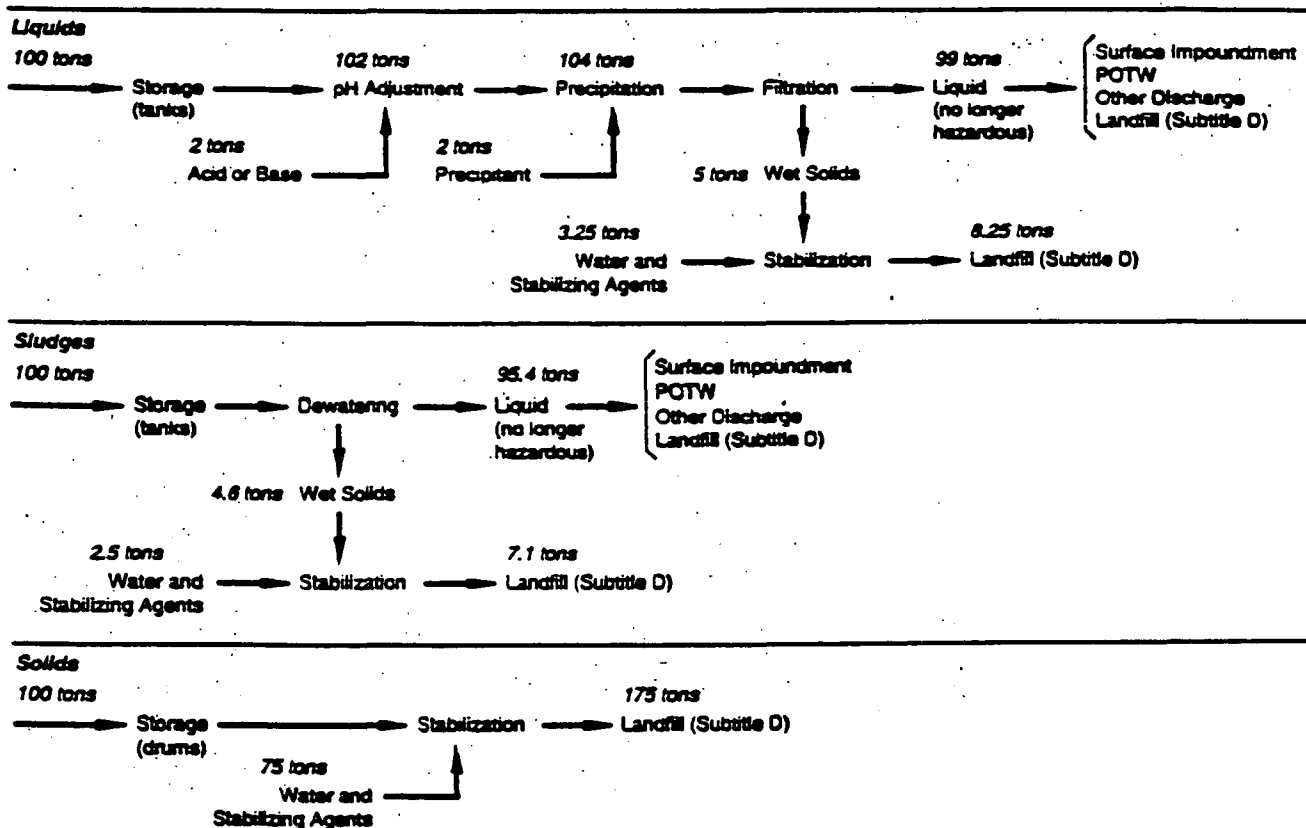


**Figure A-1. One Model for TC Metals Treatment Practices.**

A major visual difference between the equations listed here and in Appendix D of the minerals processing regulatory impact analysis (RIA) is the form of the functions. Because TC costing is based on an annualized format, all of the mineral processing capital cost functions are converted to an annualized form. For ease of use, two or more equations may be aggregated into a single function. Each of the equations used for the TC metals wastes is related below to its companion equation for minerals processing. Changes to the equations caused by differences between TC wastes and mineral processing wastes in processing or treatment quantities and techniques are discussed. New equations not used for mineral processing are also described. Except as noted, the assumptions and ranges used to form the mineral processing waste functions are assumed also to apply to the TC metals waste functions. Although costing in this RIA is required only for solids associated with foundry wastes, the generalized equation sets for other TC waste forms are presented as precursors to the foundry equations. Separate equations for foundry operations are described in the body of the report.

Equations used for TC wastes are listed below for current and proposed regulations. The term Q is the quantity of material presented for treatment in metric tons per year. Table A-1 shows the application of equations by case.

Current Regulations for Liquid Wastes

Storage—Equation Set 1

$$cost = -4 \times 10^{-8} Q^2 + 0.1175 Q + 3,679.5$$

This equation was developed for 7-day tank storage based on the general assumptions used to generate other storage cost functions for minerals processing wastes.[1] The equation is taken directly from the February 12, 1997 draft RIA, Exhibit D-35.) Note that this equation, and all other equations with exponents or logorithms (non linear equations) will give erroneous answers if used to estimate costs for incremental increases in quantities of waste treated. For example, the cost estimated for a Q of 5 tpy is not the same as the cost of, say, 60 tpy minus the cost of 55 tpy.

pH Adjustment—Equation Set 2

$$cost = 11,471 \qquad \text{for } Q < 350 \text{ mt/yr}$$

$$= -203,310 + 36,594 \ln (Q) + 14.34 \, Q^{0.5}$$

$$+ (6,493/1.07^{21}) \times 0.09439$$
$$\text{for } 350 \leq Q \leq 37,910 \text{ mt/yr}$$

$$= -203,310 + 36,594 \ln (Q) + 14.34 \, Q^{0.5}$$

$$+ ((6,361 + 0.003 \, Q)/1.07^{21})) \times 0.09439$$
$$\text{for } Q > 37,910 \text{ mt/yr}$$

Telecon between Jen Mayer, ICF, and Jim Turner, Research Triangle Institute (RTI). September 24, 1996.

## Table A-1. Application of Equations by Case

| Case | Equation set[a] |
|---|---|
| Current regulation | |
| Liquid | 1,2,3,4,5,6 |
| Sludge | 1, and 4,5,6 with new factors |
| Solid | 8, and 5,6 with new factors |
| Proposed regulations | |
| Liquid | 7 applied to 1 through 6 |
| Sludge | 1, and 4,5,6 with new factors |
| Solid | 8, and 5,6 with new factors |
| Foundry wastes | |
| Current regulations | |
| cement | 9,10,11 |
| iron filings | 9, and 10,11 with new factors |
| TSP | 9, and 10,11 with new factors |
| Proposed regulations | |
| cement | 9, and 10,11 with new factors |
| iron filings | 9, and 10,11 with new factors |
| TSP | 9, and 10,11 with new factors |

[a]Basic equations are developed for treatment and disposal operations. As cases change, the basic equations are modified by factors developed for each case as listed in the column. The changes generally represent changes in quantity of material being processed or changes in size (and cost) of required facilities. See text for further explanation. Equation sets are for;
1: storage for liquids and sludges, 2: pH adjustment, 3: precipitation,
4: dewatering, 5: stabilization, 6: disposal, 7: all operations (proposed regulations for liquids), 8: storage for solids,
9: storage for foundry wastes, 10: stabilization of foundry wastes, 11: disposal of foundry wastes.

These equations are taken, in aggregated form, from the February 12, 1997 draft RIA. The individual terms are discussed below.

The term 11,471 is the value obtained at the lower limit of the next equation below. This limit is used for small quantities to avoid negative values obtained outside the valid range of the next equations. A lower limit on cost is also assumed because the physical plant required for processing cannot be economically built below a certain size.

The term $-203,310 + 36,594 \ln (Q) + 14.34 Q^{0.5}$ is the sum of two equations derived from the February 12 draft RIA, p. D-4 for on-site neutralization. Two costs are included: capital (in annualized form) and operation and maintenance (O&M). The elements of the equation from the RIA are:

$(36,131 + 151.95 Q^{0.5}) \times 0.09439$      (capital cost x an annualization factor)

$-206,719 + 36,594 \ln (Q)$.      (annual O&M cost)

The terms $6,493$ (for $Q < 37,910$ mt/yr) or $6,361 + 3.0 \times 10^{-3} Q$ (for $37,910 \leq Q \leq 370,000$ mt/yr) are also taken in part from p. D-4, and represent the annualized versions of closure costs. The only elements not found on p. D-4 are the factors $1.07^{21}$ and $0.09439$, which are used to annualize the capital costs. The term $1.07^{21}$ is used in lieu of a sinking fund term to represent the annual payment required to accumulate capital necessary at the end of 20 years to pay for closure costs beginning in the 21st year and continuing thereafter. The term is taken directly from the February 12 draft RIA, p. D-2, and assumes 7 percent interest and closure payments beginning in the 21st year.

The term $0.09439$ is also taken directly from the February 12 draft RIA, p. D-2. It is a capital recovery factor, based on 7 percent interest and 20-year equipment life, that is applied to the closure cost to complete the equivalent of a sinking fund factor.

Precipitation—Equation Set 3

$$\text{cost} = (3,613 + 15.195 Q^{0.5}) \times 0.09439 + 0.3465 Q + 826.48 \qquad \text{for } 350 \leq Q \leq 370,000$$

Precipitation operations take place in the same equipment used for pH adjustment, hence costs are estimated as a fraction of pH adjustment costs and added to the total costs. This equation is taken directly from the February 12 draft RIA, p. D-4.

Dewatering—Equation Set 4

$$\text{cost} = 0.09439 (95,354 + 664.48 (1.04 Q)^{0.5}) + 12,219 + 286.86 (1.04 Q)^{0.5}$$

The term $0.09439 (95,354 + 664.48 (1.04 Q^{0.5}))$ is taken from the dewatering capital cost equation on p. D-7 of the February 12 draft RIA, but modified in two ways. The equation is annualized using the capital recovery factor $0.09439$ described above, and Q is increased by an estimated 4 percent to account for the increased volume of waste after pH adjustment and precipitation (see Figure A-1).

The term $12,219 + 286.86 (1.04 Q)^{0.5}$ is also taken from p. D-7 as the O&M cost for dewatering. The quantity of waste is increased by 4 percent as for the previous term.

Stabilization—Equation Set 5

$$\text{cost} = 0.09439 (8,008 + 3.47 \times 0.05 Q)$$

$$+ 82,748 + 5.12 \times 0.05 Q$$

$$+ ((9,806 + 0.19 \times 0.05 Q)/(1.07^{21})) \times 0.09439$$

The capital cost term (8,008 + 3.47 x 0.05 Q) was developed (in different form as described below) for stabilization of residues produced after neutralizing and dewatering mineral processing wastes. However the term was not used for those wastes and was not included in the Appendix D description of cost functions.[2] The term is used here because of the residues obtained after TC metals waste treatment. The factor 0.05 is applied to Q because the quantity of solids to be stabilized is 5 percent of the original mass of material entering the treatment process. The term is multiplied by 0.09439 to annualize the cost as described above.

The term 82,748 + 5.12 x 0.05 Q, which estimates the annual O&M costs, is a companion to the previous equation and, except for the factor of 0.05, was developed at the same time. The factor again represents the reduction in mass to be stabilized to 5 percent of the original quantity.

The term (9,806 + 0.19 x 0.05 Q), except for the factor of 0.05, is taken directly from p. D-7 of the February 12 draft RIA and represents closure costs. The 0.05 factor again represents the reduction in mass to be treated. The factors $1.07^{21}$ and 0.09439 are used for annualization as described above for pH adjustment.

Disposal in a Subtitle D Landfill—Equation Set 6

$$cost = (35 + 5.68) Q \times 0.0825 \times 0.9072 \times (381.1/358.2)$$

This equation is developed from a more general equation for off-site nonhazardous waste landfill costs.[3] Disposal cost is taken as $35/ton tipping fee plus $5.68/ton-mile for 20 miles transportation. The factor of 0.0825 represents a reduction in volume from the original 100 tons of liquid waste to 8.25 tons of dewatered, stabilized solids sent to the landfill. The remaining terms represent conversion to metric tons and escalation of costs to the current year.

Proposed Regulations for Liquid Wastes—Equation Set 7

cost = 1.15 x cost for current regulations for D007 wastes

= 1.29 x cost for current regulations for D008 wastes

The factors for proposed regulations are based on one third of the fractional difference between the current regulatory level and the proposed regulatory level. For example, D007 wastes (chromium) must currently be treated to a concentration of 5 ppm. The proposed limit is 2.77 ppm which represents a 44.6 percent change. One third of this value is 15 percent, or a fraction of 0.15. This fraction is added to the original cost to obtain a factor of 1.15 increase in treatment and disposal cost.

Current Regulations for Sludges

The basic equations for storage, dewatering, stabilization, and Subtitle D landfill do not change from those used for current liquid regulations. However, the factors representing changes in volume to be treated have new values. For dewatering, there is no four percent increase in quantity treated (see

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[2]     Telecon Between Carolyn Peterson, DPRA, and Jim Turner, RTI. July 19, 1996.

[3]     Letter from Carol Sarnat DPRA, to Paul Borst, U.S. Environmental Protection Agency. March 4, 1993.

Figure 1). For stabilization, the 0.05 factor applied to Q for liquids is changed to 0.046 for sludges to represent the different reduction in waste volume to 4.6 tons of wet solids (instead of 5 tons) from 100 tons initially. For landfilling, the quantity disposed of is 7.9 tons, resulting in a factor of 0.079 applied to the landfill equation.

## Proposed Regulations for Sludges

As for current regulations, proposed regulations use the same basic cost functions except for factors based on changes in quantities of waste entering the various processes. Storage and dewatering do not change, but stabilization requires a proportionally greater amount of stabilizing agent for a reduced quantity of wet solids compared to liquids. To reiterate:

$$cost = 0.09439 \ (8{,}008 + 3.47 \times 0.046 \ Q) \times 1.05$$

$$+ \ 82{,}748 + 5.12 \times 0.046 \ Q \times 1.20$$

$$+ \ ((9{,}806 + 0.19 \times 0.046 \ Q)/(1.07^{21})) \times 0.09439$$

The term $(8{,}008 + 3.47 \times 0.046 \ Q)$ was developed for stabilization of residues produced after neutralizing and dewatering mineral processing wastes. However the term was not used for those wastes and was not included in the Appendix E description of cost functions.[4] The term is used here because of the residues obtained after TC metals waste treatment, but the factor 0.046 is applied to Q because the quantity of solids to be stabilized is 4.6 percent of the original mass of material entering the treatment process. However, a further factor of 1.05 is used for the entire term to account for the 5 percent increase in capital costs estimated to be required for larger equipment and storage capacity due to proportionally larger amounts of stabilizing agent. Similarly, the 1.2 factor used in the second line of the equation represents the proportional increase in O&M costs for the added stabilizing agent.

Landfilling costs for proposed regulations are slightly higher than for current regulations because of increased stabilizing agent (7.9 tons to be disposed of rather than 7.1 tons). Compared to the function for current regulations, the factor applied to the equation is 0.079 instead of 0.071.

## Current Regulations for Solids

The basic cost functions for solids remain the same for stabilization (no dewatering is required) and landfilling, but storage equations are different. Instead of storage in tanks, small quantities of solids are stored in drums, while larger quantities are stored in roll-off containers.

## Storage—Equation Set 8

$$cost = 24.589 \times Q + 132.23 \qquad \text{for } Q < 200 \text{ mt/yr}$$

$$= -0.0022 \times Q^2 + 29.272 \times Q + 4{,}840.9 \qquad \text{for } 50 \leq Q \leq 7{,}500 \text{ mt/yr}$$

Both equations are taken directly from the February 12 draft RIA, p. D-21. On the basis of equivalent costs, the drum storage equation could be used up to about Q = 2,900 mt/yr.

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Telecon between Carolyn Peterson, DPRA, and Jim Turner, RTI. July 19, 1996.

Stabilization

       The stabilization equation for solids under current regulations is the same as for sludge under current regulations except that the factor 0.046 is not required because there is no reduction in waste volume before the stabilization step.

Disposal in a Subtitle D Landfill

       The disposal cost function remains the same except for a factor of 1.75 to account for the added 75 tons of stabilizing agent required for each 100 tons of waste to be treated (see Figure A-1).

Proposed Regulations for Solids

       The only changes under proposed regulations are for factors in the stabilization and landfill equations. As with sludges, capital costs are assumed to be increased by 5 percent and O&M costs by 20 percent because of proportionally increased stabilizing agent usage. The landfill factor changes to 1.98, also because of the increased quantity of stabilizing agent.

# APPENDIX B

## DEVELOPMENT OF COST FUNCTIONS FOR

## CONVERSION FROM IRON FILINGS TO TSP

As stated in Appendix A of this document, the cost functions developed for toxicity characteristic (TC) wastes are based on functions used for estimating impacts on mineral processing wastes. The mineral processing waste regulatory impact analysis (RIA), Appendix D, forms the basis for cost functions used here and largely explained in Appendix A of this document. The body of this document further describes functions to obtain cost differences associated with the change from cement (used for mineral processing wastes) to trisodium phosphate (TSP) as a stabilizing agent used for foundry wastes.

Iron filings, although currently used by some facilities as a stabilizing agent for foundry waste, are not expected to be effective for meeting the proposed UTS regulations. However, this appendix is provided to show the changes associated with changing to TSP from iron filings.

The sets of equations below are a continuation of the equation sets given in Appendix A of this document and in the body of the document. Explanations for the equation sets are repeated here, but some of the terms in the equations differ from their counterparts in the rest of the report. The equation sets are numbered 1 through 8 in Appendix A, 9 through 11 in the body of the document, and 12 through 15 below.

Costs of converting from iron filings under current regulations to TSP under proposed regulations are found from the following sets of equations. Costs are summed for each process below (storage, stabilization, and disposal) under current regulations, then under proposed regulations. The difference in summed costs between the two cases represents the estimated cost increase (or decrease) in changing from current to proposed regulations.

## Current Regulations Using 15 Percent Iron Filings

### Storage—Equation Set 12 (Identical to Equation Set 9)

$$\text{cost} = 24{,}589 \, Q + 132.23 \qquad \text{for } Q \text{ to } 200 \text{ mt/yr}$$

$$= -0.0022 \, Q^2 + 29.272 \, Q + 4{,}840.9 \quad \text{for } 50 \leq Q \leq 7{,}500 \text{ mt/yr}$$

These equations, as described above, are taken directly from the February 12, 1997 draft RIA, p. D-21. They apply to solids in drums and roll-off containers, respectively. Conditions used to develop equations in the February 12 draft are also used for the equations given here. However, on the basis of equivalent costs, the drum storage option could be used up to about Q = 2,900 mt/yr.

### Stabilization—Equation Set 13

$$\text{cost} = 207.93 \, Q^{0.78} \times 0.9 \times 0.09439$$

$$+ (87{,}839 + 52.15 \, Q)(1 - (0.1113 \ln(Q) - 0.3429)$$

$$+ (0.1113 \ln(Q) - 0.3429)(116/67.00)(15/50))$$

$$+ ((9{,}806 + 0.19 \, Q)/(1.07^{21})) \times 0.09439$$

$$\text{for } Q < 100{,}000 \text{mt/yr}$$

$$= 207.93 \ Q^{0.78} \times 0.9 \times 0.09439$$

$$+ (87,839 + 52.16 \ Q)((1-0.98) + (0.98)(116/67.00)$$

$$\times (15/70)) + ((9,806 + 0.19 \ Q)/(1.07^{21})) \times 0.09439$$

$$\text{for } Q > 100,000 \text{ mt/yr}$$

These equations are taken from the February 12 draft RIA, but are modified by terms that adjust for different stabilizing agents, different ratios of stabilizing agent to waste quantity, and different ratios of stabilizing agent cost to total operation and maintenance cost. Each term in the equations is discussed below.

The term $207.93 \ Q^{0.78}$ is taken directly from the February 12 draft RIA, p. D-7. It represents the capital cost required to build a stabilization facility capable of treating Q mt/yr of waste. Because the quantity of iron filings used for stabilization of foundry wastes is significantly lower than the amount of cement assumed to be used for mineral processing wastes, the capital costs for the foundry facility are expected to be lower. This decreased cost is obtained by multiplying the capital cost equation by a factor of 0.9. A factor of 0.09439 is then applied to obtain an annualization of the capital cost.

The term $(87,839 + 52.15 \ Q)$ is taken directly from the February 12 draft RIA, p. D-7. It represents the operation and maintenance costs associated with stabilizing wastes.

The term $(0.1113 \ln (Q) - 0.3429)$ is developed from a series of data points generated from plant size *vs* cost of cement as a fraction of total operating and maintenance (O&M) cost.[1] The four data sets are:

| Plant size, mt/yr | Cement cost, % of O&M cost |
|---|---|
| 426 | 21.0 |
| 4,265 | 71.5 |
| 42,648 | 94.9 |
| 426,477 | 98.6 |

This term estimates stabilizing agent cost as a fraction of total O&M cost for any size plant within the range of sizes given in the February 12 draft RIA (the data points were developed from the mineral processing waste cost functions). When the mineral processing RIA O&M cost equation is multiplied by one minus this term (as above), an O&M cost without the stabilizing agent is estimated based on plant size. To account for the cost of iron filings as a stabilizing agent, this term is added back into the equation after modification for different reagent costs and application fractions as shown for the next two terms.

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Telecon between Caroline Peterson, DPRA and Jim Turner, RTI. September 25, 1996.

The term $(62.33/67.00)$ is the ratio of iron filings cost[2] to cement cost[3] (both in dollars per ton).

The term $(15/70)$ is the ratio of stabilizing agent used for secondary lead smelter wastes[4] to the amount used for mineral processing wastes (as given in the February 12 draft RIA).

The term $(9,806 + 0.19\ Q)$ is taken directly from the February 12 draft RIA, p. D-7. It represents closure costs for the stabilization facility. Because this cost is not incurred until after the 20-year life, but is spread over that life, it must be divided by the terms that follow ($1.07^{21}$ and $0.09439$) to obtain a uniform annual reserve.

For $Q > 100,000$ mt, the term $(0.1113\ \ln(Q) - 0.3429)$ is replace by $0.98$ to prevent obtaining factors greater than 1. Examination of the data suggests that an asymptote exists near this value.

## Landfill—Equation Set 14

$$cost = ((25.485\ Q) + 294,701) \times 1.20$$

This equation (for metric quantities) is developed from data for on-site nonhazardous waste landfill costs.[5] The three data sets are:

| Landfill size, short tons/yr | Capital cost, $ | Annual O&M cost, $/yr | Closure cost, $ | Annual post-closure cost, $ |
|---|---|---|---|---|
| 5,000 | 2,632,000 | 114,000 | 434,000 | 5,000 |
| 25,000 | 7,034,000 | 236,000 | 1,547,000 | 9,000 |
| 50,000 | 10,899,000 | 328,000 | 2,675,000 | 12,000 |

The equation is multiplied by a factor of 1.20 to account for the difference between added stabilizing agent quantities in lead wastes and in other TC metals wastes. For the small quantities of waste disposed of from many foundries, it is likely that offsite disposal would be used as described in equation set 6 of Appendix A.

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[2] Facsimile message from Lane Tickanen, RMT, Inc., to Paul Borst, U.S. EPA. February 20, 1997.

[3] Supra, Note 1. Value reported as $0.0335/lb taken from R. S. Means Construction Cost Data for 1995.

[4] Developed from a telecon between Gary Mosher, American Foundrymen's Society, and Jim Turner, Research Triangle Institute. September 24, 1996.

[5] Letter from Carol Sarnat, DPRA, to Paul Borst, U.S. Environmental Protection Agency. March 4, 1993.

## Proposed Regulations Using 15 Percent TSP

For this case, only the stabilization term for reagent cost changes. The term for reagent cost becomes (260/67.00) for TSP cost vs. cement cost. The stabilization equation for Q < 100,000 mt/yr changes to:

## Equation Set 15

$$cost = 207.93 \ Q^{0.73} \times 0.9 \times 0.09439$$

$$+ \ (87,839 + 52.15 \ Q)(1 - (0.1113 \ \ln (Q) - 0.3429)$$

$$+ \ (0.1113 \ \ln (Q) - 0.3429)(260/67.00)(15/70))$$

$$+ \ ((9,806 + 0.19 \ Q)/(1.07^{21})) \times 0.09439$$

for Q < 100,000 mt/yr

The change is only in the ratio of reagent costs.

Storage costs under the proposed regulation for a typical foundry generating 375 tons of waste sand annually do not increase because the mass of reagent does not change.

Disposal costs are increased using equation set 6 (Appendix A) because of the small quantities involved. The amount disposed of is increased to 375 x 1.15 tpy (340.2 x 1.15 mt/yr) both at baseline and for the proposed regulation.

Capital and annual incremental costs can be estimated as shown at the end of section 5.1 in the body of this report.