# ASSESSMENT OF INDUSTRIAL HAZARDOUS WASTE PRACTICES
# IN THE METAL SMELTING AND REFINING INDUSTRY

## Volume IV

## Appendices

*This final report (SW-145c.4) describes work performed for the Federal solid waste management programs under contract no. 68-01-2604 and is reproduced as received from the contractor*

The report is in four volumes: (I) Executive Summary, (II) Primary and Secondary Nonferrous Smelting and Refining, (III) Ferrous Smelting and Refining, and (IV) Appendices

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An environmental protection publication (SW-145c.4) in the solid waste management series.

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## APPENDIX A

### Chemical Analyses of Residuals from Metal Smelting and Refining

This appendix contains the results of chemical analyses of waste samples from various metal smelting and refining industries. Samples were either collected by Calspan personnel at the time of plant visits or collected and shipped to Calspan by industry personnel. Chemical analyses were conducted at the Calspan Corporation laboratory. Analyses of wastes from the following industries are given:

| | Table No. |
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TABLE A-1 SAMPLE ANALYSES - PRIMARY COPPER PLANTS

Concentration of Potentially Hazardous Constituents (PPM)

| Plant | Type of Sample | As | Cd | Cr | Cu | Hg | Mn | Ni | Pb | Sb | Se | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A | Fine Dust From ESP on Converters | --- | 520 | 50 | 280000 | 0.8 | 90 | 110 | 8000 | 500 | 30 | 28000 |
| A | Reverb. Furnace Slag | --- | <5 | 45 | 10000 | 0.9 | 230 | 10 | 250 | 250 | 40 | 3700 |
| A | Fine Dust From ESP on Reverb. Furn. | --- | 310 | 45 | 240000 | 2.5 | 100 | 35 | 12000 | 750 | 80 | 44000 |
| A | Sludge from Lagoon Receiving Acid Plant Blowdown | --- | 180 | 25 | 22000 | 5.0 | 8 | 10 | >12000 | 800 | 550 | 1900 |
| B | Electric Furnace Slag | --- | <5 | 50 | 3700 | 0.5 | 165 | 5 | 250 | <100 | 10 | 8000 |
| C | Reverberatory Furnace Slag | --- | 10 | 100 | 6200 | 0.7 | 450 | 25 | 100 | 400 | 20 | 7800 |
| D | Converter Slag | --- | <5 | 40 | 40000 | 0.5 | 140 | 100 | 200 | 200 | 20 | 1000 |
| D | Reverb. Slag | --- | <5 | 160 | 6100 | 0.8 | 170 | 20 | 80 | 100 | 20 | 650 |
| D | Solids from Acid Plant Blowdown Thickener Overflow | --- | <5 | 30 | 150000 | | 10 | <10 | 10000 | 1200 | 150 | 120 |
| D | Water from Above | 6.64 | 10.5 | 1.7 | 390 | 0.25 | 5.1 | 1.8 | 4.0 | <1. | 0.30 | 45 |
| D | Solids from Acid Plant Blowdown Thickener Underflow | --- | 60 | 90 | 380000 | 6.0 | 72 | 95 | 5800 | 200 | 40 | 1000 |
| D | Water from Above | 1.44 | 1.1 | 0.2 | 3.7 | 0.20 | 12.5 | 4. | 6. | <1 | 0.090 | 40 |

- Not analyzed

Table A-2

SAMPLE ANALYSES – PRIMARY LEAD SMELTERS AND REFINERS

| PLANT | MATERIAL ANALYZED | CONCENTRATION OF POTENTIALLY HAZARDOUS CONSTITUENTS (ppm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Cd | Cr | Cu | Hg | Pb | Zn | Sb | Tl | Mn |
| A | FRESH BLAST FURNACE SLAG | 10 | 34 | 1,850 | – | 33,500 | 131,000 | – | – | – |
| | OLD BLAST FURNACE SLAG | 88 | 37 | 2,330 | – | 68,500 | 51,000 | – | – | |
| | SINTER SCRUBBER SLUDGE | 900 | 11 | 10,400 | 0.1 | 164,000 | 25,600 | – | – | – |
| | LAGOON DREDGINGS (SLAG GRANULATION) | 700 | 28 | 1,490 | – | 115,000 | 132,000 | – | – | – |
| | BAGHOUSE DUST (FROM BLAST FURNACE) | 14,000 | 10 | 5,350 | – | 148,000 | 82,000 | – | 20 | – |
| B | FRESH BLAST FURNACE SLAG | 1,150 | 37 | 2,750 | – | 61,900 | 110,000 | – | – | – |
| | OLD BLAST FURNACE SLAG | 73 | 79 | 2,250 | – | 46,700 | 160,000 | – | – | – |
| C | FRESH LEAD FUMING SLAG | 10 | 150 | 1,500 | – | 25,000 | 42,000 | 33 | – | 14,560 |
| | OLD LEAD FUMING SLAG | 5 | 90 | 1,600 | – | 20,000 | 31,000 | 20 | – | 13,500 |
| | BLAST FURNACE SLAG | 350 | 30 | 1,500 | – | 94,000 | 120,000 | 440 | – | 11,500 |
| | LAGOON DREDGINGS FROM LEAD SMELTER | 640 | 60 | 6,200 | – | 140,000 | 80,000 | 3,000 | – | 2,900 |
| D* | BLAST FURNACE SLAG | – | – | 2,600 | – | 38,000 | 108,000 | – | – | – |
| E* | BLAST FURNACE SLAG | – | – | 2,500 | – | 35,000 | 150,000 | – | – | – |
| F* | BLAST FURNACE SLAG | – | – | – | – | 25,000 | 120,000 | – | – | – |

*DATA FROM BUREAU OF MINES, ROLLA, MISSOURI. ALL OTHER DATA FROM SAMPLES OBTAINED BY CALSPAN CORP.

– NOT ANALYZED

Table A-3

SAMPLE ANALYSES – PRIMARY ZINC SMELTERS AND REFINERS

| PLANT | MATERIAL ANALYZED | CONCENTRATION OF POTENTIALLY HAZARDOUS CONSTITUENTS (ppm) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Cd | Cr | Cu | Hg | Pb | Tl | Zn |
| A | GYPSUM CAKE (NEUTRAL COOLING TOWER) | < 10 | 10 | 38 | – | 98 | – | 27,000 |
| | GYPSUM CAKE (ACID COOLING TOWER) | < 10 | 9 | 10 | – | 1,750 | – | 30,500 |
| | GYPSUM CAKE (LAND DUMP) | 550 | 11 | 1,580 | – | 18,100 | – | 222,500 |
| | FRESH ANODE SLUDGE | 12 | 10 | 85 | – | 170,000 | – | 12,800 |
| | OLD ANODE SLUDGE (FROM DUMP) | 1,400 | 8 | 1,900 | – | 89,000 | – | 39,200 |
| B | FRESH ACID PLANT SLUDGE | 2,000 | 25 | 900 | 9.5 | 4,350 | – | 195,000 |
| | OLD ACID PLANT SLUDGE | 640 | 39 | 700 | – | 4,280 | – | 225,000 |
| | FRESH VERTICAL RETORT FURNACE RESIDUE | 850 | 46 | 4,600 | – | 2,400 | – | 107,000 |
| | CADMIUM PLANT RESIDUE (IRON PRESS) | 280 | 24 | 1,150 | – | 215,000 | <40 | 39,000 |
| | OXIDE FURNACE RESIDUE | 10 | 17 | 810 | – | 68 | – | 62,000 |

– NOT ANALYZED

TABLE A-4

SAMPLE ANALYSES - PRIMARY ALUMINUM PLANTS

| Plant | Type of Sample | Concentration of Potentially Hazardous Constituents (PPM) Fluoride | Cyanide | Cu | Zn | Pb | Cr | Cd | Mn | Ni |
|---|---|---|---|---|---|---|---|---|---|---|
| A | Cast house dust | | | 6200 | 550 | 4600 | 230 | <1.0 | 200 | 150 |
| | Solids to lime treatment plants | 180 | | | | | | | | |
| | Water to lime treatment plant | 126 | | | | | | | | |
| | Spent pot liners(cathodes) | 84 | 1050 | | | | | | | |
| | Shotblasting baghouse dust | 26 | | 15,000 | | | | | | |
| | Lime treated water to primary lagoon | 14 | <.01* | | | | | | | |
| | Solids to primary lagoon | 14 | <2.5 | | | | | | | |
| | Sludge dredged from primary lagoon | 67 | <2.5 | | | | | | | |
| | Primary lagoon effluent | 12 | | | | | | | | |
| | Secondary lagoon effluent | 16 | | | | | | | | |
| B | Spent potliners (cathodes) | 44 | 15 | | | | | | | |
| | Cryolite recovery plant lagoon sediment "black mud" | 2.2 | 92.5 | | | | | | | |
| C | Spent potliners (cathodes) | 49.6 | 58 | | | | | | | |
| | Spent anode dust | 120 | | | | | | | | |
| | Lagoon sludge (line scrubber water -lagoon no longer in use | 118 | | | | | | | | |
| | Shotblasting baghouse dust | | | $5.6 \times 10^5$ | 320 | 40 | 620 | | | |
| D | Spent potliners (cathodes) | 186 | <2.5 | | | | | | | |
| | Cryolote recovery plant lagoon sediment "black mud" | 1.0 | <2.5 | | | | | | | |

*The use of < indicates that there is no positive detection of cyanide; if present it is at lower concentration than indicated value.

TABLE A-5

SAMPLE ANALYSES - PRIMARY ANTIMONY PLANTS

| Plant | Type of Sample | Concentration of Potentially Hazardous Constituents (PPM) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Sb | Pb | Cu | Zn | Ni | Mn | Cr | As | Cd |
| A | Blast furnace slag (Pyrometallurgical) | 18,000 | 66 | 50 | 500 | - | - | - | - | - |
| B | Anolyte Sludge | 27,000 | 5 | 50 | 2 | 5 | 21 | 32 | 16 | 1.0 |

\- not analyzed

TABLE A-6

SAMPLE ANALYSES - PRIMARY MERCURY

| Plant | Type of Sample | Concentration of Potentially Hazardous Constituents (PPM) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Hg | Zn | Sb | Cd | Pb | Cr | Cu | Mn | Ni |
| A | Fresh calcine residue | 1.5 | 50 | 250 | <5 | 100 | 410 | 15 | 850 | 2700 |
| A | Old calcine residue | 2.5 | 110 | 100 | <5 | 200 | 450 | 850 | 1200 | 2500 |

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TABLE A-7

SAMPLE ANALYSIS - PRIMARY TUNGSTEN PLANT

| Plant | Type of Sample | Concentration of Potentially Hazardous Constituents (PPM) Cu | Zn | Pb | Sb |
|---|---|---|---|---|---|
| A | Digestion residue | 38,000 | 850 | 90 | <10 |

## Table A-8
## SAMPLE ANALYSES—SECONDARY COPPER SMELTERS

| PLANT | MATERIAL ANALYZED | CONCENTRATION OF POTENTIALLY HAZARDOUS CONSTITUENTS (ppm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Cd | Cr | Cu | Mn | Ni | Pb | Sb | Sn | Zn |
| A | BLAST FURNACE SLAG | < 5 | 20 | 12,000 | 7,000 | 260 | 2,800 | < 100 | – | 75,000 |
| B | WATER TREATMENT SLUDGE | 10 | 94,000 | 170,000 | – | 16,600 | 900 | – | 20,000 | 1,850 |
| | BRASS CASTING DROSS | 160 | | 340,000 | – | 4,100 | – | – | 17,000 | 330,000 |
| | NICKEL BRASS DROSS | 160 | | 420,000 | – | 1,200 | – | – | 1,000 | 210,000 |
| | CHROME BRASS DROSS | 25 | 15,500 | 100,000 | – | – | – | – | 100,000 | 460 |
| | BAG HOUSE DUST | 5,000 | | 47,000 | – | – | 12,000 | – | 7,500 | 520,000 |

– NOT ANALYZED

## Table A-9
## SAMPLE ANALYSES–SECONDARY LEAD SMELTERS

| PLANT | MATERIAL ANALYZED | CONCENTRATION OF POTENTIALLY HAZARDOUS CONSTITUENTS (ppm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Zn | Cd | Cr | Cu | Mn | Ni | Pb | Sb | Sn |
| A HARD AND SOFT LEAD | SCRUBBER SLUDGE | 25 | 340 | 30 | 20 | 120 | 5 | 53,000 | 1,100 | – |
| | WASTEWATER TREATMENT SLUDGE | 140 | 10 | 35 | 80 | 74 | 5 | 2,700 | 250 | – |
| B WHITE METAL (LEAD-TIN ALLOY) | SMELTER FURNACE SLAG | 500 | 5 | 500 | 120 | 800 | 5 | 50 | 100 | 5,000 |
| | SMELTER FURNACE DUST* | 120,000 | 900 | 150 | 400 | 5 | 5 | 120,000 | 1,800 | 117,000 |
| C WHITE METAL (LEAD-TIN ALLOY) | WHITE METAL DROSS* | 4,700 | – | – | – | – | – | 160,000 | – | 5,000 |
| | WHITE METAL DROSS* | 2,600 | – | – | – | – | – | 145,000 | – | 90,000 |

*THIS MATERIAL IS RECYCLED

–NOT ANALYZED

Table A-10

SAMPLE ANALYSES – SECONDARY ALUMINUM PLANTS

| PLANT | MATERIAL ANALYZED | CONCENTRATION OF POTENTIALLY HAZARDOUS CONSTITUENTS (ppm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Al | Cl | Cr | Cu | F | Na | Sn | Pb | Zn |
| A | SMELTING DROSS | 210,000 | – | 20 | 3,300 | – | 4,000 | – | 5,800 | 2,300 |
| B | SMELTING DROSS | 340,000 | – | 900 | 4,800 | 114 | – | – | 540 | 4,300 |
| | CASTING DROSS | 280,000 | – | 280 | 27,000 | – | – | 17,000 | 380 | 2,600 |
| | BAGHOUSE DUST (INCOMPLETE CYCLE) | 96,000 | – | 20 | 2,600 | 630 | – | – | 80 | 160 |
| | BAGHOUSE DUST (COMPLETE CYCLE) | 90,000 | – | 20 | 230 | 98 | – | – | 200 | 380 |
| C | SMELTING DROSS | 120,000 | – | 190 | 5,300 | – | 11,000 | – | 1,050 | 4,200 |
| | WET SCRUBBER SLUDGE | 9,000 | – | 20 | 1,250 | < .01 | – | – | 140 | 6,500 |
| D | SLAG FURNACE | 17,500 | 450,000 | 60 | 310 | – | 190,000 | – | 300 | 240 |

– NOT ANALYZED

TABLE A-11 Sample Analyses - Iron and Steel Plants

| Sample Description | Sample Period* | Chemical Analysis (ppm) Cr | Cu | Mn | Ni | Pb | Zn | CN | F | Oil & Grease | Phenol |
|---|---|---|---|---|---|---|---|---|---|---|---|
| BOF Slag | A | 870 | 34.2 | 36,000 | <10 | <10 | <5 | ** | 5000 | - | - |
| | B | 1300 | 30.0 | 48,000 | <10 | 25 | <5 | - | 3000 | - | - |
| | C | 2310 | 41.7 | 49,000 | <10 | <10 | <5 | - | 4200 | - | - |
| | D | 1500 | 47.7 | 48,500 | <5 | 50 | <5 | - | 1000 | - | - |
| Blast Furnace Slag | A | 43 | 18.3 | 2,400 | <5 | <10 | <5 | - | 2000 | - | - |
| | B | 67 | 21.8 | 2,500 | <5 | <10 | 20 | - | 1120 | - | - |
| | C | 53 | 23.3 | 2,200 | <5 | <10 | <5 | - | 2140 | - | - |
| | D | 56 | 19.7 | 2,700 | <5 | <10 | <5 | - | 1300 | - | - |
| Ammonia Still Lime Pit | A | 43 | 35.0 | 550 | 5 | 33 | 550 | <0.25 | - | 19,000 | 7.9 |
| | B | 43 | 26.7 | 550 | 10 | <10 | 700 | 3.0 | - | 34,000 | 6.8 |
| | C | 80 | 22.5 | 550 | 15 | 67 | 730 | <0.25 | - | 40,000 | 3.4 |
| | D | 53 | 23.3 | 500 | 8 | 33 | 710 | 43.1 | - | 32,000 | 8.1 |
| Reladling Baghouse Dust | A | 176 | 67.0 | 2,400 | 110 | 117 | 950 | - | - | - | - |
| | B | 187 | 65.0 | 2,800 | 110 | 180 | 980 | - | - | - | - |
| | C | 200 | 40.0 | 2,450 | 100 | 42 | 400 | - | - | - | - |
| | D | 176 | 46.7 | 2,400 | 90 | 42 | 670 | - | - | - | - |
| Pickle Liquor (solid phase) | A | 1710 | 60 | 6,040 | 280 | 9 | 10,700 | - | - | - | - |
| | B | 1000 | 70 | 3,050 | 273 | <18 | 9,300 | - | - | - | - |
| | C | 1590 | 133 | 4,830 | 750 | 167 | 36,700 | - | - | - | - |
| | D | 870 | 64 | 2,520 | 320 | 248 | 16,400 | - | - | - | - |
| Pickle Liquor (liquid phase) | A | 6.5 | 8.6 | 220 | 9.5 | <0.2 | 1 | - | - | 39 | - |
| | B | 8.1 | 9.6 | 240 | 8.0 | <0.2 | 1 | - | - | 78 | - |
| | C | 5.5 | 7.6 | 180 | 9.4 | <0.2 | 1 | - | - | 19 | - |
| | D | 6.0 | 8.6 | 200 | 11.5 | <0.2 | 1 | - | - | 43 | - |
| Water Control Station #7 Final Thickened Sludge | A | 107 | 80 | 1,100 | 170 | 83 | 15,000 | - | 839 | 138,000 | - |
| | B | 127 | 87 | 1,500 | 180 | 117 | 18,000 | - | 960 | 47,000 | - |
| | C | 107 | 88 | 1,350 | 190 | 130 | 20,000 | - | - | 169,000 | - |
| | D | 123 | 68 | 800 | 170 | 83 | 17,000 | - | 580 | 116,000 | - |

- Not Analyzed

## Sample Analyses - Plant A (cont.)

### Chemical Analysis (ppm)

| Sample Description | Sample Period | Cr | Cu | Mn | Ni | Pb | Zn | CN | F | Oil & Grease | Phenol |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | 160 | 148 | 2,300 | 250 | 92 | 400 | - | 776 | - | - |
| Secondary Settling Sludge | B | 133 | 125 | 1,800 | 200 | 42 | 330 | - | 420 | - | - |
| | C | 140 | 143 | 1,850 | 210 | 35 | 360 | - | 680 | - | - |
| | D | 137 | 140 | 1,790 | 200 | 82 | 360 | - | 600 | - | - |
| | A | 85 | 48.0 | 1,250 | 90 | 3,000 | 70,000 | - | 1,160 | - | - |
| Blast Furnace Sludge | B | 147 | 61.3 | 1,900 | 100 | 2,000 | 30,000 | - | 760 | - | - |
| | C | 85 | 38.3 | 2,250 | 80 | 1,400 | 9,900 | - | 680 | - | - |
| | D | 93 | 30.0 | 1,900 | 80 | 4,000 | 40,000 | - | - | - | - |
| | A | 385 | 67.0 | 6,000 | 150 | <10 | 340 | - | 4,400 | - | - |
| BOF Sludge | B | 338 | 58.0 | 5,800 | 150 | 42 | 500 | - | 760 | - | - |
| | C | 324 | 85.0 | 7,550 | 160 | 83 | 250 | - | 4,560 | - | - |
| | D | 324 | 64.2 | 9,000 | 780 | 67 | 600 | - | 741 | - | - |
| | C | 878 | 380 | 5,050 | 400 | 79 | 90 | - | - | - | - |
| Mill Primary Settling Pit | D | 919 | 180 | 5,050 | 580 | <10 | 70 | - | - | - | - |
| | C | 1600 | 80.8 | 7,900 | 170 | <10 | 35 | - | - | - | - |
| Mill Scarfer Primary Settling Pit | D | 1800 | 97.0 | 9,000 | 250 | <10 | 15 | - | - | - | - |

* Sampling Periods:
- A December 9 - 13
- B December 16 - 20
- C December 30 - January 3
- D January 6 - 10

- Indicates no analysis made

Sample Analyses - Plant B

Chemical Analysis (ppm)

| Sample Description | Sample Period | Cr | Cu | Mn | Ni | Pb | Zn | CN | F | Oil & Grease | Phenol |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Soaking Pit Slag | A | 400 | 330 | 6,800 | 150 | 860 | 58 | ** | - | - | - |
| | B | 350 | 400 | 7,300 | 170 | 400 | 120 | - | - | - | - |
| | C | 450 | 330 | 6,200 | 140 | 2,200 | 80 | - | - | - | - |
| | D | 500 | 320 | 6,200 | 130 | 2,600 | 150 | - | - | - | - |
| Open Hearth Slag | A | 2,000 | 25 | 61,000 | 14 | 35 | <5 | - | 2,100 | - | - |
| | B | 1,800 | 26 | 60,000 | 14 | 165 | <5 | - | 1,000 | - | - |
| | C | 2,200 | 30 | 42,000 | 19 | 170 | <5 | - | 4,900 | - | - |
| | D | 2,300 | 37 | 39,000 | 31 | 260 | <5 | - | 2,040 | - | - |
| Electric Furnace Slag | A | 7,000 | 80 | 57,000 | 64 | 30 | <5 | - | 3,260 | - | - |
| | B | 7,600 | 86 | 50,000 | 66 | 10 | <5 | - | 1,130 | - | - |
| | C | 5,500 | 91 | 51,000 | 84 | 75 | 15 | - | 3,490 | - | - |
| | D | 3,900 | 84 | 49,000 | 40 | 185 | 400 | - | 2,040 | - | - |
| Electric Furnace Baghouse Dust | A | 1,300 | 1,800 | 38,000 | 500 | 20,000 | 75,300 | - | 2,940 | - | - |
| | B | 1,500 | 2,400 | 39,000 | 320 | 22,000 | 75,800 | - | 2,040 | - | - |
| | C | 1,200 | 1,900 | 40,000 | 340 | 21,000 | 54,000 | - | 2,940 | - | - |
| | D | 1,400 | 1,900 | 45,000 | 400 | 25,000 | 70,000 | - | 1,700 | - | - |
| Open Hearth E.S.P. Dust | A | 280 | 250 | 4,000 | 500 | 2,700 | 850 | - | 1,370 | - | - |
| | B | 550 | 550 | 9,700 | 400 | 11,000 | 14,500 | - | 1,000 | - | - |
| | C | 350 | 220 | 3,000 | 480 | 2,650 | 1,000 | - | 600 | - | - |
| | D | 930 | 400 | 12,000 | 500 | 4,000 | 7,600 | - | 600 | - | - |
| Grinder Baghouse Dust | A | 3,000 | 1,850 | 5,500 | 4,340 | 125 | 45 | - | - | - | - |
| | B | 19 | 400 | 1,300 | 300 | 50 | 25 | - | - | - | - |
| | C | 1,200 | 1,000 | 7,200 | 900 | 60 | 50 | - | - | - | - |
| | D | 770 | 550 | 10,100 | 750 | 35 | 20 | - | - | - | - |
| Grit Blast Dust | A | 1,300 | 2,000 | 8,600 | 800 | 48 | 50 | - | - | - | - |
| | B | 8 | 500 | 156 | 200 | 30 | 40 | - | - | - | - |
| | C | 900 | 750 | 6,000 | 750 | 35 | 42 | - | - | - | - |
| | D | 28 | 500 | 3,000 | 300 | 9 | 45 | - | - | - | - |

Sample Analyses - Plant B (cont.)

Chemical Analysis (ppm)

| Sample Description | Sample Period | Cr | Cu | Mn | Ni | Pb | Zn | CN | F | Oil & Grease | Phenol |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Decanter Tar Sludge (Coke Byproduct Plant) | A | - | - | - | - | - | - | 8.7 | - | 144,000 | 2,121 |
| | B | 4 | 1 | 44 | <10 | 30 | 20 | 9.8 | - | 278,000 | 3,127 |
| | C | - | - | - | - | - | - | 1.3 | - | 297,000 | 1,711 |
| | D | - | - | - | - | - | - | 3.1 | - | 182,000 | 1,715 |
| Water Treatment Plant 1&2 Filter Cake | A | 50 | 3 | <1 | <10 | <10 | <5 | - | - | 54,000 | - |
| | B | 400 | 550 | 5,500 | 650 | 450 | 1,000 | - | - | 34,000 | - |
| | C | 370 | 520 | 5,200 | 620 | 550 | 900 | - | - | 104,000 | - |
| | D | 11 | 3 | <1 | <10 | <10 | <5 | - | - | 89,000 | - |
| Water Treatment Plant 1&2 Wire Mill (liquid + solid phase) | A | 1.6 | 0.14 | 24.0 | 0.08 | 0.08 | 6.3 | - | - | - | - |
| | B | 0.52 | 0.21 | 1.4 | 0.13 | 0.17 | 5.0 | - | - | - | - |
| | C | 1.1 | 0.32 | 39.0 | 0.23 | 0.12 | 9.0 | - | - | - | - |
| | D | 0.9 | 0.16 | 2.1 | 0.58 | 0.12 | 23.5 | - | - | - | - |
| Water Treatment Plant 1&2 CCA (liquid + solid phase) | A | 0.5 | 0.22 | 0.42 | 0.1 | 0.12 | 0.3 | - | - | - | - |
| | B | 0.9 | 0.22 | 0.62 | 0.09 | 0.03 | 0.5 | - | - | - | - |
| | C | 0.9 | 0.18 | 0.51 | 0.07 | 0.05 | 0.4 | - | - | - | - |
| | D | 0.8 | 0.08 | 0.20 | 0.05 | 0.04 | 0.49 | - | - | - | - |
| **Pickle Liquor** (Solid phase) | | | | | | | | | | | |
| low carbon | A+B | 410 | 740 | 14,400 | 60 | 1,840 | 520 | - | - | - | - |
| low carbon | C+D | 195 | 330 | 15,600 | 52 | 4,500 | 180 | - | - | - | - |
| alloy + high carbon | B | 98 | 75 | 860 | 66 | 115 | 150 | - | - | - | - |
| CCA | C | 5,100 | 1,050 | 2,500 | 640 | 7 | 125 | - | - | - | - |
| **Pickle Liquor** (Liquid phase) | | | | | | | | | | | |
| low carbon | A+B | 8.0 | 1.0 | 180 | 18 | 1.85 | 20 | - | - | 47 | - |
| low carbon | C+D | 11.0 | 1.4 | 450 | 23 | 4.0 | 65 | - | - | 63 | - |
| alloy + high carbon | B | 16.0 | 1.1 | 330 | 32 | 2.5 | 15 | - | - | 8 | - |
| CCA | C | 9.3 | 3.1 | 360 | 36.4 | 0.28 | 30 | - | - | 88 | - |

- No Analysis made

Sample Analyses - Plant C

| | | Chemical Analysis (ppm) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample Description | Sample Period* | Cr | Cu | Mn | Ni | Pb | Zn | CN | F | Oil & Grease | Phenol |
| BOP Slag | A | 1,750 | 60 | 45,000 | <10 | 34 | 2 | ** | 4,560 | - | - |
| | B | 1,150 | 43 | 44,500 | <10 | 34 | <2 | - | 4,720 | - | - |
| | C | 1,700 | 47 | 44,500 | <10 | 4.8 | <2 | - | 8,400 | - | - |
| | D | 2,400 | 38 | 46,500 | <10 | 30 | <2 | - | 5,500 | - | - |
| Electric Furnace Slag | A | 6,300 | 120 | 79,500 | 21 | 74 | 600 | - | 1,700 | - | - |
| | B | 6,000 | 67 | 67,800 | 13 | 38 | 4 | - | 2,800 | - | - |
| | C | 7,800 | 56 | 80,500 | <5 | 4.5 | <2 | - | 1,400 | - | - |
| | D | 8,500 | 90 | 81,000 | <10 | 61 | <2 | - | 500 | - | - |
| Soaking Pit Slag | A+B | 380 | 300 | 3,500 | 90 | 3.0 | 5 | - | - | - | - |
| | C+D | 580 | 400 | 5,100 | 70 | 7.2 | 15 | - | - | - | - |
| Blast Furnace Slag | A | 30 | 26 | 2,600 | <10 | 12 | <2 | - | 1,400 | - | - |
| | B | 38 | 20 | 3,750 | <10 | 42 | 15 | - | 940 | - | - |
| | C | 40 | 23 | 3,750 | <10 | 56 | 10 | - | 1,440 | - | - |
| | D | 48 | 23 | 4,100 | <10 | 42 | 12 | - | 2,220 | - | - |
| BOP Centrifuge Cake | A | 260 | 210 | 8,500 | 58 | 2,800 | 6,500 | - | 2,100 | - | - |
| | B | 10,500 | 270 | 11,000 | 140 | 2,000 | 6,000 | - | 3,090 | - | - |
| | C | 380 | 190 | 8,500 | 38 | 1,650 | 3,500 | - | 2,640 | - | - |
| | D | 420 | 190 | 11,500 | 58 | 2,150 | 4,000 | - | 1,840 | - | - |
| Electric Furnace Drum Filter Cake | A | 810 | 580 | 28,000 | 200 | 2,300 | 8,900 | - | 7,500 | - | - |
| | B | 12,000 | 590 | 34,000 | 210 | 2,800 | 4,300 | - | 1,700 | - | - |
| | C | 2,800 | 660 | 44,000 | 300 | 1,800 | 8,300 | - | 4,000 | - | - |
| | D | 760 | 710 | 43,800 | 230 | 2,900 | 3,850 | - | 2,800 | - | - |
| Blast Furnace Sludge | A | 30 | 44 | 2,600 | 6 | 500 | 1,400 | <0.25 | 1,140 | - | 1.7 |
| | B | 32 | 50 | 2,700 | 10 | 450 | 1,100 | 7.4 | 1,140 | - | 2.1 |
| | C | 36 | 44 | 2,750 | 10 | 550 | 1,450 | 3.0 | 2,260 | - | 1.8 |
| | D | 39 | 56 | 2,600 | 7 | 700 | 1,500 | 9.6 | 1,160 | - | 2.4 |

Sample Analyses - Plant C (cont.)

Chemical Analysis (ppm)

| Sample Description | Sample Period | Cr | Cu | Mn | Ni | Pb | Zn | CN | F | Oil & Grease | Phenol |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Central Treatment Plant Clarifier Sludge | A | 320 | 440 | 7,000 | 150 | 1,780 | 2,800 | - | 1,140 | 106,000 | - |
| | B | 1,200 | 440 | 9,800 | 145 | 1,500 | 1,600 | - | 800 | 104,000 | - |
| | C | 1,200 | 400 | 6,000 | 150 | 1,000 | 2,700 | - | 1,040 | 98,000 | - |
| | D | 700 | 380 | 8,000 | 147 | 1,250 | 1,250 | - | 700 | 87,000 | - |
| Effluent Water from Scale Settling Pit for 96" Plate Mill (liquid + solid phase) | A | 0.3 | 0.04 | 0.05 | <0.03 | <0.1 | 0.18 | - | - | - | - |
| | B | 0.3 | 0.15 | 0.11 | <0.03 | 0.13 | 0.15 | - | - | - | - |
| | C | 0.31 | 0.04 | 0.11 | <0.03 | <0.1 | 0.15 | - | - | - | - |
| | D | 0.19 | 0.07 | 0.07 | <0.03 | <0.1 | 0.15 | - | - | - | - |
| Effluent Water from Scale Settling Pit for Continuous Casting Mill (liquid+solid phase) | A | 0.26 | 0.13 | 0.13 | <0.03 | 0.15 | 0.15 | - | - | - | - |
| | B | 0.15 | 0.06 | 0.07 | <0.03 | <0.1 | 0.06 | - | - | - | - |
| | C | 0.15 | 0.05 | 0.13 | <0.03 | <0.1 | 0.09 | - | - | - | - |
| | D | 0.20 | 0.04 | 0.07 | <0.03 | <0.1 | 0.1 | - | - | - | - |
| Effluent Water from Scale Settling Pit for Structural Mill (liquid + solid phase) | A | 0.11 | 0.25 | 0.44 | 0.16 | <0.1 | 0.13 | - | - | - | - |
| | B | 0.16 | 0.12 | 0.3 | 0.05 | <0.1 | 0.08 | - | - | - | - |
| | C | 0.80 | 0.15 | 0.3 | 0.13 | 0.16 | 0.16 | - | - | - | - |
| | D | 0.21 | 0.26 | 0.4 | 0.15 | <0.1 | 0.09 | - | - | - | - |
| Effluent Water from Scale Settling Pit for 30" Plate Mill (liquid + solid phase) | A | 0.16 | 0.06 | 0.16 | <0.03 | <0.1 | 0.37 | - | - | - | - |
| | B | 0.16 | 0.02 | 0.1 | <0.03 | <0.1 | 0.06 | - | - | - | - |
| | C | 0.21 | 0.06 | 0.07 | <0.03 | <0.1 | 0.04 | - | - | - | - |
| | D | 0.21 | 0.09 | 0.11 | <0.03 | <0.1 | 0.08 | - | - | - | - |
| Effluent Water from Scale Settling Pit for Alloy Bar Mill (liquid + solid phase) | A | 0.15 | 0.44 | 0.19 | 0.1 | 0.2 | 0.11 | - | - | - | - |
| | B | 0.16 | 0.12 | 0.09 | <0.03 | <0.1 | 0.07 | - | - | - | - |
| | C | 0.12 | 0.17 | 0.13 | <0.03 | 0.16 | 0.05 | - | - | - | - |
| | D | 0.21 | 0.12 | 0.09 | <0.03 | <0.1 | 0.07 | - | - | - | - |

- No analysis made

Sample Analyses - Plant D

Chemical Analysis (ppm)

| Sample Description | Sample Period | Cr | Cu | Mn | Ni | Pb | Zn | CN | Oil & Grease | Phenol | pH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Blast Furnace Flue Dust | A | 170 | 230 | 2,700 | 130 | 850 | 250 | 1.15 | - | 0.97 | - |
| | B | 120 | 300 | 3,300 | 100 | 750 | 250 | 1.96 | - | 0.34 | - |
| | C | 150 | 190 | 3,200 | 120 | 600 | 250 | 1.19 | - | 1.20 | - |
| | D | 135 | 210 | 3,300 | 76 | 800 | 900 | 5.81 | - | 0.39 | - |
| Clarifier Sludge Central Treatment Plant | A | 150 | 110 | 3,400 | 90 | 3,000 | 1,700 | 0.40 | 220,000 | 2.53 | - |
| | B | 130 | 110 | 3,000 | 100 | 2,500 | 1,600 | 1.18 | 157,000 | 0.23 | - |
| | C | 75 | 110 | 2,500 | 80 | 2,200 | 1,500 | <0.25 | 133,000 | 0.58 | - |
| | D | 110 | 140 | 2,500 | 96 | 2,300 | 1,200 | <0.25 | 45,400 | 0.86 | - |
| Mill Scale - 18" Bar Mill | A | 300 | 120 | 2,700 | 190 | 23 | 22 | - | 30,800 | - | - |
| | B | 190 | 100 | 2,700 | 110 | 50 | 34 | - | 53,900 | - | - |
| | C | 200 | 150 | 3,000 | 100 | 50 | 34 | - | 59,700 | - | - |
| | D | 240 | 110 | 2,300 | 128 | 33 | 9 | - | 7,300 | - | - |
| Bar Mill Scale Pit (8", 10", 18" Mills) | A | 660 | 350 | 4,500 | 270 | 340 | 30 | - | 204,000 | - | - |
| | B | 570 | 330 | 4,700 | 190 | 450 | 30 | - | 169,000 | - | - |
| | C | 340 | 230 | 3,200 | 160 | 970 | 25 | - | 174,000 | - | - |
| | D | 270 | 230 | 2,300 | 120 | 330 | 45 | - | 88,100 | - | - |
| BOF ESP Dust | A | 330 | 200 | 12,000 | 140 | 8,000 | 3,800 | - | - | - | - |
| | B | 310 | 200 | 11,600 | 90 | 8,200 | 2,600 | - | - | - | - |
| | C | 350 | 220 | 11,000 | 130 | 6,700 | 3,400 | - | - | - | - |
| | D | 270 | 190 | 11,000 | 100 | 6,500 | 3,600 | - | - | - | - |
| Baghouse Kish (metal pouring BOF) | A | 180 | 120 | 4,000 | 70 | 750 | 2,000 | - | - | - | - |
| | B | - | - | - | - | - | - | - | - | - | - |
| | C | - | - | - | - | - | - | - | - | - | - |
| | D | 105 | 50 | 3,000 | 15 | 67 | 130 | - | - | - | - |
| Steel Conditioning Scarfing Scale | A | 330 | 180 | 7,500 | 140 | 30 | 42 | - | - | - | - |
| | B | 400 | 160 | 5,800 | 130 | 60 | 30 | - | - | - | - |
| | C | 390 | 160 | 5,500 | 140 | 60 | 31 | - | - | - | - |
| | D | 330 | 130 | 3,500 | 96 | 60 | 8 | - | - | - | - |

Sample Analyses - Plant D (cont.)

Chemical Analysis (ppm)

| Sample Description | Sample Period | Cr | Cu | Mn | Ni | Pb | Zn | CN | Oil & Grease | Phenol | pH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Bar Finishing Pickle Liquor | A | 14. | 2.2 | 210. | 9.0 | 0.5 | 1.0 | - | 30.5 | - | <1 |
| | B | 9.6 | 2.0 | 170. | 8.0 | 1.0 | 1.0 | - | 25.5 | - | <1 |
| Steel Conditioning Pickle Liquor | C | 10. | 2.5 | 180. | 4.1 | 2.0 | 1.3 | - | 5.0 | - | <1 |
| | D | 32. | 2.7 | 205. | 15. | 2.0 | 2.0 | - | 95.0 | - | <1 |
| BOF Slag | A | 1,400 | 15 | 35,000 | 5.2 | <10 | <3 | - | - | - | - |
| | B | 1,400 | 13 | 27,000 | 3.5 | <10 | <3 | - | - | - | - |
| | C | 1,400 | 13 | 21,000 | 4 | <10 | <3 | - | - | - | - |
| | D | 1,500 | 22 | 24,000 | 12 | <10 | <3 | - | - | - | - |

- No analysis made

## Sample Analyses - Plant E

| Sample Description | Sample Period | Cr | Cu | Mn | Ni | Pb | Zn | CN | Oil & Grease | Phenol | Sn | $NH_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Blast Furnace Flue Dust | A | 50 | 20 | 31,000 | 27 | 67 | 140 | 1.46 | - | 2.01 | - | - |
| | B | 37 | 13 | 12,500 | 18 | 47 | 90 | 8.46 | - | 0.1 | - | - |
| | C | 33 | 13 | 18,000 | 20 | 73 | 130 | 3.12 | - | 0.36 | - | - |
| | D | 59 | 17 | 18,500 | 20 | 73 | 280 | 1.60 | - | 0.99 | - | - |
| Blast Furnace Filter Cake | A | 30 | 20 | 8,500 | 22 | 400 | 780 | 5.34 | - | 0.60 | - | - |
| | B | 22 | 24 | 6,700 | 31 | 600 | 850 | <0.7 | | 0.44 | | |
| | C | 22 | 17 | 6,700 | 22 | 420 | 860 | 7.21 | - | 0.21 | - | - |
| | D | 20 | 14 | 8,100 | 20 | 420 | 880 | 0.62 | - | 0.14 | - | - |
| Plate Mill Scale | A | 80 | 170 | 4,800 | 200 | <10 | 9 | - | 2,700 | - | - | - |
| | B | 90 | 220 | 5,200 | 220 | <10 | 11 | - | 7,000 | - | - | - |
| | C | 95 | 210 | 5,700 | 240 | <10 | 20 | - | 18,500 | - | - | - |
| | D | 75 | 180 | 5,200 | 190 | <10 | 9 | - | 4,400 | - | - | - |
| Hot Strip Mill Scale | A | 27 | 80 | 2,700 | 78 | <10 | 9 | - | 5,850 | - | - | - |
| | B | 23 | 80 | 2,500 | 78 | <10 | 9 | - | 5,040 | - | - | - |
| | C | 20 | 90 | 2,500 | 90 | <10 | 11 | - | 8,600 | - | - | - |
| | D | 21 | 90 | 2,500 | 90 | <10 | 9 | - | 27,000 | - | - | - |
| BOF Fines | A | 55 | 110 | 14,800 | 78 | 600 | 890 | - | - | - | - | - |
| | B | 60 | 120 | 15,600 | 90 | 650 | 960 | - | - | - | - | - |
| | C | 60 | 130 | 15,200 | 80 | 620 | 960 | - | - | - | - | - |
| | D | 60 | 130 | 15,200 | 100 | 500 | 920 | - | - | - | - | - |
| BOF Sands | A | 50 | 60 | 10,700 | 50 | 17 | 58 | - | - | - | - | - |
| | B | 50 | 90 | 11,100 | 33 | 40 | 260 | - | - | - | - | - |
| | C | 50 | 70 | 11,900 | 44 | 23 | 60 | - | - | - | - | - |
| | D | 40 | 30 | 10,400 | 33 | <10 | 40 | - | - | - | - | - |
| BOF Slag | A | 50 | 23 | 47,500 | 11 | <10 | 13 | - | - | - | - | - |
| | B | 42 | 43 | 47,500 | 9 | <10 | 13 | - | - | - | - | - |
| | C | 75 | 23 | 47,500 | 15 | <10 | 12 | - | - | - | - | - |
| | D | 39 | 19 | 43,000 | 9 | <10 | 16 | - | - | - | - | - |

Sample Analyses - Plant E (cont.)

| Sample Description | Sample Period | Chemical Analysis (ppm) Cr | Cu | Mn | Ni | Pb | Zn | CN | Oil & Grease | Phenol | Sn | $NH_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BOF Kish | A | 20 | 16 | 5,600 | 18 | 87 | 230 | - | - | - | - | - |
| | B | 16 | 17 | 5,200 | 15 | 21 | 170 | - | - | - | - | - |
| | C | 18 | 16 | 4,800 | 18 | 27 | 530 | - | - | - | - | - |
| | D | 18 | 19 | 5,400 | 20 | 37 | 540 | - | - | - | - | - |
| Tin Plate Sludge | A | 29 | 1,100 | 240 | 170 | 700 | 630 | - | - | - | 66,500 | - |
| | B | 27 | 2,500 | 190 | 72 | 720 | 660 | - | - | - | 67,500 | - |
| | C | 35 | 3,500 | 430 | 310 | 1,080 | 880 | - | - | - | 62,500 | - |
| | D | 54 | 9,000 | 480 | 700 | 1,060 | 960 | - | - | - | 55,000 | - |
| Treatment Plant Sludge | A | 63 | 190 | 10,000 | 140 | 300 | 880 | - | - | - | - | - |
| | B | 60 | 170 | 8,300 | 130 | 260 | 770 | - | - | - | - | - |
| | C | 73 | 190 | 8,900 | 160 | 260 | 870 | - | - | -- | - | - |
| | D | 71 | 170 | 7,000 | 130 | 240 | 730 | - | - | - | - | - |
| Waste Ammonia Liquor | A | - | - | - | - | - | - | 28.4 | 40 | 161 | - | 250 |
| | B | - | - | - | - | - | - | 36.7 | 88 | 210 | - | 250 |

- No analysis made

## Sample Analyses - Plant F

| Sample Description | Sample Period | Chemical Analysis (ppm) Cr | Cu | Mn | Ni | Pb | Zn | CN | Oil & Grease | Phenol | $NH_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Open Hearth ESP Dust | A | 580 | 1,200 | 3,400 | 190 | 18,400 | 700,000 | - | - | - | - |
| | B | 618 | 1,300 | 3,600 | 230 | 15,000 | 250,000 | - | - | - | - |
| | C | 659 | 3,200 | 3,900 | 320 | 15,000 | 130,000 | - | - | - | - |
| | D | 560 | 1,700 | 3,300 | 230 | 18,000 | 130,000 | - | - | - | - |
| Open Hearth Slag | A | 5,000 | 47 | 47,000 | 11 | <10 | 77 | - | - | - | - |
| | B | 2,200 | 54 | 40,000 | 32 | <10 | 80 | - | - | - | - |
| | C | 2,100 | 50 | 38,500 | 26 | <10 | 20 | - | - | - | - |
| | D | 4,300 | 50 | 43,000 | 18 | <10 | <3 | - | - | - | - |
| Electric Furnace Baghouse Dust | A | 900 | 1,700 | 40,000 | 170 | 32,000 | 240,000 | - | - | - | - |
| | B | 840 | 3,300 | 39,000 | 207 | 48,000 | 174,000 | - | - | - | - |
| | C | 770 | 3,400 | 39,500 | 217 | 46,000 | 166,000 | - | - | - | - |
| Electric Furnace Slag | A | 3,400 | 73 | 49,000 | 9 | <10 | 59 | - | - | - | - |
| | B | 2,700 | 100 | 50,000 | 26 | 10 | 110 | - | - | - | - |
| BOF Wet Scrubber Slurry | A | 440 | 350 | 17,000 | 100 | 16,400 | 16,000 | - | - | - | - |
| | B | 370 | 286 | 14,100 | 133 | 13,000 | 14,000 | - | - | - | - |
| | C | 180 | 257 | 11,400 | 167 | 11,000 | 10,000 | - | - | - | - |
| | D | 400 | 270 | 13,200 | 100 | 15,200 | 15,000 | - | - | - | - |
| BOF Slag | A | 2,500 | 23 | 43,000 | 46 | < 10 | 20 | - | - | - | - |
| | B | 1,400 | 32 | 49,000 | 23 | < 10 | 200 | - | - | - | - |
| | C | 1,200 | 20 | 48,000 | 17 | 10 | 56 | - | - | - | - |
| | D | 1,700 | 68 | 42,000 | 17 | < 10 | < 3 | - | - | - | - |
| Structural Mill Scale | A | 200 | 300 | 3,400 | 130 | 30 | 38 | - | 5,900 | - | - |
| | B | 150 | 257 | 3,200 | 150 | <10 | 19 | - | 3,750 | - | - |
| | C | 210 | 243 | 4,100 | 133 | 62 | 60 | - | 4,580 | - | - |
| | D | 200 | 330 | 4,700 | 150 | 300 | 12 | - | 27,900 | - | - |

Sample Analyses - Plant F (cont.)

Chemical Analysis (ppm)

| Sample Description | Sample Period | Cr | Cu | Mn | Ni | Pb | Zn | CN | Oil & Grease | Phenol | $NH_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ammonia Still Lime Sludge | A | - | - | - | - | - | - | 343 | 14,900 | 670 | <6.25 |
| | B | - | - | - | - | - | - | 1,440 | 104,000 | 1,160 | <6.25 |
| | C | - | - | - | - | - | - | 1,630 | 30,700 | 1,910 | <6.25 |
| | D | - | - | - | - | - | - | 1,940 | 12,100 | 1,550 | 252 |
| 80" Hot Strip Mill Clarifier Sludge | A | 170 | 220 | 2,400 | 240 | 100 | 60 | - | 79,700 | - | - |
| | B | 230 | 257 | 3,400 | 300 | 230 | 40 | - | 40,100 | - | - |
| | C | 210 | 229 | 5,000 | 240 | 3,600 | 2,550 | - | 9,040 | - | - |
| | D | 180 | 220 | 2,300 | 230 | 280 | 24 | - | 52,300 | - | - |

- No analysis made

## Sample Analyses - Plant G

| Sample Description | Sample Period | Cr | Cu | Mn | Ni | Pb | Zn | CN | Oil & Grease | Phenol | pH |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Chemical Analysis (ppm) | | | | | | | | | |
| Blast Furnace Flue Dust | A | 80 | 30 | 3,300 | 22 | 80 | 1,000 | 26.2 | - | 9.87 | - |
| | B | 75 | 30 | 3,000 | 40 | 80 | 900 | 8.67 | | 1.09 | - |
| | C | 100 | 34 | 3,600 | 51 | 104 | 1,020 | 37.8 | - | 0.14 | - |
| | D | 100 | 31 | 3,200 | 67 | 104 | 980 | 12.3 | - | 0.35 | - |
| Blast Furnace Sludge | A | 65 | 40 | 3,000 | 21 | 1,100 | 5,000 | 30.6 | - | 1.18 | - |
| | B | 55 | 40 | 3,000 | 30 | 900 | 3,600 | 7.54 | - | 1.22 | - |
| | C | 65 | 41 | 2,700 | 41 | 1,500 | 9,000 | 22.1 | - | 0.87 | - |
| | D | 71 | 31 | 2,500 | 45 | 1,200 | 10,100 | 7.56 | - | 0.24 | - |
| Open Hearth Slag | A | 1,800 | 60 | 40,000 | 10 | < 10 | 70 | - | - | - | - |
| | B | 1,900 | 90 | 30,000 | 40 | < 10 | 180 | - | - | - | - |
| | C | 1,300 | 69 | 35,000 | 24 | 23 | 80 | - | - | - | - |
| | D | 1,400 | 59 | 37,000 | 45 | < 10 | 56 | - | - | - | - |
| Open Hearth ESP Dust | A | 500 | 830 | 3,600 | 200 | 9,000 | 15,000 | - | - | - | - |
| | B | 550 | 1,100 | 3,500 | 230 | 15,000 | 17,000 | - | - | - | - |
| | C | 580 | 1,050 | 4,100 | 250 | 14,000 | 37,000 | - | - | - | - |
| | D | 660 | 1,800 | 3,600 | 233 | 15,000 | 53,000 | - | - | - | - |
| Blooming Mill Scale | A | 280 | 250 | 4,500 | 160 | 50 | 25 | - | 2,500 | - | - |
| | B | 320 | 280 | 8,000 | 90 | 50 | 60 | - | 5,400 | - | - |
| | C | 140 | 286 | 12,700 | 167 | < 10 | 16 | - | 6,460 | - | - |
| | D | 210 | 510 | 4,300 | 250 | < 10 | 18 | - | 2,330 | - | - |
| Hot Strip Mill Waste Pickle Liquor | A | 2.5 | 2.0 | 90. | 6.0 | < 0.1 | 0.65 | - | 44.5 | - | < 1 |
| | B | 2.0 | 1.7 | 69. | 4.7 | < 0.1 | 0.6 | - | 50.0 | - | < 1 |
| | C | 3.8 | 2.57 | 111. | 7.0 | < 0.1 | 0.67 | - | 134 | - | < 1 |
| | D | 3.8 | 2.0 | 100. | 6.7 | 0.1 | 1.0 | - | 150 | - | < 1 |
| Surface Glaze Grinder Waste | A | 50 | 340 | 1,500 | 160 | 15 | 850 | - | - | - | - |
| | B | 75 | 470 | 1,800 | 190 | 15 | 1,400 | - | - | - | - |
| | C | 71 | 370 | 1,270 | 183 | 17 | 3,700 | - | - | - | - |
| | D | 82 | 490 | 1,500 | 250 | 23 | 1,400 | - | - | - | - |
| South Side Cold Finishing Waste Pickle Liquor | A | 10. | 10. | 190. | 7.7 | 3.5 | 6.0 | - | 71.0 | - | < 1 |
| | B | 19. | 30. | 185. | 13. | 3.5 | 1.6 | - | 253 | - | < 1 |
| | C | 9.5 | 25. | 157. | 5.0 | 2.85 | 3.0 | - | 141 | - | < 1 |
| | D | 9.4 | 45. | 182. | 6.0 | 3.23 | 1.1 | - | 115 | - | < 1 |

## Sample Analyses - Plant H

| Sample Description | Sample Period | Chemical Analyses (ppm) Cr | Cu | Mn | Ni | Pb | Zn | Oil & Grease | pH |
|---|---|---|---|---|---|---|---|---|---|
| Electric Furnace Slag | A | 3,800 | 18 | 57,000 | 135 | <10 | 60 | - | - |
| | B | 1,900 | 39 | 37,000 | 51 | <10 | <3 | - | - |
| Electric Furnace Baghouse Dust (wet) | A | 2,700 | 550 | 55,000 | 3,750 | 2,000 | 2,500 | - | - |
| | B | 1,800 | 520 | 48,000 | 3,000 | 2,000 | 3,800 | - | - |
| BOP Slag | A | 1,400 | 16 | 38,500 | 31 | <10 | <3 | - | - |
| | B | 1,300 | 17 | 40,500 | 28 | <10 | <3 | - | - |
| BOP Sludge | A | 310 | 114 | 11,400 | 133 | 700 | 440 | - | - |
| | B | 220 | 114 | 11,400 | 102 | 2,000 | 800 | - | - |
| Soaking Pit Slag | A | 130 | 67 | 3,200 | 80 | <10 | 33 | - | - |
| | B | 190 | 79 | 3,900 | 102 | <10 | 13 | - | - |
| 46" Primary Mill Scale | A | 870 | 143 | 6,400 | 533 | <10 | 19 | 55,600 | - |
| | B | 580 | 114 | 5,500 | 167 | <10 | 22 | 10,600 | - |
| Waste Pickle Liquor | A | 48. | 8.0 | 179. | 105. | <0.1 | 7.0 | 11 | 1.21 |
| | B | 69. | 6.0 | 280. | 135. | <0.1 | 26. | 88 | <1 |
| Grinder Dust - Conditioning Bldg. | A | 980 | 129 | 6,300 | 330 | <10 | 9 | - | - |
| | B | 3,700 | 157 | 6,100 | 3,200 | <10 | 40 | - | - |

- No analysis made

## Sample Analyses - Plant I

| Sample Description | Sample Period | Chemical Analysis (ppm) Cr | Cu | Mn | Ni | Pb | Zn | CN | Oil & Grease | Phenol |
|---|---|---|---|---|---|---|---|---|---|---|
| Melt Shop Sludge | A | 1,100 | 1,500 | 30,000 | 480 | 12,000 | 18,000 | - | - | - |
| | B | 980 | 1,700 | 27,000 | 580 | 11,000 | 18,000 | - | - | - |
| | C | 1,850 | 1,600 | 30,000 | 900 | 16,600 | 30,000 | - | - | - |
| | D | 1,190 | 1,700 | 36,000 | 470 | 13,800 | 17,000 | - | - | - |
| Electric Furnace Slag | A | 2,500 | 90 | 20,500 | 80 | <10 | 10 | - | - | - |
| | B | 2,470 | 90 | 19,000 | 40 | <10 | 18 | - | - | - |
| | C | 3,700 | 110 | 27,000 | 170 | <10 | <3 | - | - | - |
| | D | 4,000 | 70 | 34,000 | 56 | <10 | <3 | - | - | - |
| Stainless Steel Processing Sludge (Plant No. 2) | C | 23,500 | 370 | 560 | 2,700 | <10 | 48 | - | - | - |
| Stainless Processing Grinder Dust (Plant No. 2) | C | 37,500 | 500 | 2,300 | 27,000 | <10 | 8 | - | - | - |
| Combined Sludge Disposal (at Neutralization Plant) | A | 300 | 360 | 220 | 220 | 140 | 900 | 8.30 | 11,000 | <0.25 |
| | B | 2,300 | 280 | 460 | 880 | 45 | 1,100 | <0.25 | 31,400 | 4.80 |
| | C | 650 | 470 | 650 | 840 | 250 | 880 | 11.3 | 68,300 | 0.65 |
| | D | 3,200 | 500 | 1,300 | 6,200 | 330 | 380 | 17.9 | 32,900 | 1.49 |
| Slab Mill Grinder Dust | A | 42,000 | 1,600 | 12,000 | 30,000 | <10 | 18 | - | - | - |
| | B | 125,000 | 1,700 | 10,500 | 70,000 | <10 | 30 | - | - | - |
| | C | 100,000 | 1,600 | 10,500 | 63,000 | <10 | 22 | - | - | - |
| | D | 13,000 | 1,300 | 13,200 | 8,700 | <10 | 24 | - | - | - |
| Slab Mill Scale | A | 490 | 1,400 | 7,000 | 1,200 | 140 | 15 | - | 5,000 | - |
| | B | 270 | 560 | 3,800 | 530 | 130 | 15 | - | 2,500 | - |
| | C | 300 | 900 | 2,200 | 730 | 200 | 50 | - | 6,000 | - |
| | D | 240 | 600 | 3,500 | 630 | 20 | 140 | - | 14,100 | - |
| Hot Strip Mill Scale | A | 200 | 540 | 2,400 | 430 | 220 | 150 | - | 29,700 | - |
| | B | 260 | 750 | 1,300 | 1,300 | 100 | 35 | - | 29,000 | - |
| | C | 600 | 770 | 1,200 | 6,500 | 300 | 24 | - | 20,300 | - |
| | D | 290 | 800 | 1,000 | 2,700 | 700 | 25 | - | 52,600 | - |

Sample Analyses - Plant J

| Sample Description | Sample Period | Cr | Cu | Mn | Ni | Pb | Zn | CN | Oil & Grease | Phenol | Sn |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Chemical Analysis (ppm) | | | | | | | | | |
| Tin Mill Sludge | A+B | 8,400 | 160 | 2,500 | 130 | 320 | 5,000 | - | - | - | 24,000 |
| | C+D | 8,000 | 130 | 2,400 | 120 | 250 | 5,400 | - | - | - | 45,000 |
| C and E Lagoon Sludge | | 340 | 160 | 2,000 | 130 | 400 | 1,800 | 25.2 | 47,800 | 0.47 | - |
| BOF Scrubber Sludge | A | 110 | 250 | 5,700 | 70 | 7,700 | 47,000 | - | - | - | - |
| | B | 100 | 220 | 5,000 | 60 | 5,900 | 38,000 | - | - | - | - |
| | C | 160 | 160 | 6,000 | 65 | 4,200 | 29,000 | - | - | - | - |
| | D | 120 | 230 | 5,700 | 80 | 5,300 | 27,000 | | | | |
| Hot Strip Mill Scale | A+B | 40 | 190 | 2,300 | 90 | <10 | <3 | - | 8,070 | - | - |
| | C+D | 44 | 200 | 2,200 | 120 | <10 | 18 | - | 50,700 | - | - |
| Blooming Mill Scale | A+B | 60 | 210 | 3,300 | 90 | 43 | 8 | - | 2,830 | - | - |
| | C+D | 60 | 130 | 3,700 | 70 | 43 | <3 | - | 8,830 | - | - |

\- No analysis made

TABLE A-12

Sample Analyses - Iron and Steel Foundries

| Plant | Material Analyzed | Concentration of Potentially Hazardous Constituents (ppm) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mn | Zn | Cd | Pb | Cu | Ni | Cr | Phenol |
| A | mold, pour, and shakeout wet collector system sludge | 375 | 250 | 2.3 | 130 | 150 | - | 50 | - |
| | cleaning room baghouse dust | 4200 | 200 | 2.0 | <10 | 950 | - | 200 | - |
| | baghouse dust from sand reclaimer | 41 | 30 | <1.0 | 15 | 7.0 | - | 41 | - |
| | furnace slag | 5200 | 42 | 1.0 | 16 | 52 | - | 150 | - |
| B | burned core sand | 230 | 7 | - | 480 | 26 | 200 | 18 | 1.73 |
| | shotblast cleaning baghouse dust | 2060 | 210 | - | 840 | 40 | 150 | 100 | - |
| C | Cupola furnace slag | 760 | 10 | - | <10 | 18 | 10 | 17 | - |
| | cyclone dust from cupola | 870 | 500 | - | 130 | 90 | 32 | 21 | - |
| | baghouse dust from cupola | 19,000 | 7000 | - | 310 | 300 | 60 | 100 | - |
| | burned sand | 29 | 6 | - | <10 | 6 | 4 | 3 | 1.01 |
| | shotblast cleaning baghouse dust | 6,700 | 53 | - | 21 | 90 | 130 | 150 | - |

\- Not Analyzed

## TABLE A-13 SAMPLE ANALYSES - FERROALLOY PLANTS

| Type of Ferroalloy | Type of Sample | Concentration of Potentially Hazardous Constituent (PPM) CO | Cr | Cu | Pb | Zn | Mn | Ni | Cd | F |
|---|---|---|---|---|---|---|---|---|---|---|
| Ferrochrome Silicon | Electric furnace baghouse dust | - | 41 | 45 | - | 700 | 700 | - | - | - |
| | furnace slag | - | 2140 | 18 | - | 150 | 500 | - | - | - |
| Ferronickel | Glasswool from slag granulation process | 87 | 2320 | 36 | - | 100 | 900 | 1540 | - | - |
| | Ferrosilicon furnace baghouse dust | 82 | 160 | 2180 | - | 1300 | 1500 | 3250 | - | - |
| | Reject ore screening | 235 | 27 | 7 | - | 50 | 900 | 5400 | - | - |
| | Granulated slag | 104 | 321 | 50 | - | 100 | 1100 | 1850 | - | - |
| | | 159 | 2140 | 23 | - | 125 | 2000 | 4100 | - | - |
| | Skull plant tailings | 47 | 380 | 21 | - | 500 | 500 | 1330 | - | 180 |
| Silicomanganese and Ferromanganese | Silicomanganese slag | - | 27 | 23 | 20 | <20 | 70,000 | - | - | - |
| | Silicomanganese furnace baghouse dust | - | 9 | 36 | 3200 | 8000 | 90,000 | - | - | - |
| | Ferromanganese furnace baghouse dust | - | 32 | 200 | 6000 | 45,000 | 155,000 | - | - | - |
| | Water phase of ferro-manganese baghouse dust slurry | - | 0.05 | 0.05 | 2.0 | 1.7 | 0.12 | <0.05 | <0.05 | - |
| | Ferromanganese furnace scrubwater solids | - | 18 | 50 | 5000 | 35,000 | 20,000 | - | - | - |

- Not Analyzed

TABLE A-13 (cont.)

| Types of Ferroalloys | Type of Sample | Cr | Cu | Pb | Zn | Mn | CN |
|---|---|---|---|---|---|---|---|
| | | Concentration of Potentially Hazardous Constituent (PPM) | | | | | |
| Silicomanganese | Electric furnace scrubwater | 24,800 | 210 | 8,900 | 16,400 | 232,000 | 0.02 |
| | Lagoon dredgings (#3) | 1,070 | 44 | 3,500 | 900 | 60,000 | - |
| | Acid waste stream after liming | 2,680 | 27 | 210 | 50 | 16,000 | - |
| | Solids from slag concentrator lagoon | 3,390 | 14 | 10 | 100 | 70 | - |
| | Furnace #1 scrubwater solids (from settling pit) | 45 | 82 | 25,000 | 10,000 | 300,000 | - |
| Ferrochrome | Ferrochrome Slag concentrator residue (coarse fraction) | 4,540 | 23 | $<$ 10 | 25 | 500 | - |
| | Solids from dredged slag concentrator lagoons | 3,210 | 14 | 20 | 70 | 300 | - |
| | Solids from final lagoon | 1,790 | 45 | 100 | 2,500 | 2,000 | - |
| | Furnace scrubwater Solids (from concrete settling pit) | 1,610 | 35 | 70 | 650 | 800 | - |
| | Electrostatis precipitator dust from ferrochrome | 3,390 | 54 | 300 | 14,000 | 7,200 | - |

## APPENDIX B

## SOLUBILITY TESTS AND OTHER CRITERIA FOR HAZARDOUS WASTE ASSESSMENT

For the land disposed or stored waste streams (i.e.,slags, sludges, dusts, others) from each of the metal smelting and refining categories,an assessment has been made as to whether the wastes are considered either "non-hazardous" at this time or "potentially hazardous" at this time. Hazard ratings were made using a number of criteria including the following:

- Types and concentrations of potentially hazardous constituents (Cd, Cr, Hg, Pb, Zn, Cu, Ni, As, phenol, cyanide, fluoride, oil and grease)

- Physical characteristics of residuals

- Susceptibility to leaching of potentially hazardous constituents as indicated in solubility tests described below.

The mere presence of toxic constituents in significant concentrations in a waste did not automatically result in a hazardous rating. The most important criteria was the tendency of toxic constituents to be leached from residuals at significant concentrations.

Collected samples of slag, sludges, dusts and other wastes believed to be representative of wastes discarded or stored by the metal smelting and refining industries were selected for testing. Particle size distribution of sludges and dusts were comparable to those encountered at disposal sites. Particle size distributions of selected slags ranged from silt size to 1 to 2 inch chunks. Much larger chunks of slag are found at disposal sites. Selected samples probably represent the more comminuted fraction of disposed slags and pot liners.

Approximately 50 grams of each sample was placed in a 200 ml jar and two parts by weight of water added. The bottles were then gently agitated on a rotary tumbling apparatus (approximately 4 RPM) for a period of 72 hours. Samples were then filtered through a 0.45 micron micropore filter and collected filtrate analyzed for trace metals and other parameters of interest. Tables B-1 through B-5 give the results of the chemical analyses of filtrate from the various waste samples after agitation and filtration.

If lead, cadmium, mercury, cyanide, phenol or other highly toxic materials leached at greater than 1 ppm in solubility tests, the waste was designated as potentially hazardous at this time.

TABLE B-1

SOLUBILITY TESTS

Primary Copper, Zinc, Antimony, Mercury, Tungsten and Lead

Chemical Analysis (ppm) of filtrate

| Type of Waste | As | Cd | Cr | Cu | Hg | Mn | Ni | Pb | Sb | Zn | Se | pH | Cond. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Primary Copper SIC 3331** | | | | | | | | | | | | | |
| reverberatory slag | 0.040 | <0.01 | <0.01 | 0.37 | <0.02 | <0.01 | <0.05 | 0.3 | <0.2 | 0.24 | 0.09 | 10.8 | 600 |
| electric furnace slag | 0.052 | 0.15 | 0.02 | 0.58 | <0.02 | 0.2 | <0.05 | 6.0 | <0.2 | 3.0 | 0.13 | 7.8 | 100 |
| converter dust | 3.44 | 170 | 0.9 | 31,000 | 0.030 | 33 | 15 | 8.3 | 2.0 | 9,000 | <0.05 | 3.9 | <20 |
| acid plant sludge | 0.805 | 8.4 | 0.5 | 850 | - | 1.0 | 0.64 | 7.8 | <0.2 | 300 | - | 3.0 | 2,700 |
| reverbatory dust | 0.300 | 130 | 0.1 | 29,000 | 0.008 | 15 | 2.5 | 7.3 | <0.2 | 13,000 | <0.05 | 4.2 | >10,000 |
| **Primary Zinc SIC 3333** | | | | | | | | | | | | | |
| gypsum cake (neutral cooling tower) | 0.178 | 24 | 0.04 | 5.4 | <0.02 | 260 | 0.16 | 2.1 | <0.2 | 9,600 | <0.05 | 6.4 | >10,000 |
| gypsum cake (acid cooling tower) | 0.325 | 11 | 0.67 | 25.0 | <0.02 | 550 | 2.3 | 1.0 | <0.2 | 9,500 | <0.05 | 1.4 | >10,000 |
| anode sludge | 0.040 | 12 | 0.05 | 2.0 | <0.02 | 13 | 0.26 | 2.0 | <0.2 | 3,050 | <0.05 | 2.5 | 8,000 |
| retort furnace residue | - | 0.04 | 0.02 | 0.23 | <0.02 | 65 | 1.1 | 0.3 | <0.2 | 230 | <0.05 | 7.1 | 2,000 |
| cadmium plant residue | 0.029 | <0.01 | 0.02 | 2.4 | - | 3.7 | 0.4 | 9.0 | <0.2 | 4,000 | - | 6.3 | - |
| oxide furnace residue | - | 0.02 | <0.01 | 7.7 | <0.02 | 16 | <0.05 | 0.2 | <0.2 | 78 | <0.05 | 8.2 | 2,000 |
| acid plant sludge | <0.003 | <0.01 | <0.01 | 0.27 | <0.02 | 0.03 | <0.05 | 1.3 | <0.2 | 0.37 | <0.05 | 10.0 | <20 |
| **Primary Antimony SIC 3339** | | | | | | | | | | | | | |
| blast furnace slag | 3.00 | 0.09 | <0.01 | 5.0 | - | 0.01 | <0.05 | <0.2 | 100 | 1.7 | <0.05 | 9.2 | <20 |
| electrolytic plant sludge | - | 0.22 | <0.01 | 0.27 | - | 0.03 | <0.05 | 0.3 | 1.6 | 0.5 | - | 11.0 | >10,000 |
| **Primary Mercury SIC 3339** | | | | | | | | | | | | | |
| rotary kiln calcine | - | <0.01 | 0.03 | <0.03 | - | <0.01 | 0.08 | <0.2 | <0.2 | <0.01 | 0.05 | 10.4 | 450 |

- Not Analyzed

TABLE B-1 (cont.)

| Type of Waste | As | Cd | Cr | Cu | Hg | Mn | Ni | Pb | Sb | Zn | Se | pH | Cond. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Chemical Analysis (ppm) | | | | | | | | | | | | |
| **Primary Tungsten SIC 3339** | | | | | | | | | | | | | |
| digestion residue | <0.003 | 0.15 | 0.05 | 90 | <0.02 | 75 | 60 | 0.7 | <0.2 | 1.5 | <0.05 | 6.4 | >10,000 |
| **Primary Lead SIC 3332** | | | | | | | | | | | | | |
| blast furnace slag | <0.003 | 0.03 | <0.01 | 0.1 | <0.02 | <0.01 | <0.05 | <0.2 | <0.2 | 0.22 | 0.12 | 6.7 | <20 |
| lead fuming slag | 0.089 | <.01 | <0.01 | 1.0 | <0.02 | 0.03 | <0.05 | <0.2 | 1.0 | 0.64 | <0.05 | 9.2 | 80 |
| blast furnace dust | 0.177 | 8.0 | <0.01 | 130 | <0.02 | 0.25 | 0.09 | 7.3 | <0.2 | 45 | <0.05 | 8.8 | <20 |
| sinter scrubber sludge | - | 9.1 | <0.01 | 2.6 | <0.02 | 1.3 | <0.05 | 5.5 | <0.2 | 7.5 | 0.17 | 6.8 | 2,500 |
| lagoon dredgings (smelter) | 0.231 | 11 | <0.01 | 0.53 | <0.02 | 27 | 0.08 | 4.5 | <0.2 | 9.5 | <0.05 | 6.7 | 4,000 |

TABLE B-2

SOLUBILITY TESTS

Secondary Lead and Secondary Copper

| Type of Waste | Chemical Analysis (ppm) | | | | | | | | pH | Cond. |
|---|---|---|---|---|---|---|---|---|---|---|
| | Zn | Cd | Cr | Cu | Mn | Pb | Sb | Sn | | |
| **Secondary Lead SIC 33413** | | | | | | | | | | |
| scrubber sludge | 1.3 | 5 | .05 | 0.50 | 0.21 | 2.5 | < 0.2 | 1.6 | 8.4 | >10,000 |
| furnace slag | 0.24 | <0.01 | <0.01 | 0.68 | 0.03 | < 0.2 | <0.2 | <0.2 | 9.6 | 190 |
| furnace dust | 4,000 | 230 | 12.0 | 45 | 4.0 | 24 | <0.2 | 860 | 3.9 | > 10,000 |
| **Secondary Copper SIC 33412** | | | | | | | | | | |
| blast furnace slag | 55 | 1.0 | 0.03 | 170 | 0.3 | 6 | < 0.2 | < 0.2 | 9.4 | 90 |
| water treatment sludge | < 0.01 | 0.05 | 7.1 | 0.63 | 0.06 | 0.5 | < 0.2 | <0.2 | 8.6 | 2,000 |

- Not Analyzed

TABLE B-3

SOLUBILITY TESTS

Ferroalloys

| Type of Waste | Chemical Analysis (ppm) Cr | Cu | Zn | Mn | Ni | Pb | Co | pH | Cond. |
|---|---|---|---|---|---|---|---|---|---|
| **Ferrochrome SIC 3313** | | | | | | | | | |
| furnace slag (ferrochrome) | 0.02 | 0.02 | 0.2 | 0.3 | < 0.05 | 0.4 | - | 9.9 | 100 |
| furnace slag (ferrochrome silicon) | 0.28 | 1.0 | 110 | 0.2 | < 0.05 | 15 | - | 9.9 | 60 |
| furnace baghouse dust (Fe Cr Si) | 190 | 0.44 | 0.3 | 0.1 | < 0.05 | 1.5 | - | 8.8 | - |
| ESP dust (Fe Cr) | 710 | 0.20 | 0.09 | 0.07 | 0.14 | 0.7 | - | 12.3 | >10,000 |
| **Ferronickel SIC 3313** | | | | | | | | | |
| granulated slag | 0.01 | 0.74 | 2.0 | 0.07 | < 0.05 | 1.0 | < 0.02 | 8.5 | 90 |
| pond dredgings | 0.08 | 0.14 | 0.1 | 0.02 | < 0.05 | 0.30 | < 0.02 | 8.8 | 600 |
| skull plant tailings | 0.01 | 50 | 64 | 0.11 | < 0.05 | < 0.2 | 0.06 | 11.0 | 1,000 |
| reject ore | < 0.01 | 0.10 | 0.05 | 0.14 | 0.70 | < 0.2 | < 0.02 | 8.0 | 60 |
| **Silicomanganese SIC 3313** | | | | | | | | | |
| furnace slag | < 0.01 | 0.17 | 0.05 | 0.10 | < 0.05 | < 0.2 | - | 6.8 | 90 |
| baghouse dusts | 0.6 | 0.37 | 0.60 | 2.2 | 0.27 | 1.2 | - | 13.0 | - |
| scrubwater solids | 0.55 | 0.14 | 0.03 | < 0.02 | < 0.05 | 1.3 | - | 11.0 | < 20 |
| **Ferromanganese SIC 3313** | | | | | | | | | |
| baghouse dust | 0.20 | 4.50 | 110 | 7.5 | 0.53 | 560 | - | 9.7 | < 20 |
| slag (Fe Mn) | 0.02 | 0.04 | 0.03 | 2.1 | < 0.05 | < 0.02 | - | 5.9 | 120 |
| **Ferrosilicon SIC 3313** | | | | | | | | | |
| baghouse dust | 0.30 | 0.24 | < 0.01 | 0.06 | 0.10 | < 0.02 | - | 9.6 | - |

- Not Analyzed

TABLE B-4

SOLUBILITY TESTS

Primary and Secondary Aluminum

| Type of Waste | Chemical Analysis (ppm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | F | Cn | Cu | Zn | Pb | Cr | Mn | Ni | Na | Cl | pH | Cond. |
| **Primary Aluminum** SIC 3334 | | | | | | | | | | | | |
| shot blast dust | - | - | 0.14 | 0.2 | < 0.02 | < 0.01 | 20 | 0.13 | - | - | 7.4 | 5,000 |
| spent pot liners | 10,400 | 5,460 | - | - | - | - | - | - | - | - | 12.6 | >10,000 |
| lagoon sludge (pumps) | 8.0 | - | - | - | - | - | - | - | - | - | 8.5 | 2,500 |
| cryolite recovery sludge ("black mud") | 600 | 83 | - | - | - | - | - | - | - | - | 9.8 | >10,000 |
| **Secondary Aluminum** SIC 33417 | | | | | | | | | | | | |
| dross | 2.6 | - | 1.5 | <0.01 | 0.17 | 0.90 | 0.37 | 0.70 | 30,000 | 110,000 | 8.3 | >10,000 |
| baghouse dust | 16.0 | - | 0.7 | 20 | 0.70 | 0.04 | 20 | 0.34 | - | - | 7.0 | >10,000 |
| high salt slag | 97 | - | 0.8 | <0.01 | 0.24 | 1.5 | 0.43 | 1.6 | 56,000 | 200,000 | 11.0 | >10,000 |

- Not Analyzed

TABLE B-5

SOLUBILITY TESTS

Iron and Steel and Iron and Steel Foundries

| Type of Waste | Mn | Cr | Cu | Pb | Ni | Zn | F | Phenol | Cyanide | Oil & Grease | pH | Cond. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Chemical Analysis (ppm) | | | | | | | | | | | |
| **Iron and Steel SIC 3312** | | | | | | | | | | | | |
| blast furnace slag | < 0.01 | <0.01 | <0.03 | < 0.20 | < 0.05 | <0.01 | 1.9 | - | - | - | 10.6 | 1,800 |
| open hearth slag | <<0.01 | 0.01 | 0.04 | 0.30 | < 0.05 | < 0.01 | 3.1 | - | - | - | 12.5 | 8,000 |
| BOF slag | <0.01 | 0.03 | <0.03 | 0.20 | <0.05 | <0.01 | 4.0 | - | - | - | 12.5 | 7,000 |
| electric furnace slag | <0.01 | 0.27 | < 0.03 | 0.44 | <0.05 | <0.01 | 1.5 | - | - | - | 12.4 | 7,500 |
| soaking pit slag | < 0.01 | 1.40 | 0.04 | <0.20 | <0.05 | 0.02 | - | - | 0.38 | - | 9.5 | 80 |
| blast furnace dust | 0.12 | 0.03 | 0.09 | 0.25 | <0.05 | 0.20 | 2.2 | 0.25 | < 0.25 | - | 11.7 | 5,000 |
| open hearth dust | 12 | 0.03 | 0.06 | 0.40 | 0.40 | 0.10 | 19 | - | - | - | 8.9 | 6,000 |
| electric furnace dust | 0.26 | 0.34 | 0.10 | 150 | <0.05 | 0.70 | 7.6 | - | - | - | 12.6 | >10,000 |
| blast furnace sludge | 0.08 | 0.02 | <0.03 | <0.20 | < 0.05 | <0.01 | 14.0 | 0.40 | - | - | 9.5 | 1,000 |
| BOF sludge | 0.50 | 0.09 | 0.09 | <0.20 | <0.05 | 0.13 | 14.0 | - | - | - | 10.4 | - |
| electric furnace sludge | 0.03 | 94 | 0.17 | 2.0 | <0.05 | 0.06 | 11.0 | - | - | - | 11.5 | 800 |
| mill scale | <0.01 | 0.05 | 0.03 | <0.2 | <0.05 | 0.03 | - | - | - | 0.5 | 9.6 | 80 |
| decanter tar sludge (coke byproduct plant | <0.01 | < 0.01 | <0.03 | <0.2 | <0.05 | <0.01 | - | ~500 | 0.59 | 198 | 8.9 | 350 |
| ammonis still lime pit sludge (coke byproduct plant) | 0.05 | 0.02 | 0.09 | 0.5 | <0.05 | <0.01 | - | 20 | 198 | - | 11.5 | >10,000 |
| **Iron and Steel Foundry SIC 332** | | | | | | | | | | | | |
| furnace slag | 0.06 | 0.05 | 0.25 | <0.20 | <0.05 | 0.12 | - | - | - | - | 10.6 | 60 |
| furnace dust (cyclone) | 0.01 | 0.03 | 0.15 | <0.20 | <0.05 | < 0.01 | - | - | - | - | 9.5 | 2,500 |
| furnace dust (baghouse) | 4.5 | 0.03 | 0.19 | 0.20 | <0.05 | <0.01 | - | - | - | - | 8.5 | >10,000 |
| shotblast dust | 0.05 | < 0.01 | 0.06 | < 0.20 | <0.05 | 0.09 | - | - | - | - | 10.5 | 650 |
| spent sand | 4.0 | 0.03 | 0.09 | << 0.20 | 0.20 | 1.2 | - | 0.4 | - | - | 3.3 | 2,000 |
| sand reclaimer dust | 0.18 | < 0.01 | < 0.03 | < 0.20 | < 0.05 | < 0.01 | - | 0.4 | - | - | 8.5 | 350 |

- Not Analyzed

Some leeway was allowed depending on the physical nature of the waste material and the constituents found to solubilize. Thus many materials solubilized manganese in the range of a few to 50 or 100 ppm. Leaching of manganese alone was not considered sufficient reason to designate a waste as potentially hazardous since manganese is relatively non-toxic. Manganese is highly abundant in soils and rocks and is present to an average extent of 850 ppm in soils with ranges of 100 to 4,000 ppm (Ref. 1).

Fluoride is beneficial to teeth at low concentrations as evidenced by the use of fluoridated toothpastes and fluoridated water supplies. The average concentration of fluorine in soils is 200 ppm with a range of 30 to 300 ppm (Ref. 1). Leaching of fluoride of up to 20 ppm in iron and steel making slags, sludges, and dusts was not considered sufficient to designate these wastes as potentially hazardous if there was less than 1 ppm leaching of other potentially hazardous constituents.

Although leaching of sodium, potassium and chloride from wastes would not ordinarily constitute a hazardous waste problem in the metal smelting and refining industry, the extremely high concentration of these constituents in "high salt slag" from the secondary aluminum industry and their high solubility pose a definite threat to groundwater quality. High salt slag is therefore considered potentially hazardous.

The only residual which leached a heavy metal at significant concentration and was not considered potentially hazardous at this time was retort residue from primary zinc smelting. This slag residue leached zinc at 230 ppm in a solubility test. Zinc is required in human diets at 10-40 ppm and has low toxicity. Further testing of the leachability of zinc and other metals from zinc retort residue is needed for further evaluation of toxicity.

The limitations of the solubility tests conducted must be recognized. Only one solubility test was conducted on each residual. Replications are desirable to establish statistical significance of test results. The leaching solution in all cases was distilled water at pH 5.5. Thus no information is available from these tests on the quality of leachate at lower or higher pH's.

## REFERENCES

1. "Agronomic Controls Over Environmental Cycling of Trace Elements," W.H. Alloway in Advances In Agronomy 20:235-274, 1968.

## APPENDIX C

## COSTS AND COSTS FACTORS FOR TREATMENT AND DISPOSAL TECHNOLOGIES

The predominant practices used in the United States smelting and refining industry for on land storage or disposal of process and pollution control residuals are on land storage or disposal of slags, dusts and dredged sludges, and storage or permanent disposal of slurries and sludges in lagoons. Practices considered for adequate health and environmental protection include the use of lined lagoons, chemical fixation of land disposed sludges, soil sealing at disposal areas and collection of runoff. The basic costing assumptions used in estimating the costs of the above practices are described here. All costs are in 4th quarter 1973 dollars.

### Capital Costs

Lagoons. Lagoons are assumed to be rectangular in shape with the bottom length twice the bottom width. The dikes of the lagoons form a 27° angle with the ground surface. In the construction of the dikes, excavation of the interior area is to a depth sufficient to provide all the material needed for the construction of the dikes. The earth is assumed to be sandy loam with granular material. The width of the top of the dikes is 3 meters.

Three programs were developed to facilitate the computation of factors used for estimating lagoon costs.

Program No. 1

| Inputs | Outputs |
|---|---|
| Lagoon volume | Bottom width<br>Top width<br>Bottom length<br>Top length |

Program No. 2

| Inputs | Outputs |
|---|---|
| Bottom width<br>Bottom length<br>Depth | Volume |

Program No. 3

| Inputs | Outputs |
|---|---|
| Depth of excavation<br>Height of dike above ground level<br>Width on top of dike<br>Bottom width<br>Bottom length | Dike circumference 1)*<br>Volume of material in dike<br>Total width<br>Total length<br>Total area |

1)* Measured along center line of dike.



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The initial input is the required lagoon volume. Program No. 2 computes the volume of material obtained by excavation to varying depths. It is used jointly with Program No. 3 to determine the depth of excavation necessary to provide sufficient material for dike construction.

Cost categories and cost factors used to estimate lagoon costs are noted below.

| Site Preparation | | Ref. |
|---|---|---|
| Survey | \$ 625/ha | (1) |
| Test drilling | 24.60/m for 10m hole | (1) |
| Sample testing | 62.50/sample | (1) |
| Report preparation | 1,200-2,400 | (2) |
| **Construction** | | |
| Excavation & forming | \$ 1.33/$m^3$ | (1) |
| Compacting with Sheeps Foot | 1.85/$m^3$ | (1) |
| Fine grade finishing | 0.45/$m^2$ | (1) |
| Soil conditioning | 1.24/m | (3) |
| Transverse drain fields | 4.60/m | (1) |

Survey is assumed to be performed by standard transit and chain. The number of test holes drilled is varied as function of lagoon size; at least two are drilled in all cases. Two soil samples per test hole are analyzed. Report preparation is assumed to require 1 to 2 engineering man-weeks depending on the size of the project.

Excavation, forming and compacting costs are based on the volume of material in the dike. Fine grade finishing is computed from the dike surface area, i.e. the product of the perimeter of the cross section of the dike and its circumference. Soil conditioning cost is a function of the dike circumference.

Drain fields are designed to monitor lagoon leakage. They are assumed to be of 1/3 $m^2$ cross section and are located at 30m centers along the length of the lagoons. The excavation cost is \$1.50/m (1) and 1 $m^3$ of gravel at a delivered cost of \$9.30/$m^3$ (1) is used for every 3 m of ditch.

Several cost categories listed for lagoons, such as survey and excavation and forming, also apply to other facilities. The same unit costs are employed in these cases.

Lagoon Liners. Lining of lagoons is specified for some industries for Level II and is employed extensively in Level III. There are many candidates for liner material. Hypalon, a frequently used liner material, is selected. Two cost sources (4) and (5) provide ranges of costs for the purchase and installation of the liner. The two data sources coincide closely in their estimates. The value selected is $\$4/m^2$ installed.

Other Facilities & Activities

Concrete Work. A number of industries use concrete-lined pits for temporary retention and settling of sludges and slurries. A floor thickness of about .2 m is assumed for all cases. It's cost in place is $\$15.35/m^2$ (1). The required wall thickness is a function of volume of contained material and is assumed to be 0.4 m in this study. Wall costs are computed on the basis of $\$243.75/m^3$ (1) of concrete in place.

Ground Sealing. Sealing of the ground at dump sites to prevent leaching is stipulated for many industries as Level III protection. The sealing material of choice is bentonite clay. Approximately 14.7 $kg/m^2$ (3 $lbs/ft^2$) are worked into the top layer of soil. The FOB cost of bentonite is \$.09/kg (\$.04/lb (5). An average transportation cost of \$20 MT ($0.32/M^2$) (4) is added.

Installation includes disking, spreading and compacting. These tasks are assumed to be equivalent to the fine grade finishing specified in lagoon construction and a cost of $\$0.45/m^2$ is used. The total cost is [(\$0.09 x 14.7 $kg/m^2$) + $\$0.45/m^2$ + $\$0.32/m^2$] or $\$2.09/m^2$. A cost of $\$2.00/m^2$ is used in the study.

Collection Ditches. Ditches are installed to collect runoff from dump perimeters. Excavation and installation of 6" perforated, vitrofied pipe yields a cost of \$10.10/m of ditching (1). All open dumps are assumed to be square; some slanting of the ground is assumed. Unless specified otherwise, the length of ditching installed equals 1.5 x 1 side of the dump area.

Pumps and piping to transport the collected water are discussed under stationary equipment.

Railroad Track. Intra-plant rail transport is employed by some industries to haul solid or liquid waste from the plant to an on-site dump. The construction cost for 1 km of track is shown below. It is a single track on level ground.

| | Ref. | |
|---|---|---|
| Survey ($625/ha) | (1) | $ 250 |
| Miscellaneous bulldozing (1.33/$m^3$) | (1) | 2,080 |
| Base prepare & roll sub-base ($.52/$m^2$) | (1) | 1,145 |
| Track | | |
| 100 lb rail ($19.70/m) | (1) | 19,700 |
| Spikes plates & bolts ($7.90/m) | (1) | 7,900 |
| Timber ties ($13.10/m) | (1) | 13,100 |
| Ballast ($9.50/m) | (1) | 9,500 |
| Labor ($31.65/m) | (1) | 31,650 |
| Total | | $ 85,325/km |

The width of the sub-base is assumed to be 4 m. The miscellaneous bulldozing represents 2 days work and movement of about 860 $m^3$ of earth.

Road Construction. A road must be provided where waste transport is in by truck in lieu of rail. The cost of constructing a gravel road 1 km in length is as follows:

| | | |
|---|---|---|
| Survey ($625/ha) | (1) | $ 375 |
| Miscellaneous bulldozing ($1.33/$m^3$) | (1) | 1,145 |
| Base prepare & roll sub-base ($.52/$m^2$) | (1) | 3,120 |
| Base course select gravel ($3.29/$m^2$) | (1) | 19,740 |
| Compaction ($.57/$m^2$) | (1) | 3,420 |
| Culverts ($41.60/m) | (1) | 2,500 |
| Drainage ditching ($2.25/m) | (1) | 2,250 |
| Total | | $ 32,550/km |

The road width is 6 m. A base course of gravel about .3 m deep is applied and compacted. Culverts, each 6 m in length, are assumed to be required every 100 m. Drainage ditches are provided for a distance of .5 km along both sides of the road. The miscellaneous bulldozing is the same as is included for railroad track construction.

Stationary Equipment

Slurry Pump. Slurry pumps can be used in lieu of draglines for dredging lagoons. The selected slurry pump has a capacity of 236 liters per minute and is powered by a 2 hp motor. Its cost including housing, installation, wiring and piping is $13,730 (6).

Both rigid, installed and flexible piping are used. Both are 7.6 (3" pipe). Their costs/m are $17.30 (1) and $4.40 (1), respectively.

Other Pumps. The main application of other pumps is at the on-site slag dumps to pump collected runoff water. Centrifugal pumps requiring no attendants are used. The pump capacities are selected as a function of the size of the dump. They are sized to handle a volume of water equivalent to a 2.5 cm rainfall/hr over the dump area.

The pump costs are based on Reference (7). A 3 m head is assumed. Piping costs associated with the pumps include 100 m each of rigid, installed and flexible pipe. Horsepower requirements for "other pumps" are computed as follows:

$$HP = \frac{GPM \times H}{3960 \times E}$$

where

HP = Horsepower
GPM = Gallons/min
H = Head (assumed to be 9.8 ft (3 m)
E = Efficiency (assumed to be = .9)

Belt Conveyors. A belt conveyor is used in one industry to transport slag to a slag pile. A number of conveyors are positioned in series because of the distance involved. A 36" wide belt conveyor was found sufficient to handle the waste produced. Its cost, is $44,545/30 m (100 ft) section, installed (Ref. 7 and 9).

Mobile Equipment. Generic equipment types are identified and costed for handling and trasnporting waste products. These do not necessarily represent optimum equipment in terms of capacity, power or cost. Equipment specified includes:

| | | Ref. |
|---|---|---|
| Dump truck (16-18 t) | $ 25,000 | (2) |
| Tank truck | 40,000 | (2) |
| Front loader and backhoe | 20,000 | (similar to JD-410) |
| Bulldozer | 16,000 | (similar to JD-350) |
| Dragline with 3/4 yd clam shell | 70,000 | (2) |
| Yard engine (industrial) | 30,000 (used) | (2) |
| Hopper car (45 t) | 5,000 (used) | (2) |
| Ladle car (10,8 $m^3$) | 40,000 | (2) |

Many plants do not require particular equipment full time for waste handling and transport. The approximate fraction of time a piece of equipment is actually needed for these purposes is determined and the capital cost is assigned accordingly. It is assumed that the equipment is engaged in other plant activities the remainder of the time. The fraction of use is based on an 8 hour/day or 2,000 hr/yr equipment availability.

Land. Three categories of land are considered. They are shown below together with their estimated costs.

| | | Ref. |
|---|---|---|
| Rural | \$ 1,750/ha | (6) |
| Semi-industrial | 3,955/ha | (6) |
| Improved industrial | 24,710/ha | (6) |

Annual Costs

Lagoons, Construction and Other Facilities. A twenty year useful life and a corresponding amortization period are postulated. It is assumed that equal quarterly payments are made throughout this time resulting in the following annual cost.

$$C_A = B \times \frac{\frac{r}{m}\left(1 + \frac{r}{m}\right)^{Nm}}{\left(1 + \frac{r}{m}\right)^{Nm} - 1}$$

where

$C_A$ = Annual amortization cost
B = Initial amount
r = True annual interest rate (10%)
m = No. of payments per year (4/year)
N = No. of years (20 years)

The computed annual cost essentially represents the sum of the cost of capital and depreciation.

Additionally, a cost category is included for the repair and maintenance of lagoons, facilities and other construction. This cost is estimated to be 3 percent annually of initial construction cost (excluding site preparation) except for railroad tracks and roadways for which a 5 per cent annual rate is used.

Mobile and Stationary Equipment. Annual equipment costs are treated in the same manner as lagoons, construction and other facilities. A ten year useful life is assumed for stationary and road mobile equipment and a twenty year life for railroad equipment. Pumps and piping are considered stationary equipment.

The annual maintenance and repair cost is estimated as 5 per cent of initial purchase (7) cost exclusive of fuel and operating personnel.

Land. Annual land cost represents an opportunity cost. It is on 10 per cent of initial acquisition cost. Survey costs associated with land used for slag and other dumps are added to and amortized together with lagoon construction and other facility costs.

Operating Personnel. Waste handling and transport is performed by two labor grades: heavy equipment operator and truck driver/laborer. The applicable hourly wage rates are \$12.15 (1) and \$9.45 (1) respectively. The rates include fringe benefits, overhead and supervision.

Personnel costs are charged only for the hours such personnel are actually handling and transporting wastes. It is assumed that personnel will be employed in other plant activities the remainder of their time.

Energy. Energy costs are divided into two categories: fuel and electricity. All mobile equipment is assumed equipped with diesel engines. Fuel consumption by a particular equipment unit can vary widely depending on its operational use. Based on a brief review of engine specifications the following mean fuel consumption values were determined.

| | |
|---|---|
| Trucks | 4 Gal/Hr |
| Bulldozer | 2.4 Gal/Hr |
| Front loader and backhoe | 2.85 Gal/Hr |
| Dragline with 3/4 yd clam shell | 2.85 Gal/Hr |
| Yard engine | 8 Gal/Hr |

The cost of fuel is \$0.40/gal.

The cost of miscellaneous electric energy, (e.g. lighting) is estimated at 10 per cent of fuel cost.

The power cost of electric equipment, where specified, is computed separately as follows:

$$\text{Cost per horsepower year} = \frac{\text{horsepower of motor}}{0.9 \text{ (efficiency)} \times 0.9 \text{ (power factor)}} \times$$

0.7457 x No. of yearly operating hours x cost per kilowatt hour. A kilowatt hour cost of \$0.012 is assumed.

Chem-Fix Operation. Chemical fixation where employed is shown as an annual cost. At this time, no data was found describing capital costs to establish this process for various sizes of operations. The cost of \$13.20/$m^3$ of waste treated which is used in the study reflects current experience (10).

Taxes. Taxes are computed as 2.5 per cent of the cost of land (6).

Insurance. Annual insurance premiums are 1 per cent of the capital cost (6).

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(1) Building Construction Cost Data - 1974, Roberts Snow Means Company, Construction Consultants Publishers.

(2) Calspan estimate.

(3) Process Plant Construction Estimating & Engineering Standards, Vol. 4; prepared by International Construction Analysts, Downey, California.

(4) Disposal of By-Products from Non-Regenerable Flue Gas Desulfurization Systems: Initial Report, EPA-650/2-74-037a, Office of Research and Development, USEPA, May 1974.

(5) Information provided by Mr. A. McCord, Consultant.

(6) CSMRI Project J31120, Colorado School of Mines Research Institute, October 15, 1974.

(7) Capital and Operating Costs of Pollution Control Equipment Modules - Vol. II - Data Manual, EPA-R5-73-023b, Socioeconomic Environmental Studies Series, Office of Research and Development, USEPA, July 1973.

(8) Kent's Mechanical Engineer's Handbook, 12th Edition, Power Vol., John Wiley and Sons, March 1957.

(9) Plant Engineering Directory and Specifications Catalog, 1974, Vol. 9, Technical Publishing Co., American Business Press, Inc.

(10) Data provided by Chemfix Corporation.

## APPENDIX D

## PROCEDURES FOR CALCULATING WASTE QUANTITIES FOR THE IRON AND STEEL INDUSTRY

This appendix uses the iron and steel industry as an illustrative example of the methodology employed to estimate the quantities of wastes and potentially hazardous constituents therein. Similar procedures were employed for estimating waste quantities in the other primary and secondary smelting and refining sectors. Most of the data required for calculating the amounts of wastes generated by iron and steel mills were derived from: 1) the collection and analysis of waste samples; 2) information provided by environmental control personnel at ten participating steel mills; 3) the Iron and Steel Works Directory of the United States and Canada (1974); and 4) the Annual Statistical Report, American Iron and Steel Institute (1973). The Directory and the Annual Statistical Report were used primarily in estimating the production of various types of facilities by state.

Through the cooperation of the American Iron and Steel Institute, arrangements were made to have ten integrated steel plants participate in a program to collect waste samples from selected facilities on a daily basis over a four week period, and to provide quantitative information on the amounts of waste generated. Each of the ten plants was visited to discuss the types of waste generated and to identify 10 to 15 waste sources to be included in the sampling program. The waste samples were collected by steel plant personnel and forwarded to Calspan Corporation for analysis. Wastes of each type were composited on a weekly basis, so that for each plant, four composite samples (one for each week of the sampling program) were obtained for each type of waste of interest. The analyses included determinations of chromium, copper, manganese, nickel, lead, zinc, cyanide, fluorine, oil and grease, and phenol. For any given waste type (e.g., electric furnace dust) the concentration values were averaged over all plants and over all composites.

Subsequent to each plant visit, a form indicating desired information on the quantities of waste generated was prepared and sent to the environmental control manager. Specific information of interest was the total annual production for each facility and the amounts of waste of each type produced (e.g., dust, sludge, slag). The data provided from all plants were analyzed and average waste generation factors were obtained. Table D-1 summarizes the averaged data for the quantities of each waste type generated and the concentrations of constituents of interest.

The production data for the major steel plant products (e.g., pig iron, ingot steel, cold rolled steel, etc.) and the waste generation factors for the associated facilities allows the total waste quantities to be determined. Data for a "typical" plant were presented in the main text and are reproduced here as Table D-2. Thus, for example, the yearly quantity of basic oxygen furnace slag for a typical plant is calculated as:

TABLE D-1

WASTE GENERATION FACTORS - IRON & STEEL PLANTS

| Type of Waste | Generation Factors | | Concentration Factors (ppm) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Kg/MT of Steel Produced or Processed | Kg/MT of Facility Output | Cr | Cu | Mn | Ni | Pb | Zn | Oil & Grease |
| Coke Oven - Sludge | 2.6* | 5.5 | 10.0 | 4.0 | 102 | 5.5 | 30.5 | 96.5 | 203,070 |
| Blast Furnace - Slag | 250* | 348 | 46.9 | 21.9 | 3000 | <7.5 | 21.5 | 8.2 | -- |
| Blast Furnace - Dust | 11.7* | 16.2 | 92.4 | 93.2 | 8800 | 57.6 | 302 | 516 | -- |
| Blast Furnace - Sludge | 17.6* | 24.4 | 56.1 | 37.4 | 3700 | 38.4 | 1210 | 11,650 | -- |
| Basic Oxygen Furnace - Slag | 145 | 145 | 1290 | 31.3 | 41,600 | 12.2 | 12.0 | 16.2 | -- |
| Basic Oxygen Furnace - Dust | 16.0 | 16.0 | 315 | 202 | 11,400 | 115 | 7350 | 3350 | -- |
| Basic Oxygen Furnace - Kish | 0.14 | 0.14 | 110 | 45.7 | 3810 | 56.6 | 137 | 660 | -- |
| Basic Oxygen Furnace - Sludge | 17.3 | 17.3 | 708 | 174 | 10,300 | 130 | 4190 | 10,094 | -- |
| Open Hearth Furnace - Slag | 243 | 243 | 2360 | 49.8 | 42,710 | 23.7 | 57.4 | 47.9 | -- |
| Open Hearth Furnace - Dust | 13.7 | 13.7 | 568 | 1130 | 4810 | 314 | 11,650 | 113,000 | -- |
| Electric Furnace - Slag | 120 | 120 | 4820 | 79.0 | 50,580 | 53.9 | 32.7 | 80.5 | -- |
| Electric Furnace - Dust | 12.8 | 12.8 | 1380 | 1940 | 42,610 | 246 | 24,220 | 95,710 | -- |
| Electric Furnace - Sludge | 8.7 | 8.7 | 2690 | 1130 | 34,100 | 421 | 7900 | 13,540 | -- |

*Approximately 0.72 MT of pig iron required to produce 1 MT of steel (on the average). Approximately 0.66 MT of coke required to produce 1 MT pig iron. Coke oven sludge consists of ammonia still lime sludge and decanter tank tar.

TABLE D-1 (cont.)

WASTE GENERATION FACTORS - IRON & STEEL PLANTS

| Type of Waste | Generation Factors: Kg/MT of Steel Produced or Processed | Generation Factors: Kg/MT of Facility Output | Concentration Factors (ppm): Cr | Cu | Mn | Ni | Pb | Zn | Oil & Grease |
|---|---|---|---|---|---|---|---|---|---|
| Soaking Pit - Slag | 35.2 | 35.2 | 373 | 278 | 5280 | 117 | 760 | 59.3 | -- |
| Primary Mill - Sludge | 1.87 | 1.87 | -- | -- | -- | -- | -- | -- | -- |
| Primary Mill - Scale | 44.9 | 44.9 | 318 | 449 | 5410 | 385 | 58 | 32.5 | 10,180 |
| Continuous Caster - Sludge | 0.104 | 0.104 | -- | -- | -- | -- | -- | -- | -- |
| Continuous Caster - Scale | 8.7 | 8.7 | -- | -- | -- | -- | -- | -- | -- |
| Hot Rolling Mill - Sludge | 1.74 | 1.74 | 198 | 232 | 3280 | 253 | 1050 | 669 | 45,290 |
| Hot Rolling Mill - Scale | 18.3 | 18.3 | 208 | 274 | 3170 | 545 | 154 | 26.9 | 42,246 |
| Cold Rolling Mill - Sludge | 0.16 | 0.16 | -- | -- | -- | -- | -- | -- | -- |
| Cold Rolling Mill - Scale | 0.052 | 0.052 | -- | -- | -- | -- | -- | -- | -- |
| Cold Rolling Mill - Waste Pickle Liquor | 22.8 | 22.8 | 12.7 | 7.35 | 179 | 19.2 | 1.1 | 8.3 | 63.9 |
| Tin Plating Mill - Sludge | 5.32 | 5.32 | 2760 | 2730 | 1040 | 250 | 688 | 2260 | -- |
| Galvanizing Mill - Sludge | 10.8 | 10.8 | -- | -- | -- | -- | -- | -- | -- |
| Galvanizing Mill - Waste Pickle Liquor | 5.17 | 5.17 | -- | -- | -- | -- | -- | -- | -- |

TABLE D-2

YEARLY GENERATION OF RESIDUALS BY TYPICAL IRON AND STEEL PLANT*

| | Total Quantity of Waste (MT) | Quantity of Potentially Hazardous Constituents (MT) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Cr | Cu | Mn | Ni | Pb | Zn | Oil & Grease |
| Coke Oven - Sludge | 6,200 | 0.062 | 0.025 | 0.628 | 0.034 | 0.188 | 0.594 | 1250 |
| Blast Furnace - Slag | 557,000 | 26.1 | 12.2 | 1670 | <4.2 | 12.0 | 4.57 | -- |
| Blast Furnace - Dust | 25,900 | 2.40 | 2.42 | 228 | 1.49 | 7.83 | 13.4 | -- |
| Blast Furnace - Sludge | 39,000 | 2.19 | 1.46 | 144 | 1.50 | 47.2 | 455 | -- |
| Basic Oxygen Furnace - Slag | 290,000 | 374 | 9.08 | 12064 | 3.54 | 3.48 | 4.70 | -- |
| Basic Oxygen Furnace - Dust | 280 | 0.031 | 0.013 | 1.07 | 0.016 | 0.038 | 0.185 | -- |
| Basic Oxygen Furnace - Sludge | 34,600 | 24.5 | 6.02 | 356 | 4.50 | 145 | 349 | -- |
| Electric Furnace - Slag | 60,000 | 289 | 4.74 | 3035 | 3.23 | 1.96 | 4.85 | -- |
| Electric Furnace - Dust | 6,400 | 8.83 | 12.4 | 273 | 1.57 | 155 | 613 | -- |
| Electric Furnace - Sludge | 4,350 | 11.7 | 4.92 | 148 | 1.83 | 34.4 | 58.9 | -- |
| Soaking Pit - Slag | 54,900 | 20.5 | 15.3 | 290 | 6.42 | 41.7 | 3.26 | |
| Primary Mill - Sludge | 2,520 | -- | -- | -- | -- | -- | -- | -- |
| Primary Mill - Scale | 60,600 | 19.3 | 27.2 | 328 | 23.3 | 3.52 | 1.97 | 617 |
| Continuous Caster - Sludge | 82.2 | -- | -- | -- | -- | -- | -- | -- |
| Continuous Caster - Scale | 6,900 | -- | -- | -- | -- | -- | -- | -- |

TABLE D-2 (cont.)

YEARLY GENERATION OF WASTE RESIDUALS BY TYPICAL IRON AND STEEL PLANT

| Type of Waste | Total Quantity of Waste (MT) | Quantity of Potentially Hazardous Constituents (MT) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Cr | Cu | Mn | Ni | Pb | Zn | Oil & Grease |
| Hot Rolling Mill - Sludge | 3,130 | 0.620 | 0.727 | 10.3 | 0.792 | 3.29 | 2.10 | 141 |
| Hot Rolling Mill - Scale | 32,900 | 6.85 | 9.03 | 104 | 18.0 | 5.07 | 0.886 | 1392 |
| Cold Rolling Mill - Sludge | 112 | -- | -- | -- | -- | -- | -- | -- |
| Cold Rolling Mill - Scale | 36.4 | -- | -- | -- | -- | -- | -- | -- |
| Cold Rolling Mill - Waste Pickle Liquor | 16,000 | 0.203 | 0.117 | 2.86 | 0.306 | 0.018 | 0.132 | 1.02 |
| Tin Plating Mill - Sludge | 532 | 1.47 | 1.45 | 0.553 | 0.133 | 0.366 | 1.20 | -- |
| Galvanizing Mill - Sludge | 1,350 | -- | -- | -- | -- | -- | -- | -- |
| Galvanizing Mill - Waste Pickle Liquor | 646 | -- | -- | -- | -- | -- | -- | -- |

* Quantities calculated from generation and concentration factors given in Table D-1 based on annual production figures given in Table 4 of Volume III. Divide by 365 to obtain daily quantities. Multiply by 1.1 to convert to short tons.

$$\text{quantity BOF slag/yr} = \text{generation factor } \frac{MT}{MT} \times \text{steel production (MT)}$$

$$= \frac{0.145\ MT}{MT} \times 2{,}000{,}000\ MT$$

$$= 290{,}000\ MT$$

The amount of potentially hazardous constituents in the BOF slag of the typical plant is calculated as:

$$\text{quantity potentially hazardous} = \text{quantity BOF slag/yr (MT)} \times \text{concentration factor potentially hazardous constituent}$$

The quantity of chrome as an example is calculated as:

quantity BOF slag x concentration factor for chromium

$$290{,}000\ MT \times \frac{1290\ MT}{10^6\ MT}$$

$$= 374\ MT$$

In order to calculate waste generation quantities on a state-by-state basis, production figures for various product types had to be determined. Since such data were not directly available, estimates had to be generated. For each state, iron and steel production and/or processing facilities were tabulated using the Iron and Steel Works Directory of the United States and Canada (1974). From the size and number of facilities of each type listed for all plants in a given state, production figures were estimated for that state. These figures were summed over all states and comparisons made with total U.S. production data presented in the Annual Statistical Report, American Iron and Steel Institute. The figures for the individual states were then adjusted to make the national total agree with the published national figures.

The wastes for the state totals were grouped into five categories: slag; dust; sludge; scale; and pickle liquor. The sources for each waste category are listed in Table D-3. In computing the total quantities of waste in each category for each state, the waste factors discussed previously were used with weighting factors as appropriate. The weighting factors are necessary in some cases to account for the fact that any one type of facility might produce different waste types depending on the type of control system used. For example, basic oxygen furnaces might employ dry- or wet-type emission control systems. A dry system produces dust-type waste, whereas, a wet system produces a sludge-type waste. Therefore, in order to calculate the amounts of dust and sludge produced by BOF

TABLE D-3

Major Sources of Waste

Waste Category

| Slag | Dust | Sludge | Scale | Pickle Liquor |
|---|---|---|---|---|
| Blast Furnaces | Blast Furnaces | Coke Ovens | Primary Mills | Cold Mills |
| BOF's | BOF's | Blast Furnaces | Continuous Casters | Galvanizing Mills |
| Open Hearths | Open Hearths | BOF's | Hot Finishing Mills | Tin Mills |
| Electric Furnaces | Electric Furnaces | Open Hearth's | Cold Mills | |
| Soaking Pits | | Electric Furnaces | | |
| | | Primary Mills | | |
| | | Continuous Casters | | |
| | | Hot Finishing Mills | | |
| | | Cold Mills | | |
| | | Tin Mills | | |
| | | Galvanizing Mills | | |

facilities given the total amount of steel produced in BOF's, the percentages of steel made in BOF's using wet emission control systems and dry control systems must be known. The weighted waste generation factors were then computed by multiplying the waste generation factor for a given type of waste (see Table D-1) by the fraction of product made using that type of control system. The required fractions were estimated from data obtained from the participating plants.

For the final determinations of total wastes (and their constituents) for each state, a program was written to allow the required summations to be computerized. The computed waste values are given as

$$W_k = \sum_{i=1}^{n} f_i \; c_{ik} \; P_i$$

where $W_k$ is the amount of constituent of type k, $f_i$ is the weighted waste generation factor for the $i^{th}$ source (or facility), $c_{ik}$ is the concentration of the $k^{th}$ constituent in the waste generated by the $i^{th}$ source, and $P_i$ is the total annual state-wide production of facilities of the $i^{th}$ type. The total waste quantities, as opposed to the individual constituents, correspond to $c_{ik} = 1$.

To illustrate the application of the above equation, let us consider a specific example for the iron and steel industry, namely, the amounts of dust generated in Pennsylvania. The four major sources of waste dust in the production of iron and steel are: blast furnaces, basic oxygen furnaces, open hearth furnaces and electric furnaces. Table D-4 lists the estimated 1974 production figures (P) for the State of Pennsylvania for each of these facilities and indicates the type of dust. The raw generation factors listed for waste dust are those given in Table D-1. The weighted dust factors (f) were obtained by multiplying the raw waste factors by a fraction representing the estimated percentage of the facilities of each type that utilize dry emission control systems. Specifically, it is estimated that 35 percent of the BOF's, 75 to 80 percent of the open hearths, and 90 percent of the electric furnaces control emissions with dry systems. In the case of blast furnace flue dust and BOF "kish", the raw generation factors were assumed to apply to all facilities. The chromium concentrations ($C_c$) for each of the listed dusts are also given in the Table.

In accorance with the equation given above, the amount of each dust type for a given facility is determined by taking the product $W_T = P \times f \times C$, with C = 1. Thus, to determine the amount of blast furnace flue dust, we compute (21,160,000 metric tons) x (0.0162) = 342,792 metric tons. To determine the amount of chromium in this amount of blast furnace flue dust, we take the product $W_c = P \times f \times C_c = (21{,}160{,}000) \times (0.0162) \times (92.4 \times 10^{-6}) = 31.67$ MT. Similarly, we obtain the amounts of dusts and the associated chromium content for all of the indicated dust types. The total

TABLE D-4

EXAMPLE OF WASTE GENERATION COMPUTATIONS

STATE - Pennsylvania
WASTE - Dust (Iron and Steel Production)
YEAR - 1974

| Facility and Type of Dust | P Facility Production (Metric Tons/Yr) | Raw Dust Generation Factors (MT/MT Product) | f Weighted Dust Factors (MT/MT Product) | $C_c$ Chromium Concentration (ppm) | $W_T$ Total Dust Generated (Metric Tons) | $W_c$ Total Chromium Content of Dust (Metric Tons) |
|---|---|---|---|---|---|---|
| Blast Furnace (Flue Dust) | 21,160,000 | 0.0162 | 0.0162 | 92.4 | 342,792 | 31.67 |
| BOF (Flue Dust) | 15,200,000 | 0.016 | 0.0056 (1) | 315 | 85,120 | 26.81 |
| BOF (Kish) | 15,200,000 | 0.00014 | 0.00014 | 110 | 2128 | 0.23 |
| Open Hearth (Flue Dust) | 11,900,000 | 0.0137 | 0.0105 (2) | 568 | 124,950 | 70.97 |
| Electric Furnace (Flue Dust) | 4,500,000 | 0.0128 | 0.01152 (3) | 1380 | 51,840 | 71.54 |
| | | | | Totals | ∿607,000 | ∿201 |

Notes: 1) Assumes 35 percent of BOF's have dry emission control systems.

2) Assumes 75-80 percent of open hearths have dry control systems.

3) Assumes 90 percent of electric furnaces have dry control systems.

dust is the sum of the amounts for the individual facilities. After rounding, we find the total amount of dust generated in 1974 by integrated iron and steel mills in Pennsylvania to be 607,000 metric tons. The corresponding chromium content of this dust is 201 metric tons. In a similar manner, we determine the amounts of other constituents of interest, namely, copper, manganese, nickel, lead, zinc, cyanide, fluorine, and phenol. The total amount of "potentially hazardous constituents" is then the sum of the individual constituents.

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15. Supplementary Notes

EPA Project Officers - Timothy Fields, Allen Pearce

16. Abstracts

This report covers primary and secondary metal smelting and refining industries. Characteristics of each industry sector, including plant locations, production capacities, and smelting and refining processes, have been identified and described. Land-disposal or stored residuals have been identified and characterized for physical and chemical properties. State, regional, and national estimates have been made of the total quantities of land-disposed or stored residuals and potentially hazardous constituents thereof. Current methods employed by the primary metals industry for the disposal or storage of process and pollution control residuals on land are described. Methods of residual treatment and disposal considered suitable for adequate health and environmental protection have been provided. Finally, the costs incurred by typical plants in each primary smelting and refining category for current and environmentally sound potentially hazardous residual disposal or storage on land have been estimated.

17. Key Words and Document Analysis. 17a. Descriptors

Ferrous Smelting and Refining
Nonferrous Smelting and Refining
Secondary Smelting and Refining
Primary Smelting and Refining
Hazardous Wastes
Slags, Sludges, Dust
Lagoons
Open Dump
Disposal Technology

Leaching
Heavy Metals
Lined Lagoons
Soil Sealing - Bentoni
Sludge Solidification
Cyanide
Floride
Oil and Grease

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

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