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COST EFFECTIVENESS ANALYSIS OF PROPOSED EFFLUENT STANDARDS AND LIMITATIONS FOR COPPER FORMING

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Environmental Protection Agency
Office of Analysis and Evaluation
401 M Street, S.W.
Washington, D.C. 20460

Submitted by:

JRB Associates
8400 Westpark Drive
McLean, Virginia 22102

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COST-EFFECTIVENESS ANALYSIS OF PROPOSED EFFLUENT STANDARDS AND LIMITATIONS FOR COPPER FORMING

1. INTRODUCTION

This paper reports the results of a cost-effectiveness (CE) analysis of alternative water pollution control regulations on the copper forming industry. These regulations include effluent limitations and standards based on BPT (Best Practical Control Technology currently available), BAT (Best Available Technology Economically Achievable), and PSES (Pretreatment Standards for Existing Sources), which are being proposed under authority of the Federal Water Pollution Control Act, as amended (the Clean Water Act). For each of these regulations EPA has identified several pollution control options, each with different levels of pollution abatement and compliance cost. The CE analysis is a useful tool for evaluating the options.

The primary cost of interest in this paper is total annualized direct cost incurred by industry in complying with the regulations. Other economic impacts are considered in the economic impact assessment report. The effectiveness measure used is pounds of pollutant removed weighted by an estimate of their perceived toxicity. The rationale for this measure, referred to as "pound-equivalents removed," is described later in this paper.

2. BACKGROUND METHODOLOGY ON COST-EFFECTIVENESS

Cost-effectiveness (CE) is defined as the incremental annualized cost of a pollution control option in an industry or industry subcategory per incremental pound equivalent of pollutant removed by that control option. CE offer a useful way of quantifying comparisons among alternative pollution control options.

Cost effectiveness analyses account for differences in toxicity among the pollutants by computing toxic weighting factors. These factors are necessary because different pollutants have different potential effects on human and aquatic life. For example, a pound of zinc in an effluent stream has a significantly different potential effect than a pound of PCBs. Toxic weighting factors for pollutants are derived using ambient water quality criteria and toxicity values. In the majority of cases, toxic weighting factors are derived using chronic freshwater aquatic criteria. However, in cases where a human health criterion has also been established for the consumption of fish, then the sum of both the human and aquatic criteria are used in deriving toxic weighting factors. These factors are then standarized by relating them to a particular pollutant.

Copper is selected as the standard pollutant for developing weighting factors since it is a toxic metal pollutant and is commonly detected and removed from industrial effluents. Some examples of the effects of different aquatic and human health criteria on weighting factors are shown in Table I.

Table I

WEIGHTING FACTORS BASED ON
COPPER FRESHWATER CHRONIC CRITERIA

Pollutant	Human * Health Criteria (ug/l)	Aquatic Chronic Criteria (ug/l)	Weighting Calculation	Final Weight
Copper	--	5.6	5.6/5.6	1.00
Hexavalent Chromium	--	.29	5.6/.29	19.30
Nickel	100	96.00	5.6/100 + 5.6/96	0.114
Cadmium	--	.025	5.6/.025	224.0
Benzene	400	--	5.6/400	0.014

* Based on ingestion of 6.5 grams of fish products/day.

As indicated in Table I, 224 pounds of copper pose the same relative hazard in surface waters as one pound of cadmium since cadmium has a toxic weight 224 times as large as the toxic weight of copper. Benzene, on the other hand, is less potentially toxic than copper, as 71 pounds (1/.014) of benzene would pose the same hazard as one pound of copper.

The final weights are then used to calculate the "pound equivalent" unit: a standard measure of toxicity. Pound equivalents are calculated as the number of pounds of pollutant multiplied by the weighting factor. Thus, in CE analyses, the amount of pollutant removed by a control option is weighted by its relative toxicity. Cost-effectiveness is calculated as the ratio of incremental annual cost of an option to the incremental pound equivalents removed by that option.

Indirect dischargers are treated differently from direct dischargers in the CE analyses since the POTW removal efficiency of a pollutant is reflected in the incremental pounds removed to surface waters. For example, if a plant is discharging 100 pounds of cadmium in its effluent stream to a POTW and the POTW has a removal efficiency for cadmium of 38 percent, then the cadimum discharged to surface waters is only 62 pounds. If the regulation results in a reduction of cadmium in the effluent stream to 50 pounds, then the amount discharged to surface waters is calculated as 50 pounds multiplied by the POTW removal efficiency factor (1-38 percent), i.e., 31 pounds (50 x 62 percent). Cost-effectiveness calculations reflect the fact that the reduction of pollutant discharge to surface waters is not 50 pounds (the change in the amount discharged to the POTW), but 31 pounds (the change in the amount actually discharged to surface waters).

The pollutants included in CE analyses are the regulated pollutants and selected non-regulated ones. Non-regulated pollutants are included because they can be removed incidentally as a result of a particular treatment technology, even though they are not specifically limited. Some of the factors considered in selecting non-regulated pollutants include toxicity, frequency of occurrence, and amount of pollutant in the wastestream.

Data sources for CE analyses include development documents from the Effluent Guidelines Division, economic impact analyses from the Office of Analysis and Evaluation, ambient water quality criteria documents from the Criteria and Standards Division, and POTW removal efficiency data from the Monitoring and Data Support Division.

The data set for an industry specific CE analysis contains the following information for each subcategory within the industry:

- o Wastewater pollutants
- o The pollution control options identified by EGD
- o Annual volume of loadings by pollutant
  -- Currently, and at each BAT or PSES control level
- o Toxic weighting factor for each pollutant
- o POTW removal efficiencies (applicable to indirect dischargers only)
- o Annualized costs for each control option (where results are adjusted to 1981 dollars for all industries).

Criteria or toxicity values have been developed for all of the priority pollutants and were taken from data in the 1980 Ambient Water Quality Criteria Document (EPA-440/5-80 Series). Criteria for a few of the non-conventional pollutants were taken from the Quality Criteria for Water, EPA-440/9-76-023, EPA 1976 (the Red Book.)

POTW removal efficiencies were taken from one of three sources. The preferred source was the 40-city study, US EPA Determining National Removal Credits for Selected Metals at POTWs, draft report, July 1981. When data were not available, then the POTW removal efficiency was taken from the 20-city study, US EPA Fate of Priority Pollutants in Publicly Owned Treatment Works Interim Report, October, 1980, EPA-440/1-80-301. When data were not available from either of these studies, POTW removal efficiencies were taken from the Federal Guidelines: State and Local Pretreatment Programs Volume II Appendices 1-7. January 1977, EPA 430/9-76-0176b. Report 6.

3. COST-EFFECTIVENESS ANALYSIS FOR COPPER FORMING

3.1 REGULATORY ALTERNATIVES

In the process of developing the regulatory alternatives, EPA has extensively studied the technical and economic characteristics of the copper forming industry. A discussion of the rationale for the regulatory alternatives as well as general industry economic and technical characteristics appear in the development document and the economic impact assessment report.

Three regulatory alternatives were considered for the copper forming industry. A summary of these alternatives and their costs appears in Chapter 5 of the Economic Impact Analysis. In that report, as well as in the analysis later in this paper, the alternatives are arranged in order of increasing cost and, generally, pollution abatement.

The economic impact study reported generally mild impacts for each of the three regulatory alternatives. The added annual pollution abatement costs are not expected to affect the prices of copper forming products. Small profit reductions are predicted, but they are not significant enough to cause plant closures or employee layoffs.

3.2 ANALYTICAL APPROACH

The number of pounds of each pollutant removed by direct and indirect dischargers in the industry is provided by EPA's Effluent Guidelines Division. For indirect dischargers, an adjustment is made to account for the pollution removals by POTWs. That is, the pounds removed by the recommended treatment system is multiplied by one minus the secondary treatment removal efficiency. Four sources were used for these removal efficiencies:

(1) "40 City Study" being performed for the monitoring and Data Support Division (not yet published)

(2) Fate of Priority Pollutants in Publicly Owned Treatment Works (20 City Study), October 1980, (EPA 440/1-80-301)

(3) Federal Guidelines - State and Local Pretreatment Programs, (EPA 430/9-76-017a).

(4) Guide for Performing Cost-Effectiveness Analyses, a draft report prepared by OA&E, July 29, 1982.

The estimated compliance costs in 1978 dollars were provided by the EPA Effluent Guidelines Division. The cost for each alternative is reduced by that of the previous alternative to provide the incremental cost for each alternative. Before performing these calculations, the three regulatory alternatives were arrayed in order of increasing annualized cost to the industry. Total annualized costs are used throughout the CE analyses. Total annualized costs include annual operating and maintenance costs plus depreciation and interest charges on capital equipment.

For each category:

$$CE = \frac{\Delta \$}{\sum_{i}^{n} (\Delta lb_i)(TW_i)(STW_i)}$$

where CE = dollars per pound equivalent

$\Delta\$$ = the incremental total annualized compliance cost

$\Sigma(\Delta\ lb_i)\ (TW_i)\ (STW_i)$ = the incremental changes in pound equivalents discharged

Δlb_i = change in pounds discharged of toxic pollutant i (i.e., pounds removed)

TW_i = toxic weighting factor for pollutant i

n = number of toxic pollutants

STW_i = one minus the secondary treatment efficiency factor for pollutant i (for direct discharges STW = 1)

3.3 SELECTED POLLUTANTS

The pollutants used in calculating CE ratios include all pollutants that were considered for the regulation. These include both pollutants that are specifically regulated and certain nonregulated pollutants. Although the unregulated pollutants need not be monitored, they do provide a potential benefit to the environment and, therefore, are included in the totals. The results of the CE analysis are highly sensitive to which pollutants are included in the analysis. Table 2 shows the pollutants selected for inclusion in the CE analysis.

TABLE 2. POLLUTANTS AND TOXIC WEIGHTING FACTORS IN COPPER FORMING

POLLUTANT	WEIGHTING FACTOR
Nickel	0.114
Zinc	0.119
Lead	1.5
Copper	1.0
Hexavalent Chromium	19.3
Trivalent Chromium	0.127

3.4 FINDINGS

Tables 3 and 4 show the CE results for each option considered for direct and indirect dischargers, respectively. The selected options are indicated by asterisks. The cost-effectiveness figures shown are "incremental" from the previous level. Tables 5 and 6 present the current loadings and removals of each pollutant for each option for direct and indirect dischargers, respectively. Tables 7 and 8 present industry comparisons of cost-effectiveness.

TABLE 3. COPPER FORMING INDUSTRY COMPARISON OF COST-EFFECTIVENESS FOR DIRECT DISCHARGERS

LEVEL OF CONTROL	INCREMENTAL POUND EQUIVALENTS REMOVED	INCREMENTAL PERCENT REMOVED	CUMULATIVE PERCENT REMOVED	INCREMENTAL COST ($000)[1/]	COST-EFFECTIVENESS ($/POUND-EQUIVALENT)[1/]
Current	0				
Level 1	55,229	78.63	78.63	947.4	17.15
Level 2	7,495	10.67	89.30	944.9	126.07*
Level 3	2,043	2.91	92.21	852.2	417.12

1/ 1981 dollars.

NOTE: * shows the selected option.

TABLE 4. COPPER FORMING INDUSTRY COMPARISON OF COST-EFFECTIVENESS FOR INDIRECT DISCHARGERS

LEVEL OF CONTROL	INCREMENTAL POUND EQUIVALENTS REMOVED	INCREMENTAL PERCENT REMOVED	CUMULATIVE PERCENT REMOVED	INCREMENTAL COST ($000)1/	COST-EFFECTIVENESS ($/POUND-EQUIVALENT)1/
Current					
Level 1	25,636	74.94	74.94	2,976.9	116.12
Level 2	4,918	14.37	89.31	2,062.5	419.52*
Level 3	1,152	3.37	92.68	920.8	799.70

1/ 1981 dollars.

NOTE: * shows the selected option.

TABLE 5. LOADINGS FOR COPPER FORMING DIRECT DISCHARGERS

TREATMENT OPTION AND POLLUTANT	CURRENT LOADINGS TO SURFACE WATER (lbs./year)	BAT LOADINGS TO SURFACE WATER (lbs./year)	POUNDS REMOVED (lbs./year)	TOXIC WEIGHTING FACTOR	POUND-EQUIVALENTS REMOVED PER YEAR
Level 1					
Copper	24,413.08	7,623.23	16,789.85	1.0000	16,789.85
Zinc	22,122.50	4,375.29	17,747.21	0.1190	2,111.92
Nickel	9,971.85	2,571.12	7,400.73	0.1140	843.68
Lead	6,647.31	1,714.04	4,933.27	1.4700	7,251.91
Chromium - Hex.	1,661.83	205.70	1,456.13	19.3000	28,103.26
Chromium - Tri.	1,661.83	651.38	1,010.45	0.1270	128.33
TOTAL	66,478.39	17,140.76	49,337.63	0.0000	55,228.94
Level 2					
Copper	24,413.08	3,832.32	20,580.76	1.0000	20,580.76
Zinc	22,122.50	2,155.52	19,966.98	0.1190	2,376.07
Nickel	9,971.85	1,783.00	8,688.84	0.1140	990.53
Lead	6,647.31	855.38	5,791.93	1.4700	8,514.13
Chromium - Hex.	1,661.83	102.63	1,559.20	19.3000	30,092.54
Chromium - Tri.	1,661.83	324.99	1,336.84	0.1270	169.78
TOTAL	66,478.39	8,553.85	57,924.54	0.0000	62,723.80
Level 3					
Copper	24,413.08	2,727.33	21,685.75	1.0000	21,685.75
Zinc	22,122.50	1,712.51	20,409.99	0.1190	2,428.79
Nickel	9,971.85	951.40	9,020.45	0.1140	1,028.33
Lead	6,647.31	634.26	6,013.05	1.4700	8,839.18
Chromium - Hex.	1,661.83	76.11	1,585.72	19.3000	30,604.32
Chromium - Tri.	1,661.83	241.02	1,420.81	0.1270	180.44
TOTAL	66,478.39	6,342.63	60,135.76	0.0000	64,766.80

TABLE 6. LOADINGS FOR COPPER FORMING INDIRECT DISCHARGERS

TREATMENT OPTION & POLLUTANT	CURRENT LOADINGS TO POTW (lbs/yr)	POTW REMOVAL EFFICIENCY (PERCENT)	CURRENT LOADINGS TO SURFACE WATERS (lbs/yr)	PSES LOADINGS TO POTWs (lbs/yr)	PSES LOADINGS TO SURFACE WATER (lbs/yr)	POUNDS REMOVED (lbs/yr)	TOXIC WEIGHTING FACTOR	POUND EQUIVALENTS REMOVED PER YEAR
Level 1								
Copper	24,062.55	0.42	10,106.27	8,011.64	3,364.89	6,741.38	1.0000	6,741.38
Zinc	9,986.84	0.35	3,495.39	4,463.84	1,562.35	1,933.05	0.1190	230.03
Nickel	7,296.12	0.81	5,909.86	2,673.30	2,165.37	3,744.49	0.1140	426.87
Lead	4,864.23	0.52	2,529.40	1,782.17	926.73	1,602.67	1.4700	2,355.93
Chromium - Hex.	1,215.84	0.82	996.99	213.85	175.36	821.63	19.3000	15,857.47
Chromium - Tri.	1,215.84	0.35	425.54	677.18	237.01	188.53	0.1270	23.94
TOTAL	48,641.41	0.00	23,463.45	17,821.99	8,431.71	15,031.75	0.0000	25,635.63
Level 2								
Copper	24,062.55	0.42	10,106.27	3,419.78	1,436.31	8,669.96	1.0000	8,669.96
Zinc	9,986.84	0.35	3,495.39	1,898.20	664.37	2,831.02	0.1190	336.89
Nickel	7,296.12	0.81	5,909.86	1,139.59	923.07	4,986.79	0.1140	568.49
Lead	4,864.23	0.52	2,529.40	759.62	395.00	2,134.40	1.4700	3,137.57
Chromium - Hex.	1,215.84	0.82	996.99	91.17	74.76	922.23	19.3000	17,799.03
Chromium - Tri.	1,215.84	0.35	425.54	288.70	101.04	324.50	0.1270	41.21
TOTAL	48,641.41	0.00	23,463.45	7,597.05	3,594.55	19,868.90	0.0000	30,553.16
Level 3								
Copper	24,062.55	0.42	10,106.27	2,274.20	955.16	9,151.11	1.0000	9,151.11
Zinc	9,986.84	0.35	3,495.39	1,427.99	499.79	2,995.60	0.1190	356.48
Nickel	7,296.12	0.81	5,909.86	793.33	642.59	5,267.27	0.1140	600.47
Lead	4,864.23	0.52	2,529.40	528.88	275.02	2,254.38	1.4700	3,313.94
Chromium - Hex.	1,215.84	0.82	996.99	63.47	52.04	944.94	19.3000	18,237.42
Chromium - Tri.	1,215.84	0.35	425.54	200.98	70.34	355.20	0.1270	45.11
TOTAL	48,641.41	0.00	23,463.45	5,288.84	2,494.96	20,968.50	0.0000	31,704.52

Table 8.

Industry Comparison
Cost Effectiveness for
Indirect Dischargers
(Toxic and Nonconventional Pollutants Only)
Copper Based Weights
(1981 Dollars)

Industry	Pounds Equivalent Currently Discharged (To Surface Waters) (000's)	Pounds Equivalent Remaining at Selected Option (To Surface Waters) (000's)	Cost Effectiveness of Selected Option(s) ($/pounds equivalent)
Aluminum Forming	1,434	24	8
Battery Manufacturing	1,159	10	149
Coal Mining**	N/A	N/A	N/A *
Coil Coating	2,503	9.6	9.28
Copper Forming	34.2	3.6	420
Electronics	23	22	10
Inorganic Chemicals	3,971	3,004	9
Iron & Steel	5,599	1,404	6
Leather Tanning			152
Metal Finishing	11,680	675	7
Nonferrous Metals			
Foundries			
Organic Chemicals, & Plastics and Synthetics			
Pesticides	49,929	1,080	++
Petroleum Refining			
Pharmaceuticals	7	2	79
Porcelain Enameling			14
Pulp & Paper	N/A	N/A	N/A
Steam Electric			
Textiles*	N/A	N/A	N/A
Timber			

* N/A: Pretreatment Standards not promulgated, or no incremental costs will be incurred.
** Coal mining has no known or expected indirect dischargers.
++ Less than a dollar.

Table 7.

Industry Comparison
Cost Effectiveness for
Direct Dischargers
(Toxic and Nonconventional Pollutants Only)
Copper Based Weights
(1981 Dollars)

Industry	Pounds Equivalent Currently Discharged (000's)	Pounds Equivalent Remaining at Selected Option (000's)	Cost Effectiveness of Selected Option(s) ($/pound equivalent)
Aluminum Forming	1,319	90	107
Battery Manufacturing	4,134	7	21
Coil Coating	2,289	8.5	49.34
Coal Mining	BAT=BPT	BAT=BPT	BAT=BPT
Copper Forming	70.2	7.5	126
Electronics	9	3	406
Foundries			
Inorganic Chemicals	32,503	1,290	++
Iron & Steel	40,746	1,040	2
Leather Tanning			
Metal Finishing	2,012	2,012	NA
Nonferrous Metals			
Organic Chemicals, & Plastics and Synthetics			
Pesticides	149,228	4,962	++
Pharmaceuticals	BAT=BPT	BAT=BPT	BAT=BPT
Porcelain Enameling			6
Petroleum Refining	BAT=BPT	BAT=BPT	BAT=BPT
Pulp & Paper*	1,330	748	18
Steam Electric			
Textile Mills	BAT=BPT	BAT=BPT	BAT=BPT
Timber			

++ Less than a dollar.
* PCB control for Deink subcategory only.