CHAPTER 21

Benefit-Related Expenditures for Industrial Waste Treatment

At this juncture, some discussion is useful to clarify my position of how much industry should pay to treat its industrial waste. Clearly waste treatment represents a significant cost of doing business. That cost must not only be predetermined by industry, but managers also must decide on the amount they are willing and able to spend. Understanding this expenditure will aid the reader in reaching the conclusion that regardless of the accepted cost of waste treatment, the environmentally balanced industrial complex (EBIC) is less costly and more efficient and leaves no residual environmental pollution.

In 1972, I made the following public statements, which are still valid today (Nemerow 1972):

> Industrial waste treatment is a necessity to preserve our water resources. Economical stability of our society is also equally vital to our well-being. Waste treatment may cost more than an industrial plant is willing or even able to spend. This is true especially in situations where the stream resources are limited and intense competition exists between water users and consumers. Unfortunately for us, these latter situations are becoming more and more prevalent. What then is industry to do in these cases? Move? Cease production? Enter into a legal maneuver in order to delay or prevent excessive costs for waste treatment? None of these is really desirable for industry or society. What should governmental regulatory agencies do in these critical situations? Force industry into one of the above alternatives or ignore the need to protect the stream resources and allow the plant to continue to pollute? Neither of these positions is satisfactory. How then do we solve the problem of apparently conflicting interests of two factions of our society? In this chapter, some answers should become apparent.

Lest any reader question whether treatment costs are justifiable, I have recalled a listing of primary, secondary, and intangible benefits of industrial waste treatment.

Primary Benefits

1. Savings in dollars to the industrial firm by the reuse of treated effluents instead of freshwater.
2. Savings in dollars resulting from compliance with regulatory agencies, that is, avoidance of legal and expert fees and management's time involved in court cases.
3. Savings in dollars from increased production efficiency that are made possible by improved knowledge of waste-producing processes and practices.

Secondary Benefits

1. Saving in dollars to downstream consumers from improved water quality and, hence, lowered operating and damage costs.
2. Increase in employment, higher local payroll, and greater economic purchasing power of the labor force used in construction and operation of waste-treatment facilities.
3. Increased economic growth of the area because of the commitment of industry to waste treatment and potential for expansion at the existing plant.
4. Increased economic growth of area with more clean water available for additional industrial operations, which in turn yield more employment and income for the area.
5. Increased value of adjacent properties as a result of a cleaner, more desirable receiving stream.
6. Increased population potential for the area because cleaner water will be available at a lower cost. The limiting factor of water cost and quantity has been pushed back further into the future.
7. Increased recreational uses, such as fishing, boating, swimming, as a result of increased purity of water; recreational opportunities previously eliminated are available again.

Intangible Benefits

1. Good public relations and an improved industrial image after installation of pollution abatement devices.
2. Improved mental health of citizens in the area confident of having adequate waste treatment and clean water.
3. Improved conservation practices that will eventually yield payoffs in the form of more clean water for more people over more years.
4. Renewal and preservation of scenic beauty and historical sites.
5. Residential development potential for land areas nearby because of the presence of clean recreational waters.
6. Elimination of relocation costs (of persons, groups, and establishments) because of contaminated waters.

7. Removal of potential physical health hazards of using polluted water for recreation.
8. Industrial capital investment ensures permanence of the plant in the area, thus lending confidence to other firms and citizens depending on the output produced by the industry.
9. Technological progress, resulting from the conception, design, construction, and operation of industrial waste-treatment facilities.

The most obvious and prominent observation from the listing of benefits is that one must quantify these in some manner to arrive at a specific level of justifiable expenditure. I have made an attempt to do just that in Chapter 16B. However, at this point I would like to express my opposition to the view expressed by some that all industrial waste-treatment costs are justifiable to protect stream resources. Advocates of this position make light of any attempt to quantify benefits because of their foregone conclusions. These advocates further believe that wastewater resources engineers are "poaching" on other fields in applying economic measures to treatment decisions. What these overexuberant conservationists fail to consider is that our economic ability to ameliorate society's ills is limited by not being able to afford to do everything to improve the environment instantly. Therefore, someone has to establish priorities setting forth the proper amount of waste treatment required. We are obliged to provide government with formulas or at least methods for making more objective decisions in pollution abatement situations.

Quantification of Benefits

We can begin the process of quantification by defining "benefits" as a willingness to pay or the value of avoiding payment of a given number of dollars at the given water quality by actual and potential water users (Nemerow and Faro 1970).

The dollar benefit of a water resource at a given quality may be determined by listing all the uses that are affected by water quality, by valuing each use individually, and by summing the resultant values. The major uses that are affected by water quality may be grouped in the following categories: (1) recreation uses, (2) withdrawal water uses, (3) wastewater disposal uses, (4) bordering land uses, and (5) in-stream water uses. The value of these uses may be estimated by taking surveys of the users to determine the extent of demand for each use and the amount each user is willing to pay for a unit of use or the unit benefit. Annual dollar benefits for a given use are the product of the total demand times unit benefit. Total annual dollar benefit at a given water quality is the sum of these benefits for each use.

Total annual dollar benefit at a higher water quality may be estimated by determining the probable demand for beneficial water uses at the new quality. This demand may be estimated by surveying the present need for comparable uses at a nearby lake or stream with this new water quality, or it may be estimated by questioning potential water users to determine latent demand likely to be present at this new quality for possible beneficial uses that are presently being foregone.

An expanded description of the above five receiving water uses is given in the following subsections.

Recreation Use Benefits

Water-oriented recreation uses will include sightseeing, walking and hiking, swimming, fishing, picnicking, boating, hunting, camping, water skiing, canoeing, sailing, and skin and scuba diving. These recreation uses may be valued by including all the expenditures of the average recreations as a measure of their willingness to pay. These include the costs of equipment, food, travel, and recreation area user fees.

Withdrawal Water Use Benefits

Withdrawal water uses include municipal water supply, industrial water supply, and agricultural and farmstead water supplies. The water-quality benefits reflected in the municipal water supply may be estimated to be at least equal to the cost of water treatment by chemical coagulation, sedimentation, and rapid sand filtration. Water-quality benefits for the industrial water supply may be estimated by using water-treatment costs, not to exceed those for municipal treatment. Industrial costs to produce ultrapure water are not assigned as water-quality benefits, because these costs are more related to overhead costs of particular manufacturing process, in contrast to the cost of a normally supplied public utility. Agricultural and farmstead water use benefits may be estimated as negative values, if damages have occurred to irrigation, poultry and livestock watering, and farmstead family or dairy uses.

Wastewater Disposal Benefits

Wastewater disposal benefits may be estimated to be the total annual costs for waste treatment required to meet existing minimum stream or effluent standards. The difference in annual costs between the existing level of treatment and the level required to meet the minimum standards may be considered a present benefit to the waste discharger. These costs include those for the common waste-treatment plants and the costs of industrial wastewater reduction practices, interceptor sewers, water-quality surveillance, stream low-flow augmentation, and possibly in-stream aeration.

Land Value Benefits

Bordering land value benefits at a given water quality may be estimated for a given land use by comparing the per-acre market value of shoreline property with the value of nearby nonshoreline property. These market values may be estimated using local tax records and the tax equalization rates. The difference in these per-acre values will then reflect unit benefits or damages of the shoreline location. Values at a higher water quality may be estimated by applying this technique to a nearby lake and projecting the ratio of shoreline to nonshoreline per-acre values back to the original lake.

In-Stream Water Use Benefits

In-stream water uses include commercial fishing, barge and ship navigation, flood control, and hydroelectric power generation. The value of commercially caught fish may be taken as a benefit, whereas the other uses involve damages or negative benefits.

Relationship of Treatment Costs to Benefits to Arrive at Unit Charge for Resources

As far back as 1970, I proposed that a regional board be empowered to sell the assimilative capacity of a specific water resource to dischargers using the resource (Nemerow and Karanik 1970). Such a board would require at least the following information from the users (industrial and others):

1. Identity of all discharges
2. Quantity of dischargers
3. Existing and desired pollution index (a measure of water quality)
4. Benefits of waste treatment
5. Assimilative capacity of the water resource

Then, using a method developed and proposed by our group (Nemerow and Sumitomo 1970), one can determine the present value of the pollution index of the water resource. The pollution index is developed for specific water uses when multiple items of water quality are considered. It is specific for one of three classifications of water use: human contact, indirect contact, and remote contact.

An overall pollution index can be developed as a weighted average of the three specific indices, the weight of each being related to the relative type use of the watercourse. Essentially, the formulation is

$$PIij = \left[\frac{Max(Ci^2/Lij) + Mean(Ci^2/Lij)}{2}\right]^{1/2}$$

where i = specific water use,
Ci = concentration of contaminant, and
Lij = allowable concentration of contaminant at the specific water use.

After itemizing all the annual benefits of uses of a water resource at its existing quality level, we can obtain two points on the following curve (as illustrative of actual data collected on Onondaga Lake, Onondaga County, New York State [see Figure 21.1]).

Before we examine the figure, I would like to quote some words of wisdom by former Vice President Albert Gore (1992) on our economic system:

> The hard truth is that our economic system is partially blind. It “sees” some things and not others. It carefully measures and keeps track of the value of those things most important to buyers and sellers, such as food, clothing, manufactured goods,

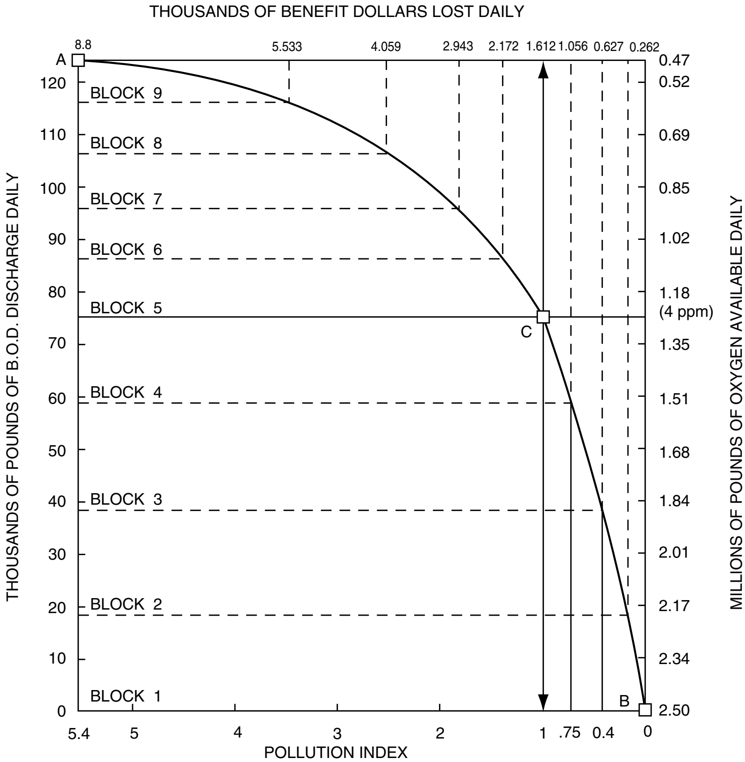

FIGURE 21.1. Unit price calculation.

work, and, indeed, money itself. But its intricate calculations often completely ignore the value of other things that are harder to buy and sell: fresh water, clean air, the beauty of the mountains, the rich diversity of life in the forest, just to name a few. In fact, the partial blindness of our current economic system is the single most powerful force behind what seem to irrational decisions about the global environment.

In Figure 21.1, two points are very significant: A, the coordinates of 5.4, the computed present pollution index of the lake, and 123,000 lb of BOD per day, the present daily BOD inflow into the lake. The other point, B, has coordinates of 0 as a pollution index (representing absolutely no contaminants) and 0 pounds of BOD being discharged into the lake each day. Although no precise data are available between these two factual points, we can make some assumptions that will help define the shape of the curve. First, the curve should descend in BOD towards a resultant pollution index of zero, but probably not precisely in a linear fashion. We also know that point A corresponds to $8,800 of benefits lost daily at the present discharge level and that point

B corresponds to no loss in benefits when there is no discharge of wastes. A third point, C, can be approximated at the intersection of the two water-quality objectives, PI = 1 and dissolved oxygen = to 4 mg/L. The curve can now be drawn with considerable certainty through the three points A, B, and C. The latter point presumes that a direct relationship exists between the daily BOD discharged (76,000 lb) and dissolved oxygen available (1.2 million 16/day at 4 ppm). From this curve, we can proceed to make a firm decision of what water quality to maintain based on constraints of dollar benefits and amount of oxygen with a resultant allowable BOD discharge. In our illustration (Figure 21.1), we decide to improve the PI to 1.0 from its current value of 5.4. This will result in a decrease in dollars of benefits lost from $8,800/day to $1,612/day (a savings of $7,188 at a discharge of 76,000 lb BOD per day) (37% reduction) or sale of BOD capacity resources up to a level of 76,000 lb/day are the two alternatives open to the board. If sale of resources is chosen, four blocks of 19,000 lb BOD each can be sold at costs directly related to the dollar benefits lost for each incremental amount of BOD contamination allowed. For example, the third 19,000 block results in a benefit loss of $1,056–627, or $429/day. Therefore, a potential and reasonable unit charge could be $429/19,000 or 2.3 cents/lb. Customers (water-polluting users) could opt to build their own waste-treatment plants to eliminate the need for purchase of these BOD units. You will note that each block of BOD capacity purchase becomes increasingly more expensive. Presumably, no more than 76,000 lb of BOD would be sold unless a lower water quality was desired and less would be sold if a higher quality was selected by the board. Customers in this case will probably select the least-cost alternative to comply with allowable BOD discharge.

Purpose of Quantified Benefits

Quantified benefits serve two major purposes. First, they allow one to compare the total annual dollar benefit with a total annual expenditure or cost of maintaining or achieving a particular water quality (*pollution index*). In the case of the Onondaga Lake analysis, it was found that the annual benefits of an improved water quality (PI = 1.0) would be about $7.5 million or $3.2 million more than at its existing water level (PI = 5.4). Annual expenditures of capital and interest payments to obtain this improved water quality have been estimated at about the same $3.2 million. Therefore, we can show that the quantifiable benefits alone would equal the annual costs. In addition, intangible benefits would certainly exist and be ample to dictate a “cleanup” policy to the board.

Second, they allow one to compute a unit charge for a pollution-carrying capacity resource. For example, in our illustration the sale of the third block of BOD at $2.3 cents/lb will decrease our water quality from a pollution index of about 0.4 to about 0.75 (see Figure 21.1). All pollution capacity consumers (BOD purchasers) are now in a position to select one of the two alternatives: (1) to purchase BOD capacity at $2.3 cents/lb, or (2) to treat its own wastes at a lower cost. In deciding between the two, the consumer must consider both capital and operating costs. Typical capital costs for many organic industrial wastes ranged from $50 to $150 per pound of BOD per day at the time of this study. Operating costs for industrial waste-treatment plants are relatively high and extremely variable and were not available for public analysis at the time of the study. It was unfortunate that many industrial plants themselves did not assess their waste-treatment operating costs at that time.

How to Determine Whether an Industrial Plant Can Afford Waste Treatment

Neither an industrial plant nor a governmental regulatory agency really knows whether a given industrial plant can afford to build and operate waste-treatment facilities. We can discount the idea that a plant must treat its wastes regardless of the cost as being unrealistic. We must provide an objective and feasible method for ascertaining a treatment cost that a plant can afford and still remain competitive in its industrial category. Vice President Gore observed that "the bad things economists want to ignore while they measure the good things are often said to be too difficult to integrate into their calculations" (Gore 1992).

In a survey conducted during the 1970s, detailed information was obtained from a questionnaire from four of nine preselected plants (Nemerow 1971). These plants were selected because of the my previous knowledge of their cooperative participation in effective waste treatment while remaining highly competitive. The four dependable replies were evaluated and are summarized in Table 21.1.

Study of the table reveals that two relationships of industrial economics have potential for application in water pollution abatement. The first is the ratio of dollar values of waste-treatment cost to the production cost or "value added." Three of the four plants reported a 1% (±0.1%) ratio. The fourth plant in the other industry showed only a 0.42% ratio. Indications are that a plant may allocate a percentage of its production cost to waste treatment. A very preliminary rough approximation of this percentage showed about 1% as a fair value. However, these plants used very economical and effective waste-treatment methods.

The second ratio results are $0.18–0.39 cost of waste treatment for each 1,000 gallons of waste treated. All costs of waste treatment include annual costs of amortized capital expenditures, maintenance, power, and chemicals. A 10-year useful life of equipment and a 7% interest rate were used to compute annual capital costs.

The most important deficiency of the usefulness for both methods is that of determining whether a plant can really afford to spend 1% of its production cost or even $24 cents/1,000 gallons of waste for treatment costs. The financial profitability as a result of business and professional management determines the ability of a plant to compete with others and, thus, be able to provide adequate waste-treatment facilities.

An attempt was then made to compute significant values such as marginal income and profit to sales ratios (Ganotis and Nemerow 1972). Total sales revenue of a plant minus the direct costs of the plant would be classified as "marginal income." Direct costs include raw basic materials, materials used in the process to produce the product, variable labor costs, utilities used in production of the product, and waste-treatment costs. All other costs are fixed costs and include such items as management salaries,

TABLE 21.1
Summary of Cost Data of Four Plants

			Cost Ratios Based on Product Economics					***Cost Ratios Based on Waste Flows***		***Cost Ratios Based on BOD Removals***		***Cost Ratios Based on Suspended Solids Removal***		***Ratio Cost Based on Total Plant Assets***
			Waste Treatment Cost	***Waste Treatment Cost***	***Waste Treatment Cost***	***Waste Treatment Cost***	***Waste Treatment Cost***	***Waste Treatment Cost***	***Waste Treatment Cost***	***Waste Treatment Cost***	***Waste Treatment Cost***	***Waste Treatment Cost***	***Cost***	***Waste Treatment Cost***
Type of Industry	*Plant No.*	*Type of Product*	*Dollar Value Added*[a] *(%)*	*Dollar Value of Raw Materials*	*Dollar Value Added Plus Raw Material (%)*	*Dollar Value of Selling Price (%)*	*Dollar Value of Profit and Overhead (%)*	*Gallons per Day*	*1,000 gals. Waste Treated ($/1000 gals)*	*Pound BOD per Day ($/# BOD per Day)*	*Pound BOD ($/# BOD)*	*# Pound SS Removed in a day ($/# SS/ day)*	*Suspended Solids Removed ($/# SS)*	*$ Plant Assets (%)*
Cannery	1	Beans	1.11	2.16	0.795	0.51	1.64	0.0236	0.374	10.30	0.1635	18.50	0.294	0.574
Cannery	2	Tomatoes Peaches	1.08	—	—	—	—	0.007	0.233	1.71	0.057	2.28	0.076	1.50
Poultry processing	3	Chickens	1.096	0.159	0.139	0.122	0.89	0.0484	0.186	1.08	0.00417	1.92	0.0074	0.925
Tannery	4	Upper leather	0.42	0.245	0.155	0.101	0.29	0.1035	0.393	47.00	0.004	0.957	0.000329	1.04

[a]Best potential for meaningful relationship for water pollution abatement.
SS, Suspended solids.

rent, mortgage and interest, loans, taxes depreciation, waste-treatment capital costs, and so on. When fixed and direct costs are added and the sum subtracted from sales revenue, one obtains the true profit income.

The resulting ratios of marginal and profit income values to the sales revenues for each plant of a given industry can be compared as follows:

$$\frac{\text{Marginal Income}}{\text{Sales Revenue}} + \frac{\text{Profit Income}}{\text{Sales Revenue}} = \text{Financial Index}$$

The higher the financial index, the more financially able a plant should be to afford additional waste treatment. When comparing indices of all plants in an industry, one can decide by using the statistical value of the financial index and the industry's agreement of which plant should be able to provide waste treatment and still remains economically competitive.

Unfortunately, although the method is sound, industry either does not know its real direct and fixed costs or does not want to disclose these to "outsiders." Without this information, the method is useless. Perhaps sometime soon, if and when marginal income and profits for each separate plant are known and made public, this method will provide a means for decision making in the environmental area.

Compromise on Practical and Feasible Method of Determining Industrial Firm's Capability to Provide Waste Treatment

A method can be developed and tested to establish a basis for determining both a reasonable amount of expenditure that potentially could be spent for treatment and for compelling the most financially able companies to instigate treatment first. Financial potential is measured by the pollution abatement cost (to meet required environmental quality) to sales ratio for each firm, hereafter referred to as the *sales index*. For a firm with sales revenue of $100 million annually and a treatment cost requirement of $5 million, the sales index would be 5/100, or 0.05. Indices can be calculated in a similar manner for all firms in the industry, placed in an array, and analyzed statistically.

A hypothetical comparison of the indices of five firms in an industry is shown in Figure 21.2 (Nemerow 1971). Indices vary from $0.025 to $0.11 per sales dollar. In our illustration, the firms in the industry arrived at a consensus that an index of more than 10 cents per sales dollar would result in an economically impossible situation. Therefore, firm A must increase its sales dollars, internalize an increased profitability or receive some sort of subsidy in order to be able to pay for pollution abatement. Its other alternative is to cease or alter production. On the other hand, firm D, with the lowest index of 2.5 cents, would be the most financially able to treat its waste first (with a resulting change in its index).

A new redistribution of the indices is then computed (see Stage II in Figure 21.2), with a mean index increasing towards the cutoff point of 10 cents and, firm E, with an index of 4 cents next in line for treatment.

Statistical Treatment of Hypothetical Data of Treatment
Costs and Sales

Hypothetical Index Calculations:

Firms	A	B	C	D	E
1. Proposed Treatment Cost (85% removal)	$ 110,000	$120,000	$30,000	$20,000	$18,000
2. Gross Sales:	$1,000,000	$1,3000,000	$600,000	$800,000	$450,000
Index ((1)/(2)) $/per sales $	$1.1	$.093	$.05	$.025	$.04

Assume: Prior industrial Agreement has been made that it is feasible to spend up to 10c per sales dollar before financial crisis occurs.

STAGE I Average index: 5.3 c/$sale, Firm D potentially will be most able to treat *first*.

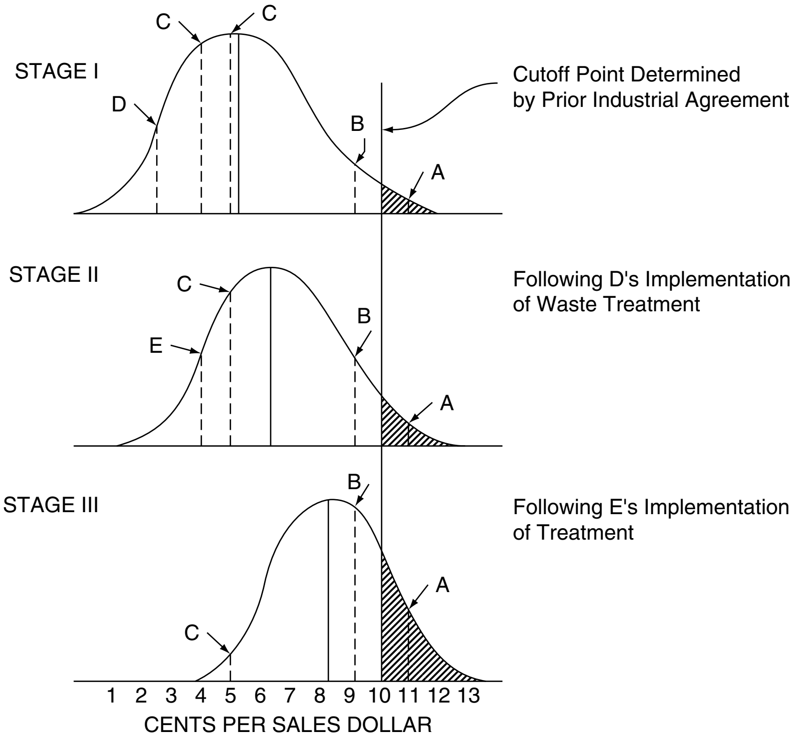

FIGURE 21.2. Sales values, treatment costs, and sales indices of the pulp and paper industry.

The sales index method was applied to the pulp and paper industry, for which data were published in 1971 (“Paper process pollution” 1971). The sales values, treatment costs, and sales indices are shown in Table 21.2.

The industrial average treatment cost of $30.68 million per company would be needed to meet requirements. In addition, it would cost an average of $4.34 cents per

TABLE 21.2
Pulp and Paper Industry Treatment Costs, Sales Revenues (1970), and Sales Indices (Computed)

Corporation	*(A) Treatment Cost $ Millions*	*(B) 1969 Sales in $ Millions*	*Sales in* $\frac{A}{B} \times 10$
1. Amer. Can	12.5	1,723.7	7
2. Boise-Cascade	42.1–50.1	1,726.0	26
3. Consolidated Paper	9.29	127.7	7
4. Cont. Can	16.5	780	9
5. Crown Zeller	58.7	919.3	64
6. Diamond Int.	8.6	498.1	17
7. Fibreboard	4.8	181.8	26
8. Ga. Pac.	23.6	1160.2	20
9. Gt. Northern Nek.	25.2–34.2	340.7	86
10. Hammermill	41.5	353.3	1175
11. Hoerner-Wald.	17.5	237.3	73
12. Int. Paper	101	1777.3	57
13. Kimb-Clark	13.5	834.7	16
14. Marcor	28.3	2500.7	11
15. Mead	26	1038	15
16. Owens Ill.	3.9	1294.4	3
17. Potlach	28–37	337.1	96
18. Riegal	11.5	184.0	62
19. St. Regis	59.8	867.8	69
20. Scott	78.8	731.5	107
21. Union Camp	9.0	449.5	20
22. U. S. Plywood	13.2–21.2	1455.5	11
23. Westvaco	36.5	419.6	87
24. Weyerhaeuser	32.5	1239.2	26

Note: Capital and estimated operating cost to reach desired treatment level as required by federal & state governments (average costs used in computation of sales index).

sales dollar (sales index) to attain this level of waste treatment. Descriptive statistics of sales index data showed widespread differences among firms, as indicated by a range of 0.3–11.75 cents per sales dollar. The relatively high standard deviation implies that pollution abatement activity in this industry varies significantly among firms. A cutoff point (upper limit of sales index) would then have to be determined by a caucus of the 24 companies, and presumably Company 16 (sales index 0.3) is in the best financial position to install necessary waste-treatment facilities while Company 10 (sales *index* 11.75) may already be financially incapable of affording waste treatment.

We only know that Company 16 is potentially capable of additional expenditure for waste treatment and likewise Company 10 is potentially incapable of the same expenditure. The method does not assess the companies' actual financial ability to pay. It gives the companies and regulatory agencies a valid indication, however, that one company should be able to afford treatment costs and the other should not be able to afford the same costs. These conclusions, in themselves, should reveal facts to both the companies and society that heretofore had been undisclosed. The findings should provide both with directives for future action that will lead to elimination of excessive pollution by an industrial sector.

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