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STEELMAKING AND THE ENVIRONMENT IN THE DEVELOPING NATIONS[1/]

by

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SUMMARY

The paper is begun with a consideration of the question of balance between industrial development and environmental quality, in particular in the context of steel operations in the developing countries.

The authors note that economic growth and industrial development have been defined in terms of consumption and trade, balance sheets and cash flows, and even in records of life spans and social services, but that no system of adequate measurement has yet been agreed upon for describing relative degrees of environmental contamination or pollution tolerance. They emphasize the need for such a comparative standard, and suggest a method for consideration that may serve to initiate broad discussion leading to a general consensus.

Environmental quality is introduced as a valuable resource and when economic features are acceptable, as a reserve that carries a current value in the iron and steel industry cost-sheet. Once this definition is accepted, provision for safe and efficient use and conservation of air, water, and solid effluents may be "naturally" included in most, if not all, developmental programs. Locations with high levels of environmental pollution tolerance will be identified as having especially desirable site potential for steel plant installations.

In describing the proposed method for measuring the characteristics of environmental pollution tolerance, the authors suggest comparative data factors which apparently indicate that superior steel plant site possibilities due to high environmental quality are more likely to be found in the developing countries.

INTRODUCTION

The industrialized nations are at the present time greatly preoccupied with two classes of conflicting problems. One of these is a shortage of energy, especially "clean" energy in technically attractive forms. The other is a set of environmental quality problems, commonly denoted "pollution". The true costs of this are only now being exposed, many for the first time, as very large in magnitude over wide areas, especially in industrially concentrated regions. Concern about environmental quality has had a profound effect upon the energy shortage because truly clean fuels are, indeed, rapidly approaching conditions of very short supply.

To the industrial operator in a developing region or nation, environmental quality is a distinctly secondary concern, and rightly so for two reasons. First, clean surroundings abound where there is minimal economic activity. Second, an industrial enterprise which may be the major cause of immediate local air and water pollution, will also produce the economic basis for direct and indirect contributions to current and long-term improvement in public life-style, health and welfare to an extent and degree that overshadows the ultimate effects of smoke and scum. If the industrial developer creates the economic tools with which men and families in developing countries may improve very poor lives and life-styles in the immediate sense, a comparison of the ultimate damage caused by emphysema and the somewhat earlier effects of malnutrition and illness is likely to be more academic than real.

We are therefore confronted with a question of balance between industrial development and environmental contamination which is the subject of this paper.

Economic growth and industrial development have been defined in terms of material production, consumption and trade; favorable balance sheets and cash-flow generation; and even by records of life span, education and social services. But, so far, no system of adequate measurement has been devised to describe the levels and relative degree of environmental tolerance. This is very much needed because many measured facts must be considered if proper decisions about industrial development are to be taken.

Development policy, which may rightly discount or ignore environmental effects in developing areas in 1973, may not be sound policy for the 1980's or 1990's. There is need, both local and global, for decisions that will be correct in the long-range future as well as today. For the iron and steel sector, those decisions will apply to questions like: Where and how shall raw materials be beneficiated and/or agglomerated?; Where and how shall ore be reduced to metallic iron?; Where and how shall raw steel be produced?; and, Where, how, and to what extent should obsolete steel be accumulated, and recycled? It is a thesis of this paper that problems such as these, in both developed and developing areas, demand responses based on considerations of long-term factors, no less than those that pertain to more immediate horizons. Furthermore, an adequate set of measurement standards, drawn from a generally accepted concensus, needs to be established, and the sooner the better.

ENVIRONMENTAL QUALITY AS A RESOURCE

Industrial development necessarily involves the careful consideration of resources. To approach the task of including environmental planning in development decisions, it is convenient to propose that environmental quality is itself a resource or set of resources. This proposition is justified by comparing certain features that clean air and water have in common with those of more conventional resources such as dispersion, extensibility, and ultimate exhaustion.

First, conventional steelmaking resources are unevenly distributed among nations and localities; so are environmental characteristics. For example, there are ore-rich, coal-rich nations such as Australia, the USSR, and the United States; ore-rich, coal-poor nations like Venezuela, Brazil and many countries of West Africa; ore-poor, coal-rich nations such as Poland and Czechoslovakia; and there are ore-poor, coal-poor nations such as Japan, Italy and Argentina. These examples illustrate the point that resource-mix and status alone do not determine potential for industrialization based on steelmaking. Turning to the environmental analog, there are almost everywhere among the populous nations sharp variations in the fundamental aspects of the environment. Natural weather patterns, geographic borders, topographic elevations and meteorological features determine that some localities have frequent atmospheric inversions and others are constantly windswept. Similar features, interacting with the character of the surface soil, dictate that some areas have plentiful, clean surface waters, others have plentiful but muddy fresh water, still others are water-short as a chronic condition, and all undergo experiences that vary according to their population densities. The rates of flow of air and water, and their primal condition as to cleanliness, are attributes which differ naturally and substantially from place to place. For the criterion of unevenness of distribution, then, environmental quality meets the test of a resource.

Secondly, conventional resources are extensible and capable of replenishment, even as they technically are being used and depleted. For a given deposit of ore or coal, there is a fraction that is of high quality (grade and size) as removed from the ground. Progressively, subsequent fractions are of relatively lower quality at the time and place of origin. Common practices of beneficiation and agglomeration are based on extending the size and value of basic resources by technical alteration, at an appropriate cost. In the environment, beneficiation and agglomeration operations are practiced upon water to improve the supply. Dams, impoundments and primary filtration plants, as well as sewage-treatment facilities are built to improve water quality or maintain it in spite of natural or people-induced degradations. Air is of course not agglomerated but, when necessary, it is conserved or beneficiated by means that limit and cleanse process emissions by filtering and washing.

Thirdly in support of the idea that environmental quality is a resource, it is ultimately exhaustible through use. For water and air, the processes of exhaustion are more subtle and complex than for ore and coal. Whereas it may be easily shown that ore and coal are literallly consumed, losing their form and substance, it would be hard to argue that air or water are truly consumed in appreciable amounts. In the environment, the mechanism of exhaustion is called contamination, a process that is rich in important side-effects and is, to some extent, reversible. Globally and, in part, on scales of lesser extent, natural reversal mechanisms exist and operate. It is usually only after the level of sulphur dioxide in the air, or after the concentration of contaminants in a liquid effluent reach levels that are unnecessarily high that pollution becomes a "problem" -- which often means that a condition of irreversibility is rapidly being approached. This position is strongly supported by the fact that even in the areas most troubled by polluting contamination, the present period of environmental "problems" is many times shorter than the preceding years of high level industrial activity.

In summary, the attributes of uneven distribution, depletability and extensibility and replenishment, plus ultimate exhaustion provide conceptual support for the idea that environmental quality is a resource like any other steelmaking resource. If that is so, environmental quality carries an economic cost to the iron and steel manufacturer, and also to local and global societies. The furore concerning the cost of pollution in heavily industrialised areas centers on the imposition of that charge directly upon the steelmaker. Once environmental quality is viewed as a valuable resource, it becomes possible to include, in any overall development plans, provision for the efficient use and conservation of air and water. Simply stated, a decision to ignore the cost and value of clean air and water is to impose that cost upon others who, perceiving this, are likely to resist a necessary element of developmental strategy.

THE MAGNITUDES OF POLLUTION

Environmental pollution is a legacy of industrial growth, especially in those parts of the world where such growth has been stimulated by technological advances in recent years. Less complicated facilities have been replaced by new and larger installations involving more efficient practices which usually generate greater amounts of by-products, useful and otherwise. The non-usable components of these secondary outputs -- gaseous, liquid and solid -- consist of materials that are difficult to isolate and process economically. They are separated out grossly, and discarded at the least possible cost.

Pollution has been correctly called a "people problem". Mining operations scatter accumulations of mineral processing wastes in both developing and developed countries. The resulting ugliness affronts individuals; the waste of mineral units dismays the involved industrialist as well as the conservationist. And, the consequent real and potential dangers of air and water pollution alarm health authorities and ecologists. Similar indictments may be drawn for industrial production and chemical transformation operations; power generation units; internal combustion engines and high-speed aircraft with noisy jet engines; community and manufacturing refuse incineration; agricultural fertilizer and pesticide applications; water treatment and sewage disposal practices; or the unplanned proliferation of populations.*

Pollution has also been termed a problem of technology. Where environments have been contaminated, it is largely because rapidly growing economic entities have drawn great benefits from new and increasingly complicated

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* In this paper, the discussion has been limited mainly to liquid, gaseous, and to a lesser degree to solid pollution.

technological practices. Confronted by demands for unprecedented magnitudes of materials, men, and machines, the operating industries as well as the consuming markets have not recognized sufficiently clearly that the application of advanced technologies almost always generates pollutants.

The pollution threat in the present period of sophisticated technologies has been obscured by past attitudes. These were acquired in simpler operations that generated smaller amounts of waste materials at lower rates in plants located in relatively sparsely settled areas. For many years, concentrations of pollutants such as sulphur oxides or gaseous and solid hydrocarbons in the atmosphere, phosphorus compounds or biological populations in feeder streams and natural water systems, solid waste piles on land, and pesticide residues in soil, water, and air, could be held to or under threshold levels below which a tolerable "self-cleansing" action could be expected. Such inherent relief, even to a partial extent, is no longer available in most industrialized areas. The processes that are now in use in industrially advanced regions involve input and output magnitudes that are often too great, rates of reactions that are too rapid, materials-transfer circuits that are too complex, temperatures and pressures that are too extreme, for effective control by past methods. Together, these factors produce polluting conditions that are far beyond any self-healing levels, except in regions where industrial activity is minimal.

Air Pollution

Industries of the developed countries must bear a large part of the responsibility for nearly every component of the environmental pollution problem and for a corresponding part of the solution. With respect to the atmosphere, industry accounts for at least 17 percent (1) of air polluting emissions, exclusive of its sizable share of another 14 percent exhausted by electric power plants. The percentages are more impressive when stated as tons of foreign material introduced into the air above us. During 1965 in the United States, no less than 142 million tons of primary air contaminants were emitted into the lower troposphere.(1) Automotive propulsion was responsible for 86 million tons of the total, electric power generating plants for 20 million tons, space heating for 8 million tons and refuse incineration for 5 million tons. Industry contributed the remaining 23 million tons; 9 million as sulphur oxides, 6 million tons in particulate form, 4 million tons as hydrocarbons, and 2 million tons each of carbon monoxide and nitrogen compounds.

Table 1 lists some of the recognized industrial producers that contribute to atmospheric contaminations. The operations that are major pollutors are chemical plants, non-ferrous metal smelters, petroleum refineries, pulp and paper mills, and integrated iron and steel plants.

Among the 5 main sources of air pollution -- automobiles, electric power plants, industry, refuse disposal and space heating -- industry leads in the production of particles and is second in the emission of sulphur oxides. But, by far the largest single U. S. offender is in the 46 percent (66 million tons in 1965) of carbon monoxide exhausted into the atmosphere by automobiles, which

(1) The 1965 figures are drawn from "The Sources of Air Pollution and Their Control"; U. S. Public Health Service Publication, No. 1548; Washington, D.C.; 1966. Authority for presenting the cited numbers as minimal ("at least") is Dr. B. E. Willard, who at the 1970 Mining Convention in Denver, refers to "33.9 million tons of sulphur oxide emissions" which is 30 percent higher than the 1965 data.

TABLE 1

AIR-POLLUTING INDUSTRIES AND ASSOCIATED EMISSIONS

Industry[a]	Emissions
Aluminum Ore Reduction	Particles; Fluorides
Calcium Carbide Manufacture	Particles
Caustic and Chlorine Production	Chlorine
Coal Cleaning	Particles
Ferro-Alloy Production	Particles
Gasoline Bulk Storage	Hydrocarbons
Grey Iron and Steel Foundries	Particles, Smoke, Odors
Hydrochloric Acid Production	HCl Mist and Gas
Integrated Steel Mills	Particles, Smoke, CO, Fluorides
Kraft Pulp Production	Sulphur Compounds, Particles, Odors
Lime Kilns	Particles
Nitric Acid Production	Nitrogen Oxides
Non-ferrous Smelters	Sulphur Oxides, Particles
Petroleum Refineries	Sulphur Compounds, Hydrocarbons, Particles, Smoke, Odors
Phosphate Fertilizer Manufacture	Fluorides, Particles, Ammonia
Phosphoric Acid Plants	Phosphoric Acid Mist, Fluorides
Portland Cement Production	Particles, Sulphur Compounds
Soap and Detergent Manufacture	Particles, Odors
Sulphuric Acid Plants	Sulphur Dioxide, H_2SO_4 Mist, Sulphur Trioxide

(a) Order of Listing does not indicate Rank of Amounts or Seriousness of Emissions

Source: Hearings before U. S. Senate Subcommittee on Air and Water Pollution of the Committee on Public Works; 90th Congress, 1st Session on S780, Part 4; page 2358.

are accountable for an additional 14 percent (20 million tons) mainly in the form of hydrocarbons and nitrogen oxides.

Given this situation plus rapidly rising populations and increasing concentrations of people in cities, the effect of a contaminated air environment becomes a matter of natural concern in most of the industrially advanced countries. And, because atmospheric pollution can hardly be limited by national boundaries or even by geographic separations, the subject must be viewed in a context of both international and intranational relationships. Legal constraints to defend the citizen and the community against adverse effects that may stem from industrial air contamination have been enacted in recent years on all governmental levels -- national, regional, and local. Nevertheless, atmospheric pollution is growing worse rather than better. Sulphur oxide emissions are increasing at an approximate rate of 6 to 7 percent per year. Ore smelting operations have been one of the main factors responsible for this increase.

Industrial air pollution appears to be increasing in spite of the application of known control technology. The oxygen-blown steel furnace is inherently a heavy producer of fume, but this has been minimized by built-in equipment in recent installations. Open-hearth furnaces, once a major generator of air pollutants, are being replaced by oxygen steel units and by electric steelmaking shops. Petroleum refineries are now often designed for H_2S recovery and conversion instead of allowing the gas to escape to the atmosphere. Scrubbers and precipitators have sharply reduced particle emissions from chemical and metallurgical operations.

Such efforts have undoubtedly improved the quality of the air environment. Yet, the relief can only be partial because many key processes are technically limited, frequently at costs that are not economically defensible. No known control is yet feasible for nitrogen oxides formed in combustion, emissions from coke ovens as now designed cannot be reduced, and a suitable method of controlling sulphur compounds from pulp mills is also an unsolved problem.

Much is known about the effects that air pollutants have on man, animals, plant life, and inanimate materials; even more is still to be learned. Standards for ambient air quality have been established (2), defining a minimal tolerance range at an "adverse level" (at which sensory irritations and diminished visibility occurs); then at a "serious level" (at which bodily functions are impaired, with a likelihood of an onset of chronic disease); and, finally, at an "emergency level" (at which acute illness or death may occur among sensitive persons).

Any of the above levels of the air environment are, of course, undesirable, and any conditions that may lead to their occurrence are obviously to be avoided. Past incidents (3) provide proof that any air pollutant at sufficient concentrations in the atmosphere may have catastrophic consequences. Within the limits of present knowledge it would appear that the complete elimination of polluting intrusions into the air environment is neither technically nor economically possible. However, given adequate precautions that insure maintenance of pollutant concentrations below established "adverse levels", complete elimination may not be wholly necessary.

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(2) See "California Standards for Ambient Air Quality and for Motor Vehicle Emissions", March 1967; Dept. of Public Health; Berkeley, Cal. Acceptable levels are defined for photochemical pollutants, nitrogen dioxide, carbon monoxide, sulphur dioxide, hydrogen sulphide, sulphuric acid, ethylene, hydrogen fluoride, lead, particles, and carcinogens.

(3) Episodes involving severe conditions of excessive pollutant concentrations have been recorded in Donora, Pennsylvania, in 1948; in the Meuse Valley, Belgium, in 1930; in London in 1952 and 1962; and in New York in 1953, 1963, and 1966. These events were each associated with higher-than-average mortality. The locations are clearly marked by concentrated industrial activity and/or population densities.

The effects of air contaminants on human and animal life are only slightly less disturbing than the impacts that may be observed on vegetation, materials, and, in a broader framework, on the total ecology. The tolerance of plants against air pollutants is less than that of animals. Vegetation is known to be highly prone to damage by sulphur dioxide, hydrogen fluoride, ethylene, and photochemical smog (hydrocarbons, ozone, oxidants, and aerosols). Some studies have been undertaken to understand the attack mechanisms involved, and to formulate offsetting criteria and standards. But, such investigations in the past have been insufficient and generally incidental to establishing the extent of economic losses caused by unusual cases of plant damage. (In such studies, the losses were almost always found to be significant.) Continuation of current research along such lines and with more extensive objectives is obviously imperative.

Equally important is the need for more knowledge about damage caused by atmospheric pollutants on materials and goods. One exception may be the determination of the mechanisms underlying the phenomenon of atmospheric corrosion, but the introduction of new materials almost daily imposes a necessity for a long-term extension of earlier studies and tests on corrosive substances and conditions.

Concerning the interaction between materials and contaminants in the air; smoke grays laundry, and acid aerosols ruin nylon stockings; H_2S blackens silver utensils; photochemical smog accelerates hardening and cracking of rubber, causes dyes to fade and lowers fabric strength, and the reasons behind excessive failures in telephone relay components have been traced to airborne concentrations of nitrates. Attempts to define reasonably accurate estimates of the cost of the damages that atmospheric pollution may cause to materials have been inhibited by the complexity of the problems, except in some specific cases.

The role that the air environment holds in the biosphere and among the total assemblage of living things that exist and interact in nature is largely unknown. Ecological interdependence of environmental sub-systems and life processes has been highlighted in conceptions that picture entire species wiped out by the toxic action of some pollutant -- frequently airborne -- on food chains, tissue health, and growth rates. The portrayal of an "Andromeda Strain" (with an oversimplified solution) in best selling books and theaters could be intellectually entertaining if the situation were not so close to practical reality. Pertinent studies are needed to separate fact from fancy. But the subject is not yet clearly defined and research on the relationships between contaminating factors and ecology is still largely directed at a determination of what the problems are, which of them should be taken up, and in what priority order.

Water Pollution

The earth's water systems have been studied to a much greater extent than the global air envelop. Different from the atmosphere, the world's total water resources are generally limited as regards location and more unevenly distributed. Society's dependence on water for transportation, commerce, and motive power is measurable in terms of 2 to 3 millenia, while the practical application of mechanical and electrical power is a matter of about 2 centuries, and the airplane has been in widespread use for no more than 2 to 3 decades. Man has therefore been impelled to learn how to manage the water environment around and below him to a far greater degree and over a far longer period than has been the case for the air environment above and around him. Long-established techniques of water management have been based on tradition, habit, and sound, but often outdated, empirical concepts. When increasing populations, improving living standards and expanding industrial activities generated demands for larger quantities and better qualities of water, the available water-management capabilities were unequal to the task even though the essentials of a pertinent technology were present. Although there is still much to be studied and learned about water and water contaminants, the present problems of water pollution are, to some degree at least, the outcome of negligence rather than ignorance. This has motivated, increasingly, legislative actions on national and regional levels aimed at the control of water pollution.

Water as a chemical compound has a fixed composition -- two molecules of H and one of O. Since all natural waters contain some minerals, they are never "pure". Water is said to be contaminated when it is not suitable for its intended use for (a) domestic purposes, (b) industry services, or (c) other ends (agricultural, fish and wildlife propagation, recreation). Man-made pollution may be indicated by the amount of suspended solids and by the weight of dissolved oxygen expressed as BOD (biochemical oxygen demand, referring to the dissolved O_2 consumed in degrading organic matter in natural waters).

Inorganic constituents of most wastes in water are ions of many common elements (S, K, NH_3, Ca, Mg, Cl). Organic compounds are numerous: in recent years the most important and most troublesome, especially in the industrial countries, have been synthetic detergents, carboxylic acids, and phenolic substances in streams, and pesticides in surface (run-off) waters. Micro-organisms participate importantly in the degradation of organic wastes in water to other forms that are more easily capable of dispersion by mixing or diffusion followed by some particle-supported movement to a suitable "receptor" or "sink".(4) Modern concepts of pollutant transport determine the quantities of organic waste that may be discharged to a particular water system. Typical of many comprehensive research programs presently supported by governments and industry are studies to identify microorganisms and chemical compounds in waste and natural waters; pollutant and particle transport in water systems; and the flow and reactions of organic substances in soil and ground waters.

Water pollution comes mainly from 3 sources; local communities, industry, and from other uses. The "other uses" include agricultural supply and recreational waters. By comparison with the domestic and industrial problem, agricultural and recreational water pollution represents a small share of the total. For this reason and because the problems are highly varied and diffuse, the abatement effort related to those areas has been minimal.

For obvious reasons, the situation is quite different as regards domestic water pollution. An estimate of the waste water treated in 1963 in the U. S. suggests an average figure of 120 gallons per person per day, or a total 5.3 trillion gallons for the year for 120 million persons in municipalities served by sewers.(5) Approximately 20 percent of the water used by them was discharged

(4) The flow line described is a highly simplified composite version of a large number of complex systems, of which probably none operates independently of the others.

(5) From "The Cost of Clean Water", Vol.1, Summary Report, 1968, U.S. Dept. of the Interior, Federal Water Pollution Control Administration. For the year in question (1963), the total population equalled approximately 189 million.

untreated, 28 percent after primary treatment, and 52 percent following secondary treatment also. By 1969, these figures had changed to 10 percent, 30 percent, and 60 percent, respectively; by 1973, Federal and State standards are expected to require secondary treatment for 90 percent of the total U. S. urban population and primary treatment for the remainder.(6)

TABLE 2

WATER-POLLUTING INDUSTRIES

Industry[a]	Waste Water Billion Gallons	Standard BOD Million Pounds	Settleable and Suspended Solids Million Pounds
ALL MANUFACTURING	13,100	22,000	18,000
Chemical & Allied Products	3,700	9,700	1,900
Electrical Machinery	91	70	20
Food & Kindred Products	690	4,300	6,600
Machinery	150	60	50
Paper & Allied Products	1,900	5,900	3,000
Petroleum & Coal	1,300	500	460
Primary Metals	4,300	480	4,700
Rubber & Plastics	160	40	50
Textile Mill Products	140	890	n.a.
Transportation Equipment	240	120	n.a.
All Other Manufacturing	450	390	930
DOMESTIC WATER[b]	5,300[c]	7,300[d]	8,800[e]

(a) Order of Listing does not indicate Rank of Amounts or Seriousness of Effluents.
(b) Representing 120 million people living in communities served by sewers.
(c) Number of persons x 120 gal/day x 365 days
(d) Number of persons x 1/5 pound x 365 days
(e) Number of persons x 1/5 pound x 365 days
SOURCE: "The Cost of Clean Water", Vol. 1, Summary Report, U. S. Dept. of the Interior, Federal Water Pollution Control Administration; Washington, D. C.; January, 1968.

(6) "Cleaning Our Environment - The Chemical Basis for Action", page 108; September 1969; American Chemical Society; Washington, D. C.

Industrial waste waters are 2 to 3 times more important than domestic discharges as a source of water pollutants, as indicated in Table 2. The data in Table 2 show that industrial water discharges are less likely than domestic wastes to contain refractory organic compounds which resist biological degradation. The "extra polluting" power of other organic compounds that must be converted to less harmful compounds before discharge is often found in industrial waters and usually not at all in domestic wastes.

Industrial plants discharge some 8 to 10 percent of their "cleaner" waste waters to municipalities, and approximately half the waste water treated by municipal plants may be of industrial origin. A trend may be developing in fully advanced situations that will increase joint use of water treatment plants by industry and nearby communities. Even so, industrial wastes are likely to receive increasing amounts of on-site treatment. In the United States, the required industrial investment to improve existing facilities and for new treatment installations is estimated at from 2.6 to 4.6 billion dollars between 1969 and 1973. These sums are distributed by industry in Table 3.

Although Tables 2 and 3 do not list the various industries in any priority order, the sums indicated in Table 3 suggest that primary metals operations is the leading producer of water pollutants. Food product processing is evidently second, followed by petroleum and coke operations, chemical product manufacturing, and paper product production. The investments for water pollution control by industry are apparently 3 times as great as the outlays by municipalities. Although the foregoing analyses are drawn from data applicable to conditions in the United States, they may be considered generally typical for some other

TABLE 3

ESTIMATED INVESTMENT REQUIREMENTS FOR U. S. INDUSTRIAL WASTE WATER TREATMENT PLANTS 1969 to 1973

Industry[a]	Million Dollars (b)	Million Dollars (c)
Chemical & Allied Products	$ 380	$1,000
Electrical Machinery	36	51
Food & Kindred Products	740	670
Machinery	39	56
Paper & Allied Products	320	920
Petroleum and Coal	380	270
Primary Metals	1,500	1,400
Rubber & Plastics	41	59
Textile Mill Products	170	170
Transportation Equipment	220	160
All Other Manufacturing	200	290
TOTAL	**$4,000**	**$5,000**
Presently on Order		
Industry	$2,200	$1,800
Municipalities	700	600
Backlog Requirements	$1,100	$2,600
New Facility Additions	700	1,000
Obsolete Facility Replacement	800	1,000
TOTAL INVESTMENT REQUIREMENTS	**$2,600**	**$4,600**

(a) Order of Listing does not indicate Priority Rank
(b) Expert Estimate
(c) By Census Projection

SOURCE: "The Cost of Clean Water", Vol. 1, Summary Report, U. S. Dept. of the Interior, Federal Water Pollution Control Administration; Washington, D. C.; January, 1968.

industrial situations; notably those in Japan, Australia, the U. K., and in the larger EEC countries. There is good reason to expect that they will apply increasingly to developing countries, as well.

A considerable body of knowledge is available on the effects of water pollutants, and much of this is reflected in current standards and proposals for water-quality criteria. Further investigations are in process to extend understanding of related complex factors, and new parameters incidental to the introduction of modern industrial products and processes. In particular, studies are being pursued to draw greater insights into the effect of water pollution on human health, tastes and odors, and eutrophication.

Growing demands for water to support industrial processes and heavier domestic water loads are reflected in the increased quantities of reused water that primary and secondary treatment plants must handle. With recycled effluents, chemical pollutant buildups will become increasingly difficult to avoid in present types of water treatment systems, which may need to be redesigned to meet the new conditions. The problem is considered particularly difficult. Long-term hazards are foreseen in the identification of new pollutants in the waste waters reaching existing treatment plants; these include selenium compounds, asbestos, nitrates, and organic carcinogens. Increased reuse of water also raises the danger of extending the range of water-borne enteric viruses.

Certain substances may impart unpleasant tastes and odors in water. For this reason, phenols in drinking water are limited to 0.001 mg/l. When combined with chlorine, the resulting chlorophenol will produce an unpleasant taste in fish at concentrations as low as .0001 mg/l. Such situations must be watched at industrial operations where phenols may be discharged in waste waters.

The process of nutrient enrichment is called "eutrophication", especially when it occurs in lakes and other relatively still waters. Generally, the phenomenon is difficult to observe since it is supposed to take place over periods of geological time. In recent years, the span has been compressed into time periods measurable in months rather than decades. The result is excess growth of algae and plant life that mars beauty spots and reduces recreational values; depletion of dissolved oxygen in water which wipes out entire fish populations; accelerated bacterial action that generates bad odors and off-tastes; and ineffective water-treatment plants with algae-clogged screens and filters.

Eutrophication is supported by nitrogen and phosphorus in various forms (also C, S, K, Mg, H, and O). Some of these nutrients are usually found in the waste waters from many sources, including industrial plants. Economic long-term controls are being sought to limit the obvious troublesome aspects of the process.

Solid Waste Pollution

The generation, disposal, classification, recovery and reuse of solid wastes constitute a relatively new activity. Recognized as a potential pollution problem only 10 years ago, solid waste control lacks a suitable background of operations that may be used as a point of reference. The techniques that are being developed are therefore generally novel rather than tested as in the case of water pollution control, and tentative as is frequently the situation for applications for air pollution control.

"Solid wastes" refer to a broad class of undesirable materials that stem from the production, processing and/or consumption of useful products. Table 4 is a tabulation of solid waste generated in the United States in a typical recent year. The largest item in Table 4, 2 billion tons of agricultural wastes, is matched by an equal weight of sediment (soil and mineral particles) that is washed down from farm lands to water streams. Notwithstanding its magnitude, this item, like the smaller 'refuse' entry, is only of indirect interest in this discussion. The item of primary significance here is the 1.5 billion tons of wastes generated in mining and mineral operations. This includes overburdens removed to gain access to mineral ores and gangue.

Generally, the solid wastes from mining and mineral processing are dumped near the sites of operations. One may judge the global situation from experience in the United States. There, solid waste accumulations were estimated at around 21 billion tons in 1968, an addition of some 2 billion tons for the preceding 3 years. Annual mining and mineral solid waste generation is expected to reach 2 billion tons of mine waste, mill tailings, washing plant rejects, process plant wastes, smelter slags, and rejects, annually by 1980. This reflects an unprecedented rate of growth of mining operations during the 1970 decade, that will be matched and surpassed elsewhere in the world.

About 60 percent of the waste accumulations have potential economic value, in their residue mineral content or for structural and fill purposes. Some 37 percent has no value and represents a nuisance as a possible health and/or safety hazard, a land-use barrier or an unesthetic intrusion in the area. The remaining 3 percent is usually distantly located and without economic value.

TABLE 4

SOLID WASTES IN THE U. S.

DESCRIPTION		ANNUAL PRODUCTION Million Tons/Year
Agriculture	- animal carcasses crop residues animal manure (85%) logging debris	2,000
Mining & Mineral Processing	- overburden gangue	1,500
Scrap Metal	- automobiles appliances machinery	20
Refuse (1)	- paper . . . . (28%) municipal waste . (23%) garbage . . . . . (15%) yard wastes . . . (14%) metal and glass . (10%) other . . . . (10%)	170

(1) "REFUSE" includes 'garbage' (animal and vegetable kitchen wastes); 'rubbish and ashes' (dry household, commercial, and industrial waste, combustion residue); and 'municipal waste' (street sweepings and construction wastes).

SOURCE - Science & Technology, June, 1969; page 35.

Copper mining generates large quantities of refuse. In the United States, several hundred thousand tons of waste are discarded daily, from which hundreds of tons of copper are recovered each day. In the process, about 50,000 tons of detinned tin plate and 250,000 tons of scrap automobiles are consumed. This underlines a special target of solid-waste recovery efforts: the economic use of discarded auto hulks. When properly sorted and stripped, such junked car bodies make an excellent scrap charge material for steelmelting furnaces.

THE MEASUREMENT OF POLLUTION

It is a currently accepted truism that the most industrially advanced countries are the most polluted. Certainly, the United States, Japan and large areas of Europe are clear examples of a direct relationship between "good" industrial products and "bad" environmental pollutants. Air and water contamination due to industrial activities are naturally most acutely felt in areas of high population density. For this reason, the environmental problem of Japan must be classed among the most serious of the world's industrial countries. One reason is that Japan's burgeoning industries, based mainly on foreign raw materials, are in fact importing pollution as their home based operations are expanded.

This rather complex fact is implicit in the decision to purchase oxide pellets from Australia, Peru, India, and other countries rather than iron ore fines for processing in Japan. On the other hand, Japanese steel companies have concluded long-term coal contracts for carbon that will be coked at home by its metallurgical coke-consuming industries. This commitment to coking operations in Japan for many years, has been taken with full knowledge that coke production in conventional slot ovens is a major source of pollution about which very little can be done, within acceptable economic constraints.

The possibilities of minimizing the importation of pollution have obviously been disregarded in this case. Although the transport of coke without excess degradation is a serious problem, and freight cost factors must be considered, such difficulties could be overcome by research, engineering, and the give-and-take of contract negotiations. It would then have been altogether reasonable to produce coke for Japanese blast furnaces at coal mines in, say, Australia or Canada or to do so at some intermediate point between those mines and Japan; for example, in Korea.

Similar situations can be visualized for other industrialized countries now concerned by the necessity for huge outlays of funds just to maintain environmental pollution at "reasonable", if not wholly satisfactory or safe levels. Such pollution control efforts through increased processing activities can obviously reduce the "importation of pollution" into developed countries. Unfortunately, the idea has the disturbing complement of the "exportation of pollution" to developing nations. But, the concept has room for preventative actions that can confine the harmful effects of pollution to manageable levels. Some of the basic factors which make this possible in the emerging areas, and which are no longer available in advanced ones, have already been suggested; they include: (1) the possibility of "self-healing defenses against pollutant effects which are still at minor levels when industrial activities are low: (2) the relatively smaller number of automobiles in developing areas that represents a margin of resistance against CO concentrations, the main cause for damaging air pollution effects; (3) the lower population densities in many emerging countries; (4) the greater availability of natural waters, which will frequently lessen incidences of eutrophication; (5) fewer cases of solid-waste accumulation and increasing awareness "from the outset" of the recovery and recycling values in such wastes.

There are undoubtedly problems that must still be identified. Broad programs of study are needed to define and evaluate all positive and negative factors -- the environmental pollution tolerance -- for particular projects in specific developing areas.

Relative Environmental Pollution Tolerance

The fact that one possible plant location may have greater or lesser capabilities to withstand the effects of environmental pollution has implications of obvious importance. Evidently, increased industrial activity in developing countries offers benefits in many directions: for the individual, dangers to health and a good life are minimized; for the community, problems of management and orderly growth are eased; for industry, an important charge on the cost of operations may be reduced. And, in the larger political and social area where the "established" nations and the "emerging" ones confront one another, the balance is drawn a little more even. A realistic means for measuring the relative environmental pollution tolerance for any country would therefore be useful, particularly for developing nations that might be candidates for one or more industrial enterprises, whether new or an expanded existing operation.

Such a procedure is suggested below. The method is largely subjective and approximate and is offered as a first step in calculating the EPT (Environmental Pollution Tolerance) for different countries.

It is proposed that Environmental Pollution Tolerance be defined by a numerical value determined by the sum of 7 individual factors, as follows:

EPT = (PD + PN + MET + WAT + AFP + VFP + TUR)

PD = Population Density: The national population divided by the area. Figures are readily available from standard sources such as the UN Statistical Yearbook. PD values drop as densities increase, the highest being placed at 15.

PN = Population Nodes: The number of cities with populations over 100,000. PN values are higher for regions with fewer nodes, up to a value of 10.

MET = Meteorological Condition: An estimated value that takes into account temperature range, wind conditions, rainfall, geography and terrain. Maximum values are set at 20.

WAT = Water Condition: An estimated value taking into account river systems, rainfall and snowfall, proximity to oceans, topography. Maximum value is set at 25.

AFP = Animal Food Production Potential (new): This represents additional capability to raise animal food stocks. It includes factors that involve pesticides, fume and atmospheric fallout. Low AFP values correspond to better EPT's. Ratings range from 0 to a maximum of 15.

VFP = Vegetable Food Production Potential (new): VFP's are similar to AFP. Maximum values are set at 10.

TUR = Tourism Potential: An arbitrary factor that reflects "beauty" and recreational factors. Maximum value is assumed at 5.

The combined values of the 7 components of EPT equal a maximum of 100. For some 70 countries tested, the EPT factor ranged between 55 and 84. The values for a selected group of countries listed in Table 6 illustrates the evaluation method. Of the 11 countries tabulated, those with the best environmental tolerance values with estimated ratings of around 80 are Brazil, Canada, Venezuela, Liberia, and South Africa; the lowest on the list are India(60) and Japan (59), both largely because of their high population loadings.

THE EVALUATION OF POLLUTION TOLERANCE

Table 7 includes the results of calculations for some 70 selected countries of various degrees of industrial development. The EPT values listed have been determined in the same manner used for the 11 examples in Table 6, but the details of the different components that add up to the pollution tolerance factors are not given. The ratings should, of course, be considered no more than relative measures of pollution resistance capabilities of different places when compared to each other, rather than absolute indications that any location in a particular country is "good" or "bad".

Within the broad latitude of that proviso, Table 7 could be said to suggest that most Latin American countries may generally be able to resist polluting contaminants more effectively than the Asian countries listed. Or, that many West European nations and a fair number of African ones have favorable EPT features at present. On the other hand, it would appear that the most highly industrialized countries; Japan, the U. K., West Germany, and the United States are less happily endowed in this respect.

TABLE 6

APPRAISAL OF ENVIRONMENTAL POLLUTION TOLERANCE FOR A SELECTED GROUP OF COUNTRIES - 1969

Country	PD (1)	PN (2)	MET (3)	WAT (4)	AFP (5)	VFP (6)	TUR (7)	EPT (8)
U. S. A.	10	8	16	22	6	2	4	68
Canada	11	8	13	22	12	6	5	77
Japan	3	3	16	18	10	4	5	59
Australia	15	9	12	16	4	8	3	67
U. K.	8	6	14	20	9	5	4	66
FR Germany	8	7	18	22	9	3	5	72
Brazil	14	8	17	20	10	4	4	77
Venezuela	14	7	16	20	13	9	5	84
India	7	2	13	18	7	8	5	60
Liberia	15	9	16	18	13	9	2	82
South Africa	13	7	16	22	11	7	3	79

EPT: (8) = (1) + (2) + ... + (7) = Environmental Pollution Tolerance

and,
PD = Population Density
PN = Population Nodes
MET = Meteorological Conditions
WAT = Water Conditions
AFP = Animal Food Potential (new)
VFP = Vegetable Food Potential (new)
TUR = Tourism Potential

TABLE 7

LIST OF ESTIMATES:CALCULATED ENVIRONMENTAL POLLUTION TOLERANCE FOR SELECTED COUNTRIES OF THE WORLD

Country	EPT
North America	
USA	68
Canada	77
Latin America	
Argentina	71
Bolivia	64
Brazil	77
Guyana	79
Chile	76
Colombia	71
Mexico	74
Peru	68
Surinam	79
Venezuela	84
Central America	
Costa Rica	62
El Salvador	65
Guatemala	65
Honduras	63
Nicaragua	67
Panama	71
Caribbean Area	
Dom. Republic	64
Haiti	66
Jamaica	74
Trinidad	68
Middle East	
Iran	69
Iraq	64
Israel	72
Jordan	70
Kuwait	68
Saudi Arabia	70
Turkey	72
Oceania	
Australia	67
Indonesia	61
New Zealand	72
Philippines	69

Country	EPT
Europe	
Austria	71
France	74
FR Germany	72
Greece	68
Ireland	74
Italy	72
Norway	80
Portugal	70
Spain	78
Sweden	73
U.K.	66
Africa	
Algeria	69
Angola	74
Ethiopia	63
Gabon	68
Ghana	70
Guinea	62
Ivory Coast	60
Kenya	76
Liberia	82
Libya	66
Mali	80
Morocco	70
Nigeria	64
So. Africa	79
S. W. Africa	70
So. Rhodesia	76
Sudan	67
Tanzania	79
Tunisia	71
AR Egypt	72
Uganda	74
Asia & Far East	
Afghanistan	67
Burma	59
Ceylon	60
India	60
Japan	59
Malaysia	61
Pakistan	55
So. Korea	63
Thailand	60

Where: EPT = Environmental Pollution Tolerance

Evaluation processes that involve component-summation almost always require a long period of time to establish a valid set of individual element coefficients. It is first necessary to postulate a group of factors that a reasonably representative section of the field will agree are, indeed, the key determinants of the phenomenon to be measured. Even then, the initial assumptions must be tested by actual experience and revised, if and as indicated. Such recalculations are frequently matters of many months and years.

The coefficient determination is complicated by the fact that the component-sum factors apply to large areas. For example, the United States or even the Republic of Mali cover expanses that are so extended that nearly any aggregated element factor may be challenged. Only after the coefficients have been repeatedly refined for many varied situations is it possible to deal with particular localities. This, too, may require much time.

This does not mean that the summation method should be discarded. Indeed, it may be the best, if not the only, way to understand the quantitative parameters of the condition under examination. What evidently is needed is some simple interim device that may be used while the comparative coefficients are being refined into broadly-accepted standard values.

Industrial experience can cite many examples of such interim procedures that are usually based on valid and long-used practices in the field. Thus, development engineers and economists are accustomed to straightforward processes of drilling, mapping and analysis to evaluate conventional steelmaking resources. These activities define the direct expense to be incurred in converting the resources to usable form. The valuation process is usually related to standards fixed for raw materials qualities, and is modified by formula to adjust for variations. For example, the information that the delivered cost of iron ore pellets with 64 percent iron, 6 percent gangue, and sized 99 percent at 10 x 13mm, is $18. per metric ton, is useful for the appraisal of a screened natural ore that contains 61 percent iron, 8 percent gangue, and ranges from 6 to 19mm in nominal size. Lacking an applicable formula, the price of a subject ore may be compared directly with that known for an ore of like kind and quality.

Similarly, it would be possible to develop a straightforward approach to the appraisal of the environmental resources at alternative sites. National or regional air and water quality standards would be used as a basis for comparison directly where these already exist, and by reference to requirements nearby, when they do not. Such standards are nominally referred to human, animal, and plant tolerance levels, all of which are more or less definite, and almost universally available as the results of publicly supported research in many developed countries. Standards will vary from place to place according to differences in the specific sensitivities of the local (human, animal, and plant) population.

The quality of the ambient air and water at any potential industrial site should be appraised, and the results compared with the established standards. This step consists of sampling and testing, coupled with rather simple meteorological studies of air flow and other pollutant-dispersal mechanisms that may occur regularly or seasonally. Such inquiries will usually yield enough data to establish the net tolerance for increased incidence of pollutants, and not dispersal rates in terms of new and larger flows of air and water.

As already noted, environmental-quality surveys for whole nations or regions are likely to be of limited usefulness. On the other hand, interactions between neighboring districts should be recognized. For example, prevailing surface winds from Chicago are known to carry the emissions from that city regularly to a large steel production district 40 miles away. The result is that there is a decided reduction in the tolerable level of new emissions that must be met by the steel plants in E ast Chicago and Gary, Indiana.

Many techniques for assigning valuation to environmental quality could be devised as an interim method.For developing countries, it will be adequate to fix valuations according to an arbitrary scale, for which the highest valuation applies to the most favorable combination of existing quality and dispersal capability, and the lowest to sites where either the background quality or dispersal characteristics are poor. Given the applicable reference data described above, the opinion of qualified impartial appraisers should be adequate to establish initial valid judgments of the environmental adequacy of a proposed industrial site.

Environmental pollution resistance, considered as a resource, can be a useful support factor for the industrial planner in reaching internal project decisions such as process choice, facility engineering, and selection and application of effluent and emissions controls. Increasingly, these controls are being demanded as assurance of environmental responsibility by authorities who approve project construction programs and the financing required to execute them. This procedure is designed to avoid overloading of the local environment by any project or group of projects. At the same time, it minimizes arbitrary demands for obligatory installation of controls that are fundamentally unnecessary. It does not make sense that a basic oxygen steelmaking shop located at Ipatinga, Brasil, should be as closely controlled as one erected near Pittsburgh.

Treatment of environmental quality as a resource suggests that the steelmaker who builds in a remote region may have some natural cost advantage over a producer who operates in a congested area. This is an entirely logical consequence of the fact that environmental quality is a scarce and unevenly distributed resource that has a very definite value that should not be disregarded. Like any other asset, that resource will be better appreciated and more effectively used when its value is clearly defined. The suggestions presented in this paper offer possible short-term and long-term paths to such evaluation.

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