CHAPTER 45

CONTROL OF INDUSTRIAL SOLID WASTE

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SCOPE OF INDUSTRIAL WASTE GENERATING ACTIVITIES

The Problem of Definition

In reducing to comprehensible terms the vast spectrum of residues of resource utilization which comprise solid waste, it is necessary to resort to some scheme of classification.

At the broadest level of definition, relating wastes to the general sector of human activity in which they originate has been the most common approach. Thus municipal, agricultural, and industrial wastes commonly appear in both the literature and the language of solid waste management as categories which by implication, at least, are essentially of the same order. That they are not in fact of the same order is of little significance when the primary concern is for municipal wastes. However, when industrial waste is the problem, some distinctions between the three classes must be clearly understood.

1. *Municipal Wastes.* The domestic and commercial activities which generate municipal wastes are characteristic of cultural and social patterns which are national in scope. Thus, with some variations in regional and climatological factors which result in ashes in one community and year-round grass trimmings in another, the term "municipal wastes" has an identifiable meaning without great refinement of definition.
2. *Agricultural Wastes.* In the case of agricultural wastes there is currently some confusion of definition. Some individuals still consider the term to include everything from crop residues left in the fields to animal manures and the residues produced in processing food and fiber grown on the land. However, much of agriculture is organized and managed in the same manner as are factories. Land is prepared, and many crops are harvested, with sophisticated machinery. Thousands of animals are concentrated in milk, egg, and meat production enterprises. The distinction between a processing plant utilizing farm products as its raw material and one processing crude petroleum, for example, is quite artificial. Therefore, except for plant residues left in the fields and animal wastes deposited in the pastures, it seems appropriate to include much of what is now classed as agricultural waste in the industrial waste category. In fact there is already a trend to consider animal manures as a source of industrial pollution.[1]
3. *Industrial Wastes.* Although, as previously noted, there is a certain logic in classifying solid wastes as municipal, agricultural, and industrial, the logic breaks down when control of industrial wastes is the problem of concern. Consequently, in terms of control there is no way to define "industrial wastes" in the context of the simple classification cited. It is everything that is not included in "municipal wastes" and a large percentage of what is included in "agricultural wastes." Therefore, it can best be isolated only in relation to certain types of human activity.

Nature of Human Activity Involved in Industry

The range of human activities which might be described by the word "industry" is so broad and varied that essentially the only thing all industries have in common is that they generate residues they do not want. Although in the aggregate these unwanted residues comprise industrial solid waste, no one approach can resolve the waste control problem it presents, for the simple reason that there is no single identifiable problem. There are, however, types of activity which generate broad types of industrial solid waste problems, each amenable to some typical approach although not to a universal solution. For the purpose of this discussion these activities are divided into three classes: 1) extractive industries; 2) basic industries, and 3) conversion and fabricating industries.

Obviously these three classes are not mutually exclusive. Processing, for example, may be a feature of any type of industry, but each class has identifiable characteristic waste generating features which differentiate it from the other two.

INDUSTRY AS A GENERATOR OF SOLID WASTES

Extractive Industries

The normal concept of an extractive industry is, as the name implies, one in which raw materials are taken from the earth and marketed in essentially their original state with little or no value added by manufacture or processing. Consequently it is to be expected that the solid wastes generated by such industries are but components or products of the earth. Four extractive industries, namely mining, quarrying, logging, and farming are of particular significance as generators of solid wastes. A fifth, the petroleum industry, is a major contribution to industrial solid waste problems, but not in the extraction process itself.

1. *Mining.* In terms of the quantity of solid wastes generated, mining probably exceeds all other industries, estimates ranging as high as 1.6 billion tons per year.[2, 3] Shaft and tunnel mining of coal and metal ores necessitates bringing to the surface large quantities of earth materials associated with the particular mineral sought, or overlaying it. Convenience, economics, and sheer weight and volume of materials dictate that these tailings be discarded near the mine head. Thus the major waste problem is fundamentally the local creation of an extremely large pile of inert material which is usually unsightly, destructive of the land resource it occupies, and may contribute to water pollution by leaching over a long period of time. Sometimes this waste pile is a menace to human life as well, as a result of instability due to fine particles, which may run as high as 40 percent.[2] A notable example is the 1966 tragedy in Aberfen, Wales, where 150 persons (mostly school children) were killed by a slide of an 800-foot-high pile of coal mine waste.

   Mine tailings are proving to be stockpiles of valuable resources, albeit by inadvertence rather than design.[2, 4] A major example is the early discarding of tungsten and vanadium ores in iron mining operations. When later a use was found for these metals, more wealth was extracted from the waste pile than was originally generated from iron. However, this secondary extraction did little to diminish the size of the original heap of wastes.

   Concentration of solid wastes often occurs at locations which are relatively close to the mine where crushing, flotation, and other processing of ores is essential to the extraction process. Such secondary waste concentrations are generally smaller than those at the mine head but they are by no means insignificant in volume. For example, about 1.3 tons of wastes are generated for each ton of pelletized iron ore processed.[5] However, they still represent materials taken from the earth's crust and simply relocated and concentrated on the land surface.

2. *Quarrying.* Quarrying is often classified separately from underground mining. Open pit, or strip mining and the quarrying of glass sand, stone, and sand and gravel are typical of this type of extractive industry. In comparison with other types of mining, sand and stone quarrying displaces and concentrates smaller amounts of unwanted materials (approximately 0.5 to 5.0 percent).[6] Otherwise the solid waste problem is the same; i.e., inert earth materials piled on the surface. Although quarrying wastes may be deplored by citizens on the basis of effects on nearby property values, or of aesthetics or other emotional response, quarrying is more an environmental problem of noise, dust, traffic, and aesthetics than one of solid waste generation.

3. *Logging.* As a generator of solid wastes the harvesting of timber differs from mining and quarrying in that its residues are organic. Hence, in a matter of years rather than of geologic time they are returned to the soil by the biochemical processes of nature. It is estimated that traditional logging procedures leave in the woods some 30 to 40 percent of the original weight of the tree, or about one ton of debris per 1,000 board feet of logs harvested.[7] As a solid waste problem this material is scattered over a wide area, is unsightly, constitutes a fire hazard to the forest, may be a reservoir of tree-destroying diseases and insects, and represents a wastage of natural resources.

4. *Farming.* The solid waste generating aspects of farming include both plant and animal wastes, the estimated per capita production averaging 43 to 60 lb./day.[8, 9] Plant residues of significance include unharvested or unharvestable crops, vines, straw and stubble, and orchard prunings. Here a variety of solid waste control problems accrue largely as a result of air pollution and other environmental considerations. Unfortunately, burning of certain seed grass stubble is necessary to control plant diseases. Straw and stubble plowed into soil increase the cost of nitrogen fertilizer to offset the carbon surplus. Unharvested products such as melons and tomatoes produce unpleasant odors and may attract insects and rodents. Tree prunings are both a physical problem and a reservoir of crop and tree-destroying pests if burning is not allowed. Burning of sugar cane remains an economic and technological necessity in eliminating leaves prior to processing.

   Disposal of manure and dead fowl constitutes an extremely difficult problem to the poultry and egg production industry. Although the wastes are organic and capable of incorporation into soil by natural processes, they are concentrated in location, 10,000 to 100,000 birds being housed in a single location. Moreover, they are aesthetically objectionable, uneconomical to collect, and unwanted by agriculturists. The same situation exists in dairy and animal fattening installations, the latter of which involve as many as 20,000 animals in a single operation and may soon involve 100,000.[1] Concentration of decomposable wastes, pollution of water, fly production, aesthetics, and economic and technological problems of collection and disposal are among the solid waste problems generated by animal husbandry as an extractive aspect of the farming industry.

In evaluating extractive industries as generators of wastes, the four examples cited have several things in common. They concentrate wastes at specific locations on the surface of the earth; the wastes are normal products of the earth and its living things; and they do little to multiply the basic value of the product. They differ, however, in nature, some being inert materials whereas others are biodegradable organic matter. Consequently, no single approach to solid waste con-

trol can overcome the problems man associates with the wastes of extractive industry.

Basic Industries

For the purpose of this analysis, basic industries are considered those which take raw materials from extractive industry and produce from them the refined materials which other industries convert into consumer goods. Basic industries differ from extractive in several ways, the most significant being in the value added by manufacture.

Products of the basic sector of industry are such things as metal ingots, sheets, tubes, wire, and structural shapes; industrial chemicals; coke; paper and paperboard; plastics materials; glass; natural and synthetic fabrics; and lumber and plywood. From the farming industry there is a tendency for fiber to go into basic industry, and food to conversion industries or directly into commercial channels. Exceptions might be the hulling of rice and the production of raw sugar from sugar cane, although these two might better be classed as conversion industries.

The solid wastes generated by basic industries may be said to differ from those generated by extractive industries in three major aspects: They are more diverse in composition; they differ markedly from the normal mineral and plant residues found in nature; and the industry itself generates a fraction of its own wastes. The solid waste generated by any type of industry in its business offices is, of course, considered a part of the normal commercial component of municipal wastes.

Eight basic industries are perhaps the major generators of solid wastes in their class: metals, chemicals, paper, plastics, glass, textiles, wood product, and power.

1. *Metals.* Blast furnace slag and ashes from the smelting of iron ore probably rank second only to mining wastes in volume of waste produced by industry. Slag produced in steel production is estimated to be more than 1,000 tons per day per furnace, or about 21 percent of the steel ingot production[10,11]. Similarly, the smelting of copper and the production of aluminum result in significant amounts (more than 5 million tons each in 1965)[10,12] of waste materials essentially of an inert nature, although subject to leaching if carelessly discarded in the environment. Like extractive industry wastes, basic metal wastes are concentrated at the points of generation. Here, however, the similarity begins to lessen. Mining wastes, for example, tend to occur in areas remote from any community which does not depend almost entirely upon mining for its livelihood. In contrast, smelting is more likely to be done in a community which through the years has diversified until it harbors many diverse urban interests. Thus both the physical freedom to create a large pile of slag at the smelter site and the willingness of people to accept it, become serious aspects of the problem of control of solid wastes from the metals industry.

   At the second level of the basic metals industry, where ingots are formed into shapes, smaller amounts of mill scale and spalls characteristic of the metal being processed appear as solid wastes. At this level of industry new types of solid waste appear: trimmings from the product itself; residues from the on-site use of other refined products associated with the process (e.g., lime sludges from the neutralization of spent pickling liquor); and miscellaneous wastes from the handling and shipping of the item produced.
2. *Chemicals.* For variety of wastes the chemical industry exceeds all other basic industries and generates some of the most economically and technologically difficult problems of solid waste management. The nature of these problems in any particular chemical plant, of course, depends upon the processes and the products involved. Producers of less exotic materials such as portland cement, carbon black, and lime have tended to locate in areas remote from urban communities. Their principal solid wastes have been air-transported particulates, deposited over a large downwind area, plus ashes and mineral residues accumulating at the plant site. In contrast, such industries as petro-chemicals have generally located in urban centers or have been overrun by urban expansion. The same may be said of producers of sulfuric acid, fertilizers, and many other basic chemicals.

   The range of waste materials generated by the more complex chemical industries is too extensive to catalog in detail in this summary. However, it includes off-specification material, tars, process sludges, and a vast variety of chemical residues. Although roughly one-third of industrial wastes are generated by the chemical processing industries,[13] the wastes are significant because of their particular chemical properties and their environmental effects.

   Generally, solid wastes from the more sophisticated chemical processes are generated in a liquid stream which, in many cases, has been discharged to the ocean or to surface streams, or injected into deep underground strata. Nevertheless, some are generated directly in the solid state. These include chemical residues, precipitated sludges, and the miscellaneous refuse associated with the import of necessary processing materials and shipment of the finished products. In the environmental climate of the 1970's an increasing fraction of air-borne particulates and water-borne process brines and sludges will have to be collected as solids and controlled by solid waste management techniques.
3. *Paper.* Although much public attention has been directed to paper as a waste material, most of the problems associated with its original production have been in the context of water pollution rather than solid waste control. As a generator of solid wastes the production of paper and paperboard is similar to other basic industries in that residues of materials used in the process and residues of the product itself must be dealt with. In the first category

are such things as tree bark, wood fiber, paper pulp, and inert filler, which are not difficult to remove from transporting water; and process chemicals and wood extractives which can be isolated as solids only with difficulty, at considerable expense. As in the case of basic chemicals, both components of this first category of residues are destined to be controlled as solids if they are allowed to become wastes.

The second category of wastes — residues of the product — consists primarily of trimmings of paper or paperboard, plus wastage occasioned by malfunction of the processing equipment. Much of this material may be reprocessed; some may be incinerated or deposited in landfills as are similar residues from the paper fabricating industry and from commercial and domestic sources.

The total volume of solid waste produced by the basic paper industry, although not insignificant, is not as much of a management problem as is the separation of dissolved solids from liquids in the waste stream which has historically been a water pollutant.

4. *Plastics.* In the case of plastics, the residues associated with production of the basic material are essentially a problem of the chemical industry. Much of this material then goes directly to the conversion and fabricating industries, but some is converted by basic industry into sheets and other forms used by fabricators. Wastes from this segment of the industry are largely trimmings from the product itself. No estimate is available of the amount of such solid waste, but it is undoubtedly only a small fraction of the overall plastics disposal problem of a community.
5. *Glass.* Solid wastes generated by basic producers of glass include slag from the purifying of glass sand, plus miscellaneous containers and residues from products used in coloring and laminating glass, cullet (glass fragments) from breakage during manufacture and trimming of sheets, off-grade, resin coated fibrous glass, and residues from on-site crating of glass for shipment to conversion and fabricating industries. Except in situations where cullet of various colors becomes mixed, the major fraction of solid waste from the basic glass industry is reused and hence does not appear as a waste requiring control measures.
6. *Textiles.* Basic textile industries vary in the nature and spectrum of solid wastes generated, depending upon the type of material being processed. Trash from the ginning of cotton may be generated at the extractive industry level or as an intermediate step between extractive and basic industries. It is a fraction of the original cotton plant and is generally concentrated as a waste in comparatively small fractions of the total at a number of dispersed locations in cotton farming communities. Wastes specifically characteristic of the cotton textile mill are more commonly such things as strapping and burlap used in baling, plus comber wastes and fibers damaged during storage or shipment which are generally reutilized in the industry.[14]

   Linen textile manufacturers likewise must dispose of plant residues and materials used in shipment of the raw flax. Fiber, twine, dirt, and wool fat characterize the wastes from preparing wool for textile processing. In addition to waste fibers, synthetics generate special wastes in the form of containers used in shipping chemicals from the basic chemical producers.

   Residues from spinning, weaving, and trimming operations occur with all types of fabrics. Dye containers and residues from on-site preparation of cloth for shipment are a fraction of the overall solid waste generated by the basic textiles industry.
7. *Wood Products.* Tree bark, sawdust, shavings, splintered wood, and trimmings constitute the major solid wastes of the lumber producing industry. In weight they amount to some 10 percent of that of the original tree in the forest, or about 1.26 tons per 1,000 board feet.[15] Conversion of wood to plywood sheets contributes plywood trimmings, knots, and glue containers to the overall solid waste of the wood products industry at its basic level. Wood ashes are typical wastes of this industry as a result of on-site burning of wastes for power production or to dispose of sawdust and other wood wastes.

   Typically, sawmills are located in smaller communities and are notable for their untidy appearance. Broken cable, discarded machinery, and miscellaneous debris often characterize the environment of a wood processing plant, albeit out of scale with the amount of such wastes generated.

   Air pollution and aesthetic considerations may be expected to intensify the solid waste control problems of the basic wood products industry as particulates now discharged to the atmosphere by burning become converted to solid wastes in response to restrictive legislation.
8. *Power.* Fly ash, bottom ash, and boiler slag accompany the production of power by burning of coal. Production of these three wastes by the U.S. power industry in 1969 was 21, 7.6, and 2.9 million tons, respectively.[16] Often such power plants are located in metropolitan areas, hence the objection to air-borne fly ash, dust, and ash heaps confronts the power producing industry with solid waste problems. Where high ash coals are utilized, the volume of ashes and clinkers may approach that of the original coal consumed, although, of course, its dry weight is generally appreciably less than 20 percent of that of the coal from which it was derived.

As generators of solid waste, basic industries such as those herein cited have several things in common. With few exceptions, they draw upon more than one extractive industry for raw materials; a fraction of the raw materials they refine appears as a solid waste; they utilize refined products of

other basic industries and of conversion industries, importing in the process things such as shipping containers which become wastes for which they must assume responsibility; a fraction of their own product must be handled as a waste; and a considerable value is added by manufacture, or processing by the basic industry. In comparison with a purely extractive industry, a basic industry produces more categories of solid waste, some of which it can recycle directly in its own processes. However, in comparing one basic industry with another, the things they have in common are not reflected in any similarity of waste generated. Hence no common approach to solid waste control characterizes the problem of basic industries.

Conversion and Fabricating Industries

It is beyond the scope of this chapter to attempt any listing of the myriad enterprises which convert the products of basic industry into the goods which characterize our economy and our standard of living. Value added by manufacture is a maximum in the conversion and fabricating industries. As generators of solid waste, such industries also have many things in common. Particularly significant is the extent to which the output of one type of industry comprises a combination of raw materials and solid waste for another. For example, one modest sized industry engaged in converting plate glass to windows and mirrors in the Los Angeles area estimates its cost of disposing of crating materials received from its suppliers at one thousand dollars per month.

A second common characteristic of the conversion and fabricating industries is that residues of the basic materials they utilize generally constitute the greatest fraction of the waste they generate. Moreover, unlike a basic industry which may directly recycle the trimmings and rejects of its own product, the conversion or fabricating industry must rely on some secondary enterprise to take such of its residues as are reclaimable. Thus broken glass, metal trimmings, imperfect castings, and similar salvable residues can seldom be utilized directly by the conversion industry which generates them.

To illustrate the type of solid waste problems associated with the conversion and fabricating industries, such broad categories of industry as packaging, automotive, electronics, paper products, hardware, soft goods, food processing, and construction may be cited as typical, though by no means all inclusive.

1. *Packaging.* For the purpose of this summary, production of packaging materials is classed as basic industry, hence only the conversion of packaging materials to containers is considered. However, the scope of this sector of the industry is itself extremely broad and varied as regards the nature and resource value of the waste it produces. Aluminum, steel, glass, plastics, cardboard, corrugated paperboard, plastic-paper laminates, and paper with or without any of a broad range of coatings are among the materials used by the container industry. Whether or not an appreciable number of these items appear in any industrial waste stream depends, of course, upon the range of activities engaged in by a single company or plant. Recoverability of residues often depends upon the cleanness and uniformity of the waste material. For example, conversion of glass to containers generates an appreciable amount of cullet; however, whether this is recoverable or useless, generally depends upon the extent to which colored and clear glass is mixed in the waste. Nevertheless it may be said that, at the industrial level, wastes from the packaging industry are primarily fractions of the material converted, although the range of possible materials is unlimited.

   A secondary waste of any individual packaging plant is packages passed along to it by its suppliers, together with residues on its own on-site shipping preparations.

2. *Automotive.* There are two major waste-generating sectors of the automotive industry. One makes and ships specialty components; the other assembles the components into a finished vehicle. Conversion and fabricating industries in the first of these categories produce such things as tires, generators, carburetors, radios, speedometers, wheels, bumpers, hub caps, lamps, bearings, and other of the dozens of systems or devices that go to make up an automobile. In each of these the solid waste generated is a function of the special activity of the individual industry, and comprises residues of the materials used and the packaging received from suppliers.

   Painting and upholstering of automobile bodies adds both container and material residues to the solid waste stream of the manufacturer. However, by far the greatest component of the automobile assembly plant waste is the discarded packaging and shipping materials associated with the delivery of components from other industrial suppliers. In fact, there is probably no other sector of industry which compares with automobile assembly in the amount of solid wastes it inherits from its relationship with other industrial activities.

3. *Electronics.* Like the automotive industry, the electronics industry includes both a components and an assembly sector. Plastics, glass, wire and sheet metal scrap and residues of a variety of other basic products appear as solid waste of the many industries associated with production of electronic components. However, in comparison with the waste from most other conversion and fabricating industries, the actual amount is relatively small.

   Packaging materials, particularly cardboard, corrugated paperboard, polystyrene foams, and padding materials utilized in shipping electronic components is the major waste generating problem of the assembly activity of the electronics industry. Shipping of the assembled equipment is generally in specially designed containers, the manufacturing wastes of which are ascribable to the packaging industry.

4. *Paper Products.* Conversion of paper into products used in commerce and by the public largely results in solid waste in the form of paper trimmings. Facial and toilet tissue, paper towels and napkins, and similar products yield a high quality waste which may or may not be salvable through a secondary enterprise, depending upon whether white and colored paper residues are mixed together in the conversion process. Conversion of kraft paper into bags, for example, yields a readily salvable waste. Publishing of books and magazines, which might be classed as a fabricating industry in the context of solid waste generation, is a major source of filled paper residues which are commonly disposed of as solid wastes.
5. *Hardware.* The term "hardware" rather than "hard goods" is used herein because the latter embraces many classes of basic as well as conversion and fabricating industries. "Hardware" is confined further herein to the metals industry which produces the machines and tools (with the exception of the automobile), and the utensils and gadgets used by all classes of industry and by the public. Solid waste from such hardware industry includes residues from boring and machining of metals; trimming and sizing of plates, tubes, and structural shapes; and miscellaneous residues from casting and forging processes. It also includes plating, etching, and similar liquid borne wastes which, like similar wastes from the basic chemical industry, must eventually be managed in the solid form.
6. *Soft Goods.* Conversion of such materials as textiles, leather, and plastics into articles of commerce constitutes the soft goods industry in the context of conversion and fabrication. As is characteristic of all industries in this classification, residues of the material processed represent the major item of solid waste generated, with incoming and outgoing goods yielding secondary wastes associated with shipping.
7. *Food Processing.* As a waste generating industry, food processing presents problems somewhat different from other conversion industries. Like extractive and basic industries concerned with material of plant and animal origin, food processing produces wastes which are subject to the normal recycling processes of nature. However, they are generated seasonally and in large amounts at locations which may be either urban or intermediate between farm and city. With the exception of a few residues such as rice hulls, food wastes are putrescible, attractive to insects, and occur in a semi-liquid or liquid state. Preparation of fruits and vegetables for canning yields a slurry of such things as leaves, soil, skins, peelings, pits, seeds, and cores, along with spoiled, outsized, and damaged fruit. In California alone this type of cannery waste totaled 750,000 tons in 1967.[7] Washing and cooking operations yield a companion stream of water-borne dissolved and suspended solids. Because of water pollution problems, these solids increasingly are being removed from water for disposal by solid waste management techniques.

   Processing of fish and animals for marketing or canning likewise generates putrescible liquid and semi-liquid wastes. The solids content of these waste streams, along with bones and other inedible fractions, are destined to be handled as solid wastes as water quality objectives become more restrictive.

   Because the food processing industry is linked directly to extractive industry without an intermediate basic refining, containers coming to the plant are reused in the fields and orchards. Furthermore, shipment of the finished product makes use of containers already prepared by the packaging industry. Consequently, wastes from the food processing industry are predominantly fractions of the material processed.
8. *Construction.* Among the most significant generators of solid waste is the construction industry. In its purely fabricating activities its waste products are typical residues of the materials it employs — lumber, plasterboard, wire, paper, cement bags, sheet metal scrap, etc. However, unlike other industries in the conversion and fabricating category, most construction wastes result from peripheral activities essential to its production phase. Demolition of buildings, breaking up of pavement, and preparation of site produce very large volumes of such materials as earth; rock; broken concrete, tile, brick, lumber, and plaster; tree stumps, poles, and piling; and miscellaneous rubble.

The eight foregoing examples by no means cover the full range of activities which might be classed as conversion and fabricating industries. They illustrate, however, that the wastes generated by this class of industry are primarily residues of the materials they process or convert into consumer goods, and that the measures necessary to move products from one sector of industry to another impose a secondary solid waste burden on the receiver. More important, it is significant that at this most complex level of industrial solid waste generating activity the value added by manufacture is greatest. This suggests that the economic capability of conversion and fabricating industries should generally be greater than that of a basic or an extractive industry as such. Moreover, conversion and fabricating industries tend to be activities of a diverse urban community. Therefore, social pressure for solid waste control can be expected to be exerted most heavily upon such industries, especially since their products, along with the associated packaging, constitute the major solid waste which the citizen himself ultimately casts off.

MANAGEMENT OF SOLID WASTES

Earlier in this chapter it was found convenient to arrange industry into three categories, each having specific waste generating characteristics. These categories were presented in ascending order of magnitude of value added by manufacture,

responsibility for creating wastes, and degree to which their activities are conducted in urban communities. To evaluate each category, and type of industry within that category, as a generator of wastes it was necessary to treat extractive, basic, and conversion and fabricating industries as discrete entities. In the real world of industry, however, these three may be only sectors of a single large industry which owns and operates every aspect from raw material source to the finished consumer product. Thus the conclusion that no common waste management technique is appliable to all types of industry in a single category, although valid, is complicated by the fact that industry may be stratified vertically along ownership lines as well as horizontally along functional lines. To get at the general problem of solid wastes management in such a complex situation, it is convenient to consider waste control approaches in relation to the source of solid wastes rather than the composition of the waste itself.

Disposal as a Condition of Production

The simplest situation in solid waste control applies especially to an extractive industry in which the feasibility of operating at all is contingent upon satisfactory control of its solid wastes. In such a circumstance a mining, quarrying, or logging operation might be undertaken by industry only when waste control is not an economically overwhelming consideration. Feasibility may, of course, be based on geographic or topographic conditions, property holdings, access, or regulation by public law or public policy. It does not necessarily imply environmental perfection, although there is a tendency (1971) for aesthetics to be given increasing weight where public interest or public opinion is a factor. Uneconomical conditions, whether natural or man-imposed in a wastes management context, generally have discouraged an extractive industry operating entirely on its own resources. However, in an industry which covers the whole range from extraction to conversion, extraction of raw material may well be operated at a loss in order to produce profits at the higher industrial level where value added by manufacture is sufficient to offset losses. Moreover, control of solid wastes by an industry of this sort may be subject to considerable upgrading in technique and cost without causing the system to fail economically. Nevertheless, in such activities as mining there is no choice but to dispose of wastes upon the land, albeit under conditions acceptable to society.

In the case of farming as an extractive industry, constraints imposed by solid waste management have seldom been insurmountable unless urban environmental conditions are required of the farmer. Generally, he is not part of an industrial complex which can take a loss continually at the extractive level. Thus if society asks too much in the name of solid waste control or other environmental context, the agriculturist, unless subsidized, ceases operations and converts his land to urban development.

Incidental Residues Produced By An Industry

As noted in a preceding section, processing, converting or fabricating activities within several types of industry result in slag, ashes, clinkers, and similar solid residues, as well as air-borne particulates or liquid carried process sludges, generated at the site of operation. For air and water-borne solids, control measures may include electrostatic precipitators, bag filters, wet scrubbers, sedimentation, chemical precipitation, or other conventional waste treatment processes. Disposal of bulky worthless solids involves simple deposition on the land in some location and under some conditions, acceptable to the public. More valuable incidental wastes may, however, be reclaimable or convertible to useful resource materials if the level of cost is acceptable. For example, about 14 percent of power plant solid wastes were utilized outside the power industry in 1969.[16] Other measures which may assist in controlling the residues produced incidental to industrial output may include such expedients as abandoning on-site generation of power, or making changes in process. Abandonment of an entire plant, especially one with obsolescent processes, is a measure sometimes taken by industry confronted with solid wastes which are a by-product of its fundamental processes.

Product Residues Generated By A Basic Industry

When refinement rather than conversion of raw materials is the goal of production, product wastes occasioned by spillage, breakage, or malfunction of process may be managed by direct recycling within the plant. The same is true of metal trimmings, cullet, and paper trimmings in industries producing metal, glass, or paper as basic products.

Residues From Materials Conversion Or Fabricating

Cullet, metal trimmings, packaging materials, and other residues resulting from the conversion of basic industrial products into consumer goods cannot be directly reused by the waste producer. To him they represent a solid waste, some of which might be salvaged or reused economically; some of which he shall have to pay someone to remove for disposal. Metal scrap, clear glass, and uncoated corrugated paperboard are typical of the material which might be returned to more basic industries for reprocessing. Similar trimmings from plastics, fiberboard, laminated plastic-paper, lumber, cloth and a host of other materials are generally useless and are relegated to the landfill or incinerator.

Waste From Interindustry Transfer

Packaging and shipping of basic materials or finished products, a necessary part of industrial activity, require that most industries accept various amounts of materials, which immediately become a waste, in order to acquire the materials necessary to their enterprise. Thus each industry helps to create a solid waste management problem for those with which it does business. In general, the waste-to-product ratio goes up from basic to conversion industry, reaching its maximum value at the conversion industry-to-consumer level. Most of the waste generated by interindustry transfer of materials and components is waste, although there

are instances where intra- or inter-industry practices work to hold down waste production. Where producer and fabricator are favorably located with respect to each other, such things as cable spools and protective packaging for television tubes are commonly reused repeatedly for their original purpose.

Special Problem Materials

Waste materials which present especially difficult problems of management at present (1972) include both natural and synthetic products. Organic wastes, particularly food processing wastes, are a nuisance because they are putrescible, whereas plastics are a nuisance because they are not. Process sludges of a wide variety of activity, ranging from industrial waste treatment to saline water reclamation, present an unsolved problem both because of their high liquid content and because they are so newly recognized as solid waste problems that no economic technology for converting them to drier solids has been developed.

CONTROL OF INDUSTRIAL SOLID WASTES

In the preceding section attention is directed to the internal management of solid waste generated at various levels in the industrial scale. However, to determine what methods of control are needed in solving the overall problem of industrial solid wastes, it is first important to understand the relationship of industrial practice to the generation of society's total solid waste problem.

To a significant degree it is true that the entire industrial effort of the nation is dedicated to the production of solid wastes. The product of extractive industry is the raw material of basic industry; and the product of basic industry feeds the conversion and fabricating industry. Each sector of the system discards what it cannot pass along to the next in line. Finally, the entire product of the conversion and fabricating industry becomes the solid waste of all sectors of society — industry, commerce, and citizens. The rate at which the overall system functions governs the economy of the nation and depends upon the acceptance of goods by the consumer at the top of the scale. This encourages industry to mistake the act of physical acceptance of goods by the citizens for actual consumption of these goods. The next logical step is to create through advertising a dissatisfaction on the part of the consumer so that he discards his purchases on the basis of obsolescence rather than loss of utility. Thus it is clear that quite aside from any question of whether industry is giving the public what it demands, or the public is accepting what industry persuades it to demand, the overall waste generation of the commercial and municipal sectors of society is a function of what flows from industry into these sectors.

Carried to its logical conclusion, this system would eventually convert all nonrenewable resources into discarded wastes unless reuse and recycling are a matter of industrial practice and public policy. Therefore it seems logical to conclude that public agencies, industry, and education of the public each play a role in industrial solid waste control.

Role of Public Agencies in Industrial Solid Waste Control

In the absence of any public agency concerned with overall environmental quality, solid waste control would be a problem of individual enterprises in specific locations rather than one confronting the entire sector of human activity loosely described as "industrial." Thus, for example, a mining operation with land area for spoils would have no disposal problems, whereas waste disposal might be the most compelling problem of a less fortunately situated operator. Without public constraints, wastes generated incidental to production, and residues of materials conversion as well, might be hauled to some public or private dump and so pose no problem other than that of cost to the generating industry. The same may be said of particulates discharged to the atmosphere, or of process brines and sludges discharged to the water resource.

Industry would, of course, share in any ultimate disaster that wastes might bring upon mankind, but in the interval industry's wastes like those of everyone else would react only to degrade the general environment. In such a situation, responsibility for deciding what sort of a world society wants accrues to the public; and implementing public goals is the function of public agencies. Therefore, some agency of the public must decide what constitutes an environmental problem, at what level the problem is to be tolerated, and what measures should be taken to alleviate it.

In the context of problems associated with industrial solid wastes public agencies play a role in four distinct areas: public health, environmental quality, resource conservation, and economics.

1. *Protecting Public Health.* The concept that industrial solid waste poses a threat to public health apart from that of municipal refuse is of quite recent origin. It developed from a realization that air pollution is a menace to human health and that industrial pollution of water has health implications beyond that of historical water-borne disease. Constraints imposed on industry in the interests of health of workers and citizens in general are, therefore, currently reflected in the concept that air and water pollutants should be separated from their transporting media and dealt with directly as solid wastes. As with municipal refuse, however, industry is expected to handle its putrescible organic residues in such a manner as to keep down insect and rodent vectors of disease.

   Thus, the role of the public health agency in industrial solid waste control is essentially regulatory.
2. *Attaining Environmental Objectives.* Environmental objectives which call for clean air, pure water, freedom from nuisance and affront to the aesthetic sensibilities of man, and a healthy ecological balance in nature are perhaps the major concern of public agencies in relation to industrial (and other) solid wastes. At the local level attainment of such objectives may be the responsibility of the health department, but at the federal level and in many

states protection of the environment is a role assigned to some agency with broader regulatory powers than the department of health. It is the role of this agency to determine where and under what conditions wastes may be deposited on land, burned, or otherwise disposed of by those who generate them. In carrying out this role the agency, in the long run, continuously must strike a balance between the environmental perfection desired by an emotional public and the industrial freedom considered necessary to an ever-expanding and changing civilization to arrive at a point at which environmental objectives are attainable at an acceptable reduction in our level of civilization.

3. *Implementing Resource Conservation Policies.* Resource conservation is a matter of public concern which has been assigned to numerous agencies with various powers and specific interests for more than half a century. In relation to solid waste, conservation has been interpreted[17,18] in terms of both land resources and the value of resource materials in the solid waste. Thus, a public agency, alone or in concert with other public agencies, might decree in one case that a spoils dump or a slag heap in a certain location would be destructive of a land resource either by physical occupancy of land or by environmental degradation. In another case the conclusion might be that a properly constructed landfill in a particular location would create a new land resource.

   Concern for the resource value of residues such as glass, metal, and paper wastes from the conversion and fabricating industries might lead a public agency to any of several alternate decisions. For example, the decision might be that enhancement of land resources is important enough to justify sacrificing resource residues as landfill material. In contrast, there might be reason to decide that resource residues should be stockpiled in a fill for reclamation at some future date; or that they should immediately be recycled in the interest of resource conservation regardless of cost.

   Both the multiplicity of public agencies having interest in land use and in resource conservation, and the scope of possible policy decisions, gives the public agencies a broad and flexible role in determining the conditions industry must meet in managing its solid wastes.

4. *Overcoming Economic Constraints.* In the matter of economic constraints, public agencies may play either of two important roles. They may force industry into actions regarding solid waste control previously thought to be too costly by regulatory actions directed to resource conservation, environmental quality, or any other objective. At the other extreme, they may establish economic incentives for action by industry.

   It is not likely that regulation of what conversion and fabricating industries must do with their solid wastes will be a deciding factor. Instead, a requirement that resource materials be recycled will strike at the consumer-waste hinge of the system and so feed back through the entire industrial equilibrium. That is, it will change the kind of materials required by the conversion industry and, consequently, what basic industry produces and what amounts of specific raw materials are extracted.

   In the matter of economic incentives, tax breaks or tax penalties,[19] demonstration grants for exploring new processes, direct subsidy of recycling, and equalization of freight rates for new and scrap metal* are examples of actions which might be taken by public agencies under appropriate public policy. The result might be both a change in the nature of solid waste generated by industry, and in the ultimate fate of such wastes.

Role of Industry in Industrial Solid Waste Control

Because industry accounts for a very large fraction of the total solid wastes of society and the processes by which many wastes are generated are proprietary to industry, it is logical to expect that industry should play a significant role in the control of its wastes and, consequently, of the total waste load upon the land.

The Matter of Options. If all discarded material is considered as waste, the mining and basic metals industries appear as the major source of industrial waste. To deal with such things as mine tailings and blast furnace slag, however, man has few options. Thus at the lower end of the scale the role of industry in solid waste generation is relatively fixed. Similarly, the small value added by processing at the extractive level limits feasible disposal methods, unless higher levels of industry or government subsidize waste control.

Further up the scale, however, such rigidity no longer pertains. The material to be used for any given purpose, as well as the resulting waste-to-product ratio, is a function of the inventiveness and ingenuity of man. Competition for markets encourages the producer of consumer goods to use that ingenuity in finding better processes and cheaper materials and production methods. Constraints imposed by public policies concerning resources, environment, and waste management may likewise react to this same end. Therefore, at the higher end of the scale the role of industry in the overall waste problem is not fixed by circumstance.

Reducing the Amount of Waste. Better processes and cheaper materials do not lead necessarily to a lesser amount of wastes generated. In fact, it is possible that quite the opposite might result. Therefore, industry's role in controlling the amount of solid waste society generates is one of looking to its own design and materials selection activities with consideration for the final disposition of its product in the environment.

The concept that purchase is synonymous with consumption of goods leads logically to a limitation of the objectives of design to such traditional factors as ease of manufacture, saving in cost of fab-

*In Minnesota the 1970 freight rate for scrap was $4.25/ton as contrasted with $1.84 for raw material.[20]

rication, appeal to the buyer, novelty, and obsolescence. Responsibility for solid waste control and for resource conservation, however, now requires that degradability of synthetic materials, ease of dismantling for segregating component materials, minimum number of types of material, and other materials recovery considerations or disposal objectives be among the specifications designers should seek to meet.

Role of Public Education

It is particularly important that people understand the inter-relationships within industry and the dependence of our level of civilization upon industrial activity.

An informed public plays an especially significant role in the control of industrial solid wastes, both because public opinion is respected by industrialists and because public attitudes are the basis of policy legislation which creates the institutions which carry out public policy. Public education is both important and urgent at such times in history as the 1970's when prophets of doom abound, and citizens are bombarded daily with propaganda and with naive and simplistic answers to complex environmental problems.

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Recommended Reading

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4. *Solid Waste Management-Refuse Removal Journal.* 150 E. 52nd Street, New York, New York 10022 ($6 per year).
5. *Compost Science-Journal of Waste Recycling.* 33 E. Minor Street, Emmaus, Pennsylvania 10849 ($6 per year).
6. *Chemical Engineering.* 330 W. 42nd Street, New York, New York 10036 ($6 per year).
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