WASTE MANAGEMENT AND MINIMIZATION

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Summary

Waste management is universal. Every instance of human civilization has had to deal with its waste. The more complicated societies have become, the more extensive and complicated their waste issues. The need has existed throughout history, and exists today entirely independent of part of the world or socioeconomic standing. Furthermore, as human population continues to grow, and all persons seek a standard of living equivalent to that afforded developed countries, waste generation continues to grow in total tonnage, and as a global issue.

The very existence of waste comprises a loss of a resource to the economy: through a

combination of factors, that resource has ceased to have intrinsic value, and has therefore assumed a negative value to its owner. That cost is a market externality, not found in analysis of the market economy. If disposal of that waste is permitted, the resource is scattered over the Earth's surface, rendering it virtually impossible to recover over generations.

The first need is waste reduction, which requires an alteration in industrial policy, and corporate and citizen practice. In the foreseeable future, there will still be material that is no longer useful to its current owner, and therefore is waste, perhaps better characterized as a residual resource. A waste comprises a loss to the resource economy. It is therefore a financial burden, and a potential threat to the environment and public health; those two factors are not separate.

Since the Second World War, the only new industry developed from virtually nothing has been the computer industry. Today, a similar intense need exists for the development of an industrially-efficient approach to integrated waste management. The apparent barriers are that waste has a history of crude management best kept hidden, and that it has, in this century, been primarily the province of local government. Technical opportunities are limitless, and must be explored, developed, and implemented. These exist in the home, throughout all walks of business, in collection, in treatment and disposal, and in processing.

1. Introduction

Waste is ubiquitous. It is everywhere humans are. Waste is the most heterogeneous material in existence: it must be, as it contains everything else. Even very solid-seeming buildings can easily be turned to rubble by natural disasters; that rubble is waste.

Waste is any type of material that is perceived as no longer useful by its owner. Sewage is properly called "waste-water." Solid waste is a no-longer useful material that, for a variety of reasons, is considered non-aqueous. In some regulatory structures, sludge resulting from sewage treatment is considered solid waste, simply because it cannot be further processed as a wastewater, and is managed like municipal waste. Municipal solid waste, while it may have water content up to 50% by mass, comprises materials that are mostly non-liquid, even if of high moisture content.

Many terms have evolved over the years to describe waste streams. Municipal solid waste (MSW) may be divided into residential waste; industrial waste from manufacturing operations; commercial waste from businesses such as banks; medical waste; yard waste from gardens; food-service waste from restaurants and cafeterias; construction and demolition debris; litter, and institutional waste arising from schools and the like. Historically, homes were heated with solid fuel such as coal and wood, and many apartment or rural residences burned their MSW, giving rise to ash as a waste stream. Ash no longer comprises significant fractions of waste streams, but those investigating old landfills must be prepared to encounter substantial amounts; older citizens may refer to a garbage can as an "ash can." MSW is also known as refuse. Often, the word garbage is used to refer to putrescible waste, in contrast to trash, which is everything else in the waste stream. The trash component is considered to contain the majority of recyclable materials. Recyclables are materials collected for potential recycling, although those carefully following the fate of waste must account for the residue stream from recycling operations. Categories have also arisen to describe wastes with special characteristics, such as white goods, which are larger home appliances, and brown waste, which comprises electronics such as computers and small appliances.

The sections below provide an overview of the aspects of waste management that make it interesting. As an integral part of human activity, it is an aspect that grows as human activity grows. Proper management and control are key components to sustainable development.

2. History

Waste has been an integral consequence of human existence since its beginning. Due to its inherent unpleasantness, societies have often created repositories for their waste. As that waste contains everything the society used that has worn out its welcome, and therefore comprises a record of activity, it is of great interest to archaeologists and anthropologists. Rathje, of the long-running "Projet du Garbage" in applied archaeology at the University of Arizona is fond of saying that he studies the same thing as all other archaeologists; his is just a bit newer. In primitive societies, the distinction between waste and sewage was not observed; cesspits could be expected to have experienced degradation of their organic content over the millennia, leaving non-degradable materials behind for the archaeologists.

Persons in the current era are often surprised at the sophistication of ancient civilizations' management of solid wastes. As far back as 2500 BC, in the Indus Valley of India, homes had built-in trash chutes and containers. Often, actual collection trash was left to the private sector: scavengers, in particular. Clearly, if one were an independent scavenger, one would do better serving areas where waste would contain more salable materials; hence, wealthy areas were better served. For the Jews, Moses' laws required all Jews to take responsibility for removing and burying their waste; the Talmud required daily street washing, which is clearly not easy in the desert. Athens was surrounded by municipal dumps, which, though apparently vile, comprised coordinated disposal. Chinese records dating from 200 BC indicate that modern astonishment at the need for sanitation police is misplaced: such police existed at that time to enforce cleaning.

Rome was one of the more modern, large, and dense cities with records. In the first century AD, Rome's administration included all modern municipal services, including water, wastewater, and waste. Rome, too, had laws requiring personal responsibility for proper waste disposal. However, Rome's size and density led to such an uncoordinated system's falling short of the need. Continuing to follow documented Western history, the disappearance of the Roman Empire led to migration of the population towards a more agrarian existence. Cities, in effect, had to be re-constructed. As Mediaeval cities grew, agricultural persons brought their habits, and livestock, into the cities. Pigs, especially, then comprised an automated scavenging system. Gradually, attention had to be re-applied to waste management. In the fourteenth century, England passed a law against improper waste disposal. Paris eventually required that waste be taken out beyond the city walls; clearly, the citizenry took a minimalist approach, depositing waste as close to the walls as possible. In thereby reducing the effective height of the walls, waste compromised Parisian defenses!

Despite the Mediaeval and Renaissance health problems, the modern era of difficulties in waste management had to await the Industrial Revolution. The fact that the nature of threats to public health and livability posed by waste management was significantly altered by the Industrial Revolution makes clear that solid waste is integrally-tied to the consumption of resources by modern society. True industrial development means accelerating production efficiency; more and more people are able to afford and use more and more resources. Both the production of those resources, and the fate of manufactured products, produce solid waste. It is estimated that the lower part of Manhattan Island, the oldest part of New York City, is up to 2 m deeper than it was originally due to deposition of the detritus of human activity. Thus, life in some sections of cities became truly horrific in the nineteenth century, as painted by Charles Dickens.

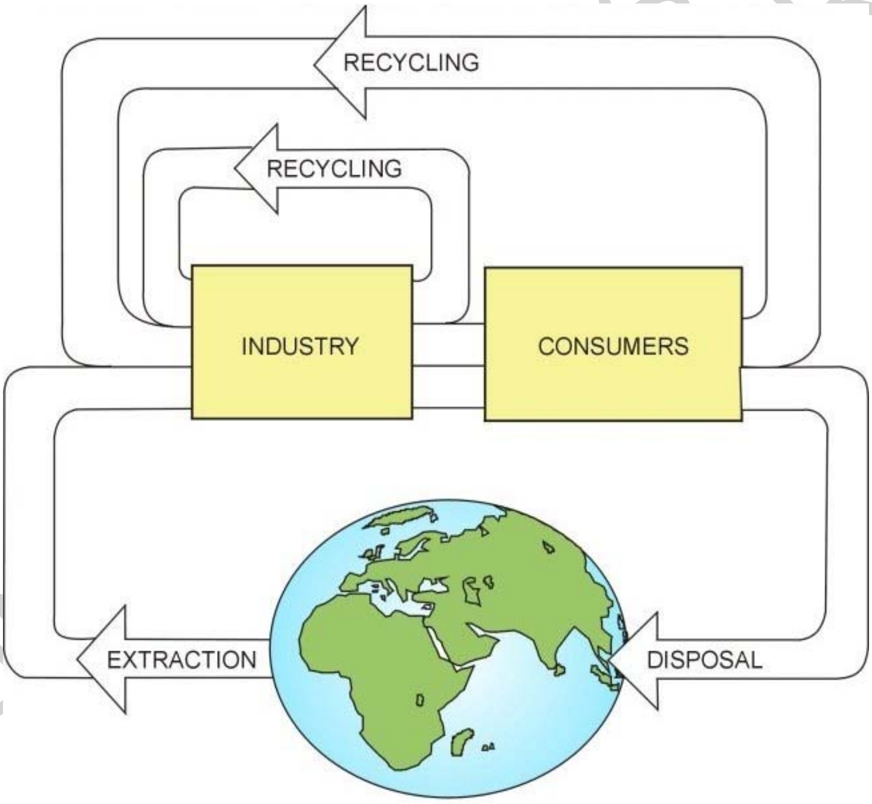

Figure 1. Cycle of Resources

In these areas, sanitation of all types was non-existent. Two factors fundamentally altered waste management: (a) the wealthy were not immune from the effects of the filth; (b) the amount of waste simply exceeded the ability of individual citizens to take full responsibility. Industrialists going to their factories had to pass by their workers' domiciles; it was not conceivable that hundreds of thousands of London residents would take their wastes out of the city every day. It is an interesting historical note that urban officials had determined that sanitation was critical to public health before ever the germ theory of disease was developed: needs must! There began the era of centralized, municipal waste management.

The biggest advance in modern resource management was municipal waste collection, which relieved the citizen from an impossible chore, and greatly improved the efficiency of waste management. Waste could be burned, in pits or crude incinerators, following which the ashes could be buried. Alternatively, wastes could be directly buried. Either way, burial comprised the ultimate fate of waste. Combustion close to the source greatly reduced the volume to be hauled to the burial site, resulting in domestic and building incinerators, which contributed greatly to air pollution. Burial, until only a few decades ago, comprised dumps: local geographic depressions, small valleys, disused mines, or wetlands were all candidates. As an illustrative example, of the City of New York's current geographic extent, land equivalent to the area of Manhattan Island was "reclaimed" from surrounding waters by waste landfilling. First, the need to improve combustion and disposal practices, followed by a recognition among advanced thinkers that waste comprised disused resources of potential value, led to engineered waste control objectives of the modern era.

3. Resource Economics

The processes in the Earth's crust, through geologic time, result in depositions of concentrated resources. Effects of heat, pressure, water, and time produce deposits of mineral and petroleum resources. While small amounts of all minerals are found throughout the Earth, to a remarkable extent, resources are concentrated in geographic scale. Bauxite, the fundamental source of aluminum, is heavily concentrated in South Africa and Russia. It is common knowledge that some areas of the globe are oil producers, and others are not. The cycle of resources begins with extraction from the Earth.

At its most fundamental level, economics comprises two factors: land and labor. Labor indicates all the transformations that result from human action; those transformations are affected on resources that derive from the land. In an industrial economy, humans extract resources from the natural environment, process them to extract desirable components, and use those components to produce salable goods. People thus devote labor to extracting a resource from the environment, and adding economic value, whereafter the goods produced may be sold at a net profit. Industrial activity, preparing resources to be sold to the public, is shown in Figure 1. To a remarkable extent, these steps comprise modern economics. Many products comprise numerous resources combined, interwoven, bonded, and otherwise mixed.

A good definition of waste is that of a material that has lost value to its current owner. A consumer will buy a product; after a certain amount of use, for one or another reason, the product will no longer be useful to the owner. The consumer has derived her or his value from the product; in continuing to buy the product, the consumer indicates that she or he has derived the economic return expected, for which payment was made. However, in falling to zero value for the consumer, the product turns into a liability. Its value passes zero, and becomes negative, because the consumer must now pay for the product to be disposed. In a sense, waste disposal means returning resources to the

Earth, again as shown in Figure 1. Proper waste disposal is generally undertaken to reduce environmental damage. Damages cost money. The consumer can directly pay for more sophisticated waste management options that better protect the environment, or manage the waste poorly, whereupon the cost is expressed in terms of environmental damage. Costs of environmental damage are borne by society in general. Either type of cost: waste management costs paid by the consumer, or environmental damage charged to society in general, are not part of traditional economic calculations: they are called market externalities. Thus, the industrial economy transforms natural resources of low economic value into industrial products of high value, and then into wastes of negative value; the resources, in one form or another, are still within the product.

In the waste stream, a wide variety of products are mixed: unless steps are taken where wastes are generated, the waste stream constitutes an intermingling of everything consumed by the waste generator. The waste stream therefore constitutes a mixture of resources, as opposed to concentrations of resources of like properties, as found in nature. That mixed stream is often then taken to disposal, meaning landfilling, or re-deposition in the Earth. The US Environmental Protection Agency has formulated a notably direct definition of waste disposal:

Disposal means the discharge, deposit, injection, dumping, spilling, leaking, or placing of any solid waste or hazardous waste into or on any land or water such that such solid waste or hazardous waste or any constituent thereof may enter the environment or be emitted into the air or discharged into any waters, including ground-waters.

As humans have contrived to occupy greater parts of the Earth’s surface, waste disposal therefore comprises dilution all over the Earth’s surface of resources furnished, by Nature, in convenient deposits. Further, it is understood that such wastes may then further migrate from their disposal sites into the surrounding environment. Costs are those of a further reduction in the availability of those resources, and environmental contamination.

Thus, the very production of waste means that resources, formerly valuable, assume a cost. Management, good and bad, costs money in separate ways. Waste is a leak of resources and value from an industrial economy. A waste crisis results from sufficient wealth to assign more resources to the “waste” category, combined with a reduced supply of land for facile disposal. The proper management of waste is a core principle of industrial ecology. Corporate accounting begins with a “waste audit,” wherein the resources used by the firm are examined as regards their fate. Significant savings can be achieved through attention to this often-ignored cost area.

4. Public Health

Waste is a public health issue. Its management is frequently dubbed sanitation. There are many, and growing, reasons to retain that concept in waste control: all of the many policy aspects of waste control are overridden by the need to protect the public.

As discussed above, proper management of waste was recognized as important in the prevention of disease even prior to the evolution of the germ theory. Today, waste remains of primary concern as a biologically active material. Wastes are fully supplied with a bacterial population arising from their human producers, as well as the pets owned by the humans. Waste degradation is, by definition, the action of microbial activity on the waste; waste is stocked with nutrients for microbial growth. Even the distinction with sewage is lost with the advent of the disposable diaper, that which carries raw, undiluted sewage into the waste stream. Through table scraps, bathroom waste, and tissues, waste is copiously supplied with pathogens.

Modern industrial waste contains substantial amounts of hazardous materials. Organic materials arise from paint, solvents and other cleaners, fuels, etc. Inorganic materials, primarily toxic metals, arise from paints, plastics, electrical equipment, thermometers, etc. Not even the most bucolic residence fails to produce some of these hazardous materials; the term “household hazardous waste” has arisen as a descriptor.

It is highly desirable to set policies that greatly reduce hazardous wastes, such as battery collection schemes. Experience shows that it is impossible to eliminate such wastes; often program success is of a fleeting nature, proportional to immediate attention in the media.

Medical waste is an important contributor of pathogens. Waste from medical-care facilities, such as hospitals and clinics, is usually controlled so that biologically-active waste does not enter the waste stream. To identify medical waste, it is standard practice to use a specific color of plastic bag, hence the name “red-bag waste.”

It is never clear that smaller operations, such as individual doctors’ offices, properly manage wastes. Especially with the rise of home health care, more untreated medical waste appears in the waste stream. Medical waste also contains medicinal residues which may be hazardous; a current issue is that some of these materials may not be altered by some forms of medical waste treatment.

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Biographical Sketch

Richard Ian Stessel earned his BA in Physics from Harvard University; and an MA in Public Policy, and his MS and PhD in Engineering from Duke University. He has worked for the US Environmental Protection Agency, and currently teaches sustainable resource engineering in the Department of Civil and Environmental Engineering at the University of South Florida. He is a licensed engineer, and board-certified in solid waste management. His research has involved landfill liner systems, landfill mining, development of the aerobic biocell concept of landfill degradation, and analysis and development of unit operations in material processing. He is author of the book *Recycling and Resource Recovery Engineering: Principles of Waste Processing*, published by Springer-Verlag, Berlin. He is a member of the International Solid Waste Association; in the Solid Waste Association of North America, he is a member of the Aerobic Processes Subcommittee, and Chair of the Landfill Reclamation Committee; he has served as Chair of the Municipal and Medical Waste Division of the Air and Waste Management Association. He is also President of the Society for Solid Waste Management and Research.