# INDUSTRIAL WASTE MINIMIZATION

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## Contents



## Summary

Industrial pollution emitted to the environment has created a drastic damage to the environment. Natural purification processes such as dilution and dispersion are not applicable due to the enormous amounts of discharged wastes, as they exceed the assimilative capacity of the local environment. Concern about the environment by the general public has forced governments to establish effluent standards for industrial wastes and emissions. Increasing numbers of industries each year has exerted pressure on the environment compelling regulators to further tighten the standards. This has led to modification and improvement in the existing end-of-pipe treatment facilities resulting in higher investment as well as operation and maintenance cost, whereas in recent years, implementation of proactive methods of waste minimization is gaining much attention within industrial sectors. Various waste minimization techniques such as improved housekeeping, change in process technology, change in products, change in input materials, recycling of chemical and raw materials, and recovery of byproducts are discussed in detail. A number of successful examples discussed in this paper indicate that substantial benefits can be gained by implementing waste minimization programs.

## 1. Introduction

Uncontrolled and rapid industrialization and urbanization is the major cause of rapid environmental degradation. Use of nature's freely available resources in an uncontrolled manner and throwing of waste into the environment has caused more stress to the assimilative capacity to dilute and disperse the wastes and recover the used natural resources. The depletion of resources has threatened the life of future generations. Increasing numbers of industries and production of various categories of wastes cause major environmental pollution. These problems have forced governments to control the industrial activities of waste discharge directly into natural environments. Formation of effluent and emission standards and regulation for wastes to be discharged into natural bodies of water, air and soil has forced industries to establish waste treatment facilities in their own industrial premises. This was the concept of end-of-pipe (EOP) treatment, in which the basic production process was the same with addition of waste treatment facilities. The basic concept of the installation of treatment units was to bring down the concentration and load of the effluent within the allowed limits before discharging into natural resources.

Rapid depletion of resources was not the focal point in EOP treatment process. But, with time, government bodies were asked to look towards solutions to control the rapid depletion of resources. The EOP treatment was unable to improve the environmental condition as expected, although the degradation speed was slowed down. Increasing pressure from the public about environmental condition has forced governments to implement more stringent standards. This has resulted in the concept of waste minimization in terms of quality and quantity.

Advantages of waste minimization are:

- minimum use of resources;
- minimum waste production;
- improvement in production process.

The basic components of waste minimization are:

- improved housekeeping;
- change in process technology;
- change in products, change in input materials;
- recycling process and chemical and raw materials;
- recovery of by-products and wastes.

Since industries have been adopting the EOP treatment technology for almost two decades, they are not attracted to the waste minimization due to uncertainty in waste minimization techniques.However, some of the industries are now in a position to achieve the goal of waste minimization through effective ways, encouraging others to join in this stream. Slowly it is gaining much attention in medium and small-scale industries also. Although industries are not able to implement all the above mentioned waste minimization techniques, substantial reduction in waste has been reported by implementation of some of the activities and at low cost. This is one of the achievements in industrial minimization activities.

This article is about the industrialization and its effects on the environment and the development of waste management technology. Development in waste management technology and the importance of waste minimization, various techniques of waste minimization, and some successful examples are described in this paper.

## 2. Background

Living standards and quality of life in most of the developed countries have increased since the Second World War, due to rapid industrialization and urbanization. This growth and development, however, have involved a nearly thirty-fold increase in use of fossil fuels over the past century and an over fifty-fold increase in industrial production for the same period. Most of the consumption of fossil fuel and production has taken place since 1950. It is estimated that between 1955 to 1988 world industrial output increased approximately six times, the World's population only doubled. The result of rapid industrialization is the rapid depletion of resources, and environmental impacts due to production of enormous waste exceeding assimilation capacity of the environment. At the beginning of this industrialization process, not enough attention was given about the state of the environment; assumptions were made that the nature has the capacity to restore the resources we extract and accept what we throw into it. These wastes have now become pollutants due to their enormous volume and multiple characteristics.

The various impacts are change in:

physical parameters of receiving water bodies threatening the aquatic life;
higher concentration of pollutants in the ambient air;
deterioration of aesthetic appearance.

Based on the effects of pollutants in the environment, pollutants can be classified either as threshold (dangerous even at low concentration) or non-threshold (dangerous when present at a certain level) pollutants. Waste generated from industries is non-homogeneous, with differing characteristics and composition. Similarly, these wastes are multimedia in nature with wastes disposed in all three media namely air, water, and soil. Effect of mixed pollutants of different characteristics can be synergistic and antagonistic depending upon the resultant effects. For example, the combined effects of sulfur dioxide in the air could produce acid rain. On the other hand it is advantageous to have wastes with two different pH ranges (acidic and alkaline) which could eliminate the neutralization unit completely.

Continuous degradation of earth's environment mainly due to industrial pollution is one of the major concerns of many environmental regulators. In addition to this, public attitude towards environmental protection has led governments to control industries disposing high load waste in to the environment. Pollution control standards defined first for ambient air and water and soil quality standards were mostly derived from public health considerations and ecological justifications. Public concern over industrial wastes led the application of more stringent regulations, authorization, and procedures.

But standards and regulations vary from country to country depending on various factors including the present state of environmental condition, financial constraints, capability of regulatory government bodies. For example the developed countries had regulations on almost all pollutants, while developing countries were fighting against poverty. Meanwhile, these developed countries also produced and disposed more pollutants in the past. But the standards were fixed, based on the carrying capacity of the environment as a whole. The standards were not so stringent at the time when the developed countries were degrading the environment. On the other hand, standards were fixed based on the locations depending upon the decrease in carrying capacity of the environment, temperature, rainfall of that area, and increase in the level of treatment technology. Examples can be taken from nitrogen and sulfur concentration in India where the concentration is different in different locations (120 mg/L for commercial areas, 70 mg/L for residential areas, and 30 mg/L for sensitive areas).

The regulation requirements are of volume and concentrations for liquid wastes (such as mg/L, kg load, etc.), and concentration and mass emission standards for air pollutants (particulate matter, oxides of sulfur nitrogen, and some volatile organic compounds). The standards and regulation tend to become stricter with time depending upon various factors including state of present environment and progress in waste treatment technology. The effluent standard for phenol concentration in India is one of the example which has decreased from 300 mg/L in 1968 to 1 mg/L in 1992.

The new restrictions on the discharges led to the concept and practices of “end-of-pipe (EOP)” treatment. In this concept, the basic process of production remains the same, but that the devices to trap and treat the pollutants emitted to all three environments are installed at the end of the industrial process sequences. So various technologies were developed to treat the pollutants of different media. It is just an add-on system and industries are free to choose among the available treatment technologies based on their capacity and regulatory requirements. As a result of which the industries were more concerned about discharging the wastes of required standards into the environmental media. Not much attention was given how the waste is generated in the process.

The treatment technologies employed in the industry were selected based on their elastic nature so that the changes in standards and regulations up to certain limits can be incorporated with small modifications. Blending and equalization, neutralization, precipitation, chemical or biological oxidation and final settlement or polishing were the major components included in effluent treatment plants to treat wastewater. The sludge, produced from the operations was collected, dewatered or dried and then disposed of wherever directed or possible.

Cost of the treatment is another factor considered by the industries. Although cost of waste treatment facilities depends on the waste characteristics, limiting standards for discharge and the treatment technology adopted. Mostly it is around 2% to 5% of capital investment and operation costs around 15% to 30% of the investment in the treatment plant. Normally the cost of the waste treatment facility is viewed by industry as a kind of unproductive investment, as a result of which, most of the treatment units are located at the most unwanted backyard locations and run with ill-trained operating staff.

In EOP treatment the waste is not eliminated, rather transformed from one form to another through treatment.

The *reactive nature* of the environmental management is often questioned when considering the rapid depletion of natural resources in line with industrialization. More stringent standards, increasing number of parameters due to increasing number and type of industries as well as information about new chemicals and their effects on the environment and health, new raw materials, increase in awareness on environmental issues etc. have all forced governments and industrialists to search for more effective solution to waste treatment, over traditional EOP treatment systems.

The technology adopted in an EOP systems is suitable to meet the specified requirements. However, the rate of cost escalation is higher for higher percentages of removed pollutants. For example, the treatment cost is almost double for 99% removal of color or dissolved solids compared to 90% removal. Wastage of raw materials as well as cost of waste treatment are the two major drawbacks of EOP treatment technologies.

Conventional EOP treatment techniques are not as efficient in achieving goals of cleaner air and water environment. On the other hand, the gradual restriction of free available raw materials, the hike in price of basic resources, trade barriers including consumers' interests in green issues, and global concerns on various pollutants (greenhouse gases) are some of the factors and forces acting on the industrial production processes. Figure 1 represents the various forces acting on the industry. These forces also cause the deterioration of economic status and a continuous increase of the unit cost price of the products.

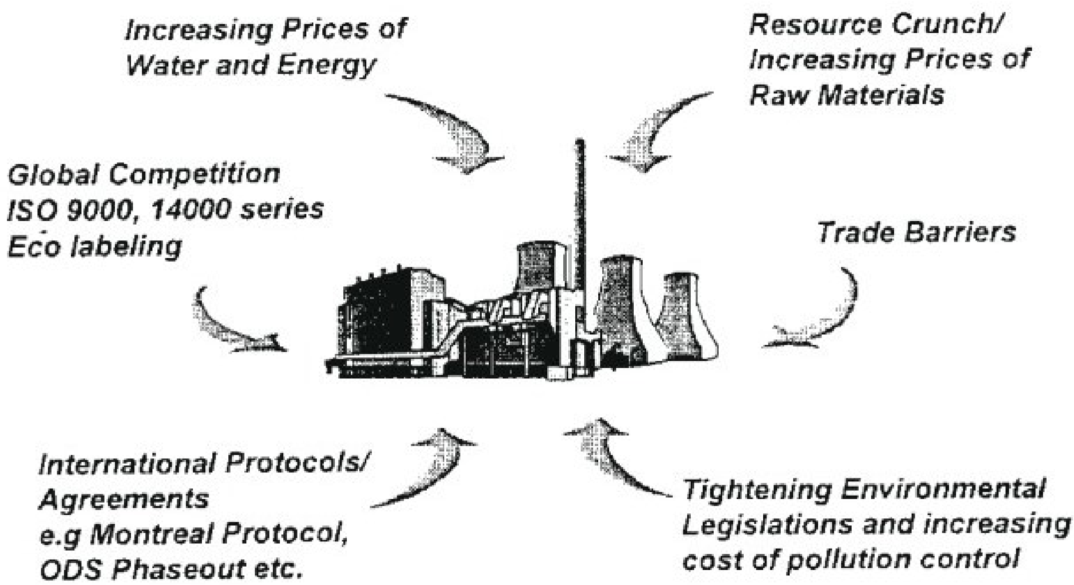


Figure 1. Various forces acting on the industries

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**Bibliography**

Aldokhin N. A., Goncharov A. I., Grachev M. A., and Suturn A.N. (1990). Recycling of wastewater and solid waste at the Selenginsk Pulp and Paper Plant. *Industry and Environment*. **13**(3-4), 21–23. [Recycle and reuse practices adopted in a pulp and paper mill are described in this paper.]

Chongkol P.K., Visvanathan C., and Dattar R. V. (1997). Green productivity audit approach for small scale electroplating industries: APO demonstration factory project. *Proceedings of APO World Conference on Green Productivity*, Philippines, Manila: 106–117. [This paper highlights the waste audit conducted in an electroplating industry and how such audits can help in developing waste recycle programs.]

Gromov B. V. (1984). Utilization of metallurgical slag in the Soviet Union. *Industry and Environment*. **7**(2), 12–16. [Reuse of slag generated in metallurgical industries in the former USSR is discusses in this paper']

Huisingh D. (1989). Cleaner technology through process modification, material substitution and ecologically based ethical values. *Industry and Environment.* **12**(1), 4–8. [This paper highlights the concept of industrial ecology and discusses waste minimization techniques.]

Maksimenko Y. L. (1989). Developing low waste technologies in the soviet mining industry. *Industry and Environment*. **12**(3-4), 51–56 [This paper presents strategies to develop cleaner production technologies in the mining industry sector.]

Matilla E. M. (1989). Clean technologies policy of the European Economic Community. *Industry and Environment*. **12(**1), 11–12 [Policy issues involved in adoption of cleaner technologies in Europe is discussed in this paper.]

Nemerow N. L. (1995). *Zero Pollution for Industry: Waste Minimization through Industrial Complexes.* A Wiley-Interscience Publication, John Wiley and Sons, Inc. New York. [This book gives a comprehensive review of industrial waste minimization.]

NIEM, UNEP, AIT. (1999). Cleaner Production in the pulp and paper industry: *Technology Fact Sheets.* UNEP and AIT, Bangkok. [This report presents the waste minimization practices already adopted in several pulp and paper mills in the Asia-Pacific region.]

Overcash M. R. (1986). *Techniques for Pollution Prevention—A Compendium for Hazardous and Nonhazardous Waste Minimization*, Lewis Publishers, Inc.,Chelsea, MI 48118. [This books presents an excellent review of pollution prevention techniques being adopted in several core industrial sectors.]

Vigneswaran S., Visvanathan C., and Jegatheesan V. (1998). Industrial waste minimization. ENSEARCH. Environmental Management and Research Association of Malaysia. Petalyng Jaya, Malaysia. [This book reviews the various techniques used for waste minimization, with a number of case studies from both developed and developing countries.]

**Biographical Sketches**

**C. Visvanathan**, is an Associate Professor of the Environmental Engineering Program, School of Environment, Resources and Development, Asian Institute of Technology. He has a Ph.D. (Chemical

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