WASTE MINIMIZATION IN INDUSTRY

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Summary

Waste minimization is an important element of sustainable development because it allows improvements to business performance to be created concomitantly with improvements to environmental performance. Elimination of waste followed by reduction at source and then recycling form the preferred hierarchy of options. Reduction at source techniques includes good practice as well as changes to raw materials, processes, and products.

Recycling on-site is preferred to recycling off-site, and of the four levels in the hierarchy of recycling, direct re-use is preferred since the material to be recycled is homogeneous, and from a known and reliable source. Systematic approaches to design and change can be implemented by considering first the service that needs to be provided, then the products needed to provide the service, and then the processes in which the products are made. Such a logical approach allows wastes arising from a variety of activities to be incorporated into integrated waste minimization studies. Such risings include product waste, process waste, and utility waste, the latter being created in the utility systems that drive manufacturing processes.

1. Introduction

Waste minimization is an important element of sustainable development since it is concerned with the conservation of resources, protection of the environment and the reduction of production costs usually by one or more of three principal means: elimination, reduction at source and recycling. Waste minimization is not concerned with treatment and disposal. Nor is it concerned with actions that only dilute waste and those that simply transfer waste from one environmental medium to another.

Realistically, elimination can only ever be an unattainable goal, since any industrial activity will consume energy at the very least and thereby contribute to waste generation via the formation of emissions to the atmosphere. In the universally accepted hierarchy of waste management options, reduction of waste at source is preferred over recycling. The main reason for this is that recycling requires a waste to have been generated in the first place.

1.1 Basic Principles

Waste minimization is founded on the basic principles of mass and energy balancing. The fundamental law of conservation of mass states that, for any non-nuclear process, matter (or mass) can neither be created nor destroyed. Hence, the flow of mass into a system must equal to the flow of mass out of the system for a steady state process. Matter can accumulate within the system if it operates at unsteady state, that is, when all or parts of the system vary with time.

The nature and appearance of the matter can change within the system, for example, as steel, glass, and plastics, etc are converted into motorcars. In chemical and biological processes, the chemical compositions will additionally change from raw material input to product output. The law of conservation of energy is founded on the first law of thermodynamics and is broadly comparable with the law of conservation of mass. Thus, in any non-nuclear process, energy can neither be created nor destroyed. In contrast to mass, however, energy can exist in many interchangeable forms (kinetic, potential, and internal, etc), and as heat and work.

An additional principle, particularly applicable to recycling, is that mixing is easy but separation is always more difficult. This principle should be applied in two main ways:

- To the segregation of waste in order to facilitate recycling.
- To the design of components wherein simple designs with single components are preferred to facilitate recycling unless composite components are required for structural, rather than aesthetic reasons.

1.2 Benefits

The law of conservation of mass can be used to demonstrate the principal advantages of waste minimization to industrial organizations. Referring to Figure 1, if waste is minimized in a system that is used to manufacture a fixed number of units, say 100 000 motorcars a year, then not only is the cost of managing and disposing of the waste minimized but so is the consumption of raw materials minimized, thereby saving on raw material costs. The system is also smaller, requiring less capital investment, less floor space, and less energy to run. Successful waste minimization projects therefore create "win–win" situations, that is, improvements to environmental performance are gained concomitantly with improvements to financial performance. Waste minimization in terms of reducing energy consumption also means that the costs to a business can be reduced at the same time that emissions to atmosphere (a form of waste) are reduced. Waste minimization also attracts a number of less tangible opportunities, including:

- The promotion of a positive image for stakeholders.
- A reduction of risks and liabilities.
- A reduction of risks of breaching regulations and compliance.
- A potential reduction in insurance premiums.
- A potential improvement to health and safety.
- A reduced administrative burden.

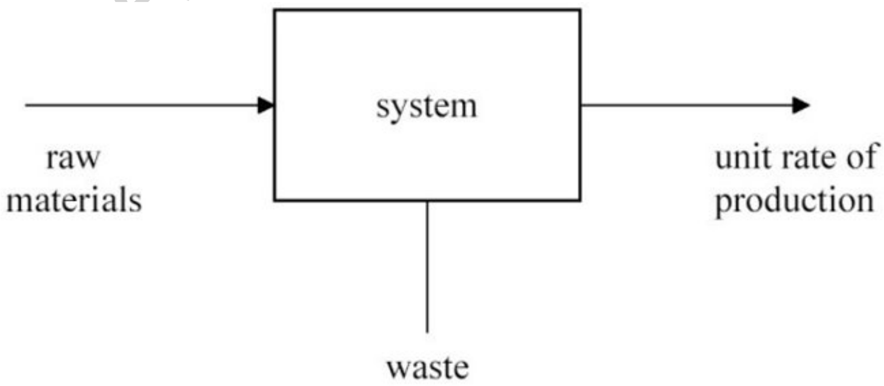

Figure 1. Conceptual diagram for a system in which waste is generated.

1.3 Challenges

Inevitably, there are risks when changes are made to industrial processes. The symptoms of risk often manifest themselves as challenges that fall into four main categories: economic, technical, regulatory, and cultural.

Economic barriers can arise if it is believed that there is insufficient financial incentive to implement waste minimization. Clearly, all of the less tangible benefits need to be taken into account in economic feasibility studies if an element of doubt arises from the initial financial appraisal. Technical barriers may include the following:

- A lack of suitable scientific or engineering information on techniques.
- Concerns about changes to product quality and customer acceptance.
- An interruption to production whilst changes are made.
- The creation of new bottlenecks to the production process.

Since waste minimization should improve environmental performance, it is generally considered that regulatory barriers would be unlikely. However, changes to processes might involve changes to licenses, consents, Integrated Pollution Control authorizations, and other regulatory approvals. For larger developments, planning applications and perhaps even environmental impact assessments might need to be made. Cultural barriers might arise from:

- A lack of commitment from senior management.
- A lack of awareness of corporate goals and objectives.
- The resistance to change by individuals.
- Poor internal communication and inadequate training.
- Restrictive employment practices.
- An inflexible organizational structure.
- Bureaucracy, particularly in the generation of cost data.

1.4 Commitment

Most barriers to waste minimization can be overcome by having strong commitment from senior management within the organization. There should be a declared company policy and a strategy for its implementation. The policy might form part of the environmental policy statement of an environmental management system (EMS) such as the international standard ISO 14001 or the European standard EMAS. Waste minimization goals, objectives, and targets might also be encompassed within the EMS.

Adequate resources in terms of both staff time and finance should be made available for new projects and for training programs. In order to carry out financial appraisals on each waste minimization project efficiently, and effectively, the true and total costs of wastes must be allocated, as far as possible, to the sources of waste generation. If exact allocations cannot be introduced then the following alternatives can be used:

- Each operating department can be allocated some portion of the fixed costs of the overall on-site service.

- Each operating department can be charged the variable costs of treatment and disposal on the basis of the quantity and nature of wastes arising.
- Various operating departments can be charged transfer prices for the quantities and types of wastes treated and disposed of.

2. Scientific and Engineering Principles

The principles underlying waste minimization are inevitably particular to an industrial activity. Thus, for example, the principles pertinent to automobile manufacturing will inevitably be different in many respects to those that pertain to the petrochemical industries. Studies of waste minimization opportunities can be made on various scales: on an industry sector basis (macro scale, or strategic study), on a unit operation basis (meso scale), or on a molecular interaction basis (micro scale).

2.1 Scales of Activity

Macro scale studies can provide perspectives on the flow of materials in an industrial economy, from the raw material inputs to the finished products. This is mass and energy balancing on the grandest scale. Macro scale studies provide the scope for improving the environmental performance and the business performance of a particular sector, and thus the study is a strategic one in the context of sustainable development. An example might be the use of herbicides in agriculture.

Life cycle assessment is often used in macro scale studies. Whilst macro scale studies help to identify needs and targets from international, national and industry sector perspectives, meso scale studies are more concerned with waste minimization on existing industrial facilities, either as a whole, e.g. an oil refinery, or in terms of their component parts, e.g. crude oil distillation units.

The development of better products and processes may well depend on the understanding of how new molecules can be synthesized and used, and how they might behave in the environment. Such an understanding requires micro scale studies. The development of a new systemic herbicide for targeted application in order to reduce the indiscriminate spraying of fields would need a micro scale study that would follow inevitably from a macro scale study.

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Biographical Sketch

Barry Crittenden is Professor of Chemical Engineering at the University of Bath. He was Head of the School of Chemical Engineering from 1994 to 1997. He has over 30 years of research experience in fields ranging from combustion, fouling, selective adsorption and ceramic membrane processes to environmental control, waste minimization and environmental management. He is Director of the MSc in Integrated Environmental Management by Distance Learning and the author of four Clean Technology Workbooks for this course. He led the development of the undergraduate M. Eng degree in Chemical Engineering and Environmental Management. He was Chairman of the Editorial Panel for the Environmental Protection Bulletin, a member of the Environmental Technology Best Practice Programme Management Advisory Committee, and currently is a member of the Programme Management Committee for the DTI/EPSRC LINK Programme on Waste Minimization by Recycling, Recovery and Reuse in Industry. He has authored, or co-authored 155 publications that include 47 contract reports, 3 environmental statements, and 11 books. He chaired the Institution of Chemical Engineers' Working Party that produced the Environmental Training Package on Waste Minimization, managed its translation into Chinese, and launched its introduction in Shanghai.

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