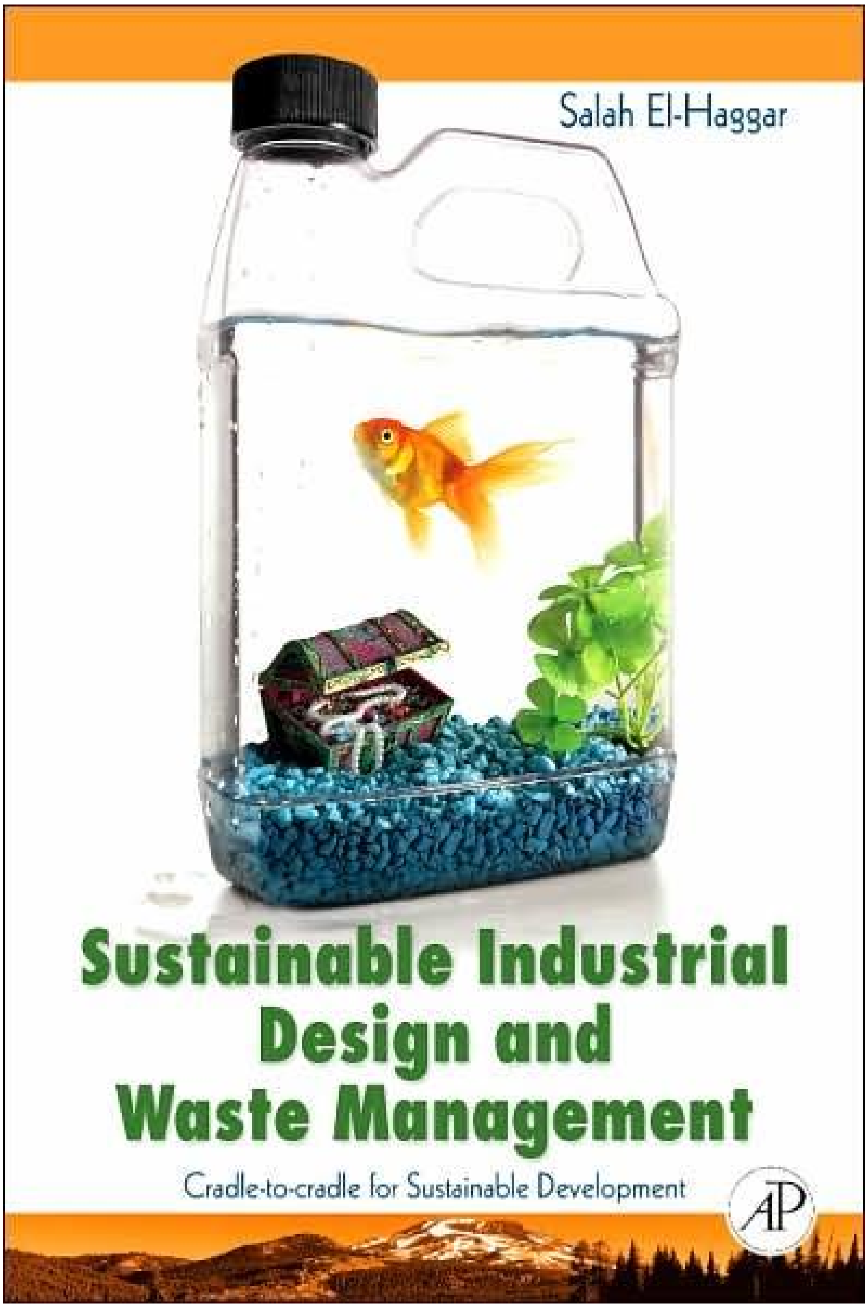

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About the author

Dr El-Haggar has more than 30 years of experience in energy and environmental consulting and university teaching. Dr El-Haggar was a visiting professor at Washington State University and at the University of Idaho, and is presently the Professor of Energy and Environment at the Mechanical Engineering Department at the American University in Cairo.

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Dr El-Haggar's environmental consulting experience includes more than 40 environmental/industrial auditing for major industrial identities, 20 compliance action plans, nine environmental impact assessments in addition to extensive consulting experience in environmental engineering, environmental auditing, costal zone management, environmental impact assessment (EIA), environmental management systems (EMS), energy management, hazardous and non-hazardous waste management, recycling, pollution prevention and waste minimization, zero pollution, biogas/solar/wind technology, community/desert development, solid and industrial waste, and environmental assessment for the local government and private industries. Dr El-Haggar is a member/board member of 14 national and international societies in the areas of mechanical engineering, environmental engineering and community development.

Dr El-Haggar has been working in environmental technologies since 1987. His paramount objective is to transform waste into useful products. He developed a very simple theory called the 7Rs rule that applies cradle-to-cradle concepts to waste handling and management. Dr El-Haggar was able to develop different technologies for recycling unrecyclable waste such as Tetra-Paks, dippers, municipal solid waste rejects, etc. He has published two series of books on *Cleaner Production Technologies* and *Fundamentals and Mechanisms for Sustainable Development*. Dr El-Haggar has also written a number of chapters in several books on the environment.

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Introduction

> Some people see things as they are and ask why?
> I dream of things that have never been and ask why not?
>
> Senator Robert Kennedy

Ever since the Earth Summit of Rio de Janeiro back in 1992, much has been written and continues to be written about "sustainability". Throughout this time, however, we seem to have lost a direction for measuring sustainability. We need first to think about how we can develop sustainable projects and industries, and then think about how we can develop indicators to measure the sustainability or percentage of sustainability within these projects and industries. These two issues will help us draft plans for further sustainable developments. This book will discuss such indicators and the tools necessary for sustainable development. In this way, it suggests a formula for sustainability.

The real environmental and economical problem of the 20th century is that scientific and technological developments have increased the human capacity to extract resources from nature, process them, and use them, but have not offered parallel and similar insight into how these resources can be returned to their environmental origin or how they could be entered into a new cycle of extraction, processing, and use. Much of the resources extracted from nature are used in unsustainable activities and end up as waste. This can be described as a cradle-to-grave scenario in which the resources have a "lifetime" and are disposed of after they are used, ending up in a "grave" (a landfill, for example). If this were to continue unabated, we may end up completely depleting our natural resources. The only way to evade this dead end is to develop newer production and processing techniques that use up resources in an alternative cradle-to-cradle scenario.

This book is original in that it presents cradle-to-cradle production and processing alternatives to most of the traditional industries common today. These alternatives are not only environmentally friendly, but are also economically advantageous (either cutting costs or increasing profits). This book is replete with creative ideas and innovative technologies that, when implemented, would lead to cradle-to-cradle production and manufacturing in all industrial sectors.

Perhaps the major problem industries have with current environmental protection regulations is their cost and return. Pollution control and treatment, and environmental protection procedures, are all considered very expensive activities and, as such, they are seen as economic burdens and impediments to further industrial development.

Indeed proper waste handling and management is posing a complex problem for the entire world. On the one hand, it can be highly costly, and on the other hand, improper handling of waste can have harmful effects on life and habitat and at the same time lead to depletion of our natural resources.

Because of the universality of this problem, any comprehensive solution should be appropriate and applicable in both developed (industrial) and underdeveloped nations. And for any solution to be sustainable, it should promise economic benefits, require available or obtainable technology, and comply with the social and environmental norms within a given nation.

The main objective of this book is to conserve our natural resources by attempting to reach a 100% utilization of all types of waste. It offers alternative production and waste management techniques that employ cradle-to-cradle concepts and the methodologies of cleaner production and industrial ecology. It is filled with case studies that demonstrate the applicability of these techniques in most industrial sectors such as textile, food, oil and soap, etc. Case studies were also implemented in the heavy industries such as petroleum, iron and steel, cement, etc. Touristic activities are also included because they are considered an industry that uses up natural resources and generates waste.

The traditional waste management hierarchy implemented in most countries, which involves reduction, reuse, recycling, recovery, treatment, and disposal, should now be modified to exclude treatment (especially thermal and chemical) and disposal in landfills. Waste treatment converts harmful waste into less harmful waste, but produces in the process an effluent that itself becomes waste and must be disposed of in a landfill. A "disposal" of anything means depletion of our natural resources, and may also lead to environmental pollution (in the air, water, and soil). In contrast, recovery, as used in the hierarchy above, attempts to convert waste into energy. It is a very expensive procedure that cannot be afforded by most countries. And thus throughout this book, recovery will mean material recovery – for example, attempting to separate waste oil from water employing gravity using a gravity oil separator (GOS) technique, or employing air bubbles using a dissolved air flotation (DAF) technique. This book thus suggests a new hierarchy for waste management that would apply cradle-to-cradle concepts in order to conserve natural resources.

Natural resources are becoming a very crucial issue for sustainable development because finding new sources of raw material has proven to be very costly and difficult. Waste disposal has very significant impacts on the environment since it may cause contamination in the air, soil, and/or water. In order to make waste management more sustainable, it should shift from cradle-to-grave systems to ones that apply cradle-to-cradle concepts. These systems should also reduce or completely eliminate any disposal stages.

Chapter 1 of this book will cover the common waste management procedures currently practiced worldwide and will discuss their impacts on future sustainability and conservation of natural resources. The life cycle of waste in these procedures will be analyzed to demonstrate that it follows a cradle-to-grave approach. We will then examine the impact these procedures have on environmental protection and conservation of natural resources. Subsequently, the cradle-to-cradle concepts will be discussed in detail with a listing of their pros and cons. We will explain the role of the government and civil society in effecting these cradle-to-cradle concepts for the conservation of our natural resources using the principle of extended producer responsibilities. We will introduce a new term in environmental engineering – "sustainable treatment" – as well as a new hierarchy for waste management, which will apply cradle-to-cradle concepts. The following chapters will serve as applications and implementations of this definition.

Chapter 2 will introduce the concept of cleaner production (CP), its techniques, and its benefits. Obstacles or barriers to cleaner production will be discussed and solutions will be offered. This chapter attempts to successfully develop cleaner production opportunities and assess their implementations. A discussion will follow of various case studies in the different industrial sectors (food, textile, oil and soap, etc.), with elaborate cost/benefit analyses. The case studies will demonstrate and assess different cleaner production opportunities and implementation techniques.

Chapter 3 is about sustainable development and industrial ecology. It will discuss the principles of industrial ecology and will attempt to integrate our industrial activities within a natural ecosystem. Barriers to industrial ecology will also be discussed in all their dimensions: technical, marketing and awareness, financial, and barriers involving regional strategy and regulations. Eco-industrial parks (EIP) will be discussed in further detail with case studies implemented in different parts of the world demonstrating EIP applications using a top-down scheme, bottom-up scheme, or combinations of both. These case studies are intended to guide the readers in developing their own EIP implementation schemes in their own country or community. It also hopes to equip the readers with the methodologies for converting existing industrial estates into environmentally friendly ones – eco-industrial parks.

Chapter 4 on sustainable development and environmental reform will employ the first three chapters to develop a framework for sustainable development and environmental reform. Sustainable development tools and methodologies will be discussed such as the environmental management system (EMS), cleaner production (CP), environmental impact assessment (EIA), and environmental information technologies (EIT). This chapter will then move on to suggest an integration of cleaner production and environmental management systems to promote and manage cleaner production implementation throughout the different industrial sectors. This is a proposed modification to the ISO 14001 standard to be discussed by the ISO Technical Committee in its next round. This chapter will also propose an environmental reform structure and present a detailed discussion of all the relevant elements such as regulation, environmental impact assessment (EIA), environmental management system (EMS), cleaner production (CP), and industrial ecology (IE).

Chapter 5 will tackle the issue of municipal solid waste management sustainability (MSWMS). It is the most challenging chapter as it attempts to apply all the principles covered in the previous four chapters to reach practical cradle-to-cradle implementations. The fundamental issue in this chapter is limiting the use of landfills (i.e. reducing disposed waste) or completely eliminating disposed waste from MSWMS. Different techniques for recycling MSW will be presented such as recycling food waste, bones, tin cans, plastics, glass, and textiles. The recycling of composite material, used in packaging, will also be discussed.

The remaining kinds of waste (rejects), which cannot be recycled by any technique, will be discussed in Chapter 6. Chapter 6 is a completion for MSW, which allows the full and practical realization of a cradle-to-cradle model. This chapter will discuss technology developments to recycle unrecyclable wastes (rejects) as well as product developments to meet or match the needs of a given community. The properties of the resulting new materials and suggestions for its suitable applications will also be presented.

Chapter 7 on the sustainability of agricultural and rural waste management is very important for most developing countries as well as some developed countries. The unsustainable nature of agricultural and rural waste results in environmental pollution and may ultimately lead to complete depletion of our natural resources. Different technologies for handling this type of waste, such as composting, animal fodder, briquetting, biogas, construction materials, silicon carbide, etc., will be discussed in this chapter. These technologies are appropriate for and applicable in both developed and underdeveloped countries. Two different case studies are included in this chapter. The first involves converting soil conditioners into organic fertilizers for organic farming by composting agricultural and rural waste. The second will combine all agricultural and municipal solid waste, as well as municipal liquid waste, into one complex called an eco-rural park.

Chapter 8 will discuss the sustainability of construction and demolition waste and will explain the relevant guidelines to owners and contractors. This chapter includes three case studies. The first case study uses the 7Rs rule as a guideline for handling construction waste in a manner that applies cradle-to-cradle concepts. The second case study demonstrates how much money is typically spent on getting rid of construction waste. The third and final case study demonstrates how cradle-to-cradle implementations on construction waste can be advantageous and beneficial.

Chapter 9 on the sustainability of clinical solid waste management is the most critical chapter in this book because clinical wastes can be very hazardous, are generated from very sensitive resources and should thus be handled and treated in a very sensitive manner. The chapter will discuss the most popular technologies used in clinical waste treatment and compare and contrast the advantages and disadvantages of each one. Technologies discussed in this chapter include incineration, autoclave (steam sterilization), chemical disinfection, microwave disinfection, pyrolysis, gasification, plasma systems, and irradiation. Current clinical waste management practices applied in both the developed and developing countries will be examined, and a final discussion will be given about the use of electron beam technology in sterilizing clinical waste and how that could be applied to achieve a cradle-to-cradle implementation.

The final chapter, Chapter 10, will discuss sustainability of industrial solid waste management. It attempts to define an outline for transforming the different traditional industries into more environmentally friendly ones that apply cradle-to-cradle concepts. Some industrial sectors discussed in this chapter have not been mentioned before in previous chapters such as the sugarcane industry, aluminum foundry, iron and steel, marble, petroleum, cement, and tourism.

In conclusion, this book advocates sustainable development and the conservation of our natural resources without inflicting harm on the environment. It discusses most types of waste generated in most industries and within our communities, and suggests techniques for utilizing it according to cradle-to-cradle concepts and avoiding the use of landfills, incineration, and treatment in general. I hope the reader finds it as stimulating and enjoyable to read as it was for me to write. Any questions, comments or suggestions – positive or negative – for further improving this book would be highly appreciated. Please feel free to contact the author at: elhaggar@aucegypt.edu

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Chapter 1

Current Practice and Future Sustainability

1.1 Introduction

One of the major problems facing the world today is the environmental protection cost and return. The current practice of pollution control, treatment and environmental protection can be considered very expensive activities where people consider it a burden for development. There is a worldwide misconception that "environmental protection comes at the expense of economic development or vice versa". This is not true if sustainable development is achieved. Sustainable development promotes economic growth given that this growth does not compromise the management of the environmental resources. The traditional approach for clinical waste, agricultural waste, industrial and municipal solid waste, industrial and municipal liquid waste, etc. can be considered disastrous worldwide because it is depleting the natural resources and may pollute the environment if it is not treated/disposed of properly. Any solution should suit not only the developed countries but also the developing countries should include the economical benefits, technological availability, environmental and social perspectives otherwise they will never be sustainable. The objective of this book is to conserve the natural resources by approaching 100% full utilization of all types of wastes by a cradle-to-cradle concept through sustainable treatment.

1.2 Waste Management

Waste generations vary from one country to another, but many previous studies indicated that as gross domestic product (GDP) per capita increases, per capita municipal solid waste (MSW) generation and other types of wastes also increases. So, waste management is a must for conservation of natural resources as well as for protecting the environment in order to approach sustainable development.

The selection of a combination of techniques, technologies and management programs to achieve waste management objectives is called integrated waste management (IWM). The hierarchy of actions to implement IWM is reduction, reuse, recycle, treatment and final disposal (Tchobanoglous *et al.*, 1993). Different sources use different terms and categories to describe the waste management hierarchy. The USEPA 1989 publication "The Solid Waste Dilemma: An Agenda for Action" states that their hierarchy for waste management is source reduction, recycling, waste combustion and landfilling. Others would list source prevention, source reductions and reuse as two categories, while most of the literature combines them under source reduction. The New Jersey Department of Environmental Protection includes recycling, on-site composting and reusing at the source under source reduction. However, reviewing diverse literatures reveals that the traditional waste management hierarchy is dominantly reducing, reusing, recycling, recovery, treatment, and disposing. Incineration might be included within treatment because it is thermal treatment, or within recovery as waste-to-energy recovery, or can be discussed as an independent item as will be discussed in this chapter.

Reducing: Reduced material volume at the source can be enforced through extended producers and consumers polices (e.g. less unnecessary packaging for products). Indeed, changing the consumer's practices is part of the source reduction concept. Reducing the raw material at the source will conserve the natural resources for other uses. Fortunately, statistics show that these trends are declining in developed countries. For example, the total source reduction in the USA, which includes prevention and reuse, increased from less than one million tons in 1992 to more than 50 million tons in 1999 (USEPA, 1999).

Reusing: Reuse means to continue using the product in its original or in a modified form. Reuse of materials involves extended use of a product (retrading auto tires) or use of a product for other purposes (tin cans for holding nails, glass bottles for holding water in refrigerators). Reusing the product does not return the material to the industry for remanufacturing or recycling. Reuse can be considered another aspect of source reduction which could be carried out not only by consumers but also by producers. Chemicals used in the tanning industry could be reused by installing an on-site chromium recovery unit. Source reduction and reusing can be encouraged through numerous regulations and programs such as the Pay-As-You-Throw program developed by USEPA as well as other programs.

It is clear that source reduction does not only include reduction in the use of material, but includes as well the activities that increase product durability and reusability. Source reduction, which includes source prevention and reuse, is the best option in waste management because it preserves natural resources and reduces pollution, and waste landfilling or incineration. The less preferred option in waste management is recycling.

Recycling: What cannot be reduced at the source is pumped in the waste stream. The above discussion shows that reuse has much to do with cultural habits and this is also the case with recycling but recycling involves additional technical know-how and could involve some capital investment. Recycling is the process of converting these wastes to raw material that can be reused to manufacture new products.

Through regulations governments have a great role to play in promoting recycling. Such regulations are even emerging in developing countries. For example, the Republic of Korea explicitly prescribes the Extended Producer Recycling system under the Resources Conservation and Recycling Promotion Law, amended in 2003 (IGES, 2005). In India and the Philippines, laws on the management of MSW have been enacted recently and the importance of material cycles is clearly mentioned in the laws (IGES, 2005).

Recovery: Recovery of materials or energy can take numerous forms. It is clear that material recovery is a limited activity worldwide and is mainly concerned with the recovery of energy from burning wastes. For example, the Oregon Department of Environmental Quality in the USA states that "construction and demolition wastes makes up the majority of the wastes being processed at MSW Recovery Facilities, followed by 'dry' commercial and industrial loads; virtually no recovery from residential garbage route trucks occurs" (ODEQ, 1997).

Recovery differs from recycling in that waste is collected as mixed refuse, and then various processing steps remove the materials. Separating oil from waste water effluent by a gravity oil separator (GOS) in the oil and soap industry is material recovery from waste. This material is then sold to another type of soap industry or returned to the industrial process within the same factory. The difference between recycling and recovery, the two primary methods of returning waste materials to industry for manufacturing and subsequent use, is that the latter requires a process to remove the material from the waste while the former does not require any processes for separation, sorting can be done manually.

1.3 Treatment

Treatment or end-of-pipe treatment or pollution control is one of the very important technologies for the traditional waste management hierarchy and environmental compliance for any industry. There is a variety of traditional treatment technologies for wastes to choose from depending on several factors such as physical form of the waste (solid, liquid, or gaseous), quantity of waste, characteristics, combined or segregated wastes, degree of treatment required, etc. The treatment technologies can be categorized into physical, chemical, thermal, or biological treatment. Combinations of treatment technologies are often used to develop the most cost-effective, environmentally acceptable solutions for waste management.

Physical treatment: Physical processes for waste treatment include screening, sedimentation and clarification, centrifugation, flotation, filtration, sorption, evaporation and distillation, air or steam stripping, membrane-based filtration processes, etc. These processes are mostly applied to liquid hazardous wastes, and involve the separation of suspended or colloidal solids from the liquid phase. The selection of the technology depends mainly on the concentration and characteristics of the suspended solids relative to the liquid phase. Physical processes segregate the waste from one form to another, reduce the volume, and concentrate the solids to facilitate further treatment or further actions. Whenever a waste containing liquids and solids is to be treated, physical separation of the solids from the liquid should be considered first because it is generally cost-effective to treat a low volume, high concentration waste. Usually physical treatment is used in combination with other treatment technologies for optimum waste treatment and disposal.

Chemical treatment: Chemical treatment involves the use of chemical reactions to transform harmful waste into less harmful, or non-harmful waste, or make it less mobile in the environment. Many different types of chemical treatment processes are used in waste management such as neutralization, precipitation, coagulation, flocculation, oxidation, reduction, etc. Chemical treatment can have some advantages such as volume reduction and promoting resource recovery from wastes. Because it can be employed for resource recovery, and to produce useful byproducts and environmentally acceptable residues, chemical treatment should be considered before sending an untreated hazardous waste to an off-site landfill for disposal. Also, since liquid wastes should not be disposed of in a landfill without prior treatment, chemical treatment is often used to make it either non-hazardous, or at least chemically convert it to a solid or semi-solid, which makes the contaminants chemically stable and not very mobile in the landfill environment.

Biological treatment: Biological treatment can be used for organic liquid wastes or organic solid wastes such as municipal wastewater, landfill leachate, contaminated soil, etc. Biological treatment may be categorized, according to the oxygen utilization, into aerobic and anaerobic processes. In the aerobic process, oxygen is required to decompose organic matter as the aerobic bacteria needs to grow and multiply. The anaerobic process uses anaerobic bacteria, in an oxygen deficient atmosphere, to decompose organic matter. Aerobic organisms are most commonly used to treat industrial and municipal wastewater. Anaerobic systems are usually used for the treatment of concentrated organic waste or organic sludges. Technologies have been developed in which anaerobic bacteria can be used to treat complex toxic organics such as solvent contaminated groundwater. Aerobic bacteria is used commonly for the treatment of petroleum contaminated soils and sludge.

Sustainable treatment: Sustainable treatment is a new term and is defined as "the type of treatment or combination of different types of treatments able to recover the raw material in order to conserve the natural resources on the condition that there is a full utilization or recycling of all effluents from the treatment facility". The first example of sustainable treatment is through mechanical treatment or recycling to convert waste into raw material and produce other products as explained above and will be explained in detail later on. The second example of sustainable treatment is through biological treatment to convert organic waste into a safe byproduct such as composting. Composting is an aerobic biological treatment process to convert organic waste into soil conditioner or organic fertilizer as will be discussed in detail in Chapters 5 and 7. The third example of sustainable treatment is through physical treatment to separate the waste streams from each other, for example the gravity oil separator (GOS) separates the oil and grease from oily water by gravity. The oil and grease can be recycled into the industrial process and the water with some remaining oil can be further treated physically through a dissolved air flotation (DAF) unit to separate the remaining oil and recycle both the remaining oil and water into the industrial process. The fourth example of sustainable treatment is through chemical treatment to separate raw material from waste by precipitation such as chromium recovery from liquid waste effluent produced by the tanning industry through pH control.

It is necessary for any establishment to treat its waste so that it complies with environmental protection regulations. Some industries resisted compliance in order to avoid costs. Now, new industries are accepting waste treatment as an integrated part of production cost. The added costs must then be passed on to consumers or deducted from the profits of the firm depending on market competition.

Through the traditional waste management hierarchy, hazardous waste should be treated before final disposal according to international regulations. Therefore, treatment means converting harmful waste into less harmful waste. In other words, treatment means converting waste from one form to waste in another form. The direct cost of waste treatment is more than just the expense of capital equipment and running cost (maintenance, operation and labor). This direct cost represents only a portion of the total cost. The other indirect cost may not be as easily identified and quantified. This includes the disposal cost and the cost related to adverse impact of the waste on the environment – contaminating air, water and land – as well as the equivalent cost of depleting the natural resources.

Some industries claim that it is not possible to have both jobs and capital spending for growth and at the same time, clean air and water. This statement is not true for industry, because wastes and emissions were originally raw material and should be treated as a byproduct not as a waste through reusing, recycling or recovery techniques – or sustainable treatment, a more generic term.

Treatment should be modified in the hierarchy of waste management for conservation of natural resources to sustainable treatment such as material recovery through physical treatment or biological treatment, etc., as explained above. In other words, what degree of treatment is required to arrive at the optimum outcome for material recovery without damaging the environment and depleting the natural resources? Thus, traditional treatment can be partially or completely eliminated for a new waste management hierarchy to sustainable treatment.

The optimum approach that industries can use to eliminate environmental damage completely is to weigh the pros and cons of each technique of the hierarchy. Economic indicators should be used through cost/benefit analysis as a primary criterion in making the decision but the health, safety and environment (HSE) intangible benefits, including the environmental monetary benefits of abating pollution, should be considered. The challenge of industry is to determine which techniques of the hierarchy, including treatment to some degree (if applicable), should be followed. Although technical parameters such as quantity and quality of waste are the primary factors, economical, political, social and psychological factors are also extremely important.

Innovative sustainable treatment technologies are required to solve the problem of industrial pollution through each of the cleaner production hierarchy techniques as will be explained later in detail in Chapter 2, such as:

- Reduction at the source by:
  - changing the raw material to one of better quality;
  - product modification.
- Reuse directly within a plant or indirectly by other industrial plants and/or recycle (on site) the waste stream resource.
- Marketing of stream resources (off-site reuse or recycling) and mixed with another industrial waste to produce a valuable product.
- Recovery of materials by sustainable treatment, for example the gravity oil separator (GOS) and dissolved air flotation (DAF) in the oil and soap industry to recover fat and grease and recycle the water in order for the effluent to comply with environment protection regulations.

On the contrary, the less the waste treatment provided by industry, the greater the cost of environmental damage. If industry does not provide waste treatment, environmental damage cost will be maximum. This will bring us to a very complicated formula, which is if no waste treatment the damage will be high, and if no proper disposal facilities the damage will be high too. Therefore, what is the solution for sustainable development without damaging the environment and depleting the natural resources? The solution is to approach a cradle-to-cradle concept through sustainable treatment as will be defined in sections 1.7 and 1.8 and implemented throughout the book.

1.4 Incineration

Hazardous and non-hazardous, solid and liquid wastes can be incinerated to convert them into ash. Incineration is the process of thermally combusting