



Materials Recycling

Abel Hall

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In today's world, population is on a rapid rise and the level of pollution is rising every day. Thus, materials recycling is the concept which is very important in the present scenario. It refers to the process of converting the old waste material into some new and useful product. This process helps in reducing different types of pollution like greenhouse gas emissions, water pollution, etc. It also reduces the consumption of fresh raw material, energy wastage, and also helps reduce waste. This book is compiled in such a manner, that it will provide in-depth knowledge about the theory and methodology of materials and recycling. The topics covered in this extensive book deal with the core subjects of materials recycling. This book unfolds the innovative aspects of materials recycling which will be crucial for the holistic understanding of the subject. This textbook will serve as a reference to a broad spectrum of readers.

Abel Hall pursued his MPhil in Materials Engineering from Newcastle University, United Kingdom. Hall's interest areas of academic research include reuse of biodegradable waste and domestic waste recycling. He is a distinguished figure with an experience of over two decades in the field of waste sorting and waste treatment technology. Hall has been awarded the "Distinguished Teacher of the Year" award for his excellence in guiding students.



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Edited by
Abel Hall

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Preface

In today's world, population is on a rapid rise and the level of pollution is rising every day. Thus, materials recycling is the concept which is very important in the present scenario. It refers to the process of converting the old waste material into some new and useful product. This process helps in reducing different types of pollution like greenhouse gas emissions, water pollution, etc. It also reduces the consumption of fresh raw material, energy wastage, and also helps reduce waste. This book is compiled in such a manner, that it will provide in-depth knowledge about the theory and methodology of materials and recycling. The topics covered in this extensive book deal with the core subjects of materials recycling. This book unfolds the innovative aspects of materials recycling which will be crucial for the holistic understanding of the subject. This textbook will serve as a reference to a broad spectrum of readers.

A short introduction to every chapter is written below to provide an overview of the content of the book:

Chapter 1 - Conservation efforts across the globe use the motto of “reduce, reuse, and recycle” to stress the necessity to save the environment. Recycling refers to process of converting waste material into reusable objects to reduce waste of useful material, prevent consumption of fresh raw materials etc. This chapter provides a comprehensive overview of the topic of recycling and its importance in current times; **Chapter 2** - This chapter divides recycling methods in three broad categories- computer recycling, retrocomputing and greening. Computer recycling techniques detailed in the chapter include data shredder, data erasure, degaussing, data remanence, electronic waste and file deletion. Retrocomputing techniques like home computer remake, minimalism (computing) and abandonware have been discussed. Greening includes methods like community greens, green alliance, community gardening, village green, park and common land. All these methods and their contribution to the recycling efforts have been comprehensively studied in the chapter; **Chapter 3** - Some strategies that aid in the recycling of materials are curbside collection, single-stream recycling, materials recovery facility and source reduction. All these strategies aim at segregating garbage into categories of biodegradable and non-biodegradable, increasing awareness about waste generation and reducing volumes of garbage. This chapter provides details about each of these strategies and their importance; **Chapter 4** - To identify the material from which an item is made and to facilitate faster and easier recycling, recycling codes are added to items. This chapter provides a comprehensive account of all the recycling codes in use, resin identification codes on plastic products and waste hierarchy. This content also helps the reader understand how useful this nomenclature and cataloguing is when recycling products; **Chapter 5** - Recycling is very important in the case of items like batteries as they cannot be degraded and pose an environmental hazard

due to the toxic constituents present. This chapter focuses on the topic of battery recycling, rechargeable batteries and energy storage. It provides an in-depth account of the types of batteries and their ease of recycling. There is a section dedicated to renewable energy as well. The topics discussed in the chapter are of great importance to broaden the existing knowledge on recycling; **Chapter 6** - This chapter explores the topic of nutrient recycling which is a natural method of exchange of organic and inorganic matter back into production of living matter. Important in this is the phenomenon of nutrition transfer among different organisms. The content provides a comprehensive outline of the topics of complete and closed loop, ecosystem engineers and ecological recycling.

I extend my sincere thanks to the publisher for considering me worthy of this task. Finally, I thank my family for being a source of support and help.

Editor

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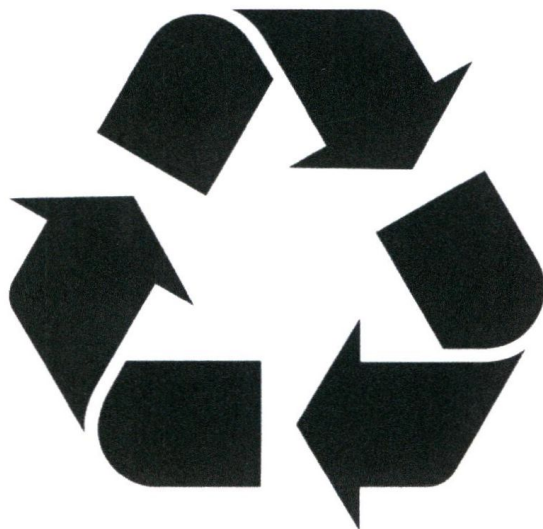
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Introduction to Recycling

Conservation efforts across the globe use the motto of “reduce, reuse, and recycle” to stress the necessity to save the environment. Recycling refers to process of converting waste material into reusable objects to reduce waste of useful material, prevent consumption of fresh raw materials etc. This chapter provides a comprehensive overview of the topic of recycling and its importance in current times.

Recycling is the process of converting waste materials into reusable objects to prevent waste of potentially useful materials, reduce the consumption of fresh raw materials, energy usage, air pollution (from incineration) and water pollution (from landfilling) by decreasing the need for “conventional” waste disposal and lowering greenhouse gas emissions compared to plastic production. Recycling is a key component of modern waste reduction and is the third component of the “Reduce, Reuse and Recycle” waste hierarchy.



The three chasing arrows of the international recycling logo. It is sometimes accompanied by the text “reduce, reuse and recycle”.

There are some ISO standards related to recycling such as ISO 15270:2008 for plastics waste and ISO 14001:2004 for environmental management control of recycling practice.

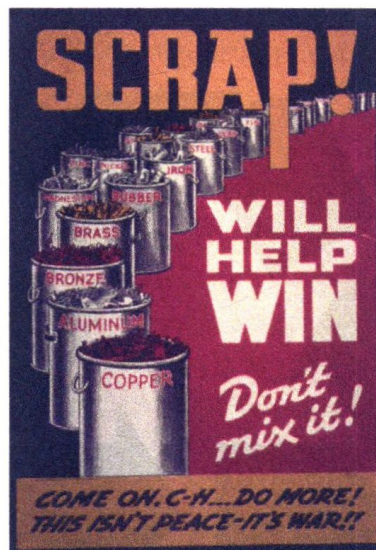
Recyclable materials include many kinds of glass, paper, metal, plastic, tires, textiles and electronics. The composting or other reuse of biodegradable waste—such as food or garden waste—is also considered recycling. Materials to be recycled are either brought to a collection centre or picked up from the curbside, then sorted, cleaned and reprocessed into new materials destined for manufacturing.

In the strictest sense, recycling of a material would produce a fresh supply of the same material—for example, used office paper would be converted into new office paper, or used polystyrene foam into new polystyrene. However, this is often difficult or too expensive (compared with producing the same product from raw materials or other sources), so “recycling” of many products or materials involves their *reuse* in producing different materials (for example, paperboard) instead. Another form of recycling is the salvage of certain materials from complex products, either due to their intrinsic value (such as lead from car batteries, or gold from circuit boards), or due to their hazardous nature (e.g., removal and reuse of mercury from thermometers and thermostats).

History

Origins

Recycling has been a common practice for most of human history, with recorded advocates as far back as Plato in 400 BC. During periods when resources were scarce, archaeological studies of ancient waste dumps show less household waste (such as ash, broken tools and pottery)—implying more waste was being recycled in the absence of new material.

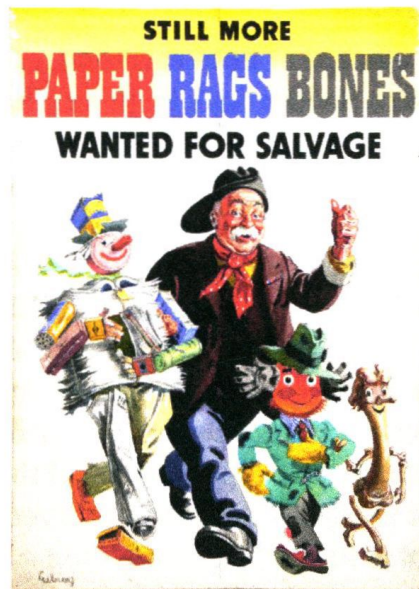


An American poster from World War II

In pre-industrial times, there is evidence of scrap bronze and other metals being collected in Europe and melted down for perpetual reuse. Paper recycling was first recorded in 1031, when Japanese shops sold repulped paper. In Britain dust and ash from wood and coal fires was collected by “dustmen” and downcycled as a base material used in brick making. The main driver for these types of recycling was the economic advantage of obtaining recycled feedstock instead of acquiring virgin material, as well as a lack of public waste removal in ever more densely populated areas. In 1813, Benjamin Law developed the process of turning rags into “shoddy” and “mungo” wool in Batley, Yorkshire. This material combined recycled fibers with virgin wool. The West Yorkshire shoddy industry in towns such as Batley and Dewsbury, lasted from the early 19th century to at least 1914.

Industrialization spurred demand for affordable materials; aside from rags, ferrous scrap metals were coveted as they were cheaper to acquire than virgin ore. Railroads both purchased and sold scrap metal in the 19th century, and the growing steel and automobile industries purchased scrap in the early 20th century. Many secondary goods were collected, processed and sold by peddlers who scoured dumps and city streets for discarded machinery, pots, pans and other sources of metal. By World War I, thousands of such peddlers roamed the streets of American cities, taking advantage of market forces to recycle post-consumer materials back into industrial production.

Beverage bottles were recycled with a refundable deposit at some drink manufacturers in Great Britain and Ireland around 1800, notably Schweppes. An official recycling system with refundable deposits was established in Sweden for bottles in 1884 and aluminum beverage cans in 1982; the law led to a recycling rate for beverage containers of 84–99 percent depending on type, and a glass bottle can be refilled over 20 times on average.



British poster from World War II

Wartime

New chemical industries created in the late 19th century both invented new materials (e.g. Bakelite (1907) and promised to transform valueless into valuable materials. Proverbially, you could not make a silk purse of a sow's ear—until the US firm Arhur D. Little published in 1921 "On the Making of Silk Purses from Sows' Ears", its research proving that when "chemistry puts on overalls and gets down to business . . . new values appear. New and better paths are opened to reach the goals desired."

Recycling was a highlight throughout World War II. During the war, financial constraints and significant material shortages due to war efforts made it necessary for countries to reuse goods and recycle materials. These resource shortages caused by the world wars, and other such world-changing occurrences, greatly encouraged recycling.

The struggles of war claimed much of the material resources available, leaving little for the civilian population. It became necessary for most homes to recycle their waste, as recycling offered an extra source of materials allowing people to make the most of what was available to them. Recycling household materials meant more resources for war efforts and a better chance of victory. Massive government promotion campaigns were carried out in the home front during World War II in every country involved in the war, urging citizens to donate metals and conserve fiber, as a matter of patriotism.

Post-war

A considerable investment in recycling occurred in the 1970s, due to rising energy costs. Recycling aluminum uses only 5% of the energy required by virgin production; glass, paper and metals have less dramatic but very significant energy savings when recycled feedstock is used.

Although consumer electronics such as the television have been popular since the 1920s, recycling of them was almost unheard of until early 1991. The first electronic waste recycling scheme was implemented in Switzerland, beginning with collection of old refrigerators but gradually expanding to cover all devices. After these schemes were set up, many countries did not have the capacity to deal with the sheer quantity of e-waste they generated or its hazardous nature. They began to export the problem to developing countries without enforced environmental legislation. This is cheaper, as recycling computer monitors in the United States costs 10 times more than in China. Demand in Asia for electronic waste began to grow when scrap yards found that they could extract valuable substances such as copper, silver, iron, silicon, nickel and gold, during the recycling process. The 2000s saw a large increase in both the sale of electronic devices and their growth as a waste stream: in 2002, e-waste grew faster than any other type of waste in the EU. This caused investment in modern, automated facilities to cope with the influx of redundant appliances, especially after strict laws were implemented in 2003.

As of 2014, the European Union has about 50% of world share of the waste and recycling industries, with over 60,000 companies employing 500,000 persons, with a turnover of €24 billion. Countries have to reach recycling rates of at least 50%, while the lead countries are around 65% and the EU average is 39% as of 2013.

Legislation

Supply

For a recycling program to work, having a large, stable supply of recyclable material is crucial. Three legislative options have been used to create such a supply: mandatory recycling collection, container deposit legislation and refuse bans. Mandatory collection laws set recycling targets for cities to aim for, usually in the form that a certain percentage of a material must be diverted from the city's waste stream by a target date. The city is then responsible for working to meet this target.

Container deposit legislation involves offering a refund for the return of certain containers, typically glass, plastic and metal. When a product in such a container is purchased, a small surcharge is added to the price. This surcharge can be reclaimed by the consumer if the container is returned to a collection point. These programs have been very successful, often resulting in an 80 percent recycling rate. Despite such good results, the shift in collection costs from local government to industry and consumers has created strong opposition to the creation of such programs in some areas. A variation on this is where the manufacturer bears responsibility for the recycling of their goods. In the European Union, the WEEE Directive requires producers of consumer electronics to reimburse the recyclers' costs.

An alternative way to increase supply of recyclates is to ban the disposal of certain materials as waste, often including used oil, old batteries, tires and garden waste. One aim of this method is to create a viable economy for proper disposal of banned products. Care must be taken that enough of these recycling services exist, or such bans simply lead to increased illegal dumping.

Government-mandated Demand

Legislation has also been used to increase and maintain a demand for recycled materials. Four methods of such legislation exist: minimum recycled content mandates, utilization rates, procurement policies and recycled product labeling.

Both minimum recycled content mandates and utilization rates increase demand directly by forcing manufacturers to include recycling in their operations. Content mandates specify that a certain percentage of a new product must consist of recycled material. Utilization rates are a more flexible option: industries are permitted to meet the recycling targets at any point of their operation or even contract recycling out in exchange for tradeable credits. Opponents to both of these methods point to the large increase in reporting requirements they impose, and claim that they rob industry of necessary flexibility.

Governments have used their own purchasing power to increase recycling demand through what are called "procurement policies." These policies are either "set-asides," which reserve a certain amount of spending solely towards recycled products, or "price preference" programs which provide a larger budget when recycled items are purchased. Additional regulations can target specific cases: in the United States, for example, the Environmental Protection Agency mandates the purchase of oil, paper, tires and building insulation from recycled or re-refined sources whenever possible.

The final government regulation towards increased demand is recycled product labeling. When producers are required to label their packaging with amount of recycled material in the product (including the packaging), consumers are better able to make educated choices. Consumers with sufficient buying power can then choose more envi-

ronmentally conscious options, prompt producers to increase the amount of recycled material in their products, and indirectly increase demand. Standardized recycling labeling can also have a positive effect on supply of recyclates if the labeling includes information on how and where the product can be recycled.

Recyclates

Glass recovered by crushing only one kind of beer bottle

Recyclate is a raw material that is sent to, and processed in a waste recycling plant or materials recovery facility which will be used to form new products. The material is collected in various methods and delivered to a facility where it undergoes re-manufacturing so that it can be used in the production of new materials or products. For example, plastic bottles that are collected can be re-used and made into plastic pellets, a new product.

Quality of Recyclate

The quality of recyclates is recognized as one of the principal challenges that needs to be addressed for the success of a long-term vision of a green economy and achieving zero waste. Recyclate quality is generally referring to how much of the raw material is made up of target material compared to the amount of non-target material and other non-recyclable material. Only target material is likely to be recycled, so a higher amount of non-target and non-recyclable material will reduce the quantity of recycling product. A high proportion of non-target and non-recyclable material can make it more difficult for re-processors to achieve “high-quality” recycling. If the recyclate is of poor quality, it is more likely to end up being down-cycled or, in more extreme cases, sent to other recovery options or landfilled. For example, to facilitate the re-manufacturing of clear glass products there are tight restrictions for colored glass going into the re-melt process.

The quality of recyclate not only supports high quality recycling, but it can also deliver significant environmental benefits by reducing, reusing and keeping products out of landfills. High quality recycling can help support growth in the economy by maximizing the economic value of the waste material collected. Higher income levels from the sale of quality recyclates can return value which can be significant to local governments, households and businesses. Pursuing high quality recycling can also provide consumer and business confidence in the waste and resource management sector and may encourage investment in that sector.

There are many actions along the recycling supply chain that can influence and affect the material quality of recyclate. It begins with the waste producers who place non-target and non-recyclable wastes in recycling collection. This can affect the quality of final recyclate streams or require further efforts to discard those materials at later stages in the recycling process. The different collection systems can result in different levels of contamination. Depending on which materials are collected together, extra effort is required to sort this