



**LAND MANAGEMENT, ENVIRONMENT & SOLID-WASTE:
INSIDE EDUCATION AND BUSINESS IN CENTRAL ASIA
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MICRO-CREDENTIAL

**CIRCULAR ECONOMY FOR LAND AND WASTE
MANAGEMENT**

6.- Recycling and Material Recovery

Recycling Systems and Material Recovery
PDF W06



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1. SUMMARY OF KEY IDEAS

As you recall, the focus of our discussion in Unit 5 was on some of the processing techniques in use in SWM systems to improve the efficiency of operations and recover resources (that could be reused) and energy. Now, in Unit 6, we analyse the recovery and recycling processes. We will, accordingly, begin the Unit by discussing the various aspects of source reduction including the design and implementation of specific source reduction programmes that inform decision-making. We will then examine how product recovery and recycling play a critical role in waste management plans. In this context, we will discuss the factors (e.g., material markets, building local expertise and fostering public participation) that are needed for planning an effective recycling programme and the elements of the recycling programme such as source separation, collection, material recovery facilities and processing. We will also look into the processing of some of the common materials that are recycled. We will close the Unit by presenting a case study on source reduction, resource recovery and recycling carried out in Bangalore.

2. LEARNING OBJECTIVES

By the end of this article, the student will be able to:

- explain waste reduction;
- discuss the significance of waste recycling;
- plan a recycling programme;
- discuss recycling programme elements;
- identify commonly recycled materials, their use and economic values;
- assess technical options and processes involved in recycling of wastes;
- explain the constraints involved in the implementation of reducing and recycling programmes.

3. SOURCE REDUCTION: BASICS

Source reduction, also known as waste prevention, is an approach that precedes waste management and addresses how products are manufactured and purchased. Put differently, this refers to the activities that reduce the amount of waste generated at source as well as activities that involve any change in the design, manufacture, purchase or usage of materials/products to reduce their volume and/or toxicity, before they become part of the solid waste stream (EPA, 1989 and 1995). Reducing waste before it is generated is a logical way to save costs and natural resources, and preserve the local environment. For instance, waste reduction cuts the municipal and commercial costs involved in waste collection and disposal, and improves the productivity by targeting wasteful processes and products.

However, a successful implementation of source reduction programme requires the co-operation of all stakeholders, (e.g., businesses, industries, consumers and state and local governments), as the goals and actions of the local waste management system are specific to local conditions. In fact, source reduction programme should be part of a community waste management plan. Source reduction activities vary widely and many factors have to be considered while evaluating them. In Subsections 6.1.1 to 6.1.4, we will examine some of the basics of source reduction processes (EPA, 1989 and 1995).

3.1. Purpose

Source reduction can serve several purposes, including the following:

- (i) Product reuse: Using reusable products, instead of their disposal equivalents, reduce the amount of materials that are to be managed as wastes. An example of product reuse is the reusable shopping bag.
- (ii) Material volume reduction: Reducing the volume of material used changes the amount of waste entering the waste stream. This helps in controlling the waste generated and its disposal. For example, buying in bulk or using large food containers reduces the amount of packaging waste generated.
- (iii) Toxicity reduction: Source reduction reduces the amount of toxic constituents in products entering the waste stream and reduces the adverse environmental impacts of recycling or other waste management activities. For example, substitution of lead and cadmium in inks (solvent-based to water-based) and paints is a source reduction activity.
- (iv) Increased product lifetime: Source reduction facilitates the use of products with longer lifetime over short-lived alternatives that are designed to be discarded at the end of their useful lives. Put differently, it encourages a product design that allows for repair and continued use rather than disposal. Manufacturing long-life tyres is a good example of increasing product lifetime.
- (v) Decreased consumption: This refers to the reduced consumption of materials that are not reusable (e.g., using a reusable shopping bag instead of picking up plastic bags from the store). Consumer education about the materials that are difficult to dispose of or are harmful to the environment is essential. Buying practices can thus be altered (e.g., buying in bulk) to reflect environmental consciousness.

In brief four main advantages of source reduction are:

- Reduction in extent of environmental impacts
- Reduction in resource consumption and generation of pollution
- It includes producer, consumer, prudent and efficient activities

3.2. Implementation

There are several specific actions that can take place at the local level to encourage source reduction, some of which are given below:

(i) Education and research: Consumers, businesses, industries, schools, etc., can implement education and research activities to address the need for source reduction, its consequences, available choices, benefits and costs. Essentially, the aim of such education and research activities is to provide and develop information about source reduction goals, needs and methods and to elicit voluntary efforts from the public and private sectors to help bring about some specific changes. Some of the activities that reflect education and research to encourage source reduction include:

forming stakeholder councils (industry, government agencies, etc.) to develop a source reduction message to the public and to carry out educational and research activities;

exploring and developing funding sources, such as government grants, financial support for industries, private funding grant, direct tax and solid waste surcharge;

developing media campaign for public outreach, including posters, conferences and forums concerning source reduction;

developing curricula for schools and universities as well as organizing a group of professionals with knowledge of source reduction and solid waste management.

(ii) Financial incentives and disincentives: Linking an economic benefit to the implementation of source reduction activities encourages source reduction. For example, financial disincentives represent additional costs to the waste producing activities that could be avoided through source reduction activities. The various measures that can be targeted at consumers and industries include the following:

Tax credit or exemption may be given to companies and institutions that follow specific source reduction procedures for manufacturing and consuming.

As variable waste disposal charges for garbage collection are generally taken for post-consumer solid waste, the fees or payment can be based on the number of garbage cans used, number of bags collected or the frequency of collection.

Graduated fee structure for garbage collection can be based on quantity and frequency.

Product disposal charges can be assessed either on the producers at the time of manufacture or on the consumers at the time of purchase. However, we need to note that though these charges can encourage source reduction on economic grounds and the funds generated from the charges can be used to correct and reduce the impacts of product disposal, it is difficult to assess such charges effectively and efficiently.

(iii) Regulation: Although most regulation occurs at the national and state level, local authorities can participate in legislative activities in developing regulations that affect municipal SWM. It is possible, for example, to establish a programme to inform the consumers about environmental impacts, durability, reusability and recyclability of products as well as to declare source reduction as a top priority in SWM. Regulatory option of source reduction can include the following:

- Quantity control regulation, which encourages substitution of products that have the same function but pose less threat to human health and environment, through restrictions and bans.
- Product design regulation, which includes products that do not meet certain design criteria and could be subjected to quality control by sales tax and restrictions.

3.3. Monitoring

Monitoring facilitates the evaluation (i.e., efficacy and efficiency) of source reduction, the identification of possible source reduction measures and programme revisions and the obtaining of funds and resources for source reduction initiatives/programmes. Monitoring should, therefore, be an integral part of a source reduction programme. We must, however, note that source reduction is more difficult to measure on a broad scale than other methods of SWM. When several waste reduction techniques are used simultaneously, for example, it is not easy to determine which portion of the diversion was due to source reduction.

Source reduction often results in substantial and measurable cost savings from activities such as waste collection, transportation and disposal, and direct savings. In addition, source reduction is cost-effective in decreasing pollution, purchase, use, and regulatory compliance costs. It also reduces product and material use and disposal costs in the manufacturing process, making business operations more efficient. There is, however, some concern that source reduction might reduce economic growth by decreasing consumption. Nonetheless, it offers opportunities for economic gain by resource recovery and employment generation in source reduction programmes. Costs associated with source reduction must, therefore, form part of the monitoring process to ensure accountability.

Life cycle analysis

An environmental economic analysis will help us understand the trade-offs between source reduction, durability, recyclability, use of recycled material and other environmental benefits. Obviously, we choose the process that yields the greatest overall environmental benefits. Ideally, to assess and quantify these trade-offs, a life cycle analysis (LCA) – variously known as life cycle assessment, ‘**cradle to grave analysis**’

or **‘econ-balance’** – is required, which involves the evaluation of some aspects, particularly most often the environmental aspect, of a product through all stages of its life cycle.

LCA, in essence, takes a detailed look at all resources used and the products and by-products generated throughout the entire life of a product or process. The analysis begins with raw materials and energy acquisition, examines manufacturing and product fabrication, filling, packaging and distribution, and consumer use and reuse, and finally ends with an analysis of waste management.

Note that LCA represents a rapidly emerging family of tools and techniques designed to help in environmental management and long-term sustainable development (European Environment Agency, 1998) and the LCA procedures are being developed to assess the overall environmental impact of products and their packages. We will discuss LCA in detail later in Unit 10.

3.4. Evaluation

Before adopting source reduction policies, it is important that we develop a framework for evaluating various options. Some of the criteria to be considered in this regard are:

- Social and economic equity.
- Economic and administrative feasibility, efficiency and cost.
- Volume requirement and scarcity of materials and natural resources in product manufacture.
- Volume of product and its by-products that must be eventually disposed.
- Useful life, reusability and/or recyclability of a product.
- Priority of source reduction of more hazardous products to less hazardous ones.

 LEARNING ACTIVITY 6.1

- (i) Explain the need for source reduction in waste management.
- (ii) List the criteria to be considered in the evaluation of various options before adopting a source reduction policy.

Note:

- a) Write your answer in the space given below.
- b) Check your answer with the one given at the end of this Unit.

Having studied the various aspects of source reduction, we will next deal with handling (i.e., reusing, recycling or disposing of) that portion of waste stream which cannot be reduced at the source. We will also explain how wastes can be recycled and utilised to derive from them optimum economic value.

4. SIGNIFICANCE OF RECYCLING

Recycling is perhaps the most widely recognised form of source reduction involving the process of separating, collecting, processing, marketing and learning activity ultimately using a material that would

have otherwise been discarded. This form of source reduction, i.e., recycling, is similar to other forms, in that it:

- lessens reliance on landfills and incinerators;
- protects human health and the environment by removing harmful substances from the waste stream;
- conserves natural resources by reducing the demand for raw materials.

Recycling is one of the fundamental parts of the waste management plan. Although it alone cannot solve a community's municipal SWM problem, it can divert a significant portion of waste stream from disposal in landfill and combustion facilities. Recycling has a lot of direct and indirect significance for the society, and this can be grouped under the following three broad areas (UNCHS, 1994):

- **Economic significance:** Economic assessment of waste recycling is a difficult task as many of the beneficial environmental and social impacts of recycling are long-term and are intangible, and, therefore, are difficult to quantify. Some of the short- and long-term economic benefits are:
- **Cost reduction:** Resource recovery through recycling of solid waste could be of interest to waste management authorities as a means of reducing the waste disposal cost. Any saving in waste management cost could be a significant incentive to the authorities to increase the coverage of service areas and improve the service level. They can save cost from fuel for transportation, operation and maintenance, and generate revenue by sale of recyclables, etc.
- **Employment:** Recycling of waste is a labour intensive activity, and its potential to ease the unemployment problem is high. Enhanced recycling activities, for example, can create an additional job market for skilled and unskilled workforce, and they can adapt to any of the occupations such as a labourer in recycling business or industry or a dealership.
- **Energy saving:** Use of recyclables in some industrial processes is known to consume less energy than the use of any other raw material. The reduction in energy consumption in one industry could mean its availability for some other industry in need.
- **Reduced health care costs:** Improved health and sanitary conditions in urban areas resulting from indirect benefits of waste recycling can reduce the investment in public health programme.
- **Saving costs for other public utilities:** Enhanced solid waste recycling practices can reduce the frequency of sewer clogging, blocking of natural watercourses and pollution of water bodies. This will benefit the concerned public utilities through reduced cost in cleaning sewers and improved public safety due to blocked sewers and narrowing of natural watercourses.

(ii) Environmental and health significance: The volume of waste is increasing rapidly because of population growth and economic development. The composition of waste is also changing, leading to waste production with more recyclables. At the same time, polluted waste fractions are increasing because of increasing complex processes being used in industries, and these contribute increasingly to environmental degradation. This notwithstanding, recycling helps, among others, in the following ways, to facilitate effective waste management:

- **Improved environment:** The environmental pollution may be due to inadequate SWM as well as due to its effect on other urban infrastructure. Recycling reduces the volume of waste that has to be finally dumped, and thereby causing reduction in pollution at the waste disposal sites. When there is reduction in volume of waste because of its increased reuse, different types of pollution (e.g., water, air and land) will get abated.
- **Natural resource conservation:** Industries with natural products as their raw material for production are depleting natural resources. Use of more and more recyclable solid wastes in industrial production will relieve the tremendous pressure on these precious resources. For example, recycling of waste paper means a lower demand for wood, which means less cutting of trees and an enhanced possibility for sustainable use of the forest. Using recyclable items in the production process would reduce the demand for energy as well.

(iii) Social significance: People engaged in waste collection activities are normally of low social and economic standing. This is especially true with scavengers, which is evident from persisting poor quality of their living and working conditions. Different groups of people engaged in waste recycling have a hierarchical social and economic status, in which, processors are at the top of the hierarchy followed by waste dealers and wholesalers, waste buyers and waste collectors in that very order, while scavengers are at the bottom. Although there is this social and economic hierarchy within the waste recycling business, the overall social esteem of waste recycling operators is low.

A formal recycling arrangement will help promote the social esteem of waste workers and facilitate their upward social mobility due to increased earning. In addition, the improved recycling activity will increase the economic value of the waste and will reduce waste scavenging activity providing opportunity for scavengers to switch to a more socially acceptable occupation. In short, institutionalised recycling programmes will help remove the stigma associated with waste scavenging and transform it to an economic enterprise.

 LEARNING ACTIVITY 6.2

Explain how recycling takes place in your locality and list its advantages?

Note:

- a) Write your answer in the space given below.
- b) Check your answer with the one given at the end of this Unit.

Now that we learnt the importance of recycling, which is more than just the separation and collection of post-consumer materials, let us plan a recycling programme, which indeed is the focus of Section 6.3.

5. PLANNING OF A RECYCLING PROGRAMME

Numerous recycling options are available, and recycling programme development requires strategic planning. Planning for recycling involves understanding markets, assessing local expertise, setting goals and fostering public participation. An efficient recycling programme requires a systematic approach to all programme components, which are interrelated, and therefore, decisions about one must be made taking into consideration other components. As a successful recycling requires public participation, programmes must be designed keeping in view public convenience and support. The factors involved in the planning process include the following (EPA, 1989 and 1995):

(i) Build local expertise: Small projects help build local expertise in recycling and minimise the problems associated with poor planning. With small-scale projects, it is easy to compare and evaluate the programmes and techniques that are considered most successful within the community. When the time comes to develop a large-scale programme, there will be practical experience and an established decision-making framework, which will enhance the programme's success.

(ii) Understand and develop a recycling market: While planning for a recycling programme, it is important to find an outlet for the recyclable material. Market analysis is both a planning and ongoing activity, as even the most successful recycling programme can be severely affected by market fluctuations. Recycling programmes must, therefore, be designed with the flexibility to handle fluctuating markets and uncertain outlets for material.

(iii) Foster public education and involvement: Public participation is one of the most important factors deciding a programme's success. The public has a right and a responsibility to understand the full costs and liabilities of managing the waste they produce. A well-planned public education and involvement programme will foster public interest in recycling.

(iv) Assess local waste stream: Planning any recycling programme requires the knowledge of the local waste stream. Choosing the right material to recycle and designing the logistics of the programme are the important parts of the planning process.

(v) Augment existing programme: Recycling should augment the success that has been attained by other groups operating recycling programmes. This is very important for planning and success. Other programmes may be run by local volunteer organisations to raise funds or as a community service.

(vi) Set goals and objectives: Part of the planning process involves setting goals and objectives. The preliminary assessment of waste stream helps in deciding long-term goals for a community. Planning objectives may include determining the type of waste stream component that should be programmed, investigating the feasibility of the curbside (kerbside) programme, public outreach avenues, etc. The community will benefit from carefully developed achievable goals and objectives, and from an integrated approach to waste management (see Unit 10 for a detailed discussion of the integrated approach to waste management).

(vii) Coordinate the programme: Recycling programme is considered a public service. Therefore, local governments are required to ensure that all services are provided properly. Like any other public service, recycling programmes should be consistent, predictable, equitable and efficient.

(viii) Evaluate the programme: New programs and technologies are evolving continuously, which make the planning for recycling an ongoing process. This requires experiment and evaluation. Even the best recycling programmes experiment with new techniques to improve on their current efforts.

If recycling programmes are properly planned and implemented, they would then add to the overall municipal waste management activity.

LEARNING ACTIVITY 6.3

List the factors that you will consider while planning a recycling programme.

Note:

- a) Write your answer in the space given below.
b) Check your answer with the one given at the end of this Unit.

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6. RECYCLING PROGRAMME ELEMENTS

Recycling programmes are designed according to the needs and priorities of the communities. Elements of a recycling programme include source separation, curbside (kerbside) collection, material resource facilities and full stream processing. Recycling, generally, has a positive impact on other municipal waste management programmes. This may include a mix of strategies, ranging from simple, single material drop-off centres to large scale, centralised processing facilities. We will discuss some of the major elements (EPA, 1989 and 1995) in Subsections 6.4.1 to 6.4.8.

6.1. Source separation

Source separation refers to the segregation of the recyclable and reusable materials at the point of generation. This requires that several designated materials be separated into their own specific containers, while other programmes use only two containers – one for the storage of mixed recyclables and the other for regular wastes. Source separation may be voluntary or mandated and is done in conjunction with several recycling programmes.

6.2. Drop-off/buy-back

A drop-off programme requires residents to separate the recyclable materials and bring them to a specified drop-off or collection centre. However, we must take into account local conditions when designing a collection programme. For a community that does not provide a curbside pickup, for example, educating and encouraging citizens to deliver materials to a drop-off site may be all that is needed. A recycling centre can be established at the same location where residents deliver waste. Mobile recycling drop-off trailers can also be used. Drop-off recycling, however, is less convenient than curbside pickup. If a thorough educational and promotional effort is not made, drop-off programme tends to have lower participation rates than curbside collection.

Buy-back refers to a drop-off programme that provides monetary incentives to participate. In this type of programme, the residents are paid back for their recyclable material directly or indirectly through the reduction in collection and disposal fees. Establishing a buy-back centre (i.e., a place where recyclables are purchased) may help induce citizens to recycle. Some buy-back centres purchase some materials and accept others, depending on current market conditions. Private or public mobile buy-back operations can serve some areas, purchasing recyclables from small communities or from neighbourhoods of large metropolitan areas on a regular schedule.

6.3. Curbside programme

In a curbside system, source separated recyclables are collected separately from regular refuse from the curbside, alley, or commercial facility. Curbside programmes vary greatly from community to community. Some programmes require residents to separate different materials that are stored in their own containers and collected separately. Other programmes use only one container to store recyclables or two containers, one for paper and the other for heavy recyclables (e.g., glass aluminium, etc.).

6.4. Storage and collection of recyclables

Collection of source-separated materials is a necessary component of recycling programme. Establishing a collection system for source-separated materials will require more careful planning than regular trash collection. Some principles of sound recyclables storage and collection should be understood, while developing a programme, and these include:

- **Resident convenience:** The easier it is for residents to separate materials, the higher the participation and recovery rates will be.
- **Collection crew convenience:** The system should be convenient for collection crews. For example, loading and sorting activities should be as simple as possible.
- **Cost effectiveness:** Equipment and procedures must be designed to maximise collection crew and vehicle productivity.
- **Integrity of materials:** The storage and collection system should keep recyclables in the best shape possible. It should be properly handled, dry and contaminant free.

How residents store recyclables in a household and curb has a direct impact on the success of a recycling programme. The storage container should provide a handy way to store materials until collected, and it must be easy for the collector to distinguish recyclables from garbage.

6.5. Collection vehicles for recycling

Collection vehicles that are designed specifically for collecting recyclables have several storage bins, which can be easily loaded and often equipped with automatic container-tipping devices. Although these modified vehicles may still be considered as options, a dedicated, closed-body collection vehicle for recycling with sufficient capacity offers such significant advantages as easy loading and unloading, flexible compartments and protection from weather. Of course, this warrants a substantial initial investment.

6.6. Processing equipment for recycling

Recycling involves a number of processing techniques and these processes require different equipments, many of which we discussed in Unit 5. However, some of the special equipments used in recycling are:

- **Balers:** Balers can be used to densify many types of materials including paper, cardboard, plastics and cans. Balers can improve space utilisation and reduce material transportation costs.
- **Can densifiers:** Can crushers are used to densify aluminium and steel cans prior to transport.

- **Glass crushers:** These are used to process glass fraction separated by colour and break it into small pieces. This crushed material is then called cullet, and can be reprocessed into new glass products.
- **Magnetic separators:** These are used to remove ferrous material from a mixture of materials.
- **Wood grinders:** These are chippers and are used to shred large pieces of wood into chips that can be used as mulch or as fuel.
- **Scales:** These are used to measure the quantity of materials recovered or sold.

6.7. Material recovery facilities (MRF)

MRF (pronounced 'murf') is a centralised facility that receives, separates, processes and markets recyclable material. It can be operated with both drop off and curbside programmes. The primary advantage of MRF is that it allows materials directly from the municipalities and processes them uniformly. It is generally designed to handle all type of recyclables. Implementation of MRF in a municipality depends upon a number of factors as follows:

- **Market demand:** When additional processing is required, MRF is more useful as buyers may have certain material specifications.
- **Separate collection:** In systems that require residents to separate their recyclables, intermediate separation and processing is required.
- **Number of different recyclables:** In general, a MRF will be more beneficial when a large number of different recyclables are collected.
- **Quantities of materials:** Because MRF involves substantial capital and operating costs (e.g., buildings, equipment and labour), it is expected to handle a significant amount of materials to justify its operation.

6.8. Full stream processing

This is a high technology separation technique, which processes all components of municipal waste. The materials recovered by this process tend to be of lower quality than those recovered or source separated in MRF because the former is a mix of various types of wastes. To achieve a better quality, the materials obtained through the full stream processing must be cleaned, which is a costly process. However, this technique remains attractive because it does not require source separation, and it is used in the following applications:

(i) Refuse derived fuel (RDF) preparation: In this application, it is used to extract the combustible portion of municipal waste.

(ii) Municipal waste composting: In this application, it is used to concentrate the compostable portion of municipal solid waste. Note that this is sometimes performed as part of RDF preparation.

(iii) Material recovery: In this application, it is used to recover and resell certain materials, and thereby making material recovery a recycling technology as well.

In full stream processing, depending on the facility design, the materials are separated either mechanically or by hand, and size and weight are the main characteristics used to separate the materials. For example:

- when the material is dumped, oversized materials such as furniture, etc., are removed;
- rotating screens are used to separate materials of different sizes (small and large);
- ferrous material is extracted using a magnet system;
- air classifier is used to separate the lighter material;
- light materials including plastic and paper are further processed into RDF; heavy fraction is mechanically or manually sorted to recover saleable materials such as cardboard, etc.

LEARNING ACTIVITY 6.4

Explain the recycling programme elements adopted in your locality.

Note:

- Write your answer in the space given below.
- Check your answer with the one given at the end of this Unit.

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7. COMMONLY RECYCLED MATERIALS AND PROCESSES

In this Section, we will discuss some commonly recycled materials, the technologies used to recycle them and their specific environmental and economic impacts.

7.1. Paper and cardboard

Paper and cardboard form the second biggest component of domestic waste after organic waste, and contribute to about 13% of the total domestic solid waste (UNCHS, 1994). Paper recycling is one of the most profitable activities and is practised extensively. It reduces the demand for wood and energy and helps solve littering problem in the city and around dumping site. It has an acceptable working condition and health risks are limited. Recovered paper and paper products are bought and sold through a well-established network of local processors and vendors who typically bale these materials for sale. Of late, paper mills have started buying directly from the collectors.

The paper industry is making a significant investment in manufacturing capacity for making paper and paper products with recycled content. Recovered paper is classified as newsprint, corrugated cardboard, mixed paper (including magazines, junk mail and cardboard), high-grade paper (white office paper, photocopying paper), and pulp substitute paper (usually mill scrap). Paper mills, the most common end users of recovered paper, use the material as a feedstock to manufacture recycled paper and paper products, such as newsprint, chipboard, craft linerboard, corrugating medium, roofing felt and tissue products. Shredded paper is used to make animal bedding, hydro mulch, moulded pulp products and cellulose insulation.

A typical input-output model of the paper processing technique consists of the following:

Material inputs: Paper/cardboard scrap, magazines, newspapers, computer paper, wrapping paper, craft sacks, cartons, etc.

Product outputs: Paper sheets, boxes, filter paper, mosquito mats (to absorb chemical repellent), merchandising packets, decorative items, etc.

And, the technology in the recycling of paper and cardboard involves the following processes:

(i) Cardboard processing (semi-mechanical) plant: In semi-mechanical plants, paper scrap is pulped in a beater machine. The paper pulp is spread on a rotating sieve and pressed mechanically. Cutting is done manually and after cutting and sun-drying, the cardboard is calendered and sheared into sheets, as illustrated in Figure 6.1 below, from which boxes for shoes, sweets, etc., are made:

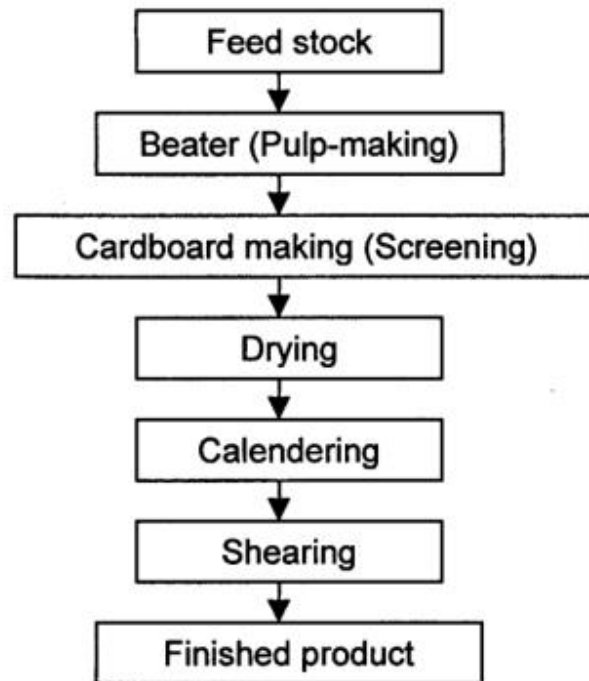


Figure 1.- Cardboard Processing (Semi-Mechanical)

The various machineries used in the processes include:

- **Beater:** This consists of a masonry and concrete tank and a mild steel beater roll, driven by an electric motor.
- **Sieving screen:** This separates materials of different size.
- **Cardboard making unit:** This is a nylon conveyor screen driven by an electric motor.
- **Calendering machine:** This is used to finish the surface of paper and is electrically operated.

(ii) Hand-made paper: In hand-operated units, pulping and beating of paper is done manually in an open masonry or concrete tank. The material is sieved in a second tank and diluted with water to a specific consistency. A wooden framed screen is dipped in the tank in order to form an even layer of the wet pulp to a desired thickness (over the screen mat). The layer is skillfully removed and transferred from the mat and the sheets are sun dried on smooth walls or on other smooth surfaces. The dried sheets are then pressed and cut into required sizes. The calendering is performed in an electrically operated machine. Figure 2 illustrates the processing sequence in a hand-made paper unit:

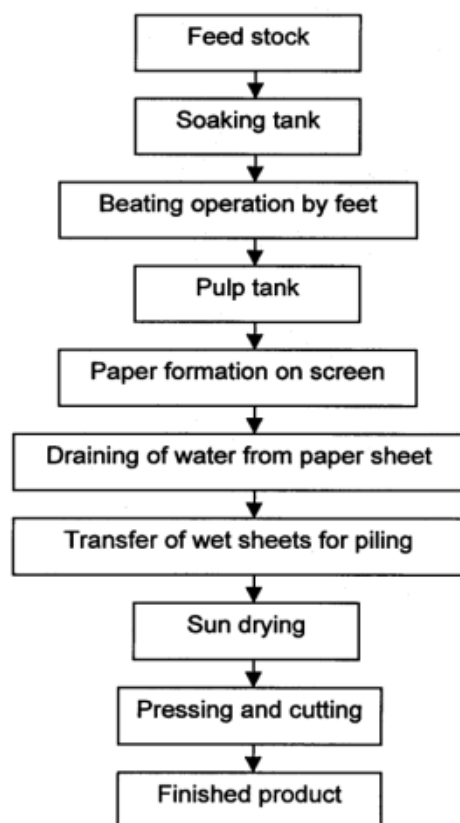


Figure 2.- Hand-Made Paper Processing

7.2. Glass

Glass is one of the most commonly recycled materials, and the market for post consumer glass has historically been steady. Glass generally accounts for 2.5% by weight of the total solid waste generated (UNCHS, 1994). Though it does not contribute to the environmental problem, glass does cause a serious problem of littering. The economic impacts are cost of waste collection and disposal, reduction in use of natural products and energy consumption.

Recycling of broken glass reduces the risk of diseases caused by cuts and wounds. Glass recycling is a labour intensive process and provides employment opportunity. Glass is typically broken for size reduction or crushed and ultimately sold to glass manufacturers as furnace-ready cullet after metal caps, rings, labels, etc., are removed.

Glass manufacturers purchase glass for reprocessing into new, clear, green and brown glass jars and bottles. The market for recovered glass has been strong and stable for brown and clear containers. Green

glass, however, is seldom used to package goods domestically, so fewer companies produce glass of this colour. Alternative markets for glass include art glass, sandblasting, and industrial windowpane glass and fibreglass insulation. Although the glass industry has made a commitment to increase the demand for recovered glass, there is an important and pervasive market concern about the quality of material being produced by collection programmes and processing facilities. Recycling programme planners must address this concern for high-quality recovered glass as well as for other commodities.

Typically, while glass scrap is the material input, glass products are the product outputs in the glass recycling technique which involves a semi-mechanical process. This, we will study next.

Semi-mechanical process

The waste glass cullet is sorted according to colour and melted in an oven at 1400 C. The oven used in a small production unit is locally made from fire clay and known as pot furnace. To improve the unbreakability of the glass product, chemicals such as soda ash, potassium carbonate, borax, lime, etc., are added to the cullet before melting. When the metal has completely melted, the temperature is raised to refine the glass. After refining, the temperature is lowered to carry out the moulding operation. After the glass takes the shape of the mould and hardens, unwanted portions are cut and removed, and sharp edges are smoothened in a machine. The product is then annealed by cooling and heating for three to four hours at 600 – 900 C to reduce the brittleness of the glass. After quality inspection, defective glass products are returned to the recycling process. The approved products are packed for marketing. Figure 6.3 depicts the processes described above:



Figure 3.- Glass Processing (Semi-Mechanical)

The following machinery is used in the process:

Furnace: It is used to melt the glass cullet. The glass cullet is melted at 1400 C (locally fabricated) and the product obtained is annealed at 600 C (locally fabricated).

Semi-mechanical die: It is used to cast the die. It uses both mechanically and manually operated moulds.

Air compressor: It is used for blowing molten glass into dies.

Printing machine: It is used for printing trademark.

7.3. Metals

Ferrous metals like iron, steel, etc., and non-ferrous metals like aluminium, copper, zinc, lead, silver, etc., are some of the metals, which exist in the waste stream. On an average, metals account for 2% of total solid waste generated (UNCHS, 1994). Extraction of metals from natural ores depletes the mineral resources. Metals when dumped at landfill sites produce hazardous leachate with heavy metals in solution.

Using recycled metals substantially reduces operating costs of industries. Metal scrap is cheap and the energy consumption is lower when products are manufactured from scrap. The long-standing track record makes ferrous and non-ferrous metal market among the most stable of all recyclable materials. Ferrous and non-ferrous metals can be bought and sold through processors and vendors. Ferrous scrap includes household appliances, equipments, cans, and other iron and steel products. Non-ferrous scrap metals include aluminium, copper, lead, tin, etc. Both ferrous and non-ferrous metals can be prepared for sale through some combination of processing by flattening, baling, and shredding of the material. In some cases, processors melt the metal into ingots before selling it to end-use markets. Several foundries and steel mills have begun or expanded recycling efforts, and steel mini-mills also appear to be increasing their use of recovered steel in regions, which typically lack large mills.

The typical material inputs and product outputs in this industry are the following:

(i) Material inputs: Aluminium, brass, copper, zinc, tin, iron, steel, etc.

(ii) Product outputs: Sanitary and gas fittings, funnels, buckets and storage bins, reinforced steel bars, hand tools, etc.

Metal processing

Now, we will discuss the process involved in recovering metals. Most of the recovered metals are processed by big industries. Ferrous metals are processed by iron industries to produce iron bars, channels, angles, etc. Local artisans process part of the ferrous metal in many cities. In a small-scale cottage industry, a particular kind of metal (ferrous or non-ferrous) is melted in a crucible in the coal furnace and the molten metal is cast into the desired mould to make ingots of required shapes and size. New and melted recycled

metals are mixed together in a 3:1 ratio for better quality products. Ingots are sold to manufacturers to obtain different products from the metal. Local artisans heat the iron ingots in a coal furnace and beat them into different shapes for various kinds of tools and implements. Annealing hardens the cutting edges of the tools. The tools used in the process include coal burner, furnace (coal fired), moulding gadgets, dies (pattern) and auxiliary tools.

7.4. Plastic

These days, plastic is posing serious littering problem in cities and around collection points and dumping sites. With an average 8% by weight of the total amount of domestic waste, plastic is one of the major constituents in waste stream (UNCHS, 1994). Un-recycled plastic, when burned, contributes to greenhouse gases. The direct benefits of recycling plastic waste are reduction in the cost of raw material and energy saving. Plastic recycling also helps in employment generation along with reduction of volume transport and space requirements for dumping.

Most plastics are densified locally by flattening, baling, or granulating, and sold either to converters, where the resins are turned into pellets, or directly to domestic or export end users for remanufacture into products such as bottles, carpet and carpet backing, flower pots, and insulation material.

Post consumer plastic-resin recycling technology has developed more rapidly than technologies for any other recovered material in the last half century. Only five to ten years ago post consumer high-density polyethylene (HDPE) and polyethylene terephthalate (PET) plastics were vaguely considered recyclable. These two resins, especially HDPE milk jugs and bottles and clear PET plastics, now hold a stronger place in the market. End uses for recycled HDPE include non-food bottles, drums, toys, pipes, sheets and plastic pallet, and for PET include plastic fibres, injection moulding, non-food grade containers and chemicals. The recyclability of other resins, such as polystyrene, polyvinyl chloride, low-density polyethylene (LDPE), polypropylene and mixed plastic resins is making strides but much remains to be done. The input materials, the output products involved in the recycling of plastics are given below:

(i) Material input: Plastic scrap (thermoplastic and thermosetting).

(ii) Product output: Toys, boxes, slippers, shoes, pellets, buckets, cans, etc.

We will now discuss the processes involved in plastic recycling.

Plastic processing

In plastic processing, the primary steps are sorting by colour and quality, and cutting and crushing the sorted material. The crushed product (granules) of plastic is melted, colour dyed and manually moulded into a cheaper product. The poly vinyl chloride plastic is blended with a specific colour dye in a mixing machine.

The coloured material passes through an extruder machine to produce thick plastic strands. The strands are manually cut into lumps and these are used for manufacturing items either manually or mechanically, as shown in Figure 4:

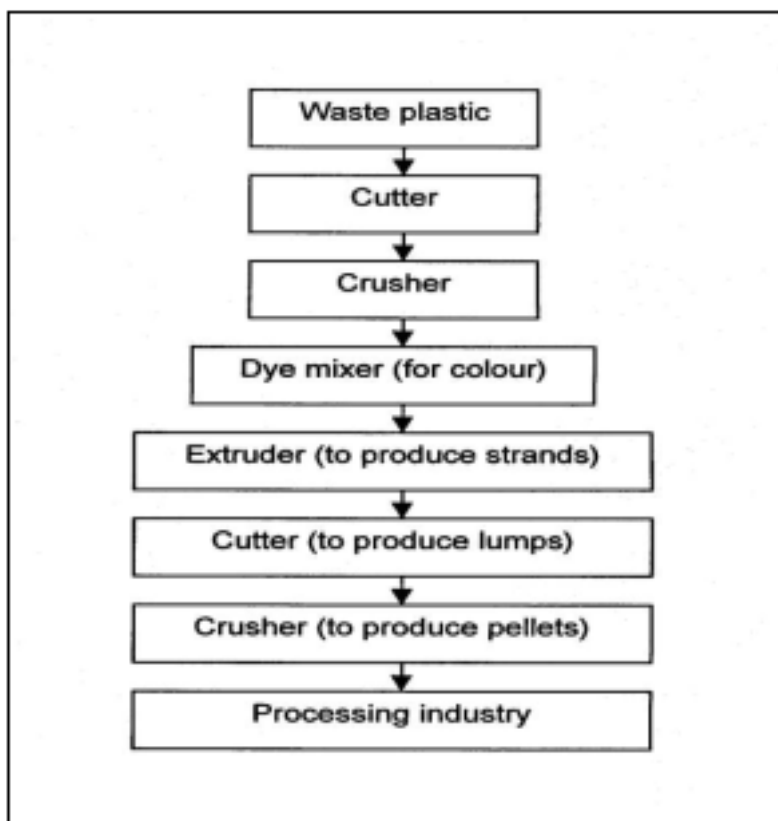


Figure 4.- Plastic Processing

Note that in the manual process, the lumps are further chopped into smaller pieces and melted. The melted material is moulded into products such as shoe soles, toys and boxes. Machineries used in this process are electrically operated crusher, extruder, mixer and manually operated moulding machine (in which material is electrically heated at 359°C).

7.5. Batteries and tyres

Battery recycling is not only a response to market condition (i.e., price of lead) but also is important due to concern over the toxic compound including lead, cadmium and mercury present in many batteries. Like other materials, battery recycling depends largely on market conditions and requires consistent collection

Electricity-generating facilities, pulp and paper mills and cement kilns are the most common processes using scrap tyres (EPA, 1989 and 1995).

This image shows a single sheet of white paper with horizontal blue or grey ruling lines. The lines are evenly spaced and run across the width of the page. There are approximately 20 lines visible. The paper has a slight shadow on the right side, suggesting it's resting on a surface.

8. CASE STUDY: SOURCE REDUCTION AND

RECYCLING IN BANGALORE

Source reduction, including reuse and recycling, can help reduce waste disposal and handling costs, because it avoids the costs of municipal composting, landfilling and combustion. Source reduction also conserves resources and reduces pollution, including greenhouse gases that contribute to global warming.

Waste reduction, reuse and recycling, thus, play an important role in SWM. In what follows, we present the statistics on waste recovery and recycling done in Bangalore, India.

In Bangalore, 66% of the waste generated is collected for recovery, i.e., about 2,373 tonnes per day. While 722 tonnes per day is reused, the rest (i.e., 1,450 tonnes) goes for recycling. The agents involved in the collection and recovery of wastes in the city include waste pickers, IWB (i.e., itinerant waste buyer), middlemen (or intermediaries), the municipality and recycling units (both large and small). While the three agents in the informal sector and the municipality are directly involved in waste collection activities, the waste is processed by the recycling units, which receive recyclable waste from middlemen and municipality. Table 6.1 gives the statistics of waste recovered and collected by stakeholders in Bangalore:

Table 1.- Waste Recovery and Collection by Stakeholders

Stakeholders	For reuse	For recycling		
		Waste pickers	IWB	Intermediaries
Households	101.7	74.5	60.4	57.7
Commercial establishments	350.8	227	0.0	24.3
• markets	112.7	200	0.0	8.8
• hotels	238.1	27	0.0	15.4
Institutes	0.0	9.6	0.0	61.3
• hospitals	0.0	1.0	0.0	0.0
• offices	0.0	8.4	0.0	0.0
• educational institutions	0.0	0.2	0.0	61.3
Industries	269.3	0.8	0.0	934.5
Total	721.8	312	60.4	1077.8

Of the 1450 tonnes collected for recycling, 1077.8 tonnes come from intermediaries, 60.4 come from IWB and 312 tonnes come from waste pickers. This amounts to 40% of the total waste (i.e., 3613 tonnes per day) generated.

9. SUMMARY

In this Unit, we discussed source reduction and recycling aspects, which precede the management of solid wastes. We began the Unit with an introduction to source reduction and its purpose, which is to reduce the amount of wastes generated at source and reduce their volume and/or toxicity before they become part of the solid waste stream. In this context, we explained how a source reduction programme could be successfully implemented and evaluated. We also said successful implementation requires education and research, financial incentives and disincentives and regulation and evaluation for various options using certain criteria.

Subsequently, we discussed recycling, which perhaps is the most widely recognized form of source reduction, and its significance. In addition, we explained the planning processes (i.e., understanding the market, identifying local expertise, setting goals and fostering public participation) and elements (i.e., source separation, curbside collection, material resource facilities and full stream processing) involved in a recycling programme. We then discussed commonly recycled materials such as paper, glass, metals, plastics and battery and tyres along with their processing techniques. Finally, we presented the source reduction and recycling programme carried out in Bangalore as a case.

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Unit 6: Source Reduction, Product Recovery and Recycling

Model Answers to Learning Activities