13. WASTE MINIMISATION AND RESOURCE CONSERVATION

13.1 Introduction

Traditionally, waste is viewed as an unnecessary element arising from the activities of any industry. In reality, waste is a misplaced resource, existing at a wrong place at a wrong time.

Waste is also the inefficient use of utilities such as electricity, water, and fuel, which are often considered unavoidable overheads. The costs of these wastes are generally underestimated by managers. It is important to realise that the cost of waste is not only the cost of waste disposal, but also other costs such as:

- Disposal cost
- Inefficient energy use cost
- Purchase cost of wasted raw material
- Production cost for the waste material
- Management time spent on waste material
- Lost revenue for what could have been a product instead of waste
- Potential liabilities due to waste.

What is waste minimisation?

Waste minimisation can be defined as "systematically reducing waste at source". It means:

- Prevention and/or reduction of waste generated
- Efficient use of raw materials and packaging
- Efficient use of fuel, electricity and water
- Improving the quality of waste generated to facilitate recycling and/or reduce hazard
- Encouraging re-use, recycling and recovery.

Waste minimisation is also known by other terms such as waste reduction, pollution prevention, source reduction and cleaner technology. It makes use of managerial and/or technical interventions to make industrial operations inherently pollution free

It should be also clearly understood that waste minimization, however attractive, is not a panacea for all environmental problems and may have to be supported by conventional treatment/disposal solutions.

Waste minimization is best practiced by reducing the generation of waste at the source itself. After exhausting the source reduction opportunities, attempts should be made to recycle the

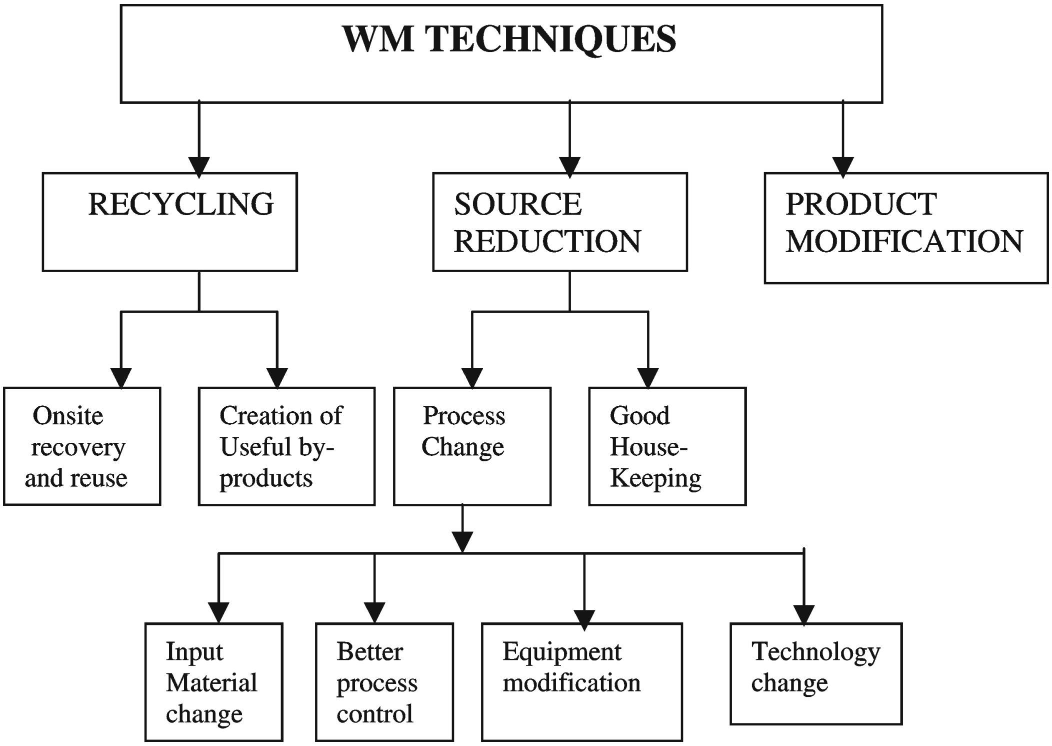
TABLE 13.1 WASTES AND POSSIBLE RESOURCES

Wastes	Resources
Fly ash from power plant	Raw material for cement or brick manufacture
Bagasse wastes from sugar manufacture	Fuel for boiler
CO_2 release from ammonia plant	Raw material for Urea manufacture

waste within the unit. Finally, modification or reformulation of products so as to manufacture it with least waste generation should be considered. Few wastes and possible resources are indicated in the Table 13.1

13.2 Classification of Waste Minimization (WM) Techniques

The waste minimization is based on different techniques. These techniques are classified as hereunder.



Source Reduction

Under this category, four techniques of WM are briefly discussed below:

a) ***Good Housekeeping-*** Systems to prevent leakages & spillages through preventive maintenance schedules and routine equipment inspections. Also, well-written working instructions, supervision, awareness and regular training of workforce would facilitate good housekeeping.

b) ***Process Change:*** Under this head, four CP techniques are covered:

(i) ***Input Material Change -*** Substitution of input materials by eco-friendly (non-toxic or less toxic than existing and renewable) material preferably having longer service time.

(ii) ***Better Process Control*** - Modifications of the working procedures, machine-operating instructions and process record keeping in order to run the processes at higher efficiency and with lower waste generation and emissions.

(iii) ***Equipment Modification -*** Modification of existing production equipment and utilities, for instance, by the addition of measuring and controlling devices, in order to run the processes at higher efficiency and lower waste and emission generation rates.

(iv) ***Technology change -*** Replacement of the technology, processing sequence and/or synthesis route, in order to minimise waste and emission generation during production.

c) Recycling

i) ***On-site Recovery and Reuse -*** Reuse of wasted materials in the same process or for another useful application within the industry.

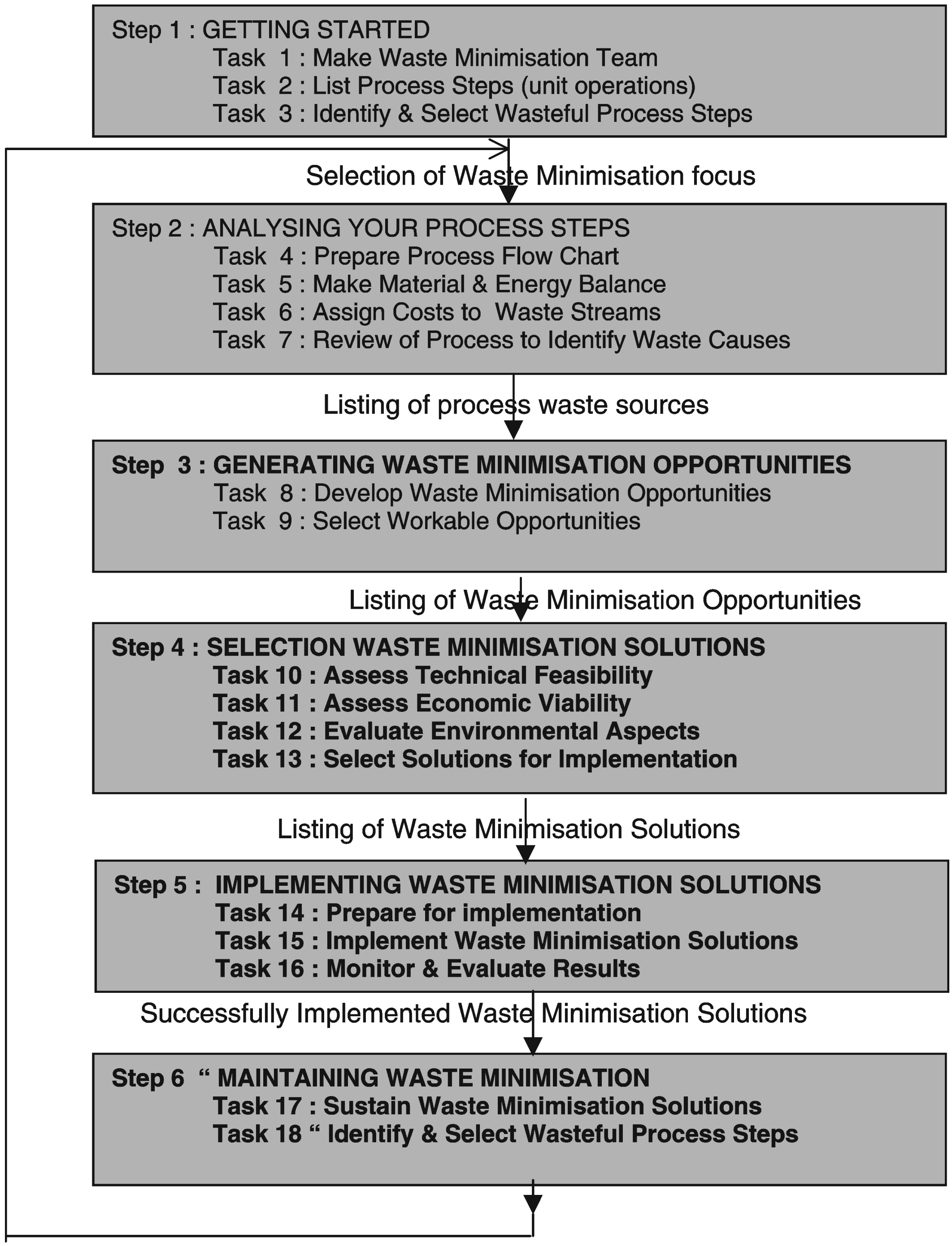
ii) ***Production of Useful by-product -*** Modification of the waste generation process in order to transform the wasted material into a material that can be reused or recycled for another application within or outside the company.

d) Product Modification

Characteristics of the product can be modified to minimise the environmental impacts of its production or those of the product itself during or after its use (disposal).

13.3 Waste Minimization Methodology

For an effective Waste Minimization programme, it is essential to bring together various groups in the industry to ensure implementation. How formalised the programme would be depends upon the size and composition of the industry and its waste and emission problems. The programme should be flexible enough so that it can adapt itself to changing circumstances. A methodical step-by-step procedure ensures exploitation of maximum waste minimization opportunities. The steps in a typical waste minimization progamme are illustrated below:



Step 1: Getting Started

Form a Waste Minimization Team

Waste Minimization (WM) concept encompasses all departments and sections in an industry. Activities involved in WM audits require assistance and cooperation not only from the personnel belonging to concerned department, but also from other related departments. Hence, making an inter-disciplinary and inter-departmental team is a prerequisite for successful conduct of a WM audit. In special cases, it would be advantageous to have external experts in order to have an unbiased, professional approach.

List Process Steps / Unit Operations

The WM team should familiarize itself with the manufacturing processes including utilities, waste treatment and disposal facilities, and list all the process steps. Preparation of sketches of process layout drainage system, vents and material-loss areas would be useful. This helps in establishing cause-effect relationships and ensuring that important areas are not overlooked. Periodic, intermittent and continuous discharge streams should be appropriately labeled.

Identify and Select Wasteful Process Steps

In multi-process type industries, it may be difficult to start detailed Waste minimization activities covering the complete unit. In such cases, it is advisable to start with fewer process steps to begin with. The selected step(s) could be the most wasteful and / or one with very high waste minimization potential.

This activity could also be considered a preliminary prioritization activity. All the various wasteful steps identified in 1.2 should be broadly assessed in terms of volume of waste, severity of impact on the environment, Waste minimization opportunities, estimated benefits (specially cost savings), cost of implementation etc. Such assessment would help in focusing on the process steps / areas for detailed analysis.

Step 2: Analysing Process Steps

Prepare Process Flow Charts

This activity follows the activity described at 1.2. Flow charts are diagrammatic / schematic representation of production, with the purpose of identifying process steps and the source of waste streams and emissions. A flow chart should list, and characterize the input and output streams, as well as recycle streams. Even the so called free or less costly inputs like water, air, sand, etc should be taken into account as these often end up in being the major cause of wastes. Wherever required, the process flow diagram should be supplemented with chemical equations to facilitate understanding of the process. Also the materials which are used occasionally and / or which do not appear in output streams (for example catalysts, coolant oil) should be specified. The periodic / batch / continuous steps should also be appropriately highlighted. Preparation of a detailed and correct process flow diagram is a key step in the entire analysis and forms the basis for compilation of materials and energy balance.

Make material and Energy Balances

Material and Energy balances are important for any Waste minimization programme since they make it possible to identify and quantify, previously unknown losses or emissions. These balances are also useful for monitoring the progress achieved in a prevention programme, and evaluating the costs and benefits. Typical components of a material balance and energy balance are given below (see Figures 13.1 & 13.2):

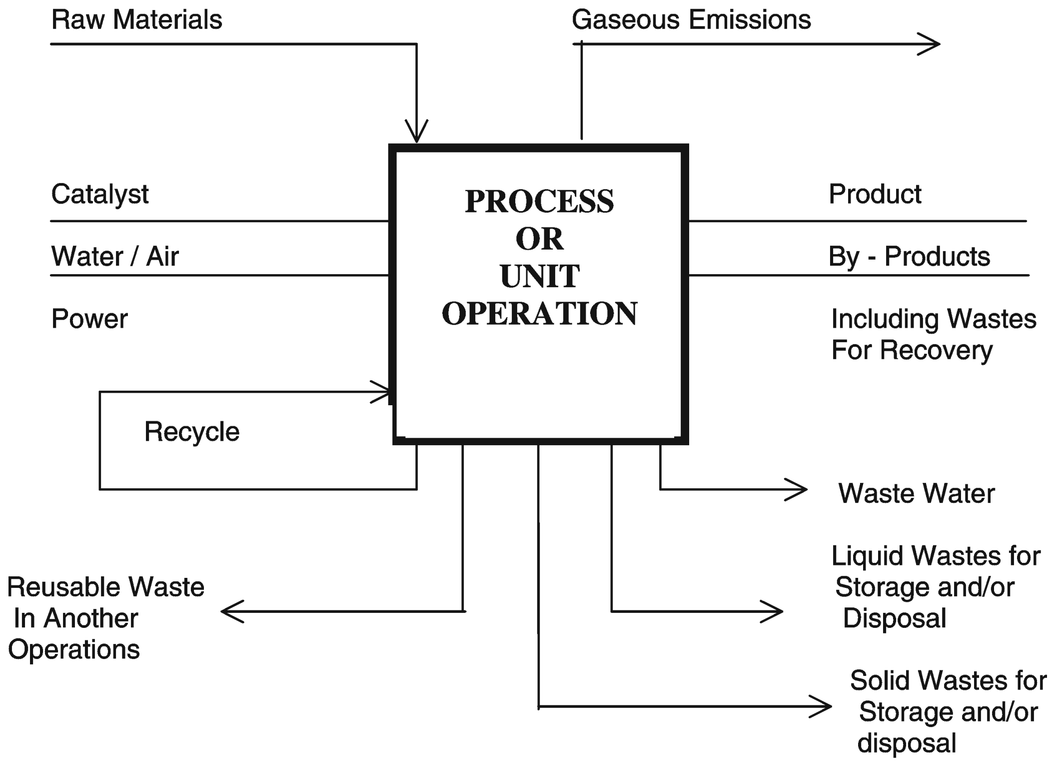


Figure 13.1 Typical Components of a Material Balance

It is not advisable to spent more time and money to make a perfect material balance. Even a rough / preliminary material balance throws open Waste Minimization opportunities which can be profitably exploited.

On the other hand, the precision of analytical data and flow measurements is important as it is not possible to obtain a reliable estimate of the waste stream by subtracting the materials in the product from those in the raw materials. In such cases, a direct monitoring and analysis of waste streams should be carried out.

Assign Costs To Waste Stream

In order to assess the profit potential of waste streams, a basic requirement would be to assign costs to them. This cost essentially reflects the monetary loss arising from waste. Apparently, a waste stream does not appear to have any quantifiable cost attached to it, except where direct raw material / product loss is associated with it. However, a deeper analysis would show several direct and indirect cost components associated with waste streams such as:

- Cost of raw materials in waste.
- Manufacturing cost of material in waste
- Cost of product in waste
- Cost of treatment of waste to comply with regulatory requirements
- Cost of waste disposal
- Cost of waste transportation

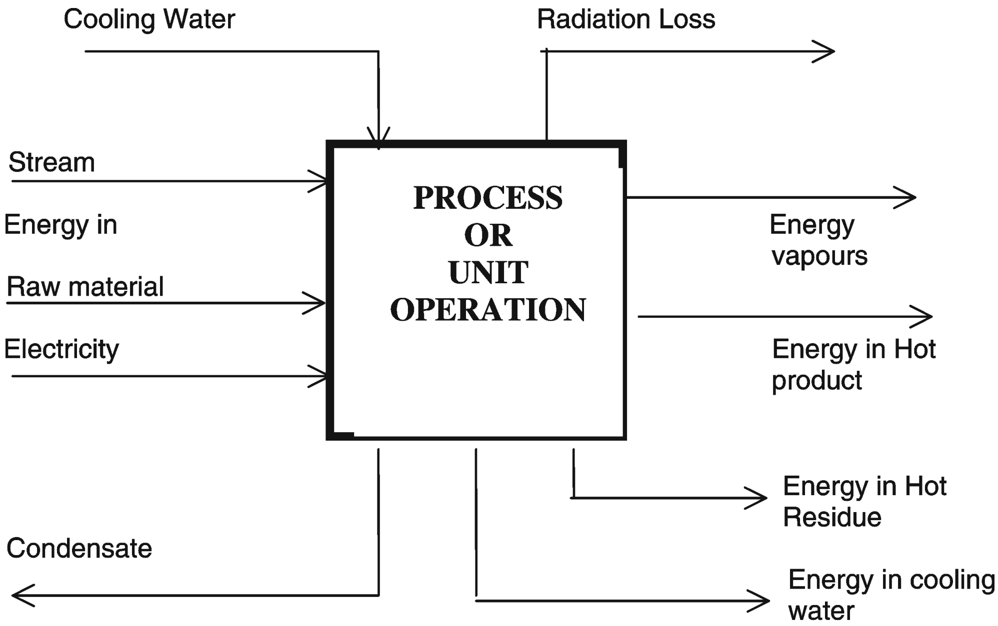


Figure 13.2 Typical Components of an Energy Balance

- Cost of maintaining required work environment
- Cost due to waste cess.

Based on this, for each waste stream, total cost per unit of waste (Rs/KL or Rs/Kg) should be worked out. This figure would be useful in working out the feasibility of the waste minimization measures. The result can also be used to categorize the waste streams for priority action.

Review of Process

Through the material and energy balances, it is possible to carry out a cause analysis to locate and pinpoint the causes of waste generation. These causes would subsequently become the tools for evolving Waste Minisation measures. There could be a wide variety of causes for waste generation ranging from simple lapses of housekeeping to complex technological reasons as indicated below.

Typical Causes Of Waste

Poor housekeeping ;

- Leaking taps / valves / flanges
- Spillages
- Overflowing tanks
- Worn out material transfer belts

Operational and maintenance negligence

- Unchecked water / air consumption
- Unnecessary running of equipment
- Sub optimal loading
- Lack of preventive maintenance
- Sub-optimal maintenance of process condition
- Ritualistic operation

Poor raw material quality

- Use of substandard cheap raw material
- Lack of quality specification
- Improper purchase management system
- Improper storage

Poor process / equipment design

- Mismatched capacity of equipment
- Wrong material selection
- Maintenance prone design
- Adoption of avoidable process steps
- Lack of information / design capability

Poor layout

- Unplanned / adhoc expansion
- Poor space utilization plan
- Bad material movement plan

Bad technology

- Continuation of obsolete technology
- Despite product / raw material change
- High cost of better technology
- Lack of availability of trained manpower
- Small plant size
- Lack of information

Inadequately trained personnel

- Increased dependence on casual / contract labour
- Lack of formalized training system
- Lack of training facilities
- Job insecurity
- Fear of losing trade secrets
- Lack of availability of personnel
- Understaffing hence work over pressure

Employee Demotivation

- Lack of recognition
- Absence of reward
- Emphasis only on production, not on people
- Lack of commitment and attention by top management

Step 3: Generating Waste Minimization Opportunities

Develop Waste Minimization Opportunities

Once the origin and causes of waste and emissions are known, the process enters the creative phase. The WM team should now start looking for possible opportunities for reducing waste. Finding potential options depends on the knowledge and creativity of your team members. The potential sources of help in finding Waste Minimization Opportunities are:

- Other personnel from the same or similar plant elsewhere
- Trade associations
- Consultancy organizations
- Equipment suppliers
- Consultants

The process of finding Waste Minimization opportunities should take place in an environment, which stimulates creativity and independent thinking. It would be beneficial to move away from the routine working environment for better results. Various analysis tools and techniques like "brainstorming", "group discussions" etc would be useful in this step.

Select Workable Opportunities

The Waste Minimization opportunities developed should be screened and those, which are impractical, should be discarded.

The discarding process should be simple, and straightforward and may often be only qualitative. There should be no ambiguity or bias. Unnecessary effort in doing detailed feasibility analysis of opportunities, which are impractical or non-feasible, should be avoided. The remaining Waste Minimization opportunities are then subjected to a more detailed feasibility analysis.

Step 4: Selecting Waste Minimization Solutions

The selection of a Waste Minimization solution for implementation requires that it should not only be techno-economically viable, but also environmentally desirable.

Assess Technical Feasibility

The technical evaluation determines whether a proposed Waste Minimization option will work for the specific application. The impact of the proposed measure on product production rate should be evaluated first. In case of significant deviation from the present process practices, laboratory testing trial runs might be required to assess the technical feasibility.

A typical checklist for technical evaluation could be as follows:

- Availability of equipment
- Availability of operating skills
- Space availability
- Effect on production
- Effect on product quality
- Safety aspects
- Maintenance requirements
- Effect on operational flexibility
- Shut down requirements for implementation

Assess Economic Viability

Economic viability would often be the key parameter to promote or discourage Waste Minimization. For a smooth take-off, it is therefore essential that the first few Waste Minimization measures should be economically very attractive. Such a strategy helps in creating more interest and sustains commitment.

Options requiring little investment, but involving more of procedural changes (housekeeping measures, measures, operational improvements) do not need an intensive economic analysis and simple methods like pay back period could be used. However as Waste Minimization measures become more involved and capital intensive, other profitability analysis methods viz. Return on Investment (IRR) or Net Present Value (NPV) are recommended to get the total picture.

While doing the economic investment, the costs may include fixed capital i.e. cost of equipment, working capital cost, shutdown cost, O & M costs etc. The savings could be direct savings of input materials / energy, increased production levels and hence lower specific input cost, lower O & M cost, value of by products, reduction in environmental cost i.e. waste treatment transportation and disposal cost etc.

Evaluate Environmental Aspects

The options for Waste Minimization with respect to their impact on the environment should be assessed. In many cases the environmental advantage will be obvious if there is a net reduction in the toxicity and / or quantity of waste. Other impacts could be changes in treatment of the wastes. In the initial stages, environmental aspects may not appear to be as compelling as economic aspects. In future as in developed countries, environmental aspects would become the most important criteria irrespective of the economic viability.

Select Solutions for Implementation

After technical, economic and environmental assessment, Waste Minimization measures should be selected for implementation. Understandably, the most attractive ones would be those having best financial benefits, provided technical feasibility is favourable. However, in a growing number of cases especially when active pressure groups are present, environmental priorities may become the final deciding factor.

The work done so far should be documented. Apart from becoming a reference document for seeking approvals in implementation, the document would also be useful in obtaining finances from external finance institutions, reporting status to other agencies, and establishing base levels for performance evaluation and review.

Step 5: Implementing Waste Minimization Solutions

Prepare for Implementation

The selected solutions could be taken for implementation. Apart from simple housekeeping measures several others would require a systematic plan of implementation.

The Waste Minimization team should be well prepared to take up the job of implementation. The preparation would include arranging finances, establishing linkages in case of multi-department solutions, technical preparations, etc.

Implement Solutions

The task comprises layout and drawing preparation equipment fabrication / procurement, transportation to site, installation and commissioning. Whenever required, simultaneous training of manpower should be taken up as many excellent measures have failed miserably because of non-availability of adequately trained people.

Monitor and Evaluate Results

The WM solutions should be monitored for performance. The results obtained should be matched with those estimated / worked out during technical evaluation to establish causes for deviation, if any. The implementation job is considered to be over, only after successful commissioning and sustained stable performance over a reasonable length of time.

Step 6: Sustain Waste Minimization

The biggest challenges in Waste Minimization lies in sustaining Waste Minimization. The enthusiasm of the Waste Minimization team wanes off with time. Such tragic ends should be avoided. Backing out from commitment, predominance of production at any cost, absence of rewards and appreciation, and shifting of priorities are some of the commonly encountered reasons, which one should check and avoid.

Also monitoring and review of the implemented measures should be communicated to all employees in the industry so that it fans the desires for minimizing wastes. Involvement of as large a number of employees as possible and rewarding the deserving ones, will help long term sustenance of Waste Minimization.

Having implemented Waste Minimization solutions in the area under study, the Waste Minimization team should go back to Step-2 i.e. analysing the process steps and identifying and selecting the next wasteful area. In this way, the cycle continues, till all the steps are exhausted.

In a nutshell, a philosophy of minimizing waste must be developed within the company. This means that Waste Minimization should become an integral part of company's activities. All successful Waste Minimization programmes, till date, have been founded on this philosophy.

13.4 Case Study

Maximising Cullet Recovery Reduces Batch Costs

At a Lead Crystal Glass Works, glass was produced by melting a charge of blended raw materials together with process cullet. However, only about 30% of the cullet produced at the glassworks was of a size appropriate for remelting. Concern about the significant amounts of valuable raw materials lost in this cullet and being sent for waste disposal, led to the installation of a crushing unit to reduce the cullet to an optimum size for recovery. Operation of the crushing unit was subsequently enhanced by the addition of a vibrating screen and cullet washing system.

The ideal size for cullet pieces, to produce a high quality melt of uniform composition and avoid faults in the blown glass, is 12 – 20 mm. Most of the heavy cullet at the company was present in large pieces that cannot be easily broken up manually to the optimum size. Lighter pieces such as those from wine glasses, were also difficult to recycle because they have to be broken up manually to obtain a satisfactory charge weight. This generates a lot of fine material, which was unsuitable because it tends to result in air bubbles being trapped in the glass gathered from the furnace pot by the glass blower.

Before waste minimization programme, about 560 tonnes of cullet were disposed for waste disposal each year, costing the company considerably in terms of lost raw materials. The company therefore decided to install a crushing plant capable of producing a consistent output of a size suitable for remelting and with minimum generation of fine material. Such a plant would allow more cullet to be recycled, leading to a reduction in the cost of both primary raw materials and cullet disposal.

Following discussions with suppliers of crushing plant, the company installed a rotary hammer mill. This resulted in recycling of 74% of process cullet as against 30% previously. Also alternative uses avoiding waste disposal have been found for the crusher fines and other forms of waste glass. Crushing has also increased the bulk density of the cullet by a factor of three and improved its size distribution.

The benefits of maximising inhouse cullet recovery include:

- Cost savings
- Reduction of 37% in the purchase of primary raw materials
- Improved yield of first quality glass
- Payback period of three weeks

Associated Waste Minimization Measures

In addition to installing the cullet crusher, the company had initiated a number of other associated waste minimization measures such as segregation by source of inhouse cullet, segregating stones from cullet, lead recovery from reject cullet, crusher fines and waste glass prior to disposal.

QUESTIONS	
1.	Explain the concept of waste minimization with suitable examples.
2.	"Waste is a misplaced resource" Explain.
3.	What are the 3R's in waste minimization techniques?
4.	Which would you prefer between recycling and source reduction? Justify.
5.	List down few housekeeping measures by which wastes can be reduced.
6.	Explain how modifying a product can help minimize the wastes with few examples.
7.	For a coal-fired boiler, draw a block diagram and indicate various material and energy inputs, outputs and wastes.
8.	Can employee be a factor in reducing wastes? Explain.

REFERENCES

1. From Waste to Profits, Guidelines for Waste Minimization by National Productivity Council, New Delhi
2. Waste Minimization Manual for Textile Processing by National Productivity Council, Chennai.