A Profile on
Waste Minimisation and Recycling in Chemical Process Industry[@]

@: Paper presented at Symposium on Chemistry in Societal and Environmental Needs, held at Central Leather Research Institute, Chennai, August 29-31, 2011

D.B. Boralkar*, A.K. Mhaskar** and Vinita Dhupkar***

Summary

Expenditure on waste minimization is necessary because it gives productive returns as economic project when handled intelligently. Chemical process must take into account the feasibility of putting waste to use either as secondary source of raw material or as fuel for power generation. A waste audit helps in assessment of the performance efficiency of chemical process and waste reduction efforts. The judicial pronouncements and environmental regulations in India provided legal basis required for efforts to minimize wastes and put in place mandatory environmentally sound technologies for reuse/recycling of wastes. The zero discharge approach via waste minimization through reclamation, recovery, recycles and reuse is suggested. The strategy is reduction of toxicity, mobility and volume through appropriate technology. The selected technology options are discussed depending on nature of waste to be reduced, minimized and the type of contaminants it contains.

Essential elements to be considered for designing waste minimization program are human resources, likely barriers, assessing options, evaluation and approach along with cost implication. This is followed by plugging failure points by way of sampling and estimation of the wastes in terms of quality and quantity. Plugging points can be controlled by utilizing microprocessors developed to plug failure points, e.g. control of temperature, pH and acid/alkali addition to control neutralization, precipitation etc. Success of waste minimization program depends on training of the people involved. As a corollary, training program will have as its objective of reaching zero discharge waste, loss prevention at every step, methods for checking environmental obligations, awareness of risk points, damage control and safety during normal operations.

It is explained in this paper how the waste minimization saves costs, generates raw materials and at the same time protects the environment. Attempt is made to provide tips to ‘leap-frog’ especially, prioritization, vender selection, predictive maintenance, efficiency tricks and designing as appropriate training approach.

*: Former Member Secretary, Maharashtra Pollution Control Board, R/o 602, Amar Residency, V. N. Purav Marg, Deonar, Mumbai – 400 088. dbboralkar@gmail.com

* * : Former Regional Officer , Maharashtra Pollution Control Board, R/o 7-8, Yogeshwar Apartment, Mahaganesh Colony, Paud Road, Kothrud, Pune – 411029. akmhaskar@hotmail.com

* * *: Former Asst. Secy. (Tech.),Maharashtra Pollution Control Board, R/o 602B, Prem Vishnu, ChaphekarBandhu Marg, Mulund (East), Mumbai – 411081. vdhupkar@gmail.com

A Profile on
Waste Minimisation and Recyclingin
Chemical Process Industry

Table of Contents

A Profile on
Waste Minimisation and Recycling in
Chemical Process Industry

1. Introduction

Since independence and especially after liberalization in the economy, India has seen rise in the industrial production and market of goods and services (domestic and import/export). The share market index and GDP has also grown. While we can boast of increases in the production of goods and energy, it is also fact that we have encroached on natural resources, converting some part into unassimilated waste. Merchandise has increased not in proportion to the population, but several times higher, indicating a high degree of consumerism. Life expectancy is high which means that the needs per person have increased both in years and quantity.Adverse effects are visible in terms of deteriorating natural resources, environment and health.Efforts for waste minimisation are critically important and necessary to ameliorate the situation.

There is increase in the hazardous by-products and waste generation from the chemical process industry. This is evident from increased production of chemicals such as H2SO4, nitrogen, oxygen, ethylene, lime, ammonia NH3, NaOH, chlorine, phosphoric acid, propylene, Na2CO3, HNO3, ethylene dichloride, NH4NO3, urea, vinyl chloride, benzene, ethylebenzene, CO2 etc. This is indicating an average growth in sectors like electrical goods, chemicals, pulp and paper, transport equipment, food, beverages, tobacco, mechanical engineering, metals, textiles, leather and general manufacturing involving processing of minerals and metals and chemicals and petrochemicals. Growth in organic chemicals is very high, and this is a source of unassimilated wastes. Chemicals meant for downstream usage result in cascading of wastes.

The "waste minimisation" can be phrased differently: for example, as waste reduction or waste strength reduction; application of clean technologies or green technologies or pollution prevention; environment-friendly and sound technologies producing low or no waste or zero discharge, ('zero' here meaning something you can hardly measure). The preference, naturally, will be reflected in the following order:

- No waste generation at all;
- If waste is generated, it is recycled (which means less need for fresh raw materials);
- Residual wastes will be reduced in volume and weight, and toxicity by treatment; and
- Disposal of treated residues should be so smooth that it does not adversely affect the recipient body (for example, discharge of treated effluent through an out fall diffuser).

The importance and urgency of the waste minimisation is widely accepted and needs no over emphasis. The environmental regulations and judicial pronouncements have not only emphasized the need for waste minimisation but also provided regulatory regime and institutional mechanism.

Indian Law: The principles and provisions in the environmental laws are presented in the Table 1.

Table 1: Principles of environment law in India

#	Principle	Relevant Rules	Suggestions
1	**The Source Reduction Principle** – Generation of waste should be minimized in terms of quantity or potential to cause pollution	Rule 5(8)(ii)	An undertaking of this kind should be sought, not only at the time of grant of authorization but also at the time of renewal of authorization.
2	**The Integrated Life Cycle Principle** – Substances and products should be designed and managed in such a way that minimum environmental impact is caused during their generation, use, recovery and disposal	Under entry 6 and 7 of Form I, information on the product life cycle is sought	No provision in the rules to promote this principle, except for the one cited
3	**The Precautionary Principle** – Preventive measures are taken, considering the costs and benefits of action and inaction, when there is a scientific basis, even if limited, to believe that release into the environment of a substance, waste or energy is likely to cause harm to human health or the environment	No mention	Needs to be included
4	**The Integrated Pollution Control Principle** – The management of hazardous waste should be based on a strategy that takes into account the potential for cross-media and multi-media synergistic effects.	No mention	Needs to be mentioned, as compatibility of different wastes needs to be ensured in final disposal fields
5	**The Standardization Principle** – Standards need to be provided for the environmentally sound management of hazardous waste at all stages of their processing, treatment, disposal and recovery.	The rules in general seek to achieve this in some manner	
6	**The Proximity Principle** – The disposal of hazardous waste must take place as close as possible to its point of generation, recognizing that economically and environmentally sound management of hazardous waste will not be achieved if specialized facilities are located at a distance that is too far from the point of generation	No such provision	
7	**The Precautionary and Polluter Pays Principles** – The potential polluter must act to prevent pollution and those who cause pollution must pay for remedying the consequences of that pollution	Rule 16	Implementation of this principle is problematic
8	**The Principle of Public Participation** – At all stages, waste management options are considered in consultation with the public and the public has access to information concerning the management of hazardous waste	Rule 8(5)(6) which concerns public hearing for location and setting up of disposal sites	Needs to be included in some form while granting/renewing authorization, enabling the public especially to access the data base of the concerned authorities. No public consultation is envisaged in the export-import process.

The Supreme Court of India, order dated 14.10.2003

The Supreme Court of India while dealing with a Public Interest Litigation (Civil WP no. 657 of 1995) regarding management of hazardous waste has dealt with, among other things, institutional arrangements and policy framework required for waste minimization. A High Powered Committee under the Chairmanship of Prof. M.G.K. Menon was appointed by the Supreme Court and recommendations of the Committee were accepted by the Supreme Court and an elaborate order was passed by the Court which inter-alia contained action plan for promotion and enforcement of waste minimisation in India. The Supreme Court also went to the extent of appointing yet another Committee under the Chairmanship of Dr. G. Thyagrajan to monitor the implementation of the order and submit quarterly report of compliance to the court.

As per the official submissions made by the State Governments / State Pollution Control Boards before the MoEF/Menon Committee, there are 13011 no. of units generating hazardous waste in India (as on March, 2002). The total quantity of hazardous waste generated is reported as 4.4 million metrictons per year. The Maharashtra State accounted for highest quantity of hazardous waste generation (2.0 million tons per year) followed by Gujarat State (0.43 million tons per year).

The Supreme Court order dated 14.10.2003 in Writ Petition No.657/1995 has clearly prescribed that efforts are required to minimize hazardous waste in India by minimisation of the generation of hazardous waste in terms of quantity and its hazardousness. Further, disposal of waste generated should be as close as possible to the point of its generation and country must reduce and control transboundary movement of hazardous waste by ensuring India's commitment to the compliance of the objectives of the Basal Convention. The Supreme Court also agreed with conclusions arrived at, among other things, by the High Powered Committee as below:

- That the MoEF made no concerted or consistent efforts of a promotional, educational and co-coordinating nature and it is necessary that henceforth, this should not be lacking on the part of the Ministry.
- Eighty-nine sites were identified out of which 30 are notified. Out of 30, 11 common landfills are ready and operational (2 in Maharashtra, 1 in Andhra Pradesh and 8 in Gujarat). (This, in other words, implies that the proposals regarding 59 sites are not dealt with seriously, and the majority of the notified sites, i.e., 19, are not yet operational. Even the sites that are in operation are not all in accordance with the criteria set out in the approved manual.)
- Rule 21 of the 2003 amendment to the Hazardous Waste (M & H) Rules, 1989, in respect of environmentally sound technologies and standards for refining or recycling, should be implemented.

- SPCBs are not making efforts to inspect facilities and to bring pressure on the units to bring the handling of hazardous wastes in line with their granted authorisations (except in a few cases like Andhra Pradesh and Gujarat). About 80% of the country's waste is generated by the States of Maharashtra, Tamil Nadu, Andhra Pradesh and Gujarat.
- The Supreme Court set out an Action Plan with 29 activities prescribed: for example, amend the rules, issue closure directions, update inventories, empower CPCB for cross checking inventories, strengthen institutions like the MoEF, CPCB, SPCBs, PCC and research wings, etc. A Monitoring Committee was constituted with Dr G. Thyagarajan, Senior Secretary, COSTED, Chennai as Chairman and seven others.

It is believed that when all these directions in the court order are fully implemented, industry will find the proposal of waste minimisation and cleaner production more attractive.

2. Preparation for WM Program :

A) Critical elements

Today, raw wastewater is treated, but after treatment it is still wastewater. Hazardous waste is dealt with by incineration, sales or secured landfill, both as treatment and disposal. This is, however, akin to an 'out-of-sight, out-of-mind' strategy. In some places, pollutants are merely transferred from one media to another, at others; dilution is seen as the solution to pollution. This, however, cannot work for long. In fact, if hazardous waste is mixed with non-hazardous waste, the entire material becomes hazardous. Thus the only sustainable solution will come with waste minimisation aimed at zero discharge

Waste generation, due to the burden of its disposal, is costlier than efforts required for waste reclamation. Though this was not apparent to begin with, the people who have undertaken such work have found in the end that there is a substantial saving by reclamation and it also has a reasonably short payback period. While preparing our WM programme, our aims should be:

- Minimise the quantity of waste.
- Minimise the toxicity of waste.
- Minimise the expenditure on recovery process.
- Minimise the potential risk.
- Maximise saving on raw material cost.
- Maximise saving on waste disposal.

These six considerations in fact can be grouped in two, namely, waste related (first two) and cost related (last four). The matrix then looks like as shown in Table 2:

Table 2: Waste matrix

	Reduction of waste [R]	Cost for programme [C]
Small [S]	SR	SC
High [H]	HR	HC

The ideal will be SCHR i.e. small cost, high reduction, but sometimes we shall have to go by HCSR i.e., high cost, small reductionin a specific situation. Cost depends on the efficiency of the gadgetthat we are employing. Cost also depends on economies of scale.Add-on is always costlier. Further, capital costs and operating costsare generally inversely proportional, and at both the extremes, smalldecrease in one cost requires large increase in the other cost.The cost of production has many components, and these can bestated as follows in Table 3:

Table 3: Costs of production

Capital	Operating	Account heads
Land and building	Fuel	Depreciation
Utilities	Raw materials	Taxes
Production	Operation and maintenance	Interest
Waste treatment plant	Labour and Waste handling	

If one commences with pure raw materials and uses modern technologies/instrumentation then it results in less requirement of utilities,raw material, labour, work-up chemicals and even wastes. Totalcost is thus an amalgamation of production direct cost, productionindirect cost, waste treatment direct cost, and indirect external costof peoples' health. If the last component is very high, WM is theonly answer.

There are many and rather difficult uncertainties in the waste reduction programmeparticularly when it comes to estimating the costs. Some of them are:

- There is no record of waste generation per unit output.
- Industrial activity and product mix change as per marketdemands.
- Waste volume may reduce but its hazard level may not similarlyreduce.
- Dilution may disperse the same amount of waste but largervolume is difficult to handle.
- There are too many industrial unit operations and unit processesin series and change in one disturbs the detailed calculationsmade earlier for all other units that follow.
- Waste generation and possibility of its reduction are all process-specific; parallels are seldom prone to extrapolation.

- The process technology and products may change widely,especially in pharmaceuticals and pesticides where the demandchanges per season or as per acquired immunity.
- Waste consistency is variable: it may be in solid, sludge orslurry form, or as a liquid or air pollutant.

Reactors and reactions:

In a chemical industry, the reactorholds thereactant raw materials and solvents and transforms them within acertain period. Whatever is generated here is in mixed form suchas the product, mother liquor and waste. These are to be separatedand then taken out separately. For running the reactor, some externalutilities are required: the furnace, steam or a cooling jacket, etc. Forrunning the reaction, some internal helping hand is required: for example,catalysts, work up chemicals, product washing water, etc.As a natural corollary, this creates two types of wastes, namely,process waste and utility waste. Our aim is to minimise these twowastes, which in turn means to minimise the requirements of:

(1) Quantity of input chemicals.
(2) Need for separation and purification.
(3) Utility inputs.
(4) Catalysts and work-up chemicals.

If (1) and (2) above are kept in check, there will automaticallybe less need of (3), and if (1), (2) and (3) are under check, there willbe less need of (4).Thus the central aspect is the chemical reaction, indicated as (1)above. It takes place in one of the following three ways, or as a combinationof these three ways, namely:

1. Raw materials A and B react and create a product as well aswaste. Thus:A+B → product + waste

2. Raw materials A and B react and create a product, as well asdiscarded product or by-product and waste. Thus:A+B → product + by-product + waste

3. Raw materials A and B react and create a product, but impuritiesin these two raw materials (say x and y) either react amongthemselves or react with the other raw materials and create manytypes of waste. Thus:(A + x) + (B + y) → product + Ay +Bx + xy. Which way the reaction will run is important. The essential pointis correct design of the reaction and the reactor (which is the work ofthe chemist and the chemical engineer respectively).

It may be noted that there are two types of reactions, viz., reversible and irreversible.If one has a choice, it is better to adopt the irreversible option.This is because in a reversible reaction, the raw material may changeinto a different product as time elapses in the reactor or if conditionschange in the reactor like temperature, pressure or mixing.An irreversible reaction namely A + B → product + waste ismuch simpler because this waste can be controlled by selecting aproper feed ratio, adjusting it, keeping it in excess, adding some inertmaterials, changing temperature if endothermic, changing pressureif the reaction leads to a decrease in number of moles, and correctlydistributing and mixing the material.

One way to avoid intermediates and by-products getting convertedinto waste is to examine whether one can carry intermediateseparations of products as the reaction proceeds. This avoids conversioninto wastes.Purer raw materials will avoid subsequent cross reactions andwaste. It is preferred either to procure the raw material in pure formor else purification steps should be introduced before charging.Catalyst selection is very important. Heterogeneous rather thanhomogeneous catalysts are preferred as the latter are difficult to segregateand recycle. Thus better flow distribution, better heat transferand instrumentation and introducing catalyst 'diluents' helps.A steady state reaction is desired and hence start-up and shutdownlosses should be reduced.If care is taken of one, there is less need of taking care of theother.

Separations:

The separation process is very important in the chemical industry as it relates to working capacity, operating costs, and sources of waste. Synthesis precedes separation. Purification precedes or follows (or both) separation. If conversion is incomplete it results in waste, and if separation is incomplete, that too results in waste. A separation process, to begin with, essentially has a mixture of more than one material, which it has to transform into different, distinct, material streams. For achieving this, a separating agent is required. This agent is either in a form of energy or in the form of another set of materials. Where the mixed materials awaiting separation are of different densities (or relatively different volatilities), separation is easily accomplished by mechanical means (i.e., by applying energy in some form). Such examples are filtration, centrifugation, settling, floatation, etc., selection of which depends on the stage of the feedand the product at the time of separation. Proper pH is required to be maintained at all manufacturing stages.

B) Initial steps:

Waste audit and emission inventory

The first step towards reducing waste and emissions is to perform thorough waste audits and accurate emission inventories. A waste audit (WA) is conducted to characterise the waste streams generated by an industrial plant, while an emission inventory (EI) is performed to quantify the direct release of pollutants into the environment from the particular shop under study. WA and EI are complementary tasks and both are vital to the development of strategies for prevention of pollution.

Preparatory steps

Most industries have only a small number of unit operations and unit processes. Going through these minutely should not be a difficult task. At least a preparatory drill can be initiated. It is only by trying different techniques and pursuing different technologies that the goal of WM can be achieved.

1. Examine whether the staff know enough to handle well thebasic utilities and their operations: for example, the boiler, the de-mineralisation and water-softening plant, the cooling tower, wateraccounting and water budgeting, refrigeration, vacuum pump, ejector,turbines, mixer selections, uniformity of distribution, weighing instrumentation, indicators, flow-meters, etc.
2. Examine whether full documentation of process routes isavailable or make a list of where this is lacking.
3. Examine what solvents are in use, their properties, proprietyof particular solvents or possible alternatives and present recoverymethod.
4. Assemble information on vendors offering not only chemicaltechnologies, but also physical techniques (like ion-exchange,reverse osmosis, dialysis, etc.)
5. Examine catalysts that are used, what substitutes are availablein the market, how good is the present recovery for prolonged useand whether an alternative will improve this.
6. Examine whether the treatment system serves only the lastlimited residuals. A large treatment plant in fact is a discredit if it isa means of absorbing the inefficiency of plant or process.
7. Make a list of the process residues in all the steps. For this,one requires knowledge of chemistry, access to mass spectroscopyand facility to identify species. Library and laboratory may need tobe upgraded.
8. Attempt a technical assessment of the industry’s present configurationand examine whether it will be beneficial to permit all thereactions in one reactor or to switch to more reactors in series i.e.to do different jobs in separate dedicated reactors. This also appliesvice versa, i.e., whether the present series of reactors can be combinedprofitably and thereby reduce the number of stages.
9. Examine whether some of the raw materials can be procuredwith short notice and reserved tanks for them can be eliminated orminimised in view of the fact that increase in the number of tanks inthe tank farm area results in increases in

handling of chemicals andmore losses. This is known as the ‘just-in-time’ (JIT) principle.

10. Examine how many inorganics are used in the process steps, and whether these can be curtailed.
11. Attempt to develop new packing.
12. Examine whether a vacuum pump can be used instead of astream jet.
13. Train the operators to turn off or shut down idle equipmentso as to minimise start-ups and shut-downs by scheduling.
14. Drying design is a common operation. Check whether thedesign is optimum. For improving this, the following techniques willbe useful:
    a) Recirculate air.
    b) Recirculate air,minimise in-leakage (improve baffling,seals, air-lock, etc.).
    c) Recover organics from the purge stream.
    d) Recover energy value from the purge stream.
    e) Abate organics from the purge stream.

Fugitive loss control

To begin at the beginning, one has to keep a watch on losses. Operators generally lose sight of small losses, but collectively these create substantial problems. The possible sources for arresting losses are tabulated below (Table 4):

Table 4: Controlling fugitive losses

Activity	Possible routes of fugitives escaping
Unloading	• Time delay in fitting hose • Leaking hose or leaking hose connection • Draining of fill lines between changing tanks • Leaking container, valves, pump packing, piping, or dykes • Electrical failure • Using of hooks, puncturing the bags
Storage	• Tank overflowing • Malfunctioning overflow alarms, level controllers • Rusted corroded containers or beds • Not seen due to unclean house-keeping • Not seen due to poor or faulty illumination.
Transfer	• Holes/apertures in hand carts, trolleys • Hooked bags especially at lower level of the heap • Old residual chemicals at the bottom of shop floor service tank, too stale and drained to refill afresh.

Process	• Improperly operated process equipment • Improperly maintained process equipment • Process/product changed, but existing old equipment pressed • in service, thus either too high or too low height of freeboard • No dyking for shop floor service tank • Sudden equipment/tank draining for cleaning at emergency • maintenance • Uncollected off-specification raw materials • Uncollected off-specification products/by-products • Leaking container, valves, pump packing, piping, or dykes • Electrical failure

Good operating practice

Many operators believe that modernisation either in process orhardware is the solution to all problems. While this may work outwell, it is also worthwhile to try afresh the existing arrangementsafter making necessary changes in operation, which may give gooddividends.Some experienced suggestions are:

1. Reactor charging:

- Feed solvent by gravity and not by pumping.
- Closed loop vapours should be recycled for pumping operation.
- Charge solids first and then solvents, sequentially.
- Lock the hopper before charging solids.
- Cut open the bags inside the reactor, or as near to it as possible.
- Pass vent through refrigerator. Condense solvents and recycle.
- Use solvent of low vapour pressure.

2. Reactor operation:

- Closed reactor is better or secure lid with good gasket andclamp.
- Improve seals on agitator (better still, replace agitator withjet nozzles).
- Sequentially add the reactants and reagents. For example,do not add all NaOH either at beginning or at the end. Addslowly, continuously, as reaction proceeds.
- Control gas purge rate with automatic flow control devicesand not by manual throttling the valve.
- Check reactor mixer and blades.
- Collect excess reactants on the spot.
- Use minimum number of intermediate steps.
- Sampling should be automatic, without the need of having toopen the lid off and on.

3. Reactor discharges:

- Discharge lines should be on an incline.
- Reduce reactor temperature before discharge.
- Do not push contents by pressure gas.

4. Reactor cleaning:

- Optimise the sequence.
- Maximise production runs.
- Minimise number of solvent rinses.
- Increase smoothness of vessel walls.
- Use high pressure rotary nozzles to reduce quantity of cleaningsolvent.
- Replace volatile chlorinated solvents with low-volatile chlorinatedsolvents or better still, with non-volatile chlorinatedsolvents or even better, with non-volatile non-chlorinatedsolvents, or best with aqueous based detergents.
- Collect final rinse wash for reusing, as first pass at the nextcleaning.
- Use plastic beads, wheat starch or sodium bi-carbonate withwater.

5. Report:

- Send observation remarks, if any, to the boss immediately.
- Communicate alternatives which can be used, to the boss atthe earliest.

Good maintenance practices

Like good operating procedures, good maintenance practices are also important. Many times these are lost sight of because those incharge are too busy with production. At best, corrective maintenanceis followed, i.e., merely keeping the machines in running condition.In fact, the concept of preventive or predictive maintenance is farmore effective. For this, one needs to first make a list of:

- All plant equipment and locations.
- Items which are critical to the process.
- Problem equipment.
- Past experience i.e., which equipment has a tendency to failoften.
- Overloading/under-capacity utilisation areas.
- Up-to-date maintenance manual of the vendor.

The common excuses one hears from O&M or process operatorsare: (1) ‘The same has been going on in the plant since the time Ijoined.’(2) ‘No time’. As corrective maintenance engages all the time ofthe staff, no preventive maintenance could be undertaken.’ (This isa vicious circle.) (3) ‘Importance was not known.’To overcome these obstacles, it is important that industry takes part in training activities.

C) Waste minimisationtechniques

Purpose

The reader who has come this far certainly shows a desire tofind ways of handling wastes; which is better than just depositingthem with the operating agency, which is ‘out of sight, out of mind.’Before one reaches zero pollution, one must have zero discharge viaWM through reclamation, recovery, recycle, and reuse. The strategyadopted is reduction of toxicity, mobility and volume through appropriatetechnology. The technology selected naturally depends onthe nature of waste one is interested in to reduce/minimise, and thetype of contaminants it contains (see table 5).

Table 5: Break-up of contaminants

# Contaminants	Type break-up
1 Organic	• Organic liquids, soils, sludge, sediments • Petroleum-contaminated soils, sludge, sediments, • Solvent contaminated soils-sludge-sediments • Rubber goods, tyre, belts, polymers, etc.
2 Inorganic	• Metal-containing solutions • Metal-containing soils-sludge-sediments, • Slag, bottom ashes, fly ash, foundry sands, • Batteries, mercury-containing materials, etc.
3 Miscellaneous	• Chemical tanks, demolition debris, transformers, ballasts etc.

Data management

Decisionmakingrelies heavily on consistent, timely and accurate data. Thechain is data assembly >data interpretation >data use >decision>data for checking success of the decision.When recycling is being considered, collect data to address thefollowing questions:

1) What type of recyclable material does the waste constitute?
2) What recycling process is used/can be usable?
3) Would the recovery process generate secondary hazardouswaste, for example?

a) Spent materials (like catalyst, mother liquor).
b) Sludge listed in Schedule 1 or 2 of the Hazardous Wastes Rules.
c) sludge not so listed (non-hazardous).
d) By-products which fall in Schedule 1 or 2 of the Hazardous Wastes Rules.
e) By-products not so listed (non-hazardous).
f) Discarded products and (g) Scrap metals.

It will be worthwhile to try to recycle all the above seven kindsof wastes, but priority WM will be as listed at b and d above.

Waste reduction (WR) before waste minimisation (WM)

WR has to precede WM. It commences at the stage of procurementof raw materials and ends with using the waste as raw material.In this section, we concentrate on four aspects:

1. **Raw material control**: This includes not only the actual rawmaterial reactants, but also the materials required for utilities, additives,work-up chemicals, water, washings, by-products, intermediateproducts, and catalysts. Waste also needs to be handled as carefullyas the ready saleable product because if it is further contaminated bypoor handling, it may lower the possibility of recovery value.

2. **Raw material stocks**: Larger the stocks means not only aremore funds locked up, but the risk is also increased. This risk couldbe in potential accidents, fire hazards or explosion and it can also bea burden, if the accumulated material becomes unusable. The concept, therefore, is just-in-time (JIT), which means that theindustry should develop such relations with the suppliers so as to getthe material just at the time of chargingthe reactor.

3. **Process modification**: This is the heart of WR and WM efforts.This prevents waste at generation, removing any further problemof waste collection, segregation, recovery, sale, or exchange.Some modifications can be very simple while others may need highlymodern technologies.

4. **Volume reduction**: This may be required either for bettermanagement and handling or as pretreatment of waste for increasingits fitness for a particular recovery technology. Both the aspects aregood but the latter has real merit. Merely concentrating the waste so that more waste can be dumped away by one truck-trip outside, is not WR. But if concentrated, for example, by de-watering, and copper is recovered from the remaining sludge (as in the electro-plating industry), it is a WR practice.

WR techniques

For WR, chemical plants can employ the following techniques:

1. Substitution, by using less hazardous equipment. For example,heat transfer done through water rather than oil or high flash pointchemicals or low toxicity solvents in place of halogenated ones.

2. Lowering impact by using the same chemicals but under conditionsthat are less hazardous, for instance, using vacuum to reducethe boiling point, or reducing temperature or pressure in a reactor, ordissolving the mass in safe solvents or preventing reactor runaway.

3. Maintaining adequate distance between different types ofequipment in order to reduce hazards, for example, keeping remotecontrols and operator distant from the operations or strengtheningthe control rooms and corresponding tanks.

4. Using concentrated materials which will reduce feed quantitiesof dilute chemicals. This can offer advantages like reducing thesize of continuous reactors or reducing the size of storage tanks. Thisin turn keeps the hazardous intermediates in check.

5. Setting up barricades or enclosures to isolate the equipment orsealing rooms of the warehouse, tank-farm, process-shops and plantengineering or shielding the vents on pollutants (air or wastewater).Placing remote and continuous monitors also will be useful, as alsonegative pressure in the reactor (as in an asbestos mill).

Selecting a WM technology

As a preparation for selecting a final WM programme, weshould be acquainted with various technologies that are available.Before we take that step, we should have some understanding aboutthe different types of waste. Wastes can be divided into the followingcategories: (a) Wastes containing mainly organic contaminants, (b) Wastes containing mainly inorganic contaminants and (c) Miscellaneous waste. These are further detailed as shown in table 6.

Table 6: Waste recycling technologies

Waste Type	Possible recycling technology
a. Wastes containing mainly organic contaminants	
Liquid organic solvent and liquid petroleum products	Distillation, energy recovery, decanting
Soils-sludge-sediments, either solvent-contaminated or petroleum-contaminated,or organic sludge	Energy recovery, decanting, thermal desorption, solvent extraction (and use as asphalt aggregate in case of petro-contaminated)
VOCs	In-situ vacuum extraction
Non-aqueous-phase liquids(NAPLs)	Pump and recover
Dissolved organics	Freeze-crystallisation
Propellant and explosives	Energy recovery, ingredient extraction, reuse and conversion to basic chemicals
Lead/acid battery cases	Energy recovery (ebonite or polyethylene), reuse as thermoplastic (polyethylene)
Rubber goods (tyres, belts)	Energy recovery, size reduction and reuse, thermolysis
Liquid monomers	Distillation, energy recovery
b. Wastes containing mainly inorganic contaminants	

Metal-containing solutions	Freeze crystallization, chemical precipitation, ion exchange, reverse osmosis, dialysis, evaporation, cementation, electro winning
Metal-containing soil, sludge, sediment or slag	Chemical leaching, vitrification, pyro metallurgical processing or use as construction material/raw material for cement
Abrasive blasting material, foundry sand	Use as construction material/raw material for cement,vitrification, physical separation.
Lead-acid battery internals, nickel-cadmium batteries.	Chemical leaching, pyro metallurgical processing, physical separation
c. Miscellaneous waste	
Scrap chemical tanks, pipes.	Decontamination and disassembly.
Nonmetal structures and demolition debris	Decontamination and disassembly, use as construction material
Wood debris.	Energy recovery.
Transformer and ballasts.	PCB flush and treat (electric), metal recovery(electrical).

Wastesminimisationstrategies are presented below in table 7:

Table 7:Waste minimisation strategies

# Waste types	Possible recycle technology
1. Ash	Aggregate/construction uses, cement raw material,chemical leaching, solution processing, physical separation, pyro metallurgy, vitrification
2. Battery cases	Chemolysis, energy recovery, polymer re-extraction, reuse plastics and particulates, thermolysis
3. Battery metals	Chemical leaching, solution processing, physical separation, pyro metallurgy
4. Construction debris	Aggregate/construction uses, decontamination/disassembly, energy recovery
5. Firing range soil	Chemical leaching, solution processing, physical separation, pyro metallurgy
6. Foundry sand	Aggregate/construction uses, cement raw material,vitrification
7. Fuel/NAPL	Pump and recover
8. Inorganic-contaminated sediments	Chemical leaching/solution processing, pyro metallurgy,vitrification
9. Inorganic-contaminated soils &sludge	Chemical leaching/solution processing, pyro metallurgy, vitrification
10. Liquid organic solvents	Decanting, distillation, energy recovery
11 Liquid petroleum products	Decanting, distillation, energy recovery
12 Mercury contamination	Bio-reduction, chemical leaching, solution processing, mercury retorting, physical separation
13 Mercury metal	Mercury distillation

14 Metal containing slag	Aggregate/construction uses, cement raw material, Chemical leaching, solution processing, pyro metallurgy, vitrification
15 Metal containing solutions	Solution processing
16 Monomers	Distillation, energy recovery
17 Organic contaminated sediments	Decanting, energy recovery, solvent extraction, thermal desorption
18 Organics-contaminated solids and sludge	Decanting, energy recovery, solvent extraction, thermal desorption
19 Paint debris	Energy recovery, thermolysis
20 Propellants & explosives	Energetic material extraction and reuse, energy recovery
21 Shredded plastic	Energy recovery, thermolysis
22 Solid polymers	Aggregate/construction uses, chemolysis, energy recovery, polymer re-extraction, reuse plastics and particulates, thermolysis
23 Spent abrasive	Aggregate/construction uses, cement raw material, physical separation, vitrification
24 Tyres and belts	Energy recovery, reuse plastics and particulates, thermolysis
25 Transformers & ballasts	PCB-containing device processing
26 Vadose zone VOCs	Vacuum extraction

D) Recycling technologies

Waste recycling technologies are listed below:

1) Distillation
2) Energy recovery (general)
3) Energy recovery (cement kiln)
4) Thermal desorption
5) Solvent extraction
6) Freeze crystalisation.
7) Chemolysis
8) Thermolysis
9) Chemical precipitation.
10) Ion exchange
11) Liquid ion exchange (LIX)
12) Reverse osmosis (RO)
13) Diffusion dialysis (DD)
14) Electrolysis (ED)
15) Evaporation
16) Cement raw materials
17) Physical separation
18) Adsorption

3. Formulation of WM program

(A) Human resources

To a great extent, the success or failure of a waste minimisationprogramme depends on its driving force, which is provided by theteam captain – the leader and motivator. His or her role being pivotal,their own conviction as regards WM or rather, zero discharge,is of paramount importance.A team of people, termed the Waste Minimisation Organisation(WMO) needs to be developed. To begin with, the WMO will haveto prepare a White Paper on WM. This paper will have two components:(A) scope of the activity and (B) preparation required.

(B) Crossing Barriers

WM programme will initially meet with objectionsfrom all sides, though the degree may vary. It may be from the financesection citing paucity of funds, or from the purchase departmentthat the new raw materials line cannot be developed quickly orfrom the quality control department that analysis methods for newraw materials or recycled waste are not available. The general engineering department will claim that neither space is available forrelocation, service and utilities, nor is labour, and the environmentsection will say that the amended consent or authorisation is not yetobtained. Finally, the production group will insist that the proposedmeasures are bound to decrease output at least temporarily.

The barriers, however, will disappear once the higher echelonsof management support the WM scheme, making it loud and clearthat the WM programme will eventually reduce the risks and occupationalhazards to the workers while simultaneously fulfilling thelegal requirements.Some of the objections, however, may be genuine. Solutionstherefore have to be kept in mind in advance.

(C) Assessing options

In an industry, there are a large variety of products, processes, unit operations, and dedicated reactors. It is not practical to take allof them simultaneously for deeper study. A sequential attempt isfavoured and selection will be dictated by factors that may vary. Theindustry therefore has to decide:

- What wastes are of interest and their hierarchy (to fix the priority)?
- How to define waste reduction (to fix the objectives)?
- What factors affect the quantity of waste available for WR?
- Minimising which waste will get the industry more credit and from whom – SPCB, public or management?

Designing and implementing the WM programme is bound to be an uphill task. The likely hurdles will be:

- Where the cost of disposal is less than the cost of recycling, (and where the mode of disposal is accepted by authorities and not objected to by the public);
- Where the cost of raw materials, freshly procured from the supplier, is lesser than the cost of the proposed recycled material involved;
- Where the purity of raw materials, freshly procured from the supplier, is better than the quality of the proposed recycledmaterial;
- Where the reclaimed material has no demand beyond the factory walls as there are no recycling or exchange centers;
- Where a lot of administrative paperwork is required for waste transfer for off-site recycling. This is cumbersome andtime-consuming, more so if interstate transport is involved.

The management will want to know what is the recovery potentialof the concerned waste. The broadly acceptable avenues are:

- Energy recovery from the concentrated organic liquid waste (for example, incineration heat recovery from organic liquids and oil);
- Recovery of materials from concentrated organic liquidwaste (for example, distillation and recovery of waste solvents);
- Recovery of metals from industrial sludge and plating waste (for instance, recovery of metals such as chromium, copper,nickel, etc., from the spent bath).

(D) Evaluation

The WM programme that is finalised also needs to be evaluated.After implementing the WM programme, repeat the exercisewhenever there are new situations. The findings of this exerciseshould be compared with the earlier scenario. This is called trackingthe WM programme.The EPA at Illinois Information Centre has listed some significant attributes (table 8) one needs to evaluate:

Table 8: Evaluation of a WM programme

# Project element	Evaluation criteria
1 Management support	• Statement of support • Approval of project • Providing ideas/input • Praise and publicity of successes
2 Team aspects/programme initiation	• Employee enthusiasm and participation • Using skills from training • Supporting projects • Providing ideas
3 Understanding process	• Processes characterized • Flow diagram developed • All wastes and sources identified • Waste accounting system implemented
4 Project implementation	• Projects completed within budget • Projects completed on schedule • Waste reduction achieved • Cost savings attained • Raw material saving achieved • Product quality improved • Worker safety improved • Cost allocation system implemented
5 Continuing the programme	• Follow-up and review procedures established Employees kept informed and involved Pollution prevention team composition rotated
(Source: "Pollution Prevention: A Guide to Program Implementation." Illinois Hazardous Waste Reduction Information Centre, 1993)	

(E) Approaches

So far, we have attempted to make a list of all the possible unit operationsfor all the products reactor-wise. We have also suggested anumber of alternatives for each waste. It is, however, clear that noindustry can undertake minimisation of all the wastes at the sametime, nor can all the options for the same waste be implemented atthe same time. One has to prioritise. There are several ways of decidingpriorities.

One approach is to look at the wastes and try to decide whichone to take up first.

- The most precious waste: It may give better monetary returnsfor the reclamation efforts that are made: for instance, gold or silverplating waste.
- The most voluminous waste: it may offer economies ofscale.
- The easiest waste: It may give sure success, which will be appreciatedby the authorities.
- The most reusable waste: It may give better monetary returns:for example, solvent extracted and reused in the same reactor.
- The most hazardous waste: It will bring necessary relief topeople, the environment and property.
- The most mal-odorous waste: It will enable industry to developharmonious relations with people in the vicinity.
- The most repetitive utility waste: It may allow a continuousuninterrupted running and better monetary returns for the effortsmade: for example, solvent extraction.

Another approach is to prioritise in terms of efficiency of technology.

- The most preferred option will be the one that will decreasethe generation of hazardous waste at the source itself (source reduction).
- The next preferred option will be the one that will reclaimsuch materials that have a positive recyclable value (reuse, recovery,recycling).
- The next preferred option will be one that will treat the contaminantsfound in various plant discharges and emissions and makethe environment congenial, but will not reclaim and recycle thewaste.
- The least preferred option is the one that stores, transports ordisposes the HW made in a manner that avoids leaks, fires and spills(storage and disposal).

One factor that must be kept in mind is that in case the technologyhas potential side-effects, it is better to select one that will createfewer problems even if the WM is reduced.

4 Implementation of WM program

A. Training

For successful implementation of the WM programme, it is necessarythat all the people undertaking the programme are properlytrained. Training includes refreshing the knowledge of those whoare to be associated with the programme. Training brings uniformityof approach, predictable behaviour and the possibility of commonerrors getting eliminated.The objective of a training programme is to (1) minimise occupationalhealth hazards and errors; (2) to maximise safety; and (3) toinstill good operating practices

B. Raw material control

Raw material is the main cause of adverse environmental impacts.Air pollution like stratosphere ozone depletion, low level ozone andfog, emission of VOC, global warming, acid rains, etc., are no longera distant possibility, they are here and now. Our own incineratoremissions (like oxides of nitrogen, SO2, CO, metals, acid gasesand toxic dioxins) may as well add to it, unless we review our rawmaterials.It is worthwhile switching towards less hazardous raw materialfor many reasons: one, it lowers the risk to workers in the shop,office and colony; two, it produces less hazardous waste, in turn reducingthe risk to transporter, environment and people; and three, itmakes waste recovery easier. The search for raw materials is a continuousone as new materials are coming into the market every day,some with less toxicity.

C. Managing utilities

We now examine how waste and loss can be minimised in utilities.

Boiler efficiency tips

(A) ***Boiler performance***

Boiler efficiency can be improved through proper maintenanceand monitoring of operation. The seven tips presented here areguidelines for improving boiler efficiency.Conduct a flue gas analysis on the boiler every two months totest for fuel/air ratio setting and adjust air/fuel ratio to optimise efficiency.The air fuel ratio can be periodically adjusted to the recommendedoptimum values; however, a boiler with a wide operating rangemay require a control system to constantly adjust the air-fuel ratio.

A high flue gas temperature often reflects the existence of depositsand fouling on the fire and/or water side(s) of the boiler. Theresulting loss in boiler efficiency can be estimated on the basis that1% efficiency loss occurs with every 40 0F (19 0C) increase in stacktemperature.

After an overhaul of the boiler, examine the tubes for cleanlinessafter thirty days of operation. The accumulated amount of sootwill indicate the frequency of boiler tube cleaning. Check the burner head and orifice once a week and clean ifnecessary.Check all controls frequently and keep them clean and dry.

For water tube boilers burning coal or oil, blow the soot outonce a day. It is estimated that operating the boilers without cleaningfor a week can result in an efficiency reduction of as much as 8%,caused solely by soot accumulation.Purity of water used for steam generation is extremely important.Impure water cannot be used as boiler feed. Water treatmentprevents the formation of scales and sludge deposits on the internalsurfaces of boilers. Scale formation severely retards the heat flowand causes overheating of metal parts.

(B) ***Combustion in oil-fired boiler***

A boiler operating with too much excess air can result in unnecessaryfuel consumption. Best performance can be obtained by theinstallation of an automatic oxygen trim system that will automaticallyadjust the combustion to changing conditions. Alternatively,the portable flue gas analyser can be used in a rigorous program ofweekly boiler inspection and adjustment for boilers. The optimumamount of O2 in the flue gas of an oil-fired boiler is 3.7%, which correspondsto 20% excess air.

Energy

Energy is required in an industry for various operations. In thechemical industry, it is needed to drive endothermic reactions, tocarry out mass transfer operations, to provide optimum reaction conditionsof temperature and pressure, to drive separation process, topower control and communication systems and to provide a satisfactorywork environment. Energy requirements are of different types. Mechanical energy is used to compress gases for high pressure reactions;thermal energy is used to raise temperature of a reaction;and electrical energy is needed for electrolytic processes, for drivingpumps or to illuminate works. Energy is derived from fuels. Fuelpreference depends on its calorific value, ease of handling and distribution,reliability, by-products (ash, sulphur), and maintenance.Normal fuel preference, in descending order, is electricity, gas, hydrocarbonliquid, fuel oil and coal.

Pumps

Pumps are widely used for the transfer of liquids from one placeto another, and from one level to another. Pumps are usually drivenby electric motors but can also be driven by compressed air or hydraulics.There are many types of pumps in use in industry, amongwhich (a)centrifugal pumps, used for transfer of large volumes;(b)metering pumps, used for precise delivery of liquids to apoint of application and ensuring constant discharge, regardlessof back-pressures in the lines; and (c)progressive cavity pumps or peristaltic pumps, used for deliveryof very viscous materials.Measures to improve pump efficiency are (a) Shut down unnecessary pumps. (b) Restore internal clearances if performance changes significantly. (c) Trim or change impellers if head is larger than necessary. (d) Control by throttle instead of running wide open or bypassingthe flow.(e) Replace oversized pumps. (f) Use multiple pumps instead of one large pump. (g) Use small booster pumps.

Fans

Fans provide the necessary energy input to pump air from onelocation to another while they overcome the resistance created byequipment and the duct distribution system. Factors that can reducefan efficiency are: excessive static-pressure losses through poor ductconfiguration or plugging duct leakage, improperly installed inletcone causing excessive air recirculation, oversized fan and buildupof negative pressure. Reductions in exhaust airflows are usually obtainedby adjustments of dampers in the duct. More efficient methodsof volume control are: install inlet damper control, reduce thespeed of the fan and provide variable speed control for the fan.

Air compressors

Air compressors often consume large amounts of electricity.There are two types of air compressors: reciprocating and screwcompressors. Reciprocating compressors operate in a manner similarto that of an automobile engine – using a piston to compressthe air. Screw compressors work by entraining the air between tworotating augers. The space between the augers becomes smaller asthe air moves towards the outlet, thereby compressing the air. Screwtype compressors, especially older models, use more energy thanreciprocating compressors. This is especially true if the compressoris oversized because the screw compressor continues to rotate,whereas a reciprocating compressor requires no power during theunloaded state. Energy used by air compressors can be reduced by:

- Repairing air leaks.
- Reducing operating pressure.
- Recovering heat from compressor exhaust or cooling water.
- Using outside air.
- Installing low pressure blowers where applicable.

D Hardware and machinery

Waste increases when efficiency of process decreases. Efficiencyof process decreases the effective agitation and mixing of solids liquids, gases, catalysts and temperature during the process. Drying of solids is meant to get the material into solid form. The solidscan be of different constituencies such as flakes, granules, crystals,powder, slabs or continuous sheets, depending on what is the degreeof drying required to be done.

Mechanical Separation’ is an extremely important operation in the manufactureof chemicals. One type is based on diffusional operationintra-phase (like gas absorption, humidification, distillation, leaching-extraction, drying of solids, membrane separation and crystallisation)while another is straightforward mechanical separation(especially seen at a large number of small scale industries). Equipment modifications should always be periodically consideredas one may find that the downtime, chemical input, water cost,etc., are reduced and thereby waste gets minimised.

E. Process modification

Reactors are key elements where most of the undesired byproductsthat will eventually make up the waste streams are created. In some cases changing process chemistry is feasible.

There are such undesirableside reactions that substantial avoidable waste is created.Such a situation makes the step of change in raw materials very attractive.

Catalysts lose their effectiveness duringuse but can be reused after undergoing a regeneration process. Carefulcontrol of the regeneration process can maximise the quality ofthe regenerated catalyst while minimising the damage caused to thecatalyst during regeneration. Catalysts can sometimes be modifiedso that they can last longer between change outs, resulting in fewerwaste-generation shutdowns for catalyst changeouts.

Heat exchangerscan be a direct source of waste when hightemperature causes the fluids they contain to form sludge whichreduce efficiency. One way to reduce sludge formation is to reducethe temperatures used in heat exchangers. Excessively high temperaturesare frequently used because of the availability of process steamat fixed pressures but these can be modified. Sludge build-up canalso be minimised through the use of online cleaning techniques,scraped wall exchangers and non-corroding tubes. Anti-foul agents alsoprevent sludge build-up. An alternative to the shell and tube heatexchanger is the plate and frame separation equipment which minimizes routine waste, controls excursions in operating conditions andthus improves efficiency.

Distillation columns produce waste due to inefficiencyin separating materials. Efficiency can be improved as follows:

- Increase the flux ratio, add a section to the column, retry/repackthe column or improve feed distribution so as to increase columnefficiency.
- Insulate or preheat the column feed to reduce the load on thereboiler. A higher boiler load results in higher temperature and moresludge generation.
- Reduce the pressure drop in the column which lowers the loadon the reboiler.
- Vacuum distillation reduces reboiler requirement, which reducessludge formation.

Changes in tray configurations or tower packing may preventpollution from distillation processes. At one facility, the conventionalpacking in a distillation column was replaced with high-efficiencystructured packing conversion resulting in more products availablefor sale and a halving of still bottoms sent for incineration.

F. Catalysts

A discussion on WM will be incomplete without understanding therole played by catalysts. Catalysts, in their simplest forms, wereknown to man by the mid-nineteenth century and have progressivelyimproved over the years. Catalysts help hasten reactions and mayhelp in increasing the conversion, thereby reducing the waste; butthe catalyst itself creates an environmental problem when it comesout as spent material. Although we cannot do away with catalysts,controlling their use is in our hands.

5. Epilogue

There are thousands of chemicals today and every year more are being added for the use in the chemical process industry. Generation of waste is due to inefficient processing of raw material. Generation of waste is unavoidable. Treatment of waste so as to make it harmless and its disposal into the environment is conventional approach practiced for dealing with the waste not found suitable for further use. Disposal of such waste into the atmosphere, water bodies and land is cost intensive and can best be called as “reactive”. When wastes are disposed in the atmosphere, it results into mixing of different pollutants and formation of secondary pollutants due to photochemical reactions. Such pollutants are synergistically toxic to the environment. Waste disposal into the water body causes enrichment and bioaccumulation of toxic compounds in aquatic ecosystem.

Adverse impacts of waste disposal into the water bodies are well documented. Land filling of solid waste - whether municipal or industrial – is extensively practiced all over. Fear of failure of safety and sustainability of landfill is not unfounded. Standards and specifications stipulated for location, design, construction material to be used, method of construction, pretreatment of waste to be disposed, method of closure and post-closure monitoring of landfills are laid down in the environmental regulations. Ineffective regulatory regime and inconsistency in proper operation and maintenance has led to the leakages and subsequent damage to the environment and health. Where the land availability is scarce, the option of landfill is not desirable. Disposal of waste into the landfill is also loss of the opportunity cost of land. There are also costs involved in the decontamination and/or remediation of the ecosystem, which is adversely affected due to waste disposal. But given the state of affairs as exist, land disposal of waste is practical approach being followed today.

Minimisation of waste generation using application of low or no-waste technology (LNWT) and environmentally sound management of the waste generated should be the most preferred direction for the chemical process industry. ‘Precautionary principle’ and ‘sustainable development’ are well settled and emerged into the laws of governance in the country. This is also clear from articles 47, 48-A and51-A(g) of our constitution and that these concepts are already implied in our environmental statues including the Environment Protection Act, 1986.

National Conservation Strategy and Policy Statement on Environment and Development (1992) and Policy Statement for Abatement of Pollution (1992) of the Government of Indiain the Ministry of Environment and Forest has an expression of its commitment for reorienting policies and actions in unison with environmental perspective and promoting development and adoption of cleaner technology. However, there has been no specific policy and legislative direction particularly aimed at planning and implementation of waste minimisationprogramme. Precious, though little, efforts were made by the Union Ministry of

Environment and Forest in collaboration with National Productivity Council of India to set up waste minimisation circles for various industrial sectors. This has been the part of assistance under a bilateral programme where systematic efforts were made over a period of time to reduce / minimize waste generation by way of process modification, efficient use of energy, raw material modification etc. in small scale industrial units in various sectors such as electroplating, pulp and paper and metallurgical units. But more needs to be done now especially the application of Low or No Waste Technology (LNWT) and minimization of waste generation from the manufacturing processes in chemical industry.

It was for the first time in the country that specific pronouncement for waste minimisation came from the Supreme Court of India in its order dated October 14, 2003 *[in the matter of WP (C) no.657 of 1995 regarding management of hazardous waste]*. The Supreme Court observed that industrialization has had the effect of generation of huge quantities of hazardous wastes. Hazardous waste required adequate and proper control and handling. Efforts are required to be made to minimize it. The Supreme Court also observed that due to alarming situation is created by dumping of hazardous waste, its generation and serious and irreversible damage, as a result thereof, to the environment, flora and fauna, health of animals and human beings. Therefore, the petitioner approached the court under Article 32, complaining of violation of Article 14 and 21 of the Constitution of India.

Responding to the directions of the Supreme Court the Union Ministry of Environment and Forest overhauled legislations in 2003 and thereafter, thereby, bringing in mandate for environmentally sound management of hazardous waste and application of environmentally sound technologies for hazardous waste recycling and disposal. Specific provisions were made in the rules for steps to be taken, wherever feasible, for reduction and prevention in the waste generated or recycling or reuseand fulfillment of requirements regarding management in an environmentally sound manner of wastes.

---o0o---