Asia-Pacific
Economic Cooperation

Eco-Efficiency in Small and Medium Enterprises
– Chemical and Plastics Industry

APEC Small and Medium Enterprises Working Group

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FOREWORD

This Manual has been prepared as a guide for the introduction of eco-efficiency practices in the CHEMICALS AND PLASTICS INDUSTRY. It is specifically aimed at small to medium sized enterprises, and provides practical guidance for identifying and evaluating opportunities for eco-efficiency in the workplace.

This manual will help you to identify opportunities for reducing costs and improving environmental performance at your company. This can be achieved through reductions in raw materials and the costs of waste management; creation of marketable by-products, new markets and increased market shares; energy savings, reduced pollution and consent charges, reduced fees and penalties; and worker health and safety.

The Manual is one of a series covering a range of industrial sectors, and has been developed following research conducted under the funding and direction of the Asia Pacific Economic Co-operation (APEC). Other sectors covered in the series include:

- the textile industry;
- the leather products industry;
- the steel and metal products industry;
- the paper and printing industry;
- the food and beverage industry;
- the vehicle parts and assembly industry; and
- the machinery and electrical equipment industry.

THIS MANUAL CONTAINS THE FOLLOWING SECTIONS:

Outlines the importance of measuring the benefits and maintaining the drive for improvement.

1 ECO-EFFICIENCY – MAKING BUSINESS MORE PROFITABLE

1.1 OVERVIEW AND COST SAVINGS

What is Eco-Efficiency?

The concept of eco-efficiency parallels that of industrial efficiency - or *good business sense*. By reducing waste (here we refer to all types of waste, including time, energy, money and resources), industrial activities can move toward efficient and profitable operation. As a management practice, therefore, eco-efficiency *aims to do more with less.*

Eco-efficiency measures need not incur large financial investment into new technologies or processes, but can often be brought about simply through better housekeeping. In this context eco-efficiency includes *...any initiative or measure undertaken by an industry which results both in reduced environmental impact and increased efficiency and resulting cost savings for the company concerned. Typical examples of eco-measures are waste minimization, clean technology, and the reduced use of energy or materials per unit output. An eco-measure may also be management, process, technology, or production orientated, but will generally not include "end-of-pipe" treatment.*

Eco-Efficiency Saves Money

Cost savings may be immediate financial returns that appear directly on the balance sheet, such as material, energy and water savings. However additional savings may well arise in the future, perhaps from the reduced 'clean-up' required for contaminated land. The following shows some examples of eco-efficiency initiatives in the chemicals and plastics industry in Chile, China, and the United States and their associated savings.

Eco-Option	Financial Information
In Chile, cooling water was recycled in an architectural coatings company, reducing water volume by 33,860m^3/ year.	The implementation costs were US$2400 per year and the financial benefits were US$5079 per year.
In Chile, a reduction in the amount of wash water used in the latex tanks was achieved in an architectural coatings company.	The financial benefits totaled US$12,000 per year.
In China, water consumption was reduced through rinse-water	The yearly savings was 18,000 RMB.

Eco-Option	Financial Information
recycling, water meters and manually controlling water usage.	
In the US, the washwaters in a photo-finishing facility were controlled through timers.	The total investment was US$675 and the net savings per annum were US$1436.
In the US, silver was recovered in a photo-finishing lab through the use of a *Metal Replacement Cartridge* (MRC).	The total investment was US$1071, and the net savings per annum was US$1325.
In Chile, water consumption was reduced by 43,000m^3 / yr by recycling the second dye rinse in the dye procedure.	The cost of two tanks and additional plumbing was $2400 pesos. The savings were estimated to be $12,800 pesos per year.
In Chile, a reduced liquor ratio was implemented in jet dyeing in the dye process, reducing water consumption by up to 4800m^3 / yr .	Water costs were reduced by $1300 pesos per year.
In the US, leaking traps were repaired to reduce air emissions and energy consumption.	The payback period of the project was 1 week.
In the US, sulfate emissions were reduced by replacing sodium sulfate with sodium chloride in the dye bath.	There was zero capital investment and cost savings of US$7500 per year was achieved.
In the US, leaks in wool laundry valves were repaired.	The financial benefit was US$3700 per year.
In the US, energy consumption and the production of hydrochloric acid mist was reduced by rebalancing internal airflow within the plant dryers.	There was zero cost associated with this option.

1.2 WHY SHOULD YOU BE CONCERNED WITH ECO-EFFICIENCY

Are You Operating Within the Law?

As economies continue to expand and develop, the regulations adopted by governments to protect the environment will become more stringent and better enforced. Businesses have in the past addressed tougher regulations by using more and more ‘end of pipe’ technologies to reduce pollution. However, these technologies are costly, and often need upgrading to keep pace with the new regulations.

An alternative approach, adopted by more forward thinking companies, is to change their existing practices to eliminate or reduce the wastes they produce. This adoption of eco-efficiency minimizes the for end-of pipe technologies and hence directly reduces costs.

Are You Missing Key Opportunities?

A good eco-efficiency program will identify and exploit the market opportunities associated with good environmental practice. Many firms have discovered new business opportunities as a result of their efforts to solve pollution problems (for example the sale of waste by-products as a raw material to other businesses) and the promotion of 'green' products. These opportunities, if properly pursued, can not only offset the costs of the program, but can lead to increased profits

Moreover, effective eco-efficiency programs can identify other opportunities for reducing production costs, meeting customer and supplier requirements, improving worker health and safety, enhancing the company's public image and preventing potential future liability problems.

How is Eco-Efficiency Linked to the ISO 14000 series?

The International Standards Organization (ISO) 14000 series of standards is the main vehicle defining and supporting the application of environmental management systems (EMS). ISO 14001, the standard appropriate to most manufacturers, requires that an organization identify the "*environmental aspects of its activities, products or services that it can control and over which it can be expected to have an influence, in order to determine those which have or can have significant impacts on the environment*."

ISO 14001 includes routine internal monitoring of environmental performance against defined targets for improvement. It is then important to note that the successful implementation of the ISO 14001 standards in many ways parallels or supports particular eco-efficiency objectives, for example to reduce raw material usage and waste production.

ISO 14001 is already required for many industrial operations in Western Europe and in North America. In addition, and with regard to international trade, overseas markets are increasingly making ISO 14001 a requirement of their suppliers, and interest is continuing to increase throughout Asia.

2 ASSESSING OPTIONS FOR ECO-EFFICIENCY IN THE WORKPLACE

This section describes how to go about identifying and evaluating potential opportunities for improving eco-efficiency in your workplace. This process is in principle the same for all types of industry, and consists of four basic steps:

- Step 1 - preparing for the assessment;
- Step 2 - identifying opportunities for eco-efficiency;
- Step 3 - measuring the baseline; and
- Step 4 - evaluating the options.

The key elements of each of these steps are summarized in the following illustration.

2.1 STEP 1 - PREPARING FOR THE ASSESSMENT

Commitment from Senior Management

Like all important business decisions, eco-efficiency requires the full commitment and support of top management for its successful implementation. Before anything else, the management must first develop its strategy for the eco-efficiency assessment. The key factors to be defined by the strategy are the objectives (what management hopes to achieve), the timescale for the assessment, and the resources which will be required (both human and financial). Once these factors have been defined, they can be put forward as an *Action Plan*, which allocates responsibilities to each of the team members.

The Focus of the Assessment

A key element of the *Action Plan* is to define the focus of the assessment, which must be made clear during this preparation stage. For example, the assessment may focus on the whole facility, or perhaps on the operations of just one unit. On the other hand, the assessment may just look at key issues of concern, such as:

- raw material losses;
- wastes that cause processing problems;
- wastes considered to be hazardous or for which regulations exist;
- wastes which are or will be costly to treat and dispose of; or
- high energy consumption.

In whichever case, it is important to use simple flow diagrams of the operations and processes which are being investigated to keep track of the assessment. As a first step, the following information should be collected and reviewed:

ECO-EFFICIENCY ASSESSMENT DATA

- the quantities and costs of raw materials, water and energy;
- the processes that consume high water volumes;
- the processes that generate high wastewater volumes;
- the sources and quantities of each type of waste;
- waste management costs (storage, collection and disposal);
- discharge points of wastewater; and

- points of air emission.

Getting Started

The size of the assessment team will of course depend upon the scale and complexity of the processes to be investigated. A more complicated process may require at least 3 or 4 individuals including technical, production and accounts staff. Informing employees of the aims of the assessment will also help the process, encouraging their cooperation and increasing their employee awareness.

The assessment should be undertaken during normal working hours so that machine operators can be consulted, actual operations can be observed, and wastes quantified.

2.2 STEP 2 - IDENTIFYING OPPORTUNITIES

The following checklist gives a general approach to identifying options for improved eco-efficiency in facilities of all types. Invest a little time in walking around your facility and ask yourself the following questions.

Resource Use

1. Are batch sizes maximized and batches sequenced to minimize unnecessary cleaning and equipment warm-up or cool-down?
2. Could high-pressure water cleaning replace chemical cleaning?
3. Can process chemicals or additives be replaced by less damaging substances or mechanical processes?
4. Can alternative processes produce the same results with fewer resources and less waste?
5. Would overflow alarms for any tanks and vessels produce cost savings?
6. Do your processes have adequate and accurate monitoring and gauging techniques? Are raw materials or additives used in excess?
7. Are you aware of any incidents of production line personnel using more of a particular chemical '*just in case*'.

Waste Management

1. Are you aware of all wastes and can you characterize them in terms of composition and quantity?
2. Are waste materials properly segregated and separately stored for appropriate disposal and possible re-use?
3. Is hazardous waste mixed with non-hazardous waste? If so, are non-hazardous wastes treated by costly hazardous waste techniques?
4. Is packaging and product filler kept to a minimum? Are products

combined or condensed to reduce packaging?
5. Are all drums and containers thoroughly emptied before cleaning or disposal?

Material Purchasing and Storage

1. Do you know the shelf life and ordering system for raw materials? Does this affects loss through ageing?
2. Do your suppliers accept the return of outdated supplies? Do they keep their packaging to a minimum?
3. Can materials in store be inspected visually for corrosion or leaks?
4. Can materials be contaminated by others in the store? Are containers damaged by forklift trucks, etc?

Re-use and of Recycling

1. Is there any potential for mutually beneficial activities with neighboring industries? Could you utilize their by-products as a material resource, or sell your by-products to others?
2. Could your waste be used as a source of energy, by yourself or others?
3. Could packaging received from your suppliers be returned and re-used?
4. Could the packaging you give to your customers be returned and re-used?

Water Conservation

1. Would high pressure nozzles on hoses save water in cleaning equipment and workspaces?
2. Could taps and faucets be fitted with automatic shut-offs or flow restricters?
3. Is fresh water discharged after a single use? Is there potential to recirculate used water (for example from cooling) for re-use for other purposes such as cleaning?

Energy Conservation

1. Are you familiar with your overall energy profile and quarterly energy consumption levels and costs?
2. Are staff aware of energy issues, eg turning off equipment and lighting if not in use?
3. Are boilers, lights and refrigeration units old and efficient? How long

would energy efficient plant take to pay for itself in savings?

4. Could more efficient motors replace old and inefficient ones? Are compressed air systems leaky?
5. How much energy might be saved through the use of better timer and thermostatic controls?
6. Do you have adequate thermal insulation on heating or cooling lines?

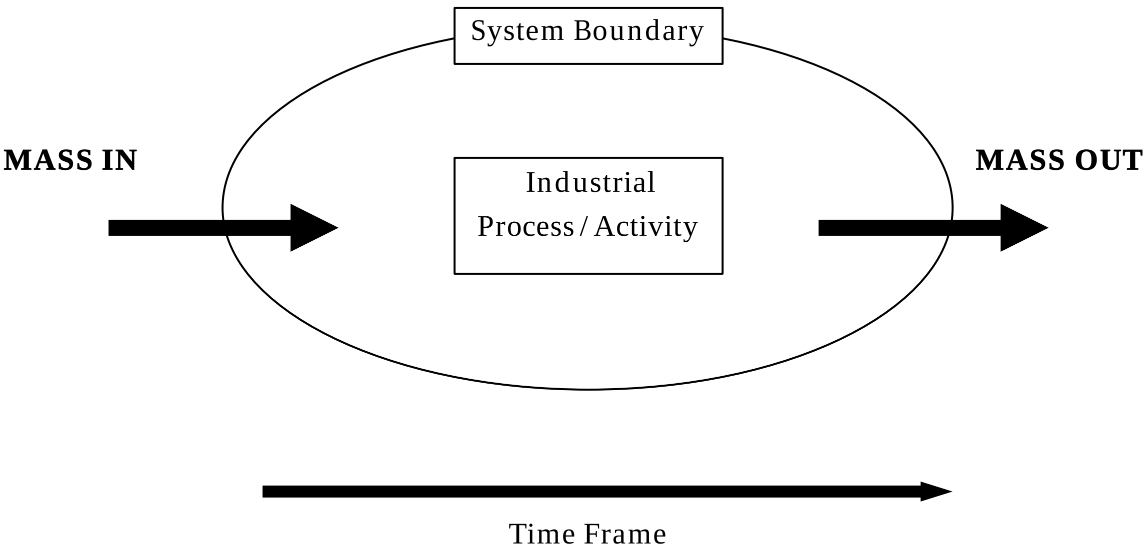
The answers to these questions will help identify where eco-efficiency can be improved, through changes in management or the processes and materials used.

2.3 STEP 3 - MEASURING THE BASELINE

Before eco-efficiency opportunities can be assessed, the current 'baseline' position needs to be quantified. Establishing the baseline situation will allow the benefits of eco-efficiency options (for example to reduce waste) to be quantified, both in terms of environmental improvement and cost savings.

Undertaking a Mass Balance

The simplest way to establish the baseline position is to undertake a *mass balance*. A mass balance measures the quantities of the inputs (raw materials, energy, water consumption, etc) going into a process, and the outputs (finished products, solid waste, effluent and air emissions, etc) which are produced as a result. In addition to measuring quantities, the mass balance is also applied to the associated costs (for raw materials, energy, water, and waste disposal, etc). The concept of the mass balance is illustrated below.



A mass balance can be undertaken to varying degrees of precision and depth. In evaluating eco-efficiency opportunities for small and medium sized companies, it is prudent to limit the detail of the initial studies of the processes under investigation. Further detail can be added when the most promising areas for savings have been identified. The secret to a good mass balance, however, lies in its systematic and methodological approach.

Measuring Inputs and Outputs

The quantification of the inputs to a process includes two approaches:

- analyze purchasing records for materials and utility bills for energy and water to determine overall quantities involved; and
- measure actual quantities entering the process by counting, weighing or metering.

The output side of the mass balance consists of the same two principles:

- analyze waste disposal records for liquid and solid wastes, effluents, and production records for end products and by-products; and
- measure quantities leaving the process by counting, weighing or metering.

The most common area in which mistakes are made with a mass balance lies within the timescale over the analysis is undertaken. Particular care is needed in choosing an appropriate time period, and this is dictated by whether a continuous or batch process is being considered. For continuous processes, the times of any starts and stops must be accurately recorded. For batch processes, several batches should be measured (perhaps over the period of a week) to give a representative analysis.

Balancing the Inputs and Outputs

In an ideal mass balance, the quantity of materials going into a process equals that which comes out. However to reach such a level of detail is seldom feasible under limited timescales, apart from for very simple processes. Despite this, the mass balance approach still provides the basis for a better understanding of the production process. This in itself is the key to identifying areas of unnecessary wastage and where production processes and their management can improve with real cost benefits.

2.4 STEP 4 - EVALUATING THE OPTIONS

If undertaken systematically, the first two steps of the assessment will reveal a range of areas in which eco-efficiency can be improved, through both better management and process technology. In order to select the most appropriate option for your business, it is also important to take a systematic approach to their evaluation. Three factors need to be taken into account:

- the environmental performance of the option;
- the nature of the option and its implementation potential; and
- the cost of the option and its payback period.

Such an evaluation will of course include subjective considerations. The following techniques, however, can be used to apply a score to each factor.

Environmental Performance

Assessing the environmental performance can be complicated, particularly where different types of environmental effects have to be compared. As a starting point, it may be most practical to consider reductions in waste and the use of toxic substances as below:

- Reduction at source (raw materials, toxins, and energy) - 5 points.
- Resource recovery and in-process - 4 points.
- End-of-pipe recycling - 3 points.
- In-process treatment - 2 points.
- End-of-pipe treatment - 1 point.

Implementation Potential

More than one eco-efficiency option may address the same problem (such as excess water use), however their implementation may involve different levels of complexity. For example, one measure may require substantial changes to existing plant and therefore result in unacceptable delays, where the other (perhaps more costly) option may provide an instant solution. Implementation potential can also be assessed using a scoring system:

- Highly likely - 4 points.
- Medium probability - 3 points.
- Low probability - 2 points.
- Highly unlikely but still worth considering - 1 point.

Cost of the option and payback

Certain eco-efficiency options are high in capital cost and may seem unattractive. However, the savings which arise from the option must also be taken into account when assessing its cost.

Calculating the simple payback period is one useful tool for assessing the cost benefit. The simple payback period shows how soon the option will pay for itself in savings (perhaps two weeks or four years), and is calculated by dividing the total capital investment (equipment and installation costs) by the expected operating cost savings per year (from reduced material, energy, water, labor and waste disposal costs). In the scoring system below, options with a high capital cost but rapid payback should therefore be considered as a *low cost* option:

- No or Minimal Cost - 4 points.
- Low Cost - 3 points.
- Medium Cost - 2 points.
- High Cost - 1 point.

Comparing the Options

Once scores have been attributed to the environmental performance, implementation potential and costs of each option, they can be more directly compared, as shown below. Those options awarded the highest scores are more likely to be successful.

Modification	Environmental Performance	Implementation Potential	Cost of Option	**Total Score**
Option A	5	4	4	**13**
Option B	4	2	1	**7**

CONDUCTING AN ASSESSMENT – A SUMMARY

- Obtain the commitment and support of top management, to establish a strategy and clear objectives.
- Formulate an *Action Plan* which identifies the focus of the assessment and allocate responsibility.
- Collect documentation, flow diagrams of processes, and relevant data .
- Establish the baseline using a mass balance to measure inputs and outputs.
- Identify opportunities for eco-efficiency through improved management and process technology.
- Evaluate options for using a systematic assessment of environmental performance, implementation potential, and option cost.

3 DEVELOPING PRACTICAL SOLUTIONS

The methodology in the previous section shows how opportunities for eco-efficiency measures can be identified, quantified, and compared to each other for appraisal.

This section describes some of the areas where eco-efficiency measures have been adopted in the chemicals and plastics industry in the past. Basic guidelines are given for the three key areas in which these opportunities are commonly found:

- housekeeping and management;
- modifications to products and processes; and
- waste management.

3.1 HOW GOOD IS YOUR HOUSEKEEPING?

Housekeeping is a general term which is used to describe how well the day-to-day activities of a facility are managed. Housekeeping measures are not necessarily technical in nature; they include basic functions such as storage, stock control, record keeping, cleaning and maintenance.

Good housekeeping is essential for making sure that a business is run efficiently. In the same way, good housekeeping is also the first and most essential step to improving eco-efficiency. Housekeeping is therefore the first place a manager should look for opportunities to save resources, reduce waste and prevent pollution. Good housekeeping provides low-cost, low-risk and low-technology solutions for improving eco-efficiency and saving money. Areas where efficiency can be improved through improved housekeeping include:

- material purchasing, handling and storage;
- spill and leak prevention;
- equipment inspection and maintenance; and
- calibration and measurement.

Improving eco-efficiency through good housekeeping requires involvement from everyone working in the facility. This ensures that all employees understand the role they play, and may require some basic training to raise their awareness. The key messages to promote are that *wherever there is waste there is wasted money*, and that *their actions bear directly on the environment*.

Material Purchasing, Handling and Storage

Badly managed purchasing, handling and storage can lead to over-stocking and poor storage, with material lost through aging, spillage and contamination. Proper chemical handling begins with procedures for ordering, purchasing, handling and storage:

- obtain details about proper packaging, handling, chemical constitution, and control of impurities from the suppliers (most of this information should be readily available in the Material Safety Data Sheet {MSDS});
- use packaging designed to minimize spills (most bulk containers are effective);
- use rinsable and recyclable drums
- purchase materials in preweighed packages
- register dates and quantities of all purchases on receipt to minimize surplus and spoilt orders;
- segregate chemicals (eg acidic, flammable, alkali, oxidizer) to prevent contamination;
- use proper racks, storage bins and bulk tanks with dikes or berms to contain leaks;
- store goods away from heavily trafficked areas to avoid container damage; and
- use a vacuum to clean-up powder spills, which under no circumstances should be washed down the drain.

Spill and Leak Prevention

Spills and leaks can result in substantial material loss and excessive costs. Good housekeeping measures to minimize leaks include:

- Using equipment and piping only for their designed purpose.
- Periodically inspecting (and testing where possible) the condition of storage tanks, drums, pipelines (especially flange and gasket connections to pumps and tanks), etc to ensure their integrity.
- Equipping storage tanks with overflow alarms and automatic pump shutoffs, and testing alarms periodically.
- Interlock devices to stop flow to a full tank or to a leaking section.
- Making staff aware of the consequences of a spill or leak, i.e. waste, pollution, and contamination of absorbent materials used for mop-up, or wash downs, which must also be disposed and may require pre-treatment.

Equipment Inspection and Maintenance

The periodic checking of components (pumps, valves, filters, switches and regulators) will avoid inaccurate dispensing, leaks, filter clogging and off-quality production. Close attention should be paid to common defects such as missing guards, loose electrical cords, and leaks of water, steam and compressed air.

Measurement and Calibration

Inaccurate measurement and calibration results in material waste, especially where too much material is used *just in case*:

- Measuring and dispensing devices should be routinely calibrated. Individual measuring vessels should be retained for each chemical, avoiding unnecessary washing.
- All chemicals should be accurately weighed, dispensed and mixed, avoiding spillage and waste. Mixing areas should be well lit and ventilated, with a smooth and sealed floor, and as close to the production area as possible.
- Wash small parts in a solvent bowl and filter and re-use the solvent. Solvent can also be wrung from wet rags using an old laundry type wringer is ideal.

3.2 TECHNOLOGICAL MODIFICATIONS AND SUBSTITUTIONS

Once the first step of improving housekeeping has been taken, the eco-efficiency assessment can move on to technology modifications and material substitutions. On the whole, such changes to the process require some capital investment, however savings in energy, water and material use can result in attractive payback periods, perhaps within a few months.

The easiest technologies to implement are often those proven in other industries. Such modifications are often made in the following areas:

- product design;
- chemical substitutions;
- solvent and solution use;
- equipment cleaning;
- continuous operations; and / or
- batch operations.

In each case, the design stage (of a product, the process and particularly a new facility) offers the unique and optimum opportunity for making change.

Product Design

Life Cycle Analysis is increasingly being used to assess the broad range of impacts associated with a product during its design. The analysis takes a "cradle to grave" approach, looking at the raw material use, transportation, packaging, impacts during use, and disposal or recyclability. Manufacturers in some sectors are beginning to apply this methodology in programs known as *"Design for the Environment"*, *"Integrated Environmental Design"* and *"Product Stewardship"*, which include:

- using raw materials with some recycled content;
- designing products which are readily recyclable at the end of their intended use lifespan; and
- designing products which are less damaging during disposal.

Chemical Substitutions

Chemicals and plastics manufacturing is a chemically intensive process, and the substitution of polluting chemicals provides a key focus for improving eco-efficiency. Such substitutions can either be chemical (using a less damaging substance for the same job), or mechanical (adjusting the process to avoid the need for the chemical altogether). In either case, reducing chemical use can eliminate the need for costly end-of-pipe treatment and disposal.

Getting the most out of solvents and solutions

The large volumes of acidic, alkaline and solvent cleaning agents, and solutions used for plating, etching and finishing, etc, presents a range of opportunities for conservation and re-use. The following measures highlight examples of where you can extend useful lifetime of solvents and solutions before their final disposal:

- operate cleaning tanks properly, remove sludges continuously;
- avoid cross-contamination of solvents;
- monitor solvent composition for re-use;
- consolidate cold cleaning operations;
- use plastic bead blasting for paint stripping; and
- increase plating solution bath life.

Equipment cleaning and filtration

Equipment cleaning can consume excessive quantities of water, energy and chemicals. Substantial reductions in all of these resources can be achieved by careful consideration of the cleaning processes:

- use counter-current washing to recycle water, and employ efficient washing and rinsing methods such as high pressure-spray systems;
- use in-process cleaning and clean mix tanks immediately after use;
- increase equipment drainage time and settling time, and maximize the de-watering of sludges;
- use corrosion resistant materials, use nitrogen blanket to reduce oxidation;
- agitate or insulate storage tanks, and use mechanical wipers on mix

tank walls, etc, to ease the cleaning process;

- eliminate the use of filter aids, use cleanable filters instead of disposable ones; and
- re-examine need for chemical cleaning.

Continuous processing

By optimizing your process schedule you can reduce the need for cleaning, saving chemicals, waste and cost. In many case, continuous processing can require less cleaning than batch processing. Other ways in which material use and efficiency can be improved during continuous processing include:

- develop more selective catalysts and tougher catalyst support;
- use alternate process routes;
- regenerate and recycle spent catalyst;
- optimize the reduction variables and reactor design;
- combust with heat (and HCI) recovery; and
- use filter inside reactor freeboard.

Batch processing

Despite some disadvantages, for example the general increase in cleaning needs over continuous processing, batch processing often provides the only means for undertaking certain processes. Examples of opportunities for reduced material use and wastage in batch processing include:

- *Reaction/processing step* - optimize reaction variables, reactor design, and reactant addition method, reduce the use of toxic catalyst, and charge materials closer to stoichiometric ratios.

- *Baghouse Fines* **-** increase use of dust suppression methods (use wet instead of dry grinding), schedule baghouse emptying and recycle baghouse fines.

- *Off-Spec Products* - ensure tighter control of reaction operating parameters, and reformulate / recycle or sell any off-specification products.

3.3 WASTE MANAGEMENT

A cornerstone of good waste management is the segregation (the capture, separation and storage) of different waste streams to allow recycling and re-use. In some cases, the chemicals and plastics industry has benefited from the establishment of formal and informal networks through which the wastes of one company can become the raw material of another. Benefits include reduced waste disposal costs, savings in raw material and supply costs and revenue generation through marketing reusable materials.

The first step in introducing a waste exchange program is to conduct a facility wide inventory of all potentially reusable products.
Most economies have Clearing Houses for waste reduction that can supply you with information pertaining to recyclers who will supply and buy products, together with information and guidance on existing waste exchanges.

Waste Stream Segregation

Segregation can reduce the quantity of hazardous waste for disposal, as this is often a combination of two or more wastes or water mixes, in that when a hazardous and non-hazardous waste are mixed the outcome is classed as hazardous. Segregation can be achieved through:

- Isolating waste by contaminant, for example temporarily storing water from a clean out process rather than disposing of it can allow for its reuse as a feed for future mixes of the same product.
- Isolating liquid from solid wastes can reduce volume and simplify treatment.
- Isolating contact and non-contact wastewaters will enable non-contact waters to be recycled or disposed with reduced treatment.

Re-use and Recycling

The opportunities for cost savings in the chemical and plastics industry presented by re-use and recycling can be considerable. However, problems arise because these measures may increase health and safety risks through the additional management and handling of materials. For this reason recycling options in the industry may generally be ranked into the following order of preference:

- In-plant reuse.
- Other on site recovery.
- Off-site recovery.
- Sale for off-site reuse.
- Energy recovery.

The following table presents a number of common recycling methods applicable to the chemicals and plastics sector. However, it should be noted that many of the processes listed below require a considerable amount of initial investment due to the specialist equipment required to perform the material recovery. Furthermore, energy usage requirements (e.g. distillation, steam stripping, refrigeration etc) also need to be taken into account in the cost-benefit analysis as they are not inconsiderable.

SOLVENT WASTES

- Liquids separation can be undertaken by batch distillation, fractional distillation, flash distillation, steam distillation, and film evaporation.
- Solids removal can be undertaken by sedimentation, filtration, and centrifugation.
- Liquid-liquid phase separation can be undertaken by decantation, API separation, and tilted plate separation.
- Breaking down emulsions and dispersions can be undertaken by coalescence, centrifugation, chemical de-emulsification, and dissolved air flotation.
- Dissolved or emulsified organics can be recovered by steam / air stripping, carbon absorption, solvent extraction, supercritical fluid extraction, and membrane separation.
- Organic vapors can be recovered by condensation, carbon adsorption, absorption.

HALOGENATED ORGANIC (NON-SOLVENT) WASTES

- The latent energy contained in halogenated organic wastes can be recovered through combusting the waste as fuel.
- Solvent extraction processes can be used to recover dissolved organics.
- Baghouse Filters and ESPs can be used to gather halogenated organic particulates.

CORROSIVE WASTES

- Thermal degradation processes can be utilized to recover hydrochloric acid and sulphuric acid.
- Crystallization methods can be used to recover ferric chloride and sulfate from spent pickle liquor.

CYANIDE/REACTIVE WASTES

- Reactive wastes such as those containing cyanide can be recovered through a number of techniques such as ion exchange, refrigeration, crystallization, evaporation, membrane separation, filtration, and metal reduction.

METAL- CONTAINING WASTES

- Metal-containing wastes can be processes to provide a viable resource by hydrometallurgical leaching, solvent extraction, ion exchange, precipitation, chemical reduction, crystallization, evaporation, membrane separation, adsorption, and foam flotation.
- Metal particulates and vapors can be recovered from gases by particulate recovery, selective adsorbents, wet scrubbers and retorting.

4 *MONITORING YOUR PROGRESS*

Once measures for eco-efficiency have been implemented, it is critical that progress is continually monitored. This is the key to identifying whether the initiatives are in fact producing the cost savings that were anticipated, and hence whether the objectives of the eco-efficiency program have been met.

In addition, monitoring is the only way to establish whether the performance targets which you have established are being achieved. This information provides the basis for setting targets in the future, and also helps identify where the implementation of subsequent eco-efficiency measures can be improved.

The following gives a simple checklist which can be used to assess the overall benefits of the eco-efficiency program. As mentioned above, this should be supported with more detailed records of material, water and energy consumption, and waste disposal charges.

THE ECO-EFFICIENCY EVALUATION CHECKLIST

Taking all costs into account, have unit costs of production fallen?

Are you still ordering the same quantity of raw materials?

Has there been a reduction in energy costs?

Has unit output remained static?

Have you received the same amount of violation notices?

Are you selling any new products?

Are you selling more of the same products?

Have waste handling and / or shipping costs remained static?

Have waste disposal charges decreased?

Are you discharging less effluent and air emissions?

Is there any reduction in the number or work-related accidents?

Has your program had any effect on the number of worker absentee days?

Is there a lower turn over of staff, perhaps through improved working environment, conditions, and moral?

Overcoming Obstacles and Maintaining Your Program

> ***HELP!!***
>
> - Contact local government and ask about pollution prevention
> - Find out what local and international Trade Associations are doing.
> - Local universities and colleges are often eager to participate.

Nearly all eco-efficiency programs depend upon the commitment of you and your staff for their success, continuation and advancement. You must therefore disseminate and publicize stories of success and acknowledge your efforts and their efforts in its contribution. You should also allow for the development and implementation of new ideas and techniques.

GOOD LUCK …………and **avoid conclusions, such as "there are no cost saving or environmental opportunities at my facility".**

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