AUDIT AND REDUCTION MANUAL

for

INDUSTRIAL EMISSIONS AND WASTES

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This is the seventh publication in a new Technical Series that regroups the Guidelines, Overviews, Technical Reviews and Workshop Proceedings previously published by UNEP/IEO. The regrouping into a single series will ensure a greater cohesion among future publications, and allows a single document to include the various elements of IEO work that had earlier been presented separately.

As before, the Technical Series aims to meet the needs of a wide range of government officials, industry managers and environment protection associations, by providing information on the issues and methods of environmental management relevant to various industrial sections.

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FOREWORD

Sustainable development will only become a reality if we adopt methods of production that generate less waste and fewer emissions than traditional industrial processes. Sometimes the change involves the adoption of new, cleaner technologies of production. Even without new technologies however, improvements in operation can often dramatically reduce the level of release. A reduced level of emissions and wastes frequently means savings in costs of production, as less valuable raw material is squandered.

Accurate information about the origins and sources of environmental releases is a prerequisite for effective reduction of industrial emissions and wastes. Once the sources are identified, the most cost-effective options for avoiding, reducing and recovering wastes can be evaluated.

In order to assist in the diagnosis of emission and waste sources UNEP/IEO and UNIDO have joined forces to produce this audit manual. The manual is based on an earlier publication by the Ontario Waste Management Corporation in 1987. In order to adapt it to as wide an international audience as possible, UNEP/IEO and UNIDO obtained the advice of an international group of experts who met in Paris for the two days of 1,2 August 1991.

The manual is a practical working document intended for use within industry. It can be used by:

- factory personnel at all levels interested in upgrading their own processes;
- consultants reporting to an industrial client;
- government personnel reviewing existing factory operations.

Depending on the outcome of the audit procedure, information on reduction options can come from a number of technical sources. In particular the International Cleaner Production Information Clearinghouse (ICPIC), established by UNEP/IEO under its Cleaner Production Programme with the support of the US EPA, allows rapid worldwide access to information on technologies, programmes and experts in a number of key industry sectors. UNEP/IEO and UNIDO are also able to provide direct advice and follow-up technical assistance in many cases. Further information about these programmes can be found in the appendices of this manual.

It is hoped that decision-makers in industry and government will find in this document the elements to develop waste audits as one of the new management tools that lead to cleaner industrial production becoming a reality in the future.

CHAPTER 1
INTRODUCTION TO WASTE AUDITING

CHAPTER 1: INTRODUCTION TO WASTE AUDITING

In the context of this manual, waste is taken as a broad term to include any non-product discharge from a process. Thus, it describes discharges in the gaseous, liquid and solid phases.

In the past, waste management has concentrated on end-of-pipe waste treatment; designing waste treatment plants and installing pollution control equipment to prevent contamination of the environment.

A different philosophy has emerged in recent times, that of waste prevention and reduction. Now we ask how can we prevent the generation of this waste? How can we reduce this waste? Can we reuse or recover this waste?

This progressive shift from waste treatment towards waste prevention has the following benefits:

- waste quantities are reduced;
- raw material consumption and therefore costs are reduced,
- waste treatment costs are reduced,
- the pollution potential is reduced;
- working conditions are improved,
- process efficiency is improved.

In order to prevent or reduce waste generation you need to examine your process to identify the origins of wastes, the operational problems associated with your process and those areas where improvements can be made.

A waste audit is the first step in an on-going programme designed to achieve maximum resource optimisation and improved process performance. It is a common sense approach to problem identification and problem solving.

A waste audit enables you to take a comprehensive look at your site or process to facilitate your understanding of material flows and to focus your attention on areas where waste reduction and therefore cost saving is possible.

Undertaking a waste audit involves observing, measuring, recording data and collecting and analysing waste samples. To be effective it must be done methodically and thoroughly together will full management and operator support.

A good waste audit:

- defines sources, quantities and types of waste being generated;
- collates information on unit operations, raw materials, products, water usage and wastes;

- highlights process inefficiencies and areas of poor management;
- helps set targets for waste reduction;
- permits the development of cost-effective waste management strategies;
- raises awareness in the workforce regarding the benefits of waste reduction;
- increases your knowledge of the process;
- helps to improve process efficiency.

The waste audit procedure can be applied on various scales. A waste audit of a region can indicate problem industries. At the plant level, wastes can be traced to particular processes allowing allocation of treatment charges where necessary; and at the process level the exact origins of wastes can be identified enabling waste reduction measures to be established.

This manual is designed to be used by staff at all levels; technical as well as non-technical. It is a practical guide to help you understand your processes.

How To Use the Manual

A waste audit approach leading to the implementation of a waste reduction action plan is illustrated in the form of a flow diagram overleaf (see also the pull-out Quick Reference Audit Guide at the back of the manual).

To undertake this approach use the Quick Reference Audit Guide and refer to the Audit Procedure in Chapter 2 for instructions for each step.

As a starting point reproduce tables along the lines of Tables 1 - 9 to give you a basis for your data collection and organisation.

Three case studies are included to illustrate the wide application of this waste audit and reduction approach.

PHASE 1: PREASSESSMENT

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- Step 2 divide process into unit operations
- Step 3 construct process flow diagrams linking unit operations

PHASE 2: MATERIAL BALANCE

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- Step 19 undertake environmental and economic evaluation of waste reduction options, list viable options

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- Step 20 design and implement a waste reduction action plan to achieve improved process efficiency

CHAPTER 2
THE AUDIT PROCEDURE

CHAPTER 2: THE AUDIT PROCEDURE

This Chapter describes a step-by-step approach for carrying out a waste audit. It is designed to be generic to apply to a broad spectrum of industry. The approach comprises three phases; a preassessment phase for audit preparation; a data collection phase to derive a material balance; and a synthesis phase where the findings from the material balance are translated into a waste reduction action plan.

It is possible that not all of the audit steps will be relevant to every situation. Similarly, in some situations additional steps may be required. However, the following approach should form the basis of your investigations.

Use the Quick Reference Audit Guide at the back of the manual in conjunction with the following explanatory notes to carry out your audit.

PHASE 1: PREASSESSMENT

Step 1: Audit Focus and Preparation

A thorough preparation for a waste audit is a prerequisite for an efficient and cost-effective study. Of particular importance is to gain support for the audit from top-level management, and for the implementation of results; otherwise there will be no real action.

The waste audit team should be identified. The number of people required on an audit team will depend on the size and complexity of the processes to be investigated. A waste audit of a small factory may be undertaken by one person with contributions from the employees. A more complicated process may require at least 3 or 4 people: technical staff, production employees and an environmental specialist. Involving personnel from each stage of the manufacturing operations will increase employee awareness of waste reduction and promote input and support for the programme.

A waste audit will probably require external resources, such as laboratory analytical facilities and possibly equipment for sampling and flow measurements. You should attempt to identify external resource requirements at the outset of the project.

Analytical services and equipment may not be available to a small factory. If this is the case, investigate the possibility of forming a waste auditing association with other factories or industries; under this umbrella the external resource costs can be shared.

It is important *to* select the focus of your audit at the preparation stage. You may wish the waste audit to cover a complete process or you may want to concentrate on a selection of unit operations within a process. The focus will depend on the objectives of the waste audit. You may wish to look at waste minimisation as a whole or you may wish to concentrate on particular wastes, for example:

- raw material losses;
- wastes that cause processing problems;
- wastes considered to be hazardous or for which regulations exist;
- wastes for which disposal costs are high.

A good starting point for designing a waste audit is to determine the major problems/wastes associated with your particular process or industrial sector. The Rapid Assessment of Sources of Air, Water and Land Pollution published by the World Health Organisation (WHO, 1982) is a useful reference for identifying the type and typical quantities of wastes associated with particular industries. For example, Table 1 describes the likely waste quantities for the tanning industry.

Table 1: Manufacture of Leather and Products of Leather, Leather Substitutes and Fur, except Footwear and Wearing Apparel

		Pulp hair/ chrome tanning/ finishing	Save hair/ chrome tanning/ finishing	Save hair/ vegetable tanning finishing
Waste volume	(m^3/t of hides)	53	63	50
BOD_5	(kg/t of hides)	95	69	67
COD	(kg/t of hides)	260	140	250
Suspended Solids	(kg/t of hides)	140	145	135
Total Solids	(kg/t of hides)	525	480	345
Total Chromium	(kg/t of hides)	4.3	4.9	0.2
Sulphides	(kg/t of hides)	8.5	0.8	1.2
Oil and Grease	(kg/t of hides)	19	43	33
Total N	(kg/t of hides)	17	13	9.2
pH		1-13	4-12.6	2-13

(Source: WHO, 1982)

All existing documentation and information regarding the process, the plant or the regional industrial sector should be collated and reviewed as a preliminary step. Regional or plant surveys may have been undertaken; these could yield useful information indicating the areas for concern and will also show gaps where no data are available. The following prompts give some guidelines on useful documentation.

- Is a site plan available?
- Are any process flow diagrams available?
- Have the process wastes ever been monitored - do you have access to the records?
- Do you have a map of the surrounding area indicating watercourses, hydrology and human settlements?
- Are there any other factories/plants in the area which may have similar processes?

Other general data which can be collated quickly and which are useful orientation material are described below..

- What are the obvious wastes associated with your process?
- Where is water used in greatest volume?
- Do you use chemicals that have special instructions for their use and handling?
- Do you have waste treatment and disposal costs - what are they?
- Where are your discharge points for liquid, solid and gaseous emissions?

The plant employees should be informed that the audit will be taking place, and they should be encouraged to take part. The support of the staff is imperative for this type of interactive study. It is important to undertake the audit during normal working hours so that the employees and operators can be consulted, the equipment can be observed in operation and, most importantly, wastes can be quantified.

Step 2: Listing Unit Operations

Your process will comprise a number of unit operations. A unit operation may be defined as an area of the process or a piece of equipment where materials are input, a function occurs and materials are output, possibly in a different form, state or composition. For example, a process may comprise the following unit operations: raw material storage, surface treatment of components, rinsing, painting, drying, product storage and waste treatment.

An initial site survey should include a walk around the entire manufacturing plant in order to gain a sound understanding of all the processing operations and their interrelationships. This will help the audit team decide how to describe a process in terms of unit operations. During this initial overview, it is useful to record visual observations and discussions and to make sketches of process layout, drainage systems, vents, plumbing and other material transfer areas. These help to ensure that important factors are not overlooked.

The audit team should consult the production staff regarding normal operating conditions. The production or plant staff are likely to know about waste discharge points, unplanned waste generating operations such as spills and washouts, and can give the auditors a good indication of actual operating procedures. Investigations may reveal that night-shift procedures are different from day-shift procedures; also, a plant tour may disclose that actual material handling practices are different from those set out in written procedures.

A long-standing employee could give some insight into recurring process problems. In the absence of any historical monitoring this information can be very useful. Such employee participation must however be a non-blaming process; otherwise it will not be as useful as it could be.

During the initial survey, note imminent problems that need to be addressed before the audit is

The waste audit team needs to understand the function and process variables associated with each unit operation. Similarly, all the available information on the unit operations and the

information, as shown in Table 2.

Table 2: Identification of Unit Operations

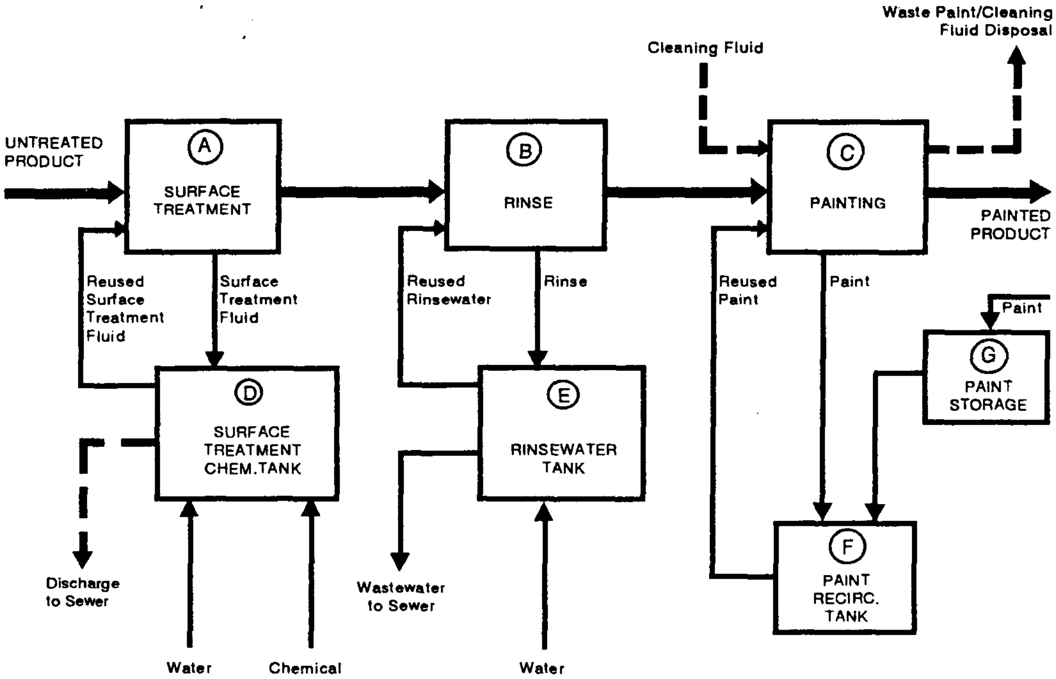
Unit Operation	Function	File Number
(A) Surface Treatment	Surface treatment of metal products 10 m^3 spray chamber, 6 jets, 100 l/min pump	1
(B) Rinsing	Washing metal products before painting	2

Identification of materials handling operations (manual, automatic, bulk, drums etc) covering raw materials, transfer practices and products is also an important aspect which could usefully be included in the above tabulation as a prelude to development of a materials balance (Phase 2).

Step 3: Constructing Process Flow Diagrams

By connecting the individual unit operations in the form of a block diagram you can prepare a process **flow** diagram. Intermittent operations such as cleaning, make-up or tank dumping may be distinguished by using broken lines to link the boxes. Figure 1 is an example of a simplified process flow diagram for a metal finishing process.

Figure 1 : A Process Flow Diagram for a Metal Finishing Process



For complex processes prepare a general flow diagram illustrating the main process areas and, on separate sheets of paper, prepare detailed flow diagrams for each main processing area. The printed circuit board manufacture case study in Chapter 3 shows how this can be done (Case Study 3).

Now you must decide on the level of detail that you require to achieve your objectives.

It is important to realise that the less detailed or larger scale the audit becomes, the more information is likely to be lost or masked by oversimplification. Establishing the correct level of detail and homing in on specific areas is very important at an early stage.

Pay particular attention to correcting any obvious waste arisings which can be reduced or prevented easily, before proceeding to the development of a material balance (Phase 2). By making simple changes at this early stage, the resultant benefits will help enlist the participation and stimulate the enthusiasm of employees for the total waste audit/reduction programme.

Phase 1 Summary

At the end of the waste audit preassessment stage the audit team should be organised and be aware of the objectives of the waste audit.

Plant personnel should have been informed of the audit purpose in order to maximise co-operation between all parties concerned.

Any required financial resources should have been secured and external facilities checked out for availability and capability.

The team should be aware of the overall history and local surroundings of the plant.

The scope and focus of the waste audit should have been established, and a rough timetable worked out to tit in with production patterns.

The audit team should be familiar with the layout of the processes within the plant and should have listed the unit operations associated with each process. Sources of wastes and their causes should also have been identified.

It should be possible to draw process flow diagrams highlighting those areas to be covered in the waste audit.

Any very obvious waste saving measures which can be introduced easily should be implemented immediately.

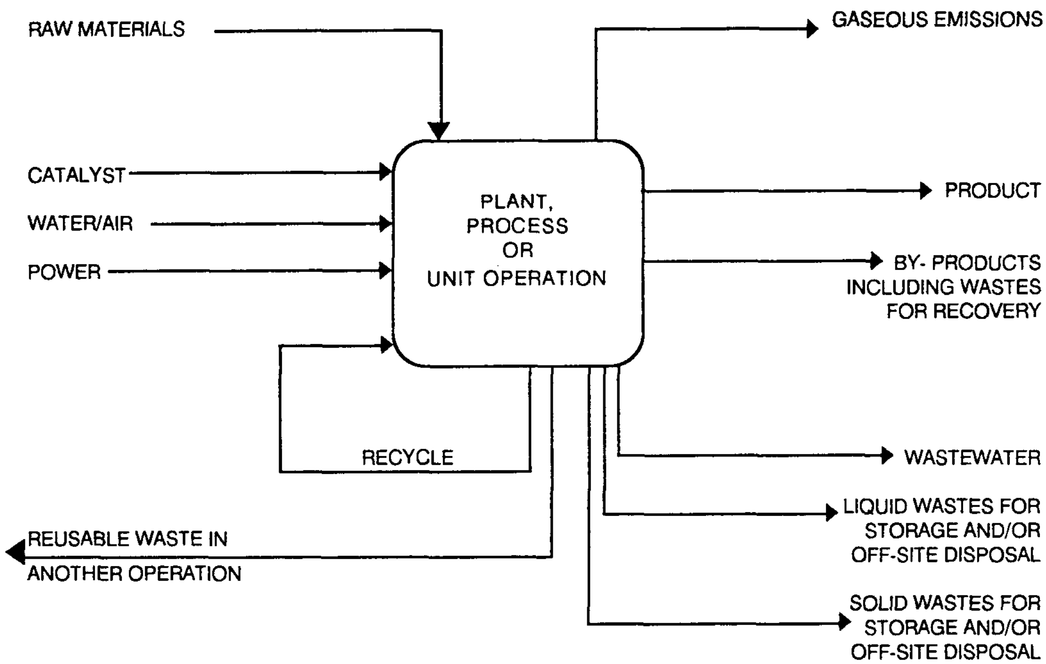
The findings of the Phase 1 investigations could usefully be presented to the management in the form of a brief preassessment report in order to reaffirm their commitment into the next phase.

PHASE 2: MATERIAL BALANCE: PROCESS INPUTS AND OUTPUTS

A material balance may be defined as a precise account of the inputs and outputs of an operation.

This phase describes a procedure for the collection and arrangement of input and output data. The procedure can be applied to derive the material balance of a plant, a process or a unit operation. Figure 2 is an example of a set of components that need to be quantified to derive a material balance. Note that infrequent outputs (eg the occasional dumping of an electroplating bath) may be as significant as continous daily discharges.

Figure 2: Typical Components of a Material Balance



The manual uses unit operations to illustrate the waste audit procedure.

Although the procedure is laid down in a step-by-step fashion it should be emphasised that the output information can be collected at the same time or before the input data; it is up to you to organise your time efficiently.

Step 4: Determining Inputs

Inputs to a process or a unit operation may include raw materials, chemicals, water, air and power (Figure 2). The inputs to the process and to each unit operation need to be quantified.

As a first step towards quantifying raw material usage, examine purchasing records; this rapidly gives you an idea of the sort of quantities involved.

In many situations the unit operations where raw material losses are greatest are raw material storage and transfer. You should look at these operations in conjunction with the purchasing records to determine the actual net input to the process.

Make notes regarding raw material storage and handling practices. Consider evaporation losses, spillages, leaks from underground storage tanks, vapour losses through storage tank pressure-relief vents and contamination of raw materials. Often these can be rectified very simply.

Record raw material purchases and storage and handling losses in a table in order to derive the net input to the process (Table 3).

Table 3: Raw Material Storage and Handling Losses

Raw Material	Qty of Raw Material	Qty of Flaw Material Purchased (per annum)	Type of Storage Used in Production (per annum)	Average Length of Storage	Estimated Annual Raw Material Losses
Raw Material 1 (Surface treatment chemical)	1OOkg	95 kg	Closed	1 month	5 kg
Raw Material 2					
Raw Material 3					

Once the net input of raw materials to your process has been determined you should proceed with quantifying the raw material input to each unit operation.

If accurate information about raw material consumption rates for individual unit operations is not available then you will need to take measurements to determine average figures. Measurements should be taken for an appropriate length of time. For example, if a batch takes one week to run, then measurements should be taken over a period of at least three weeks; these figures can be extrapolated for monthly or annual figures.

Some quantification is possible by observation and some simple accounting procedures.

- For solid raw materials, ask the warehouse operator how many sacks are stored at the beginning of the week or prior to a unit operation; then ask him again at the end of the week or unit operation. Weigh a selection of sacks to check compliance with specifications.

- For liquid raw materials such as water or solvents, check storage tank capacities and ask operators when a tank was last filled. Tank volumes can be estimated from the tank diameter and tank depth. Monitor the tank levels and the number of tankers arriving on site.

While investigating the inputs, talking to staff and observing the unit operations in action, the waste audit team should be thinking about how to improve the efficiency of unit operations. Consider the following questions.

- Is the size of the raw material inventory appropriate to ensure that material-handling losses can be minimised?
- Transfer distances between storage and process or between unit operations - could these be reduced to minimise potential wastage?
- Do the same tanks store different raw materials depending on the batch product? Is there a risk of cross-contamination?
- Are sacks of materials fully emptied or is some material wasted?
- Are viscous raw materials used on site - is it possible to reduce residual wastage in drums?
- Is the raw material storage area secure? Could a building be locked at night, or could an area be fenced off to restrict access?
- How could the raw materials be protected from direct sunlight or from heavy downpours?
- Is dust from stockpiles a problem?
- Is the equipment used to pump or transfer materials working efficiently? Is it maintained regularly?
- Could spillages be avoided?
- Is the process adequately manned?
- How could the input of raw materials be monitored?
- Are there any obvious equipment items in need of repair?
- Are pipelines self-draining?
- Is vacuum pump water recirculated?

The energy input to a unit operation should be considered at this stage; however, energy use deserves a full audit in its own right. For waste auditing purposes make a note of the energy source and whether waste reduction could reduce energy costs. If energy usage is a particularly prominent factor maybe you should recommend that an energy audit be undertaken.

Input data should be recorded on your process flow diagram or in tabular form as shown in Table 4.

Water is frequently used in the production process, for cooling, gas scrubbing, washouts, product rinsing and steam cleaning. This water usage needs to be quantified as an input.

Some unit operations may receive recycled wastes from other unit operations. These also represent an input.

Steps 5 and 6 describe how these two factors should be included in your waste audit.

Table 4: Input Data

Unit Operation	Raw Material 1 (m^3/annum)	Raw Material 2 (tonnes/annum)	Water (m^3/annum)	Energy Source
Surface Treatment (A)				
Rinse (6)				
Painting (C)				
Total Raw Material Used in All Unit Operations				

Step 5: Recording Water Usage

The use of water, other than for a process reaction, is a factor that should be covered in all waste audits. The use of water to wash, rinse and cool is often overlooked, although it represents an area where waste reductions can frequently be achieved simply and cheaply.

Consider these general points about the site water supply before assessing the water usage for individual units.

- Identify water sources? Is water abstracted directly from a borehole, river or reservoir; is water stored on site in tanks or in a lagoon?
- What is the storage capacity for water on site?
- How is water transferred - by pump, by gravity, manually?
- Is rainfall a significant factor on site?

For each unit operation consider the following.

- What is water used for in each operation? Cooling, gas scrubbing, washing, product rinsing, dampening stockpiles, general maintenance, safety quench etc.
- How often does each action take place?
- How much water is used for each action?

It is unlikely that the answers to these questions will be readily available - you will need to undertake a monitoring programme to assess the use of water in each unit operation. Again, the measurements must cover a sufficient period of time to ensure that all actions are monitored. Pay particular attention to intermittent actions such as steam cleaning and tank washouts; water use is often indiscriminate during these operations. Find out when these actions will be undertaken so that detailed measurements can be made.

Record water usage information in a tabular form - ensure that the units used to describe intermittent actions indicate a time period (Table 5).

Table 5: Water Usage

	Cleaning	Steam	Cooling	Other
Unit Operation A				
Unit Operation B				
Unit Operation C				

All measurements in standard units, for example m^3/annum or m^3/day.

Using less water can be a cost-saving exercise. Consider the following points while investigating water use:

- tighter control of water use can reduce the volume of wastewater requiring treatment and result in cost savings - in the extreme, it can sometimes reduce volumes and increase concentrations to the point of providing economic material recovery in place of costly wastewater treatment;
- attention to good house-keeping practices often reduces water usage and, in turn, the amount of wastewater passing to drain;
- the cost of storing wastewater for subsequent reuse may be far less than the treatment and disposal costs;
- counter-current rinsing and rinsewater reuse are highlighted in the case studies as useful tips for reducing water usage.

Step 6: Measuring Current Levels of Waste Reuse/Recycling

Some wastes lend themselves to direct reuse in production and may be transferred from one unit to another (eg reuse of the final rinse in a soft-drink bottle washing plant as the initial rinse); others require some modification before they are suitable for reuse in a process. These reused waste streams should be quantified.

If reused wastes are not properly documented double-counting may occur in the material balance particularly at the process or complete plant level; that is, a waste will be quantified as an output from one process and as an input to another.

The reuse or recycling of wastes can reduce the amount of fresh water and raw materials required for a process. While looking at the inputs to unit operations think about the opportunities for reusing and recycling outputs from other operations.

Steps 4,5 and 6 Summary

By the end of Step 6 you should have quantified all your process inputs.

The net input of raw materials and water to the process should be established having taken into account any losses incurred at the storage and transfer stages.

Any reused or recycled inputs should be documented.

All notes regarding raw material handling, process layout, water losses, obvious areas where problems exist should all be documented for consideration in Phase 3.

Step 7: Quantifying Process Outputs

To calculate the second half of the material balance the outputs from unit operations and the process as a whole need to be quantified.

Outputs include primary product, by-products, wastewater, gaseous wastes (emissions to atmosphere), liquid and solid wastes which need to be stored and/or sent off-site for disposal and reusable or recyclable wastes (Figure 2). You may find that a table along the lines of Table 6 will help you organise the output information. It is important to identify units of measurement.

Table 6: Process Outputs

Unit Operation	Product	By-Product	Waste to be Reused	Wastewater	Gaseous Emissions	Stored Wastes	Liquid/ Solid Wastes Off-Site
Unit Operation A							
Unit Operation B							
Unit Operation C							
Total							

The assessment of the amount of primary product or useful product is a key factor in process or unit operation efficiency.

If the product is sent off-site for sale, then the amount produced is likely to be documented in company records. However, if the product is an intermediate to be input to another process or unit operation then the output may not be so easy to quantify. Production rates will have to be measured over a period of time. Similarly, the quantification of any by-products may require measurement.

Hints on how to approach the quantification of wastewater, gaseous emissions and wastes for off-site removal are described in Steps 8,9 and 10.

Step 8: Accounting for Wastewater

On many sites significant quantities of both clean and contaminated water are discharged to sewer or to a watercourse. In many cases, this wastewater has environmental implications and incurs treatment costs. In addition, wastewater may wash out valuable unused raw materials from the process areas.

Therefore, it is extremely important to know how much wastewater is going down the drain and what the wastewater contains. The wastewater flows, from each unit operation as well as from the process as a whole, need to be quantified, sampled and analysed.

Here are some suggestions on how to carry out a thorough survey of wastewater flows on your site.

- Identify the effluent discharge points; that is, where does wastewater leave the site? Waste-water may go to an effluent treatment plant or directly to a public sewer or watercourse. One factor that is often overlooked is the use of several discharge points - it is important to identify the location, type and size of all discharge **flows.**

- Identify where flows from different unit operations or process areas contribute to the overall flow. In this way, it is possible to piece together the drainage network for your site. This can lead to startling discoveries of what goes where!

- Once the drainage system is understood it is possible to design an appropriate sampling and flow measurement programme to monitor the wastewater flows and strengths from each unit operation.

- Plan your monitoring programme thoroughly and try to take samples over a range of operating conditions such as full production, start up, shut down and washing out. In the case of combined stormwater and wastewater drainage systems, ensure that sampling and flow measurements are carried out in dry weather.

- For small or batch wastewater flows it may be physically possible to collect all the flow for measurement using a pail and wristwatch. Larger or continuous wastewater flows can be assessed using flow measurement techniques. A method using a simple triangular notch (V-notch) or rectangular weir arrangement is outlined in Appendix 1.

The sum of the wastewater generated from each unit operation should be approximately the same as that input to the process. As indicated in Step 6, note that double-counting can occur where wastewater is reused. This emphasises the importance of understanding your unit operations and their interrelationships.

The wastewater should be analysed to determine the concentration of contaminants.

- You should include wastewater analyses such as pH, chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), suspended solids and grease and oil.

- Other parameters that should be measured depend on the raw material inputs. For example, an electroplating process is likely to use nickel and chromium. The metal concentrations of the wastewater should be measured to ensure that the concentrations do not exceed discharge regulations, but also to ensure that raw materials are not being lost to drain. Any toxic substances used in the process should be measured.

- Take samples for laboratory analysis. Composite samples should be taken for continuously-running wastewater. For example, a small volume, 100 ml, may be collected every hour through a production period of ten hours to gain a 1 litre composite sample. The composite sample represents the average wastewater conditions over that time. Where significant variations occur during the discharge period, consideration should be given to varying the size of individual samples in proportion to flow rate in order to ensure that a representative composite sample is obtained. For batch tanks and periodic draindown, a single spot sample may be adequate (check for variations between batches before deciding on the appropriate sampling method).

Wastewater flows and concentrations should be tabulated (Table 7).

Table 7: Wastewater Flows

	Discharge to									
	Public Sewer		Stormwater Drain		Reuse		Storage		Total Wastewater Output	
Source of Wastewater	Flow	Conc'n	Flow	Conc'n	Flow	Conc'n	Flow	Conc'n	flow	Conc'n
Unit Operation A										
Unit Operation B										
Unit Operation C										

flows in m^3/d; concentrations of contaminants of concern in mg/l

Step 9: Accounting for Gaseous Emissions

To arrive at an accurate material balance some quantification of gaseous emissions associated with your process is necessary.

It is important to consider the actual and potential gaseous emissions associated with each unit operation from raw material storage through to product storage.

Gaseous emissions are not always obvious and can be difficult to measure. Appendix 1 outlines a possible method of measuring gaseous emissions through vents using a bag orifice. Where quantification is impossible, estimations can be made using stoichiometric information. The following example illustrates the use of indirect estimation.

Consider coal burning in a boiler house. The auditor may not be able to measure the mass of sulphur dioxide leaving the boiler stack due to problems of access and lack of suitable sampling ports on the stack. The only information available is that the coal is of soft quality containing 3% sulphur by weight and, on average, 1000 kg of coal is burnt each day.

First calculate the amount of sulphur burned:

1000 kg coal x 0.03 kg sulphur/kg coal = 30 kg sulphur/day.

The combustion reaction is approximately:

$s + 0_2 = SO_2$

The number of moles of sulphur burned equals the number of moles of sulphur dioxide produced. The atomic weight of sulphur is 32 and the molecular weight of sulphur dioxide is 64. Therefore:

kg-moles S = 30 kg/32 kg per kg-mole = kg-mole of SO, formed

kg SO, formed = (64 kg $S0_2$/kg-mole) x kg-moles SO, = 64 x 30/32 = 60 kg

Thus, it may be estimated that an emission of 60 kg sulphur dioxide will take place each day from the boiler stack.

Record the quantified emission data in tabular form and indicate which figures are estimates and which are actual measurements.

The waste auditor should consider qualitative characteristics at the same time as quantifying gaseous wastes.

- Are odours associated with a unit operation?

- Are there certain times when gaseous emissions are more prominent - are they linked to temperature?
- Is any pollution control equipment in place?
- Are gaseous emissions from confined spaces (including fugitive emissions) vented to the outside?
- If gas scrubbing is practised, what is done with the spent scrubber solution? Could it be converted to a useful product?
- Do employees wear protective clothing, such as masks?

Step 10 : Accounting for Off-Site Wastes

Your process may produce wastes which cannot be treated on-site. These need to be transported off-site for treatment and disposal. Wastes of this type are usually non-aqueous liquids, sludges or solids.

Often, wastes for off-site disposal are costly to transport and to treat. Therefore, minimisation of these wastes yields a direct cost benefit.

Measure the quantity and note the composition of any wastes associated with your process which need to be sent for off-site disposal. Record your results in a table (see Table 8).

Table 8: Wastes for Off-site Disposal

	Liquid		Sludge		Solid	
Unit Operation	Qty	Composition	Qty	Composition	Qty	Composition
Unit Operation A						
Unit Operation B						
Unit Operation C						

Quantities in m^3/annum or t/annum

You should ask several questions during the data collection stage.

- Where does the waste originate?
- Could the manufacturing operations be optimised to produce less waste?
- Could alternative raw materials be used which would produce less waste?
- Is there a particular component that renders the whole waste hazardous - could this component be isolated?
- Does the waste contain valuable materials?

Wastes for off-site disposal need to be stored on-site prior to dispatch. Does storage of these wastes cause additional emission problems? For example, are solvent wastes stored in closed tanks? How long are wastes stored on-site? Are stockpiles of solid waste secure or are dust storms a regular occurrence?

Steps 7,8,9 and 10 Summary

At the end of Step 10 the waste audit team should have collated all the information required for evaluating a material balance for each unit operation and for a whole process.

All actual and potential wastes should be quantified. Where direct measurement is impossible, estimates based on stoichiometric information should be made.

The data should be arranged in clear tables with standardised units. Throughout the data collection phase the auditors should make notes regarding actions, procedures and operations that could be improved.

Step 11: Assembling Input and Output Information for Unit Operations

One of the basic laws applied to chemical engineering is that of the material balance which states that the total of what goes into a process must equal the total of what comes out. Prepare a material balance at a scale appropriate for the level of detail required in your study. For example, you may require a material balance for each unit operation or one for a whole process may be sufficient. In this manual the preparation of a material balance for the unit operation scale is illustrated.

Preparing a material balance is designed to gain a better understanding of the inputs and outputs, especially waste, of a unit operation such that areas where information is inaccurate or lacking can be identified. Imbalances require further investigation. Do not expect a perfect balance - your initial balance should be considered as a rough assessment to be refined and improved.

Assemble the input and output information for each unit operation and then decide whether all the inputs and outputs need to be included in the material balance. For example, this is not essential where the cooling water input to a unit operation equals the cooling water output.

Standardise units of measurement (litres, tonnes or kilogrammes) on a per day, per year or per batch basis.

Summarise the measured values in standard units by reference to your process flow diagram. It may have been necessary to modify your process flow diagram following the in-depth study of the plant.

Step 12: Deriving a Preliminary Material Balance for Unit Operations

Now it is possible to complete a preliminary material balance. For each unit operation utilise the data developed in Steps 1 - 10 and construct your material balance. Display your information clearly. Figure 3 is one way of presenting the material balance information.

Figure 3: Preliminary Material Balance for Each Unit Operation

Inputs (amounts in standard units per annum)

Raw Material 1
Raw Material 2
Raw Material 3
Waste Reuse
Water
Total

↓

Unit Process A

↓

Outputs (amounts in standard units per annum)

Product
By-product
Raw Material Storage and Handling Losses
Reused Wastes
Wastewater
Gaseous Emissions
Stored Wastes
Hazardous Liquid Waste Transported Off-Site
Hazardous Solid Waste Transported Off-Site
Non-Hazardous Liquid Waste Transported Off-Site
Non-Hazardous Solid Waste Transported Off-Site
Total

Note that a material balance will often need to be carried out in weight units since volumes are not always conserved. Where volume measurements have to be converted to weight units, take account of the density of the liquid, gas or solid concerned.

Once the material balance for each unit operation has been completed for raw material inputs and waste outputs it might be worthwhile repeating the procedure with respect to each contaminant of concern. It is highly desirable to carry out a water balance for all water inputs and outputs to and from unit operations because water imbalances may indicate serious underlying process problems such as leaks or spills. The individual material balances may be summed to give a balance for the whole process, a production area or factory.

Step 13: Evaluating the Material Balance

The individual and sum totals making up the material balance should be reviewed to determine information gaps and inaccuracies. If you do have a significant material imbalance then further investigation is needed. For example, if outputs are less than inputs look for potential losses or waste discharges (such as evaporation). Outputs may appear to be greater than inputs if large measurement or estimating errors are made or some inputs have been overlooked.

At this stage you should take time to re-examine the unit operations to attempt to identify where unnoticed losses may be occurring. It may be necessary to repeat *some* data collection activities.

Remember that you need to be thorough and consistent to obtain a satisfactory material balance. The material balance not only reflects the adequacy of your data collection, but by its very nature, ensures that you have a sound understanding of the processes involved.

Step 14: Refining the Material Balance

Now you can reconsider the material balance equation by adding those additional factors identilied in the previous step. If necessary, estimates of unaccountable losses will have to be calculated.

Note that, in the case of relatively simple manufacturing plants, preparation of a preliminary material balance and its refinement (Steps 13 and 14) can usefully be combined. For more complex waste audits however, two separate steps are likely to be more appropriate.

Remember, the inputs should ideally equal the outputs but in practice this will rarely be the case and some judgement will be required to determine what level of accuracy is acceptable.

In the case of high-strength or hazardous wastes, accurate measurements are needed to design waste reduction options.

It is possible that the material balance for a number of unit operations will need to be repeated. Again, continue to review, reline and, where necessary, expand your database. The compilation of accurate and comprehensive data is essential for a successful waste audit and subsequent waste reduction action plan. You cannot reduce what you do not know is there.

Steps 11,12,13 and 14 Summary

By the end of Step 14, you should have assembled information covering process inputs and process outputs. These data should be organised and presented clearly in the form of material balances for each unit operation.

These data form the basis for the development of an action plan for waste minimisation.

PHASE 3: SYNTHESIS

Phases 1 and 2 have covered planning and undertaking a waste audit, resulting in the preparation of a material balance for each unit operation.

Phase 3 represents the interpretation of the material balance to identify process areas or components of concern.

The material balance focuses the attention of the auditor. The arrangement of the input and output data in the form of a material balance facilitates your understanding of how materials flow through a production process.

To interpret a material balance it is necessary to have an understanding of normal operating performance. How can you assess whether a unit operation is working efficiently if you do not know what is normal? A member of your team must have a good working knowledge of the process. This knowledge can be supported by texts such as the Rapid Assessment of Sources of Air, Land and Water Pollution (WHO, 1982).

To a trained eye the material balance will indicate areas for concern and help to prioritize problem wastes.

You should use the material balance to identify the major sources of waste, to look for deviations from the norm in terms of waste production, to identify areas of unexplained losses and to pinpoint operations which contribute to flows that exceed national or site discharge regulations. Process efficiency is synonymous with waste minimisation.

Different waste reduction measures require varying degrees of effort, time and financial resources. They can be categorised as two groups.

- Obvious waste reduction measures, including improvements in management techniques and house-keeping procedures that can be implemented cheaply and quickly.

- Long-term reduction measures involving process modifications or process substitutions to eliminate problem wastes.

Increased reuse/recycling to reduce waste falls between the immediate and the more substantial waste reduction measures.

Steps 15,16 and 17 describe how to identify waste reduction measures.

Step 15: Examining Obvious Waste Reduction Measures

It may have been possible to implement very obvious waste reduction measures already, before embarking on obtaining a material balance (ref Step.3). Now consider the material balance information in conjunction with visual observations made during the whole of the data collection period in order to pinpoint areas or operations where simple adjustments in procedure could greatly improve the efftciency of the process by reducing unnecessary losses.

Use the information gathered for each unit operation to develop better operating practices for all units.

Significant waste reductions can often be achieved by improved operation, better handling and generally taking more care. The following list of waste reduction hints can be implemented immediately with no or only small extra costs.

Specifying and Ordering Materials

- Do not over-order materials especially if the raw materials or components can spoil or are difficult to store.
- Try to purchase raw materials in a form which is easy to handle, for example, pellets instead of powders.
- It is often more efficient and certainly cheaper to buy in bulk.

Receiving Materials

- Demand quality control from suppliers by refusing damaged, leaking or unlabelled containers. Undertake a visual inspection of all materials coming on to the site.
- Check that a sack weighs what it should weigh and that the volume ordered is the volume supplied.
- Check that composition and quality are correct.

Material Storage

- Install high-level control on bulk tanks to avoid overflows.
- Bund tanks to contain spillages.
- Use tanks that can be pitched and elevated, with rounded edges for ease of draining and rinsing.
- Dedicated tanks, receiving only one type of material, do not need to be washed out as often as tanks receiving a range of materials.
- Make sure that drums are stored in a stable arrangement to avoid damaging drums while in storage.
- Implement a tank checking procedure - dip tanks regularly and document to avoid discharging a material into the wrong tank.
- Evaporation losses are reduced by using covered or closed tanks.

Material and Water Transfer and Handling

- Minimise the number of times materials are moved on site.
- Check transfer lines for spills and leaks.
- Is flexible pipework too long?
- Catch drainings from transfer hoses.
- Plug leaks and fit flow restrictors to reduce excess water consumption.

Process Control

- Feedback on how waste reduction is improving the process motivates the operators - it is vital that the employees are informed of why actions are taken and what it is hoped they will achieve.
- Design a monitoring programme to check the emissions and wastes from each unit operation.
- Regular maintenance of all equipment will help to reduce fugitive process losses.

Cleaning Procedures

- Minimise the amount of water used to wash out and rinse vessels - on many sites indiscriminate water use contributes a large amount to wastewater flows. Ensure that hoses are not left running by fitting self-sealing valves.
- Investigate how washing water can be contained and used again before discharge to drain. The same applies to solvents used to clean; these can often be used more than once.

Tightening up house-keeping procedures can reduce waste considerably. Simple, quick adjustments should be made to your process to achieve a rapid improvement in process efficiency. Where such obvious reduction measures do not however solve the entire waste disposal problem, more detailed consideration of waste reduction options will needed (Steps 16 - 18).

Step 16: Targetting and Characterizing Problem Wastes

Use the material balance for each unit operation to pinpoint the problem areas associated with your process.

The material balance exercise may have brought to light the origin of wastes with high treatment costs or may indicate which wastes are causing process problems in which operations. The material balance should be used to focus your priorities for long-term waste reduction.

At this stage, it may be worthwhile considering the underlying causes as to why wastes are generated and the factors which lead to these; for example, poor technology, lack of maintenance and non-compliance with company procedures.

Additional sampling and characterization of your wastes might be necessary involving more in-depth analysis to ascertain the exact concentrations of contaminants.

List the wastes in order of priority for reduction actions.

Step 17: Segregation

Segregation per se is arguably not properly part of a waste audit's step-by-step sequence, being but one of numerous measures which can lead to waste reduction activities. It is however the most central of such options and is a universal issue which needs to be addressed.

Segregation of wastes can offer enhanced opportunities for recycling and reuse with resultant savings in raw material costs. Concentrated simple wastes are more likely to be of value than dilute or complex wastes.

Mixing wastes can enhance pollution problems. If a highly-concentrated waste is mixed with a large quantity of weak, relatively uncontaminated effluent the result is a larger volume of waste requiring treatment. Isolating the concentrated waste from the weaker waste can reduce treatment costs. The concentrated waste could be recycled/reused or may require physical, chemical and biological treatment to comply with discharge consent levels whereas the weaker effluent could be reused or may only require settlement before discharge.

Therefore, waste segregation can provide more scope for recycling and reuse while at the same time reducing treatment costs.

Review your waste collection and storage facilities to determine if waste segregation is possible. Adjust your list of priority wastes accordingly.

Step 18: Developing Long-Term Waste Reduction Options

Waste problems that cannot be solved by simple procedural adjustments or improvements in house-keeping practices will require more substantial long-term changes.

It is necessary to develop possible prevention options for the waste problems.

Process or production changes which may increase production efficiency and reduce waste generation include:

- changes in the production process - continuous versus batch;
- equipment and installation changes;
- changes in process control - automation;

- changes in process conditions such as retention times, temperatures, agitation, pressure, catalysts;
- use of dispersants in place of organic solvents where appropriate;
- reduction in the quantity or type of raw materials used in production;
- raw material substitution through the use of wastes as raw materials or the use of different raw materials that produce less waste or less hazardous waste;
- process substitution with cleaner technology.

Waste reuse can often be implemented if materials of sufficient purity can be concentrated or purified. Technologies such as reverse osmosis, ultrafiltration, electrodialysis, distillation, electrolysis and ion exchange may enable materials to be reused and reduce or eliminate the need for waste treatment.

Where waste treatment is necessary, a variety of technologies should be considered. These include physical, chemical and biological treatment processes. In some cases the treatment method can also recover valuable materials for reuse. Another industry or factory may be able to use or treat a waste that you cannot treat on-site. It may be worth investigating the possibility of setting up a waste exchange bureau as a structure for sharing waste treatment and reuse facilities. The Resource Section (Chapter 4) cites sources of technical information relating to recovery, reuse, waste treatment and associated technologies.

Consider also the possibilities for product improvements or changes yielding cleaner, more environmentally-friendly products, both for existing products and in the development of new products.

Steps 15,16,17 and 18 Summary

At the end of Step 18 you should have identified all the waste reduction options which could be implemented.

Step 19: Environmental and Economic Evaluation of Waste Reduction Options

In order to decide which options should be developed to formulate a waste reduction action plan each option should be considered in terms of environmental and economic benefits.

a) Envriomental Evaluation

It is often taken for granted that reduction of a waste will have environmental benefits. This is generally true; however, there are exceptions to the rule. For example, reducing one waste may give rise to pH imbalances or may produce another which is more difficult to treat, resulting in a net environmental disadvantage.

In many cases, the benefits may be obvious such as the removal of a toxic element from an aqueous effluent by segregating the polluted waste or by changing the process in such a way that the waste is prevented.

In other cases the environmental benefits may be less tangible. Creating a cleaner, healthier workplace will increase production efficiency but this may be difficult to quantify.

For each option a series of questions should be asked.

- Consider the effect of each option on the volume and degree of contamination of process wastes.
- Does a waste reduction option have cross-media effects? For example, does the reduction of a gaseous waste produce a liquid waste?
- Does the option change the toxicity, degradability or treatability of the wastes?
- Does the option use more or less non-renewable resources?
- Does the option use less energy?

b) Economic Evaluation

A comparative economic analysis of the waste reduction options and the existing situation should be undertaken. Where benefits or changes cannot be quantified (eg reduction in future liability, worker health and safety costs) some form of qualitative assessment should be made; it may be necessary to consult an expert for advice on how to judge a change.

Economic evaluations of waste reduction options should involve a comparison of operating costs to illustrate where cost savings would be made. For example, a waste reduction measure that reduces the amount of raw material lost to drain during the process results in reduced raw
material costs. Raw material substitution or process changes may reduce the amount of solid waste that has to be transported off-site. Therefore, the transport costs for waste disposal would be reduced.

In many cases, it is appropriate to compare the waste treatment costs under existing conditions with those associated with the waste reduction option.

The size of treatment plant and the treatment processes required may be altered significantly by the implementation of waste reduction options. This should be considered in an economic evaluation.

Calculate the annual operating costs for the existing process including waste treatment and estimate how these would be altered with the introduction of waste reduction options. Tabulate and compare the process and waste treatment operating costs for both the existing and proposed future waste management options.' Table 9 shows the typical cost components. In addition, if there are any monetary benefits (eg recycled or reused materials or wastes), then these should be subtracted from the total process or waste treatment costs as appropriate.

Now that you have determined the likely savings in terms of annual process and waste treatment operating costs associated with each option, consider the necessary investment required to implement each option.

Investment can be assessed by looking at the payback period for each option. Payback period is the time taken for a project to recover its financial outlay. A more detailed investment analysis may involve an assessment of the internal rate of return (IRR) and net present value (NPV) of the investment based on discounted cash flows.

Analysis of investment risk allows you to rank options.

Consider the environmental benefits and the savings in process and waste treatment operating costs along with the payback period for an investment, to decide which options are viable.

Table 9: Annual Process and Waste Treatment Operating Costs

Process Operating Costs	Annual Cost
Raw Material 1	
Raw Material 2	
Water	
Energy	
Labour	
Maintenance	
Administration	
Other	
Total	
Waste Treatment Operating Costs	**Annual Cost**
Raw Material eg Lime	
Raw Material eg Flocculant	
Water	
Energy	
Trade Effluent Discharge Costs	
Transportation	
Off-Site Disposal	
Labour	
Maintenance	
Administration	
Other, eg violation, fires	
Total	

Step 19 Summary

At the end of Step 19 you should be able to list those waste reduction options that are environmentally and economically viable.

Step 20: Developing and Implementing An Action Plan: Reducing Wastes and Increasing Production Efficiency

Consider the immediate reduction measures identified in Step 15 along with the long-term waste reduction measures that have been evaluated in Steps 18 and 19. These measures should form the basis of the waste reduction action plan. Discuss your findings with members of staff and develop a workable action plan.

Prepare the ground for the waste reduction action plan. Its implementation should be preceded by an explanation of the ethos behind undertaking a waste audit: Waste Prevention Makes Sense.

It is necessary to convince those who must work to new procedures that the change in philosophy from end-of-pipe treatment to waste prevention makes sense and serves to improve efficiency.

Use posters around the site to emphasise the importance of waste reduction to minimise production and waste treatment/disposal costs and, where appropriate, for improving the health and safety of company personnel.

Set out the intended action plan within an appropriate schedule. Remember it may take time for the staff to feel comfortable with a new way of thinking. Therefore, it is a good idea to implement waste reduction measures slowly but consistently to allow everyone time to adapt to these changes.

Set up a monitoring programme to run alongside the waste reduction action plan so that actual improvements in process efficiency can be measured. Relay these results back to the workforce as evidence of the benefits of waste reduction. Adopt an internal record-keeping system for maintaining and managing data to support material balances and waste reduction assessments.

It is likely that you will have highlighted significant information gaps or inconsistencies during the waste audit investigations. You should concentrate on these gaps and explore ways of developing the additional data. Is outside help required?

A good way of providing waste reduction incentives is to set up an internal waste charging system, those processes that create wastes in great volume or that are difficult and expensive to handle having to contribute to the treatment costs on a proportional basis. Another method of motivating staff is to offer financial reward for individual waste-saving efforts, drawing on the savings gained from implementing waste reduction measures.

Waste auditing should be a regular event - attempt to develop a specific waste audit approach for your own situation, keeping abreast of technological advances that could lead *to* waste reduction and the development of ‘cleaner’ products. Train process employees to undertake material balance exercises.

Training people who work on the process to undertake a waste audit will help to raise awareness in the workforce. Without the support of the operators waste reduction actions will be ineffectual - these are the people who can really make a difference to process performance.

Step 20 Summary

Prepare the ground for the waste reduction action plan, ensuring that support for the audit, and implementation of the results, is gained from senior management. Implement the plan slowly to allow the workforce to adjust.

Monitor process efficiency.

Relay results back to the workforce to show them the direct benefits.

Train personnel to undertake your own waste audit for waste reduction.

CASE STUDY 1: BEER PRODUCTION

Company A operates a modern brewery in western Europe, producing beer in bottles, kegs and bulk tankers. The essence of beer production is the processing and fermentation of malt and hops in the presence 'of added sugar. Considerable volumes of wastewater containing high BOD/ COD and suspended solids (SS) concentrations are produced as a result of washing of vessels and associated equipment between production batches.

Company A has been in operation some four years. During this time wastewater flows and pollution loads have increased significantly with production increases, resulting in consent limits for discharge to the public sewer (pH 6-10 and 500 mg/l SS) being exceeded on a regular basis.

The regional water authority recently indicated however that the brewery flows could continue to be accepted into the public sewer without pretreatment other than possibly pH control and flow/ load balancing at some future date, primary settlement and biological treatment being undertaken at an extended local municipal sewage treatment works.

The water authority also informed Company A that a capital cost contribution towards the planned sewage works' extensions would not be necessary and that the normal trade effluent charging system would be applied whereby charges varied according to variations in flow and pollution loads (COD and SS).

The current trade effluent charges amount to US$332,000 per annum and are expected to increase by 10% shortly. After considering the likely implications of the increase in effluent charges, the company decided to appoint a firm of consultants to carry out a waste audit and waste reduction study to investigate the possible ways of minimising waste disposal costs.

The following case study describes the waste audit/waste reduction procedures carried out.

PHASE 1: PREASSESSMENT

Step 1: Audit Focus and Preparation

Two chemists from the consulting firm's staff were allocated to carry out the required investigations, assisted as necessary by one of Company A's brewing technologists.

With the support of senior management, the audit team first organised an in-house seminar. This enabled the study procedures and objectives to be outlined and helped to ensure the full co-operation of production staff.

With the help of the brewery's engineering staff, a V-notch weir was then installed in a manhole where all the various effluents combined so that the flow could be monitored continuously using an available ultrasonic level/flow meter and associated chart recorder.

Since an automatic sampler was not readily available, it was decided that composite samples would be taken daily by combing manually-taken samples in proportion to flow. It was also established that the brewery's laboratory was well-equipped to carry out the required wastewater analyses.

In view of the scale of the brewery operations and the time and budget constraints imposed on the project, it was decided that the study should concentrate on:

- water usage aspects (rather than attempt to obtain a complete materials balance);

- investigate methods of reducing COD and SS loads discharging to drain.

In order to put the brewery operations in perspective from a waste management viewpoint, a preliminary check on wastewater and pollution loads discharged per cubic metre of beer produced was carried out based on past records of water usage and product data together with some limited information on combined wastewater strength.

It was concluded that, in general, the brewery operated with a very low degree of water wastage with most of the useful by-products or wastes already being recycled or recovered for off-site disposal. These aspects had been considered at an early stage in the design of the brewery and had clearly paid dividends in reducing waste volumes and pollution loads discharged. Nevertheless, it was considered that there was still scope for further waste saving measures to be implemented.

The success of the measures already practised can be illustrated as follows:

Table 1: Waste Contributions from Beer Production

	Company A	Typical Brewery (a	Old Brewery (b)
Wastewater Flow (m^3/m^3 beer)	2	7	
BOD Load (kg/m^3 beer)	4.1	4.5	7.5

(a) Based on the consulting firm's project experience elsewhere
(b) Based on data published by WHO, 1982

Another factor in favour of Company A is that most of the beer is transported from the brewery in road tankers rather than bottles or kegs, both of which give rise to more waste being produced. This simplifies the brewery operations and makes for more efficient and economical operation in terms of water consumption.

Step 2: Listing Unit Operations

The study team started off the waste audit/waste reduction programme by becoming familiar with all the various production stages. This was done by walking around the plant with the brewery technologist and collecting relevant information from departmental records. It was found that so much data were being collected that a file was opened for each key area within the brewery.

The various unit operations were listed as in Table 2.

Table 2: Major Unit Operations and Brief Functional Description

Unit Operation	Brief Functional Description	File No.
Brewhouse	Processing of malt, hops and sugar to produce 'wort'	1
Fermentation	Fermentation of chilled 'wort	2
Product Treatment	Centrifugation, filtration, carbonation, colouring and final polishing and pasteurising	3
Dispatch	Bottling, kegging and bulk tanker filling	4

Step 3: Constructing Process Flow Diagrams

A schematic flow diagram was then compiled to illustrate the various unit operations within the brewery (Figure 1).

Once all the unit operations had been identified and described, the audit team proceeded to gather data on water usage, wastewater output and waste recovery.

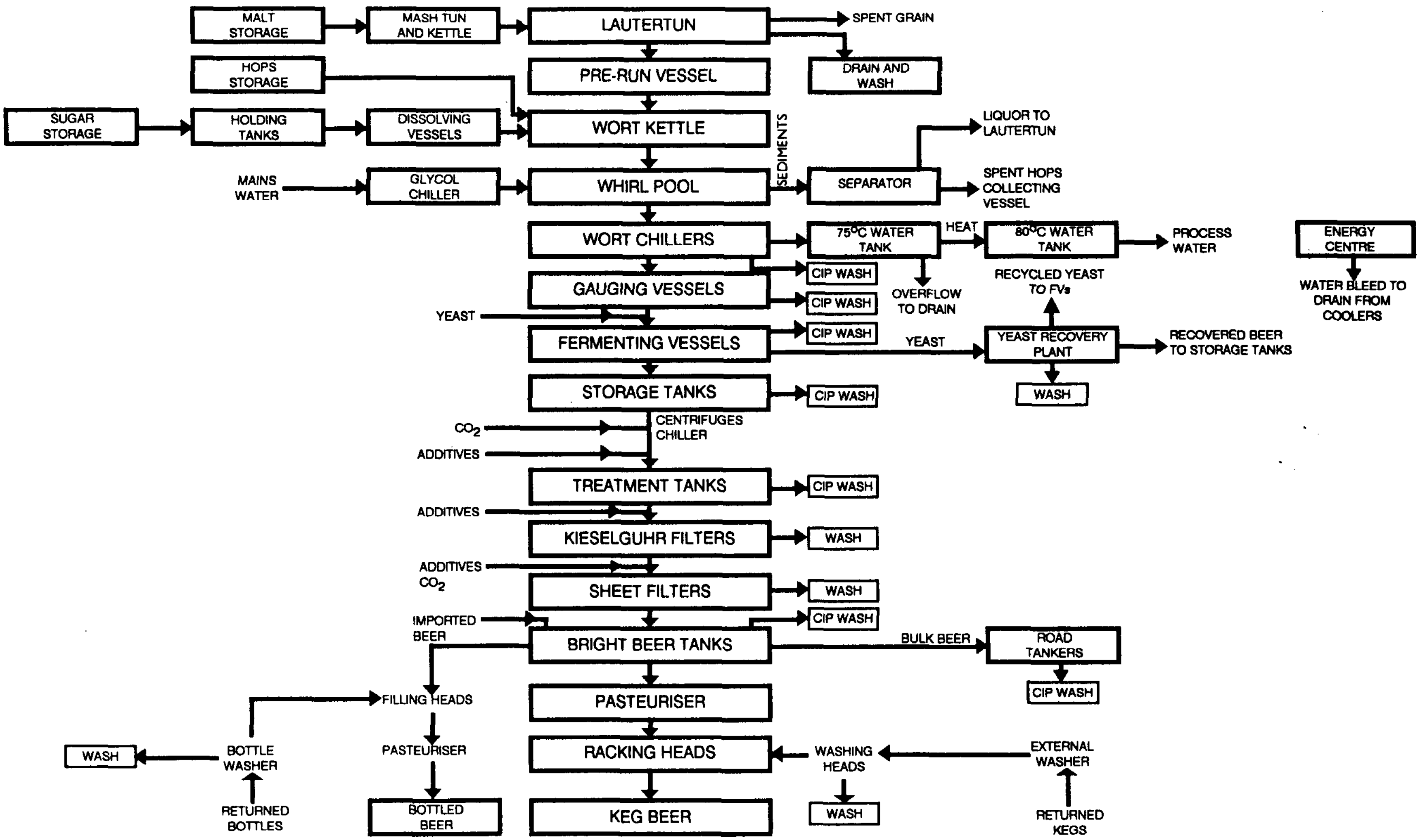


Figure 1: General Flow Diagram for the Brewery

PHASE 2: MATERIAL BALANCE: PROCESS INPUTS AND OUTPUTS

Step 4: Determining Inputs

The audit team first proceeded to gather data on material inputs, concentrating on water usage, both for the brewery process as a whole and for individual unit operations. These activities are described further in Step 5.

Step 5: Recording Water Usage

The total water consumption from water meter readings for the previous three month period was found to be 247,500 m^3, equivalent to an average 2,750 m^3/d.

This included a small domestic water allowance, evaporation make-up and water entering the beer products as well as general washdown water for equipment for cleaning operations.

The audit team then proceeded to examine how water usage was split between the various unit operations.

Step 6: Measuring Current Levels of Waste Reuse/Recycling

No attempt to quantify the extent of current waste reuse/recycling was made during the waste audit programme since it was felt that this would have involved a considerable time input disproportionate to the likely benefits obtained.

However, it was noted that reuse of caustic and sterilant rinses following discharge to drain of initial water rinses generally formed an integral part of the automatic cleaning-m-place (CIP) system employed for equipment washing.

Step 7: Quantifying Process Outputs

The principal process outputs of concern were the wastewater discharges arising from production operations and also the beer products themselves.

It was also noted that minor domestic sewage contributions discharged to the same drainage network as the brewery process wastewaters.

The audit team then proceeded to quantify these outputs.

Step 8: Accounting for Wastewater

The total wastewater flow recorded during a two-week monitoring period averaged 1,730 m^3/d. It was noted, however, from the flow patterns during each day that wastewater discharges were extremely variable with a peak flow rate of up to 100 m^3/h occurring when a hot water tank overflow was discharged. On the basis of this and a number of other assumptions, the audit team estimated that the maximum flow on any one day could reach 2,600 m^3/d.

The corresponding combined wastewater pollution loads averaged 5,980 kg COD/d and 1,500 kg SS/d. These figures equated to waste quantities per cubic metre of beer produced of 2.1 m^3, 7.1 kg COD and 1.8 kg SS. Assuming an average COD:BOD ratio of 1.7, the corresponding BOD waste load was 4.2 kg/m^3 beer produced. These unit wastewater flow and BOD load contributions proved to be similar to the approximate estimates calculated in Step 1.

An estimate of domestic water usage and hence domestic sewage discharges to the trade effluent drainage system were also made, together with an assessment of the quantity of water entering the beer products. Calculations indicated that these additional outputs averaged a total of 850 m^3/d, of which only 10 m^3/d (140 employees at 70 litres per head per day) related to domestic sewage.

Studies were then carried out to develop a breakdown of the main process outputs (wastewater and product) for each key unit operation. This involved sampling and flow measurement of individual discharges around the brewery. Since the volume and composition of some of these discharges varied considerably with the type of beer produced, the survey was undertaken over several weeks to allow a realistic assessment of the situation to be made.

Step 9: Accounting for Gaseous Emissions

Gaseous emissions were not of particular concern in the context of the terms of reference drawn up by Company A for the study. However, it was noted that the brewery boilers were gas-fired and that boiler flue-gas emissions were discharged via a tall stack such that they were not likely to give rise to any concern.

It was noted that if control of alkaline wastewater discharges associated with use of caustic soda in the CIP systems proved to be necessary in the future (a possibility if alkaline waste discharges could not be controlled at source), then use of acidic flue-gas (a source of carbon dioxide) could be considered for this purpose.

The audit team also observed that pockets of carbon dioxide in the fermentation areas could cause problems of drowsiness amongst the brewing staff and that improved ventilation would help to ensure their general health and safety.

Step 10: Accounting for Off-Site Wastes

At the time of the survey, wastes produced for transportation and disposal off-site were limited to spent grain and hops generated in the brewhouse as by-products. These were disposed of off-site by a local farmer, for cattle food and as a soil conditioner respectively, at no cost to the brewery. Total quantities were estimated at some 25,000 tonnes (wet weight) per annum.

Step 11: Assembling Input and Output Information for Unit Operations

As previously indicated, the prime interest in this waste audit and reduction programme was to concentrate on the potential for reducing wastewater and associated pollution loads.

Hence, for the purposes of the project in question, the material balance was confined to consideration of water issues only.

Step 12: Deriving a Preliminary Material Balance for Unit Operations

It was decided to conduct a preliminary material balance for the brewery as a whole, based on water usage, before embarking on the more complicated step of obtaining a balance for each key unit operation. This was then constructed as set out in below.

Inputs	m^3/d
Water	2,750

Overall Brewery -Operations

↓

Outputs	m^3/d
Domestic Sewage	10
Product	840
Wastewater	1,730
Total	2,580

Step 13: Evaluating the Material Balance

The material balance with respect to overall water usage showed a remarkably good agreement, the average daily water input amounting to 6.6% above the daily water output assessed.

Although raw materials in the form of malt, hops, sugar, additives and other process chemicals - and also wastes disposed of off-site - had not been included in the balance, it was noted that these items are relatively small in the case of breweries where water is the dominant raw material used.

Step 14: Refining the Material Balance

On studying the data collated, it was observed that no allowance for evaporation had been included in the material balance and that, from the consultant's previous experience of brewery operations, evaporation alone could account for up to 5% of total water usage. This allowance therefore effectively closed the small difference between water input and output indicated in Step 13.

The waste audit team then proceeded to build up material balances for all the major unit operations within the brewery. When this work had been completed, they felt that they had gained considerable knowledge about the various production activities, their inputs, outputs, wastes and operational problems.

Step 15: Examining Obvious Waste Reduction Measures

The audit team considered that the cost of wastewater disposal at the brewery could be minimised in two ways:

- reduction in volume, BOD* and/or SS load of the wastewater produced in the brewery;
- reduction in the BOD* and/or SS load of the wastewater discharged to sewer by pretreatment.

(* or rather COD, as used in the water authority's charging formula)

In the light of a comprehensive examination of the waste producing areas, it was possible to study both these alternatives. To assist the investigations into waste saving possibilities, reference was made to available information (including database) sources, as well as the consultant's own experience of undertaking similar projects.

The various sections of the brewhouse were studied in turn as follows.

a) *Brewhouse*

The two principal discharges in the brewhouse were the drain from the Lautertuns and a 75°C hot water tank overflow. Together these contributed 12% of the total wastewater flow from the brewery.

Study of the flow and analytical data obtained indicated that the Lautertun drain contributed 3.5% of the flow, 23% of the COD and 4% of the SS load. Discussions with the company indicated that it should be possible to store this waste flow for use as make-up water for the subsequent brew and that this should be possible without detriment to brewing standards. A 15 m^3 stainless-steel storage tank with associated pumps, valves and pipework would need to be installed with the advantage that the system would:

- reduce raw water costs;
- eliminate effluent charges previously incurred by this discharge;
- reduce energy requirements since the liquor returned as make-up water would not need heating;
- eliminate existing shock load discharges from this source which should remove any need for flow/load balancing of the total site wastewater flow.

The hot water tank overflow accounted for nearly 9% of the total wastewater flow. Since this water was clean and hot, continual reuse was the obvious possibility. Unfortunately this proved to be impossible owing to the spasmotic production of this water.

proved to be impossible owing to the spasmotic production of this water.
As the 75% tank was very large however, it was considered that its inherent balancing capacity could be utilised if the supply for reuse was taken part way down the tank rather than from the overflow when it occurred.

Reuse of this water would be preferable in a process that consumed hot water at approximately the same rate as the 75^{0}C hot water production, that is 150 m^3/d. The only process in the brewery which utilised this quantity of hot water was the pasteurising machine which had a water consumption of some 170 m^3/d. However, all of this flow was not hot water since a temperature gradient had to be maintained within the pasteuriser to ensure that bottles were not warmed up or cooled down too rapidly.

It was considered that the 75^{0}C hot water should be injected directly into the pasteuriser to replace the heating of cold water to 60°C. In addition, the hot water could be blended with the supply of cold water that already existed to give the required temperature profile thoughout the pasteuriser. It was estimated that such a system would enable at least 75 m^3 of the excess hot water to be reused each day.

b) Fermentation Cellar

The majority of waste produced in this area of the brewery originated from the CIP systems, the discharges from which contained a high COD load due principally to the high yeast content. With the exception of the initial rinse from pre-fermentation stage gauging vessels, the initial rinses from other tanks - fermentation tanks, storage vessels and yeast recovery vessels - all exceeded 6,000 mg/l COD and together accounted for over 90% of the COD load produced in the fermentation cellar.

Proposals for reducing/treating these discharges were developed as follows.

Gauging Vessels

Possibilities for reducing the pollution load from this source of CIP effluent were limited as no yeast was present which could be filtered out. However, reuse of the relatively-clean final rinse as the initial rinse for the next CIP wash would reduce the effluent flow to drain by a total of 26 m^3/d from 8 vessels.

It was also noted that the caustic wash from the brewhouse which occurred usually every week was discharged to drain from these gauging vessels every weekend and that this, together with the acid wash from Wort Kettle No.2 discharged via a fermentation (balancing) tank, had a major effect on the combined wastewater pH giving values frequently outside the allowable pH range for discharge to the public sewer of 6-10.

Tests showed that if the acid and caustic discharges were run to drain together, the neutralising effect of the acid on the caustic was neglible owing to the different volumes, strengths and neutralise the predominant caustic load, it was envisaged that closing up the system by providing additional holding tank capacity would be suitable. This could be achieved using a similar arrangement to the existing closed CIP units in order to standardise on equipment; it would reduce effluent flows to drain, raw water costs and also chemical-cleaning costs.

Fermentation Tanks

The load produced by the initial rinse was found to be 210 kg COD/d and 150 kg SS/d which could be reduced by at least 75% by passing the rinse through a yeast press. It was considered that the final CIP rinse could also be reused as the initial rinse, reducing effluent flow by 25 m^3/d from 8 tanks.

As referred to above, acid washes from the brewhouse were being discharged from the fermentation tanks; on occasions, these depressed the pH to 2.4. Containment and recirculation via a new CIP unit was considered to be the most suitable and practicable control measure.

Storage Tanks

The initial rinse in the CIP sequence was found to contain 75 kg COD/d and 10 kg SS/d. It was estimated that passing these rinses through a yeast press would reduce overall loads from this source to 22 kg COD/d and 3 kg SS/d. Also, reuse of the final rinse as the initial rinse of the next sequence would reduce effluent flows by 5 m^3/d.

Yeast Recovery Plant

Discharges from centrifuge cleaning were difficult to arrange at the time of the waste audit and reduction investigations. However, from visual observations the initial rinse clearly contained a significant quantity of yeast and so it was recommended that such wastes should also be passed to a yeast filter press. Similarly, recovery of the final rinse and reuse as a subsequent initial rinse was proposed. It was also suggested that the initial rinses from yeast storage vessels should be filtered through a yeast press.

Company A had already purchased a new yeast press to filter yeast liquors which at the time were stored until press capacity became available. This proposal was expected to reduce storage requirements, allowing a small amount of beer recovery (press filtrate) and elimination of the frequent storage tank overflow.

Therefore, instead of treating each of the fermentation cellar discharges separately which would be uneconomic, the audit team considered that the proposed filter-press installation for the yeast recovery area should be arranged to filter the initial rinses from fermentation tanks, storage vessels and yeast recovery equipment. This would not only prevent the majority of yeast from flowing to drain but would enable its recovery for resale to a food manufacturer.

In addition, any other liquor containing yeast that had to be dumped to drain, such as the initial drop from the storage tanks when the yeast storage vessels were full, could be filtered and the yeast and beer recovered. The expected increase in flow to the proposed filter press was estimated at 50 m^3/d containing 100 kg SS/d, well within the unit's design capacity.

c) Treatment Cellar

A number of waste saving options were recommended for this area. The principal measures proposed related to the bottling and kegging areas. The possibilities of utilising the 75°C hot water tank overflow for the pasteuriser supply have already been highlighted in the brewhouse section above. The audit team felt that the water flowing out of the pasteuriser could be used as an initial rinse in the bottle washer.

The existing bottle washer system used 9 m^3/h fresh deionised water. It was proposed that the final sparge pipes should continue to be supplied with deionised water but that the pasteuriser water be used to supply the remainder and also for continual replenishment of the water in the final rinse tank. Mains water would be provided as a standby supply in the event for any reason that the pasteuriser water ceased.

In the kegging area, dumping of returned beer to drain was occurring periodically giving a very significant rise in BOD and COD load during the dumping periods. It was indicated to the company that separate disposal, possibility 'directly to land, should be seriously considered as often adopted by other breweries. It was noted, however, that this would require the permission of Customs and Excise officials and be subject to the beer being destroyed in an approved manner such as by dyeing.

Step 16: Targetting and Characterizing Problem Wastes

Following completion of Step 15, the audit team realised that significant reductions in wastewater flows and pollution loads could be achieved by carrying out all the improvement measures highlighted, all of which were relatively straightforward to implement.

It was decided it would be useful to obtain an overall picture of the waste savings which could be achieved. Thus, a summary of the existing and proposed reduced waste contributions for the unit operations highlighted in Step 15 was drawn up as presented in Table 3. At this stage, no allowance was made for the benefits of avoiding returned beer being discharged to drain since this was dependent on future discussions with Customs and Excise personnel.

Table 3: Summary of Existing and Proposed Reduced Waste Contributions

Unit Operation	Waste Description	Existing Composition			Recommendation	Predicted Composition		
		m^3	kg COD	kg SS		m^3	kg COD	kg SS
Lautertun	Final run to Drain	60	1392	60	Reuse	0	0	0
75^{0}C Hot Water Tank	Overflow	150	-	-	50% reuse as make-up for pasteuriser	75	0	0
Brewhouse Vessels	Caustic and acidic wash at weekends	36	152	16	installation of CIP unit	0	0	0
Gauging Vessels	CIP wash	26	-	-	Reuse rinsewater	0	0	0
Fermenting Vessels	CIP wash	65	248	166	Reuse and yeast separation	40	62	44
Storage Tanks	CIP wash	17	89	13	Reuse of rinsewaters and pressing of initial rinse	12	22	3
Yeast Storage and recovery	CIP wash	2	17	1	Yeast recovery	2	4	0.2
Pasteuriser	Process water	100	-	-	Reuse in bottlewasher	0	0	0
Total		456	1898	278		129	88	47.2

For flow, COD and SS load savings of 327 m^3/d, 1,810 kg COD/d and 230 kg SS/d (ref. Table 3), the predicted reductions on the total wastewater discharges assessed in Step 8 were approximately 19%, 30% and 15% respectively.

Step 17: Segregation

In formulating a series of recommendations for waste reuse and recovery which could be implemented relatively quickly (ref. Step 16), the waste audit team had recognised at an early stage that waste segregation would form an integral part of the waste reduction strategy.

The proposals were discussed with the management who, in principle, were in agreement that the various measures put forward were sensible and practicable, subject to the audit team being able to demonstrate that the likely long-term cost savings to be achieved would be appreciable.

Step 18: Developing Long-Term Waste Reduction Options

Prior to the water authority stating that the increase in local sewage treatment works capacity would not require a capital contribution from Company A, the brewery's waste management consultants had prepared preliminary plans for an on-site pretreatment plant based on pH control, balancing and oxygen activated sludge treatment.

This compact treatment option had been selected in view of the limited spare land area available on site. An additional attraction was the reduced risk of developing filamentous, poorly-settling sludges compared with conventional air activated sludge systems treating brewery, or similar wastes, having a high soluble carbohydrate content.

However, in the light of the water authority's subsequent proposals and a comparative economic assessment of the two alternatives - discharge of untreated combined wastewaters (or, at worst, following preliminary treatment only) plus payment of trade effluent charges, or partial biological pretreatment plus payment of reduced trade effluent charges - plans for pretreatment facilities on-site were shelved pending the outcome of the waste audit and reduction investigations.

The audit team considered that if the good housekeeping measures as outlined in Step 16 were implemented, particularly those relating to the reuse of the significant pollution load associated with the Lautertun drain and the control of caustic and acidic discharges, then future pH control and flow/load balancing of combined flows in order to ensure compliance with discharge standards would not be necessary.

Step 19: Environmental and Economic Evaluation of Waste Reduction Options

From the waste saving studies which were orientated around possibilities for reuse/recycling and recovery, it was clear that following implementation of the measures drawn up the net discharge of wastes to the environment would be significantly reduced. Thus, there would be a clear environmental benefit.

The audit team then tabulated the estimated trade effluent charges with and without allowance for the proposed waste saving measures (Table 4). This enabled the potential savings in these charges to be identified.

Table 4: Estimated Trade Effluent Charges

Unit Operation	Waste Description	Estimated Current Charges US$/annum	Estimated Reduced Charges US$/annum	Estimated Savings in Charges US$iannum
Lautertun	Final run to drain	58,000	0	58,000
75° Hot Water Tank	Overflow	7,000	3,500	3,500
Brewhouse Vessels	Caustic and Acidic Wash at Weekends	7,800	0	7,800
Gauging Vessels	CIP Wash	1,200	0	1200
Fermenting Vessels	CIP Wash	25,000	7,000	18,000
Storage Tanks	CIP Wash	5,000	1,500	3,500
Yeast Storage and Recovery	CIP Wash	800	200	600
Pausteriser	Process Water	4,300	0	4,300
Total		109,100	12,200	96,900

The trade effluent charges listed in Table 4 were then compared with the expected total trade effluent charge for the existing combined wastewaters, estimated at US$365,000 per annum for the forthcoming year. This indicated a 26% reduction resulting from implementation of the flow/ load reduction proposals.

Based on the data set out for Step 16, the reduced average flows and loads would be some 1,400 $m^3$1d, 4,170 kg COD/d and 1,270 kg SS/d. This corresponded to reduced average waste quantities per cubic metre of beer produced of 1.7 m^3, 5.0 kg COD and 1.5 kg SS.

Further examination of all the waste audit data obtained indicated that peak wastewater flows and loads on any one production day could rise to 70% above these average discharge levels. However, the assessment of trade effluent charges based on average discharges was considered to give a realistic estimate of the savings which could be expected over a full production year.

The audit team appreciated that in addition to savings in trade effluent charges, there would be other cost benefits which were difficult to quantify during the time-frame of the consultant's brief but which included costs associated with raw water, energy and the probable elimination of combined wastewater treatment which would otherwise be required to meet discharge consent conditions consistently.

It was also recognised that some capital expenditure would be required to implement the proposed waste reduction programme. It was agreed with the brewery management that this aspect was best costed by their own engineering staff but that since the capital sums involved would be relatively small compared to the company's capital expenditure budget for the current year, and related to progressive improvements in the brewery production operations, the company would be likely to accept the waste savings proposals on the basis of the significantly reduced trade effluent charge savings alone.

Step 20: Developing and Implementing an Action Plan: Reducing Wastes and Increasing Production Efficiency

The results of the waste audit and waste reduction studies were formally presented to Company A's management in the form of a technical report. The recommendations made were accepted and plans were then made to implement the recommendations.

The waste audit had provided a sound understanding of all principal sources of waste arising within the brewery. Furthermore, the brewery technologist assigned to *assist* the waste audit team had benefitted greatly from being involved in the step-by-step approach adopted by the company's consultants.

It was considered that the experience gained by the brewery would enable company staff to take the lead in any future waste audit programme, particularly the assessment of the actual waste reductions achieved following commissioning of the plant modifications and additions proposed.

CASE STUDY 2: LEATHER MANUFACTURE

Company B operates a tannery in south-east Asia processing cattle hides into finished leather, mainly for side upper leather in shoe manufacture. Treatment of the hides involves a series of batch operations involving application of a wide range of physical and chemical processes. Wastewaters discharged contain pollutants from the hides, products from their decomposition, and chemicals and various spent solutions used for hide preparation and during the tanning process. Solid wastes and some atmospheric emissions also arise.

The company was required to meet new government standards for discharge of wastewater to the local watercourse. This necessitated improvements to existing treatment facilities which were then limited to crude settlement in three lagoons operated in series. Primary sludge produced was disposed of in liquid form on a large area of surrounding land.

In the light of this situation, the company engaged a local consulting engineering firm to assist their staff in carrying out a waste audit and waste reduction programme with a view to developing the best and most cost-effective solution to the waste treatment and disposal problems.

The principal tannery operations carried out, typical of many tanneries throughout the world, may be summarised as follows.

Pretanning (or Beamhouse) Operations

- soaking of the imported, preserved (wet-salted) hide in water overnight to remove blood, dung, curing salt and water-soluble and saline-soluble proteins;

- unhairing (complete dissolving of all hair) by immersion in lime and sodium sulphide - and subsequent reliming;

- trimming and mechanical removal of extraneous tissue from the flesh side of the hides - and subsequent splitting (lime splitting) of the upper two-thirds grain layer from the lower, less valuable split layer;

- deliming by treatment with a weak acid (lactic acid) and bating with an enzyme-based chemical to remove hair remnants and degraded proteins;

- pickling using salt and sulphuric acid solutions to give the required acidity to the skins to prevent subsequent precipitation of chromium salts on the skin fibres - pickled splits are then sold to other tanneries for further processing, only the grain layers being tanned and finished by Company B.

Thus, wastewaters from the beamhouse contain high levels of suspended solids and dissolved organic matter, curing salt and grease, in addition to unused process chemicals (particularly sulphides); they will also be alkaline, having a high oxygen demand.

Tanning

Chrome tanning is carried out using chromic sulphate. The tanning process stabilises the proteineous (collagen) network of the hide. Acidic effluents are produced which contain unused trivalent chromium salts.

Post-Tanning Operations

These involve:

- pressing (samming) to remove moisture;
- a second levelling by shaving;
- dyeing and softening of the tanned hide with emulsified oils (fatliquoring), preceded by occasional secondary tanning using synthetic tannins (syntans) and tanning extracts;
- drying and final trimming;
- surface coating and buffing (finishing)

The following case study describes the waste audit/waste reduction approach taken.

PHASE 1: PREASSESSMENT

Step 1: Audit Focus and Preparation

It was decided that the study investigations would be carried out by a chemical engineer from the consulting firm's staff who had previous experience of carrying out waste audits, assisted by the tannery's plant chemist.

Company B's own laboratory was not equipped to carry out many of the tests normally associated with wastewater analysis and so arrangements had to be made to deliver samples to a local private company providing laboratory analytical services.

In view of government pressures, it was decided to concentrate on wastewater discharges arising from the beamhouse and subsequent tanning operations. However, atmospheric emissions were also investigated having particular regard to health and safety. Solid waste arisings, in particular wastewater treatment plant sludges, were also studied.

The waste audit team was keen to gain the support of production personnel in order to ensure that comprehensive information on all tannery operations could be readily obtained. As a first step therefore, the study objectives were fully explained to selected staff responsible for the various production activities.

The investigations were initiated by gathering relevant information from company files. This preliminary search yielded site and drainage plans, raw material purchase records and water meter records associated with on-site borehole abstraction.

A preliminary check on water usage was carried out by calculating the water usage per tonne of wet-salted hide processed. This was found to be 61 m^3/tonne. It was noted that this was some 22% higher than the typical average working figure of 50 m^3/tonne reported in technical literature, suggesting that ways of introducing considerable water savings should be possible as a result of the waste audit/waste reduction study.

Step 2: Listing Unit Operations

The consultant and the plant chemist started the tannery study by walking around the processing and waste treatment areas, listing all the unit processes and making notes on their function and use. Help was also sought from various plant operators who were familiar with the day to day plant operations. The unit operations were listed in Table 1, with processes which did not produce liquid waste shown in brackets.

Table 1: Unit Operations

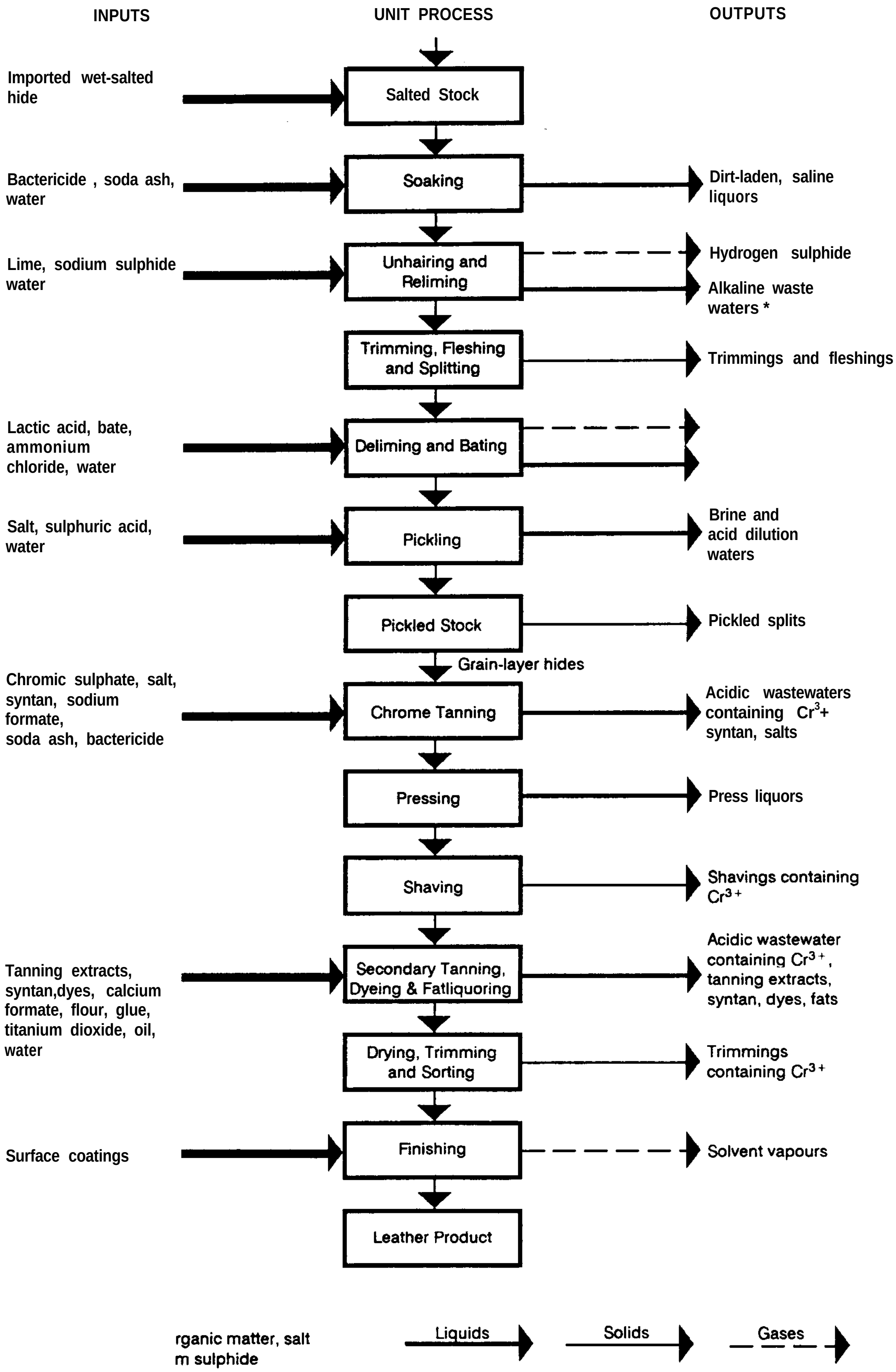
Soaking
Unhairing and Reliming
(Trimming, Fleshing and Splitting)
Deliming and Sating
Pickling
Chrome Tanning
Pressing
(Shaving)
Secondary Tanning, Dyeing and Fatliquoring
(Drying, Trimming and Sorting)
(Finishing)

As part of the company's long-term planning, the plant chemist noted that consideration was being given to moving the hide splitting operations further downstream the process line (after tanning) in order to improve the accuracy of splitting and hence overall process control, as commonly practised at other tanneries. The existing arrangement and design of process units, many of which were relatively old, did not however lend themselves to this change being implemented rapidly.

Step 3: Constructing Process Flow Diagrams

A flow diagram was then prepared to illustrate the interrelationship between the various unit operations (Figure 1).

Figure 1: Schematic Diagram of Tannery Operations



PHASE 2: MATERIAL BALANCE: PROCESS INPUTS AND OUTPUTS

Step 4: Determining Inputs

The audit preparation phase (Step 1) had already highlighted the availability of well-documented raw material purchasing records. The data produced also proved to be a good check on the raw material quantities quoted by the plant foremen per unit operation.

The raw material usage data obtained were set out as in Table 2.

Table 2: Annual Consumption of Process Chemicals

Process Chemicals	tonnes/annum
Sodium Chloride (other than curing salt present in raw hide)	622
Hydrated Lime	1,123
Sodium Sulphide (62% Na_2S)	445
Sulphuric Acid	166
Soda Ash (anhydrous sodium carbonate)	74
Bate (95% ammonium sulphate, 5% enzymes)	65
Calcium Formate	40
Lactic Acid (38%)	35
Sodium Formate	26
Bactericide	19
Ammonium Chloride	9
Sub-total	2,618
Chemicals Absorbed by the Hide (i)	
Tanolin (16% chromium)	760
Syntans A & B	424
Dyes	77
D-I Oil	17
Other Oils	295
Tannin Extracts	190
Soyarich Flour	45
Titanium Dioxide	30
Methyl Cellulose	9
Semi-Sol Glue	17
Sub-total	1,864
Total	4,482

(i) Absorption estimated at 90%, 10% discharged to waste - except for Tanolin, absorption 75%, 25% discharge to waste

Due to the nature of the raw materials and the well-organised materials storage system which was found to be in operation, no significant handling losses were occurring.

It was noted that the company incurred no charges for consumption of water drawn from a site borehole. A separate town water (potable) supply was available for domestic use. Domestic wastewater passed to the nearby watercourse via a septic tank.

Having already tabulated the key production stages (Step 2), raw material usage listed in Table 2 was used to derive average quantities per unit operation throughout the tannery, on both a daily basis and per tonne of hide processed.

The data compiled were set out in Table 3.

Table 3: Chemical Inputs per Tannery Unit Operation

Unit Operation	kg/tonne hide (at unit operation)		kg/tonne wet-salted hide	kg/d
Soaking				
Bactericide	1.6	(i)	1.6	64
Sodium Carbonate	0.8	(i)	0.8	32
Unhairing/Reliming:				
Hydrated Lime (unhairing)	48	(i)	48	1,920
Sodium Sulphide (62% Na_2S	43	(i)	43	1,720
Hydrated Lime (reliming)	58	(i)	58	2,320
Deliming/Bating:				
lactic Acid	5	(ii)	4.3	172
Bate	10	(ii)	8.7	348
Ammonium Chloride	1.3	(ii)	1.1	44
Pickling				
Sodium Chloride	60	(ii)	51.9	2,076
Sulphuric Acid	21	(ii)	18.2	728
Chrome Tanning				
Tanolin (basic chromic sulphate, 16% $Cr^{3}+$)	60	(ii)	51.9	2,076
Sodium Chloride	60	(ii)	51.9	2,076
Syntan A	25	(ii)	21.6	864
Sodium Formate	8.9	(ii)	7.7	308
Sodium Carbonate	10	(ii)	8.7	348
Bactericide	1	(ii)	0.9	36
Syntan B	41	(ii)	35.5	1,420
Secondary Tanning Dying and Fatiquoring:				
Dyes	20	(iii)	7.0	280
Calcium Formate	10.3		3.6	145
Syntan B	44	(iii)	15.4	616
Soyarich Flour	16	(iii)	5.6	224
Titanium Dioxide	8	(iii)	2.8	112
Glue/Methyl Cellulose	8	(iii)	2.8	112
Tannin Extracts & Oils	118	(iii)	41.3	1,652
Total				19,693

(i) Based on 40 tonnes wet-salted hide per day
(ii) Based on fleshed, split/trimmed hide, after reliming - 34.6 tonnes per day
(iii) Based on chrome tanned leather, after pressing/shaving - 14.0 tonnes per day

Step 5: Recording Water Usage

The next step was to record the water usage at the tannery and determine how it was used. It was noted that water obtained by the company from the site borehole was pumped to a covered storage tank at ground level and then pumped again to a high-level storage tank. Water then gravitated to the site distribution mains under static head via a water meter, readings for which were recorded weekly in a log book.

Analysis of these records indicated a daily average total water consumption for the site of 2,450 m^3/d. This figure was then broken down into average water usage per tannery unit operation in a similar manner to that carried out for the process chemicals. Since the tannery wet processes were all carried out in revolving vessels of known capacity, providing mechanical agitation to accelerate the wet-chemical operations, batch process water inputs were readily quantifiable. Rinsewater usage which was continuous for a fixed duration per batch was also known from previous work carried out by the company. This had involved checking the time taken to fill a vessel of known volume for a given water valve setting.

The results were summarised as set out in Table 4.

Table 4: Water Inputs per Tannery Operation

Unit Operation	m³/tonne hide (at unit operation)	m³/tonne wet-salted hide	m³/d
Soaking.-			
Prewash	4.3 (i)	4.3	172.0
Process Water	1.9 (i)	1.9	76.0
Rinse Water	2.1 (i)	2.1	84.0
UnhairinglReliming:			
Process Water	1.9 (i)	1.9	76.0
Rinse Water	11.0 (i)	11.0	440.0
Soak Water (reliming)	1.9 (i)	1.9	76.0
Rinse Water	2.1 (i)	2.1	84.0
Deliming/Bating			
Pre-rinse	4.2 (ii)	3.635	145.4
Process Water	1.0 (ii)	0.865	34.6
Rinse Water	1.385 (ii)	1.2	48.0
Pickling:			
Brine Water	2.49 (ii)	0.215	8.6
Acid Dilution Water	0.84 (ii)	0.073	2.9
Chrome Tanning:			
Process Water	0.586 (ii)	0.507	20.3
Rinsing	4.51 (ii)	3.9	156.0
Pressing:	0.202 (ii)	0.175	7.0
Secondary Tanning, Dyeing and Fatliquoring:			
Prerinse	9.15 (iii)	3.2	128.0
Process Water	0.4 (iii)	0.14	5.6
Rinse Water	18.6 (iii)	6.5	260.0
Process Water	0.4 (iii)	0.14	5.6
General floor and Plant Washwater		15.5	620.0
Total - Process Waters		12.115	484.6
- Rinse Waters		33.635	1345.4
- General Washdown		15.500	620.0
- Total		61.250	2,450.O

(i) Based on 40 tonnes wet-salted hide per day
(ii) Based on fleshed, split/trimmed hide, after reliming - 34.6 tonnes per day
(iii) Based on chrome tanned leather, after pressing/shaving - 14.0 tonnes per day

Step 6: Measuring Current Levels of Waste Reuse/Recycling

It was noted that no wastes were reused/recycled at the tannery.

Step 7: Quantifying Process Outputs

The audit team listed ‘the process outputs from each tannery unit operation as set out in Table 5 below.

Table 5: Process Outputs

Unit Operation	Wastewater	By-Product/ Waste Reuse	Atmospheric Emissions
Soaking	Process and Wash/Rinse Waters		
Unhairing/Reliming	Process and Rinse Waters		Hydrogen Sulphide
Trimming, Fleshing and Splitting	-	Trimmings and Fleshings	-
Deliming/Bating	Process and Rinse Waters		Ammonia
Pickling	Process Brine/ Acid Dilution Waters		-
Pickled Hide Storage		Pickled Splits	-
Chrome Tanning	Process and Rinse Waters		
Pressing and Shaving	Press Liquors	Shavings	-
Secondary Tanning, Dyeing and Fatliquoring	Process and Rinse Waters		-
Drying, Trimming and Sorting	-	Trimmings	
Finishing			Solvent Vapours
Final Product	-	Finished Leather (grain layer)	

Action was then taken to quantify these outputs in Steps 8,9 and 10.

Step 8: Accounting for Wastewater

Process wastewater flows were based on totalling up batch water inputs and making allowances where appropriate for water retention by the hide at each process stage based on percentages reported in technical literature.

Composite samples of the various discharges were also taken for laboratory analysis.

The results of this exercise were summarised in Table 6.

Table 6: Average Flows, Strengths and Pollution Loads of Strong Liquors

Unit Operation	flow			BOD			SS		
	m^3/d	%of total	pH	mg/i	kg/d	% of total	mg/l	kg/d	% of total
Soaking	276	42.1	6.8	2.200	607	19.8	4,400	1,215	30.0
Unhairing	103	15.7	11.5	15,500	1,597	52.0	22,100	2,276	56.1
Reliming	103	15.7	11.7	650	67	2.2	1,650	170	4.2
Delime and Bating	66	10.1	9.5	6,000	396	12.9	2,100	139	3.4
Pickling	37	5.6	2.7	2,900	108	3.5	5,200	192	4.7
Chrome Tan & Press Liquors	33	5.0	3.6	6.500	215	7.0	1,100	36	0.9
Secondary Tanning, Dyeing & Fatliquoring									
- 1st dump	19	2.9	4.0	2,000	36	1.2	600	11	0.3
- 2nd dump	19	2.9	3.7	2,200	42	1.4	850	16	0.4
Total	656	100.0	-	-	3,070	100.0	-	4,055	100.0

It was decided that having quantified the main, strong-liquor pollution loads per unit operation, separate quantification of running rinsewater pollution loads per unit operation was not justified since this would have meant setting up numerous V-notch weirs and many additional sampling points, thus increasing significantly the time input and analytical work required.

The relatively weak continuous-flow rinse waters were thus monitored using a V-notch weir located in a common drain *within* the tannery and combining frequent spot samples to give a daily composite for the whole tannery. Total rinsewater flow including general floor and plant washdown was estimated to be 1,944 m^3/d with an associated BOD and SS strength of 273 mg/l and 3% mg/l SS. Corresponding pollution loads (flow x strength) were thus 530 kg BOD/d and 770 kg SS/d.

The overall wastewater flows and BOD and SS strengths and pollution loads were then tabulated in Table 7.

Table 7: Combined Wastewater Flows, Strengths and Pollution Loads

Wastewater	Flow	BOD		SS	
	m^3/d	mg/l	kg/d	mg/l	kg/d
Strong liquors	656	4,680 (i)	3,070	6180 (i)	4,055
Rinse Waters/General Washdown	1,944	273	530	396	770
Total	2,600	1,430 (i)	3,600	1,950 (i)	4,825

(i) Concentrations calculated from flow/pollution load data

Based on an average 40 tonnes of wet-salted hide processed, it was noted that these overall figures equate to 65 m^3 wastewater/tonne, 90 kg BOD/tonne and 121 kg SS/tonne, ie fairly typical unit loads compared with average figures for similar tanneries elsewhere but some 20-25% high in terms of wastewater flow.

An assessment was also made of chromium and sulphide pollution loads based on selected additional wastewater analyses carried out. This yielded pollution loads of 198 kg Cr/d and 412 kg S"/d, equivalent to 4.9 kg Cr/tonne and 10.3 kg S/tonne. Again, it was noted that these loads were fairly typical in the consultant's experience even for well operated tanneries, although somewhat higher (14% and 21% respectively) with respect to figures reported by WHO, 1982.

A number of other checks were also made. It was noted that while it was difficult to measure combined wastewater flows entering the wastewater treatment system, the final lagoon effluent discharged via a rectangular weir. In order to obtain some cross-check on the combined raw wastewater flow set out in Table 7, the final effluent flow to the nearby watercourse was monitored using this weir. An average flow over the study period of 2,200 m^3/d was recorded.

A limited number of samples of the lagoon effluent were taken and results compared with the raw wastewater analyses tabulated in Table 7. These indicated pollution load reductions averaging 40% BOD and 70% SS. Based on an average sludge concentration of 6% dry solids, calculations indicated that the volume of primary sludge generated averaged 56 m^3/d. The audit team noted that while this sludge was periodically being disposed of on surrounding land, this practice would not be allowed to continue in the future as liquid run-off caused additional pollution problems in the nearby watercourse, particularly during wet weather.

Step 9: Accounting for Gaseous Emissions

It was decided that consideration of atmospheric pollution issues in the context of this project did not justify the need for making use of portable gas detection equipment, such facilities in any case not being readily available. It was also considered that resources required to quantify gaseous emissions would be out of proportion to the extent of the problems occurring. However, various useful observations were made during the site survey.

A strong smell of hydrogen sulphide (H_2S gas was evident at the primary sedimentation stage of the wastewater treatment plant. H_2S was also evident, although only to a limited extent, within the tannery processing areas where alkaline beamhouse liquors combined with subsequent acidic streams within the internal drainage system.

The plant chemist knew that the hydrogen sulphide was a highly-toxic gas having a threshold limit value (TLV) of 15 mg/m^3 (100 ppm by volume) in air. He also knew that the extent to which H_2S could be released from solution to atmosphere was pH dependent, high pHs favouring the ionised form (HS') and hence reduced risk of sulphide stripping. He therefore noted that any future wastewater treatment scheme would be best designed to **allow** pretreatment of alkaline beamhouse liquors (pH at least 10) before they were allowed to mix with other, acidic waste flows.

No release of ammonia associated with deliming/bating was apparent but it was noted that release of some solvent vapours in the working areas associated with leather fmishing could be a potential health risk to production staff. Discussions with the management subsequently revealed that plans were already underway to install forced-ventilation equipment to cater for this problem.

Step 10: Accounting for Off-Site Wastes

The only wastes which were recycled were fleshings which were transported to a local rendering company; these amounted to an average of 9,200 kg/d.

Trimmings and shavings were disposed of to a local municipal landfill site and amounted to 14,600 kg/d.

No sale costs associated with disposal of the fleshings could be readily identified at the time of the waste audit. It was later established that no charge was levied by the tannery in return for the rendering company providing transportation facilities at their cost.

Trimmings and shavings were disposed of at an annual cost of US$14,000.

Step 11: Assembling Input and Output Information for Unit Operations

From the information collected the preliminary material balances were started by assembling the input and output data for the tannery and the wastewater treatment plant. These were tabulated under Step 12.

Step 12: Deriving a Preliminary Material Balance for Unit Operations

A preliminary material balance of data associated with operations within the tannery was first drawn up on an overall input/output materials basis. The information was tabulated as set out below.

Inputs	kg/d
Raw Hide	40,000
Chemicals (other than curing salt present in raw hides)	19,693
Water	2,450,000
Total	2,509,693

↓

Overall Tannery Operations

↓

Outputs	kg/d
Trimmings and Shavings	14,600
Fleshings	9,200
Pickled Split Layer	13,500
Finished Leather	5,600
Wastewater	2,600,000
Gaseous Emissions	Not quantified but not considered to be a major output
Total	2,642,900

A material balance was then drawn up on a unit operation basis with specific reference to chromium and sulphide. A material balance for the wastewater treatment plant was also compiled.

Inputs	kg/d S"	
Unhairing	430	(a)

(a) Based on 1,720 kg/d sodium sulphide containing 25% S"

↓

Unhairing

↓

Outputs	kg/d S"	
Unhairing, Reliming, Delime and Bating	412	(a)
Rinsewaters	5	(b)
Total	417	

(a) Based on 103 m^3/d unhairing liquors at 4,000 mg/l S"
(b) Based on 1,944 m^3/d rinsewaters containing 2.5 mg/l S"

Inputs	kg/d Cr
Chrome Tanning	332 (a)

(a) Based on 2,076 kg/d Tanolin containing 16% $Cr^{3}+$

↓

Chrome Tanning

Outputs	kg/d Cr
Chrome Tan & Press Liquors	83 (a)
Chrome Leather	249 (b)
Rinsewaters	3 (c)
Total	335

(a) Based on 33 m^3/d chrome liquors at 2,500 mg/l $Cr^{3}+$
(b) Based on 2,076 kg/d Tanolin containing 16% $Cr^{3}+$ and 75% chrome absorption into hide
(c) Based on 1,944 m^3/d rinsewaters containing 1.5 mg/l $Cr^{3}+$

Inputs	m^3/d
Raw Wastewater	2,600

↓

Wastewater Treatment Plant

Outputs	m^3/d
Primary Effluent	2,200
Primary Sludge	56
Total	2,256

Step 13: Evaluating the Material Balance

The waste audit team were confident that they had obtained an adequate material balance (within 510%) for the tannery as a whole as well as for the specific chromium and sulphide chemicals used.

The material balance for the wastewater treatment plant was also considered reasonable taking into account that some water seepage was possibly occurring through the base of the crude lagoons, thus contributing to the 13% difference between inflow and total outflows recorded.

Step 14: Refining the Material Balance

It was considered that the material balance information obtained was sufficient to meet immediate requirements but that it would be useful to carry out a further waste audit once any waste reduction measures had been implemented.

Step 15: Examining Obvious Waste Reduction Measures

It was noted that the rinsewater usage following unhairing was appreciable, amounting to some 18% of the total water usage throughout the tannery.

It was considered that significant savings could be achieved at this stage by changing from a 4-hour running rinse to a two-stage batch wash operation, each of 20-25 minutes duration. It was anticipated following a short-term trial that it should be possible to achieve a consistent 60% reduction in rinsewater usage, that is, from 440 m^3/d to 176 m^3/d.

The audit team also realised that considerable water wastage was taking place by tannery staff leaving numerous hoses running in between general floor and equipment washdown operations. On the basis of an average of 15 hoses in continuous use, it was estimated that water passing to drain surplus to actual requirements could be as much as 136 m^3/d, some 5% of the total waste-water flow. Recommendations were therefore made for the fitting of pistol-grip self-closing valves on all hoses in use throughout the tannery.

Thus, it was concluded that total wastewater flows could be reduced from 2,600 m^3/d to 2,200 m^3/d, reducing the wastewater production to a more respectable 55 m^3/tonne wet-salted hide processed.

Step 16: Targetting and Characterizing Problem Wastes

a) Sulphide Liquors

As indicated in Step 9, it was evident that pretreatment of all sulphide-containing liquors was needed before they became mixed with other acidic flows; the possibility also existed of at least partial recycle of fine-screened sulphide liquors in subsequent unhairmg operations.

The management favoured a flexible approach with the treatment system designed to handle the total daily sulphide liquor flow if required, conscious that sulphide liquor recycle would probably require a higher level of surveillance of the efficiency of the unhairing operation which might not be readily achieved on a consistent basis in practice.

The audit team then proceeded to draw up design flow and strength data for the pretreatment of sulphide-bearing waste streams; and also for the subsequent combined wastewater treatment facility required to meet the government's new discharge requirements.

Sulphide-bearing liquors were taken as being all the process and rinsewaters associated with the unhairing process and all wastewater associated with deliming/bating other than the final rinse. The resultant average design flow and sulphide load assessed were as shown in Table 8.

Table 8: Characteristics of Sulphide-Bearing Wastewater's

Parameter	Actual		Design	
Flow	590 m^3/d	*	600 m^3/d	
Sulphide	412 kg/d	(700 mg/l)	420 kg/d	(700 mg/l - ave.)
			600 kg/d	(1,000 mg/l - max.)

* assuming unhairing-stage rinsing carried out on a 2-stage batch basis to reduce water usage (equivalent to 27% of total wastewater flows following instigation of water saving)

An assessment was made of the likely BOD reduction due to oxidation of sulphide. The theoretical oxygen uptake rate due to oxidation of sulphide was taken as 0.75-2.0 kg O_2/kg S" depending on the ratio of the thiosulphate:sulphate oxidation products. Taking an average 1.4 kg O_2/kg S" and a 97% S" reduction (down to 20 mg/l S"), this gave a BOD reduction of 560 kg/d.

With reference to Table 7, the combined wastewater BOD load can be expected to reduce from 3,600 kg/d to 3,040 kg/d, equivalent to 1,380 mg/l BOD in a reduced flow of 2,200 m^3/d. Regarding the effect on suspended solids loads as a result of fine-screening of sulphide liquors, actual removals were difficult to predict accurately without further test work. As a conservative approach therefore, it was decided that the calculated total SS load of 4,825 kg/d (Table 7) should be carried forward as a design SS load for sizing and budgetary costing of the combined wastewater treatment plant; this gave a concentration of 2,190 mg/l SS at the predicted future reduced flow.

b) Chrome Liquors

The audit team considered the possibility of recovering chrome from the chrome-bearing liquors by fine screening, addition of sodium carbonate to precipitate chrome hydroxide (at pH 8-8.5), filter-plate pressing of the resultant sludge and then conversion of the chrome precipitate to soluble chromic sulphate using sulphuric acid.

Discussions with the management revealed that this possibility had been considered in the past but was not favoured on overall technical and cost grounds unless the benefits of economy of scale could be introduced by providing a centralised chrome recovery plant to serve all tanneries in the local area. While some preliminary discussions had been held through the national tannery association, such a scheme was not foreseen at this stage.

It was agreed therefore that for the present, the design of a new wastewater treatment plant should assume that chrome would be precipitated and disposed of off-site as part of the primary sludge generated.

Step 17: Segregation

In order to segregate sulphide liquors for separate ‘pretreatment, it was decided to divert existing drainage outlets in the unhairing area to a batch treatment plant located within the existing tannery process building.

Treated flows would then be combined with all other wastewaters at a new treatment plant located close to the existing settlement lagoon facility.

Step 18: Developing Long-Term Waste Reduction Options

The waste audit consultant was responsible for drawing up outline proposals for the required new wastewater treatment facilities.

Consideration was *given* to available methods of sulphide treatment. These included:

- acidification to pH 2-3 and aeration, with absorption of the resultant hydrogen sulphide gas in caustic soda solution within packed-tower scrubbers prior to discharge of the resultant liquor to drain or reuse;
- precipitation with ferrous or ferric salts;
- oxidation using chlorine or hydrogen peroxide;
- oxidation using aeration with a manganese catalyst.

The latter method was considered the most technically satisfactory and cost-effective solution following line screening. This view was supported by reference to available information sources concerning operational experience elsewhere.

It was decided to divert existing drainage outlets in the unhairing area to a mechanical self-cleaning screen (1 mm) located in a modified floor channel, the upper end being designed to convey screenings to an adjacent skip.

Screened flows would then gravitate to a submersible pumping station to lift flows into one of two batch-treatment oxidation tanks, one to be used for treatment and the other to be available for receiving the next batch of liquor. A diffused-air system, using non-clog coarse-bubble diffusers, was selected to provide mixing and aeration in each tank and a facility for dosing a solution of manganese sulphate catalyst was incorporated.

The main treatment plant for pretreated sulphide liquors combined with all other wastewater flows involved the following features:

- flow/pollution load balancing incorporating coarse-bubble aeration/mixing;
- pH correction (if required), chemical flocculation with alum and polyelectrolyte and subsequent primary settlement;
- extended aeration treatment using low-speed mechanical surface aerators (sized to provide a robust biological system capable of withstanding fluctuating loads);
- batch storage/thickening of mixed primary and surplus secondary sludges prior to pumping to drying beds and subsequent disposal of sludge cake to landfill.

Provision for iron salt dosing to the sludge storage/thickening tank was incorporated to precipitate any sulphide formed as a result of anaerobic activity within the tank and hence to minimise odour problems occurring.

A schematic diagram of the proposed treatment plant was compiled as illustrated in Figure 2.

Step 19: Environmental and Economic Evaluation of Waste Reduction Options

Company B was placed in a position of having to upgrade its wastewater treatment system in order to comply with new discharge standards imposed by the government, part of a new emphasis on the need to control pollution of the environment.

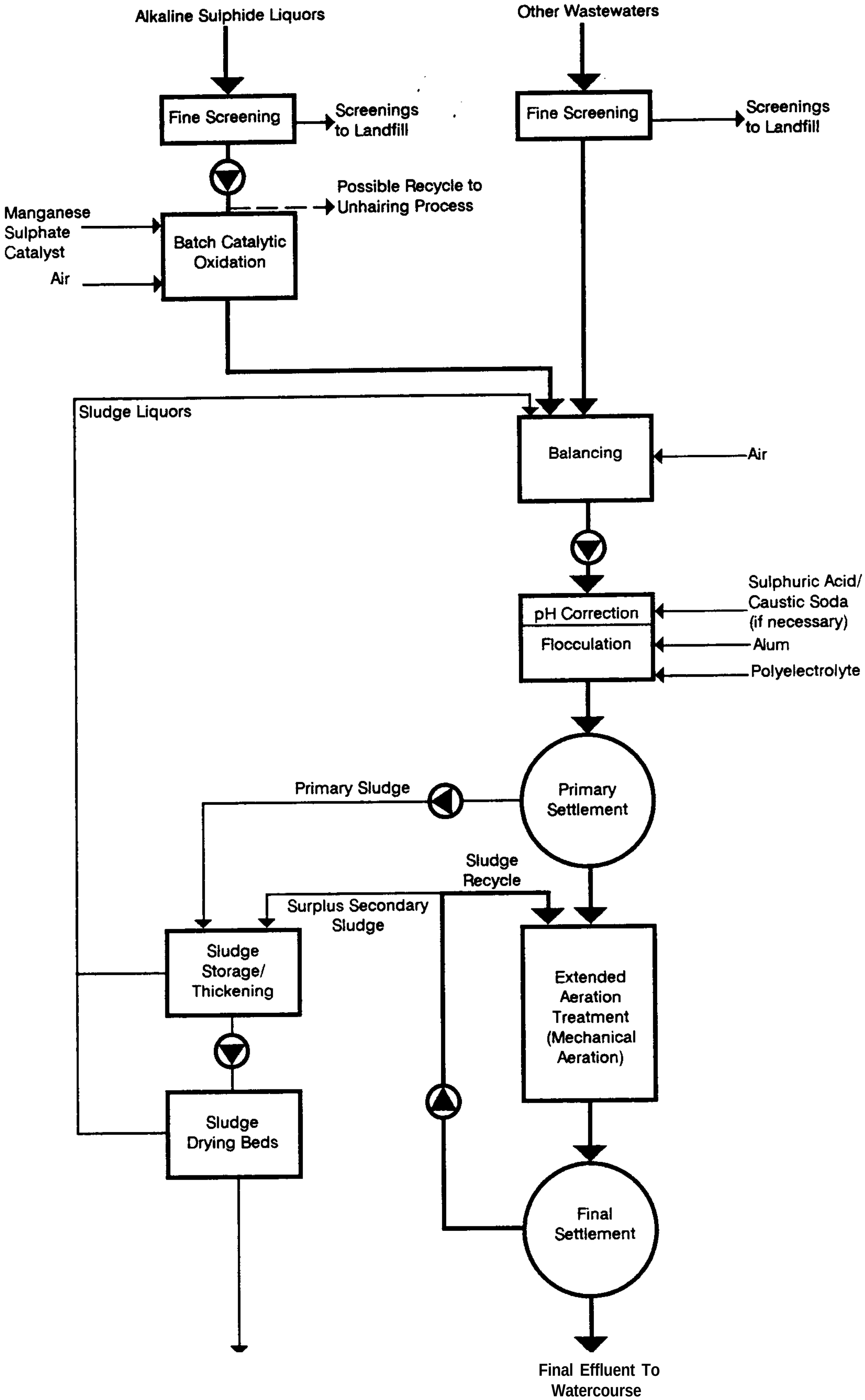
The new effluent discharge standards laid down were 40 mg/l BOD and 60 mg/l SS. Hence, provision of a new treatment facility designed to meet these standards consistently was expected to improve the quality of the local watercourse substantially.

There was a clear need to minimise capital and operating costs of the treatment scheme to ensure the overall financial viability of the company’s operations. Therefore, in preparing outline designs for budgetary purposes, particular attention was paid to providing a plant which would be robust and relatively simple to operate.

The cost of the treatment scheme drawn up was estimated at US$500,000 including contingencies and design/construction supervision fees. This reflected a conservative approach to the sizing of the activated sludge process, particularly in terms of aeration capacity. It also took into account the availability of two redundant water storage vessels suitable for use as sulphide-liquor treatment tanks.

This approach was adopted to provide some flexibility over the mode of operation of the plant with a view to minimising operating costs - it would allow the primary settlement stage to operate without addition of chemical flocculants if desired, with consequent higher strength effluent

Figure 2: Schematic Diagram of Proposed Wastewater Treatment Plant



passing forward to the biological stage; overall sludge yields requiring ultimate disposal off-site would also be minimised Provision for chemical flocculants at the primary stage was included however since it was felt that their use could enable the required final effluent quality to be achieved more consistently.

Step 20: Developing and Implementing an Action Plan: Reducing Wastes and Increasing Production Efficiency

The consultants engaged to carry out the waste audit/waste reduction studies presented the results of their findings to Company B's management. The data presented were used as a basis for submitting a planning application to the local government office for approval to design and install the proposed wastewater treatment plant.

During a subsequent meeting with the government concerning timing of the proposed design and construction work, Company B was informed that the introduction of a charging system for borehole abstraction was under consideration for possible implementation the following year. This development emphasised to the tannery management the importance of having carried out the waste audit/waste reduction investigations and the need to be alive to further water-saving possibilities in the future.

The waste audit/waste reduction investigations achieved the following objectives.

- A thorough appreciation of all the sources of waste at the tannery.
- Identification and quantification of the major sources of wastewater including waste sulphide and chromium contributions.
- Evaluation of processing efficiencies from assembled information on unit operations, raw materials, water usage, products and waste generation.
- Reduction of water usage and associated wastewater disposal problems.
- Identification of problem wastes (ie sulphide liquors) requiring special attention.
- Development of a waste management system which would comply with discharge regulations and result in a much-improved local environment.

CASE STUDY 3: PRINTED CIRCUIT BOARD MANUFACTURE

Company C manufactures double-sided and multi-layered circuit boards for the telecommunications and computer markets. The manufacturing of printed circuit boards involves a complex series of physical and chemical processing stages and as a result the wastewaters which are generated are complex, of variable composition and difficult to treat. To compound the treatment problems, many of the processing solutions contain proprietary chemicals whose composition is not readily available.

The main pollutants in printed circuit board manufacturing wastewaters are heavy metals, particularly copper. Company C's wastewater frequently exceeded the local authority's standards for discharges to the public sewerage system. Although the company had implemented some improvements to its wastewater treatment system in recent years, discharges in excess of the 5 mg/l limit on copper continued to occur and the local authority eventually decided to take legal action.

In response to these problems the company decided to conduct a waste audit in order to:

- bring to the attention of production personnel the importance of minimising wastage at source with a view to improving overall production efficiency while at the same time reducing both raw material costs and waste treatment costs;
- identify the sources of contamination;
- develop a waste reduction strategy to minimise contaminants at source;
- develop a sound understanding of the wastewater problems to facilitate the design of a cost-effective wastewater treatment system to comply with discharge standards.

The printed circuit board material is composed of a glass-fibre sheet with copper laminated on both sides. The uncut boards are received from the suppliers in large sheets and pass through a shearing stage to cut them to the desired size. The boards are then drilled and pass through a surface conditioning stage (deburring) before undergoing a series of treatments in the sensitising area (electroless plating). This treatment essentially coats copper into the holes and prepares the holes for electroplating.

The next stage involves the application of a photopolymer-resist material which masks off areas which do not need to be electroplated. The printed circuit areas are subsequently developed (to remove unexposed resist areas which are to be plated) and pass through microetching, copper electroplating, solder electroplating, resist stripping, copper etching and a number of other selected finishing treatments as specified by the customer. The last stages of manufacture involve final fabrication and electrical testing.

It can thus be seen that the printed circuit board manufacturing plant is complex and a great number of different process wastes are generated. The following case study describes the approach taken to overcome the long-standing waste treatment problems encountered by the company. The investigations were based on the step-by-step approach described in this waste audit manual and the studies highlighted a number of areas where processing and treatment efficiencies could be improved.

PHASE 1: PREASSESSMENT

Step 1: Audit Focus and Preparation

The waste audit programme was initiated by selecting an investigating team to carry out the required work and compiling all existing documentation and information relevent to the project.

In view of the scale of the investigatory work required, the audit team included representatives from each key manufacturing section. This not only increased employee awareness of and support for the study programme but enabled a full understanding of the factory processes and particular problem areas to be developed.

The audit team studied the practical aspects of initiating the required studies. It was decided that wastewater flow measurements and sampling could be readily conducted using internal resources but that it would be necessary to engage a contract laboratory to carry out the numerous wastewater analyses required.

Step 2: Listing Unit Operations

Due to the complex nature of the printed circuit board plant it was not considered appropriate to list all the unit operations in fine detail. Instead, following a detailed walk around the factory, the various manufacturing stages were compiled in terms of processing areas. Furthermore, as copper was by far the major contaminant of interest, it was decided at this stage to conduct the waste audit with specific reference to copper.

Figure 1 shows the general schematic process flow diagram which was constructed from the initial plant investigations. The areas where waste copper was generated were found to be the:

- deburring operation (sensitising);
- sensitising line (electroless plating);
- electroplating line (copper electroplating, solder electroplating, moist strip and copper etch);
- oxide coating area (including oxide deburring, oxide coating, solder stripping and lacquer finishing).

Step 3: Constructing Process Flow Diagrams

Once the main processing areas which generated waste copper had been identified the process flow diagrams were constructed for each area. This involved a more detailed study of each processing area and the identification of process inputs and outputs. In addition to the four processing areas mentioned, a process flow diagram of the existing wastewater treatment plant was also developed. Figures 2 - 6 show the process flow diagrams for these main processing areas. It should be noted that some diagrams are simplified for the purposes of the case study.

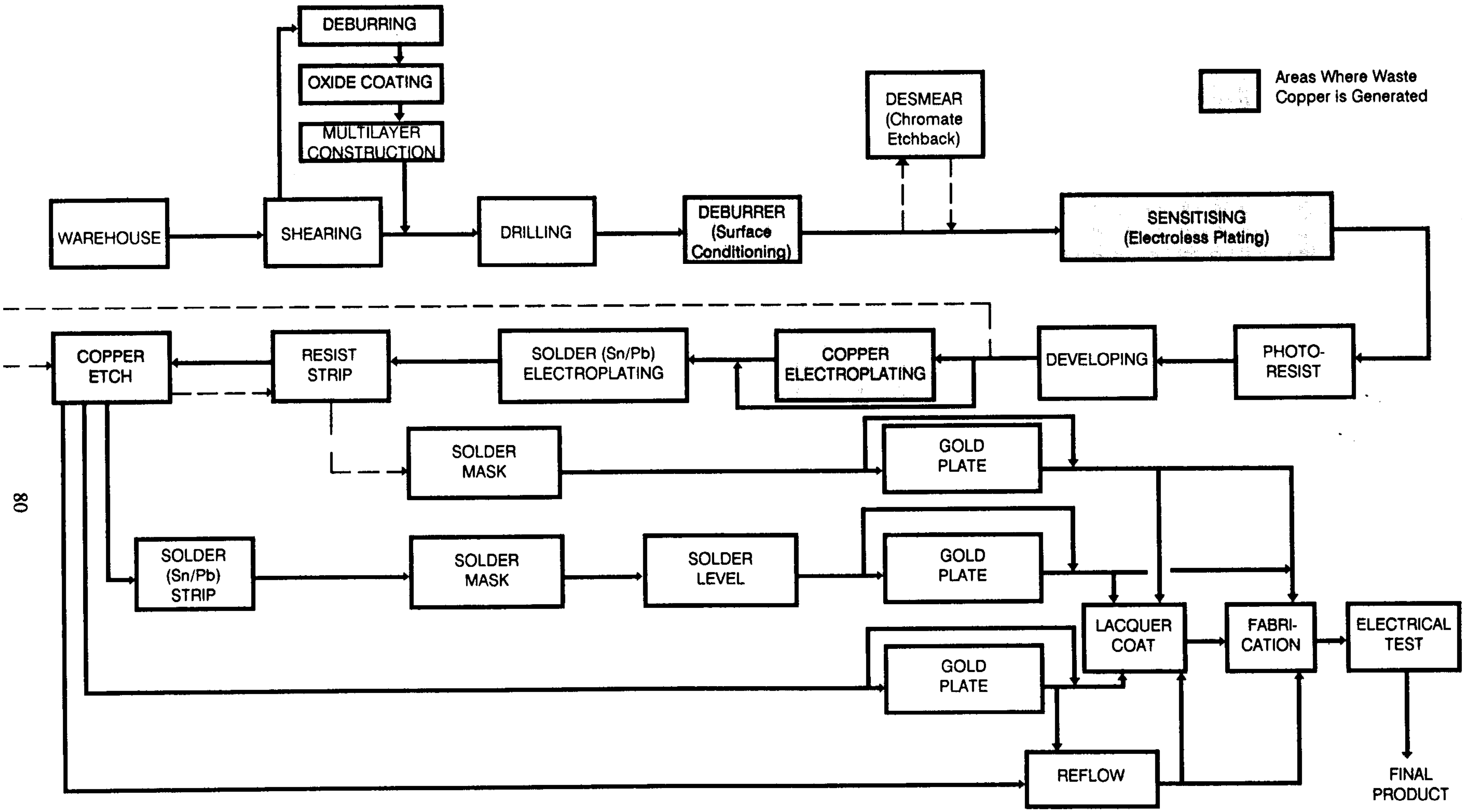
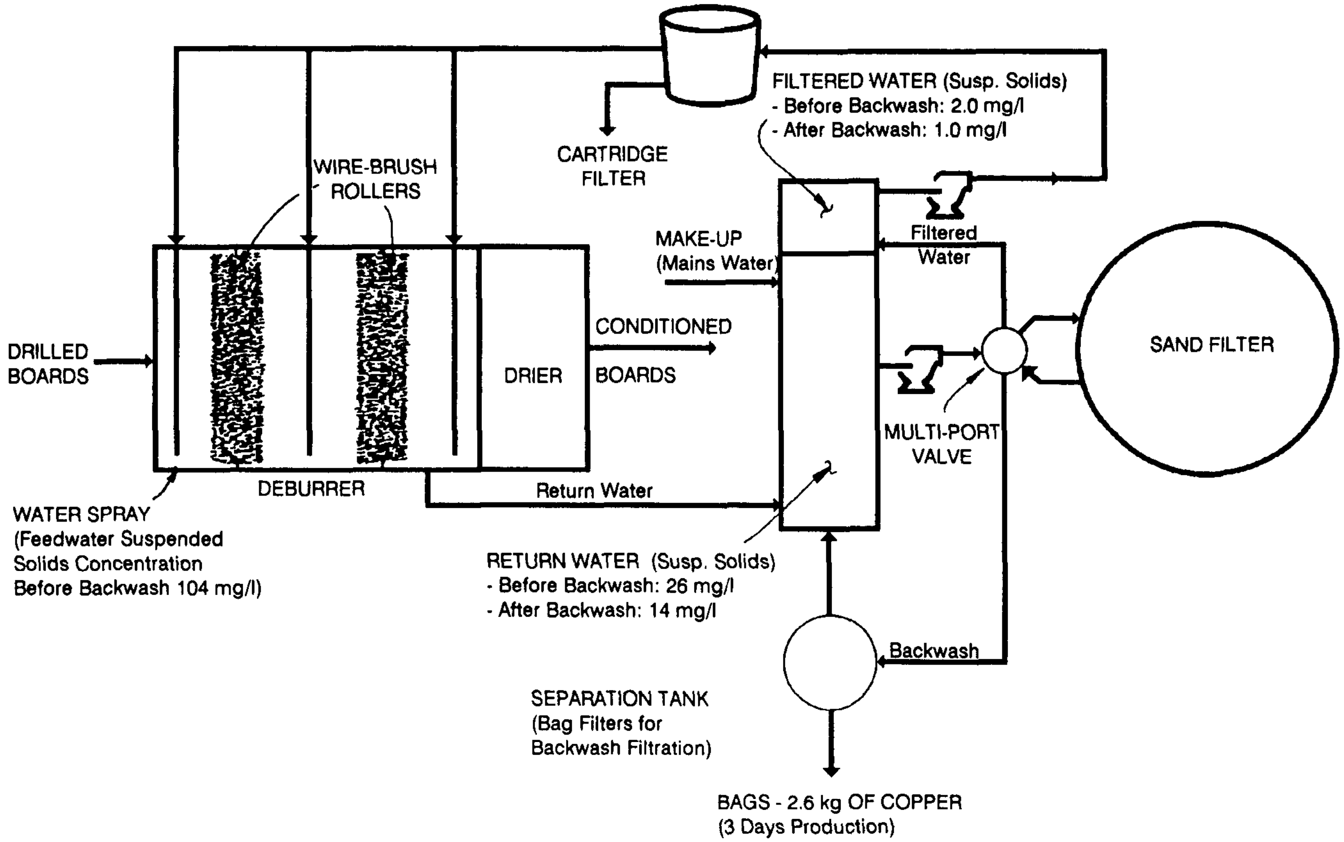
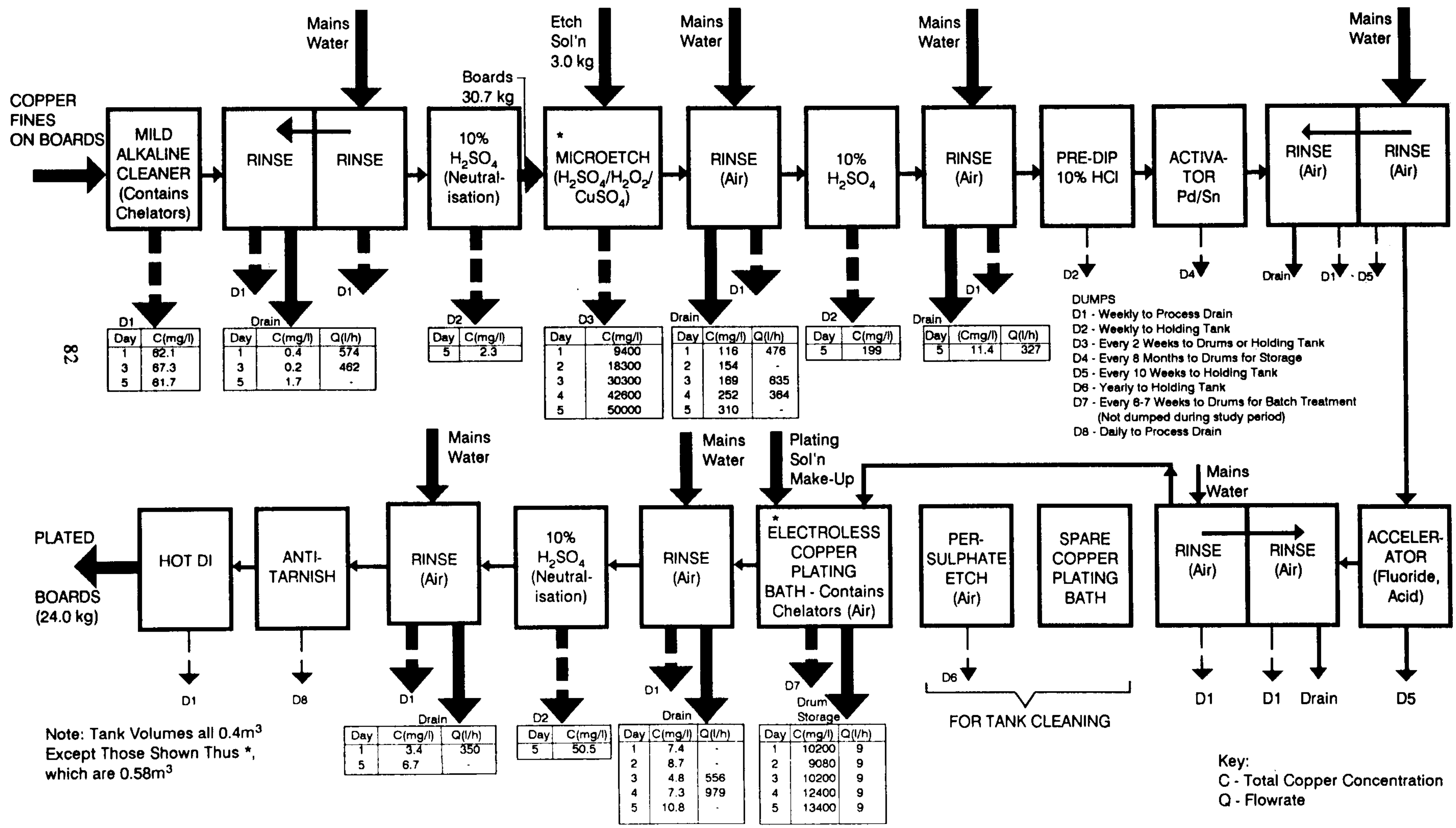


Figure 1: General Flow Diagram for the Printed Circuit Board Manufacturing Plant



2: Process Flow Diagram for Sensitising Deburrer

Figure 3: Process Flow Diagram for Sensitising (Electroless Plating) Area



Mild alkaline cleaner (D1):

Day	C(mg/l)
1	62.1
3	67.3
5	61.7

Rinse (Drain):

Day	C(mg/l)	Q(l/h)
1	0.4	574
3	0.2	462
5	1.7	-

10% H_2SO_4 (Neutralisation) (D2):

Day	C(mg/l)
5	2.3

Microetch (D3):

Day	C(mg/l)
1	9400
2	18300
3	30300
4	42600
5	50000

Rinse (Air) (Drain):

Day	C(mg/l)	Q(l/h)
1	116	476
2	154	-
3	169	635
4	252	384
5	310	-

10% H_2SO_4 (D2):

Day	C(mg/l)
5	199

Rinse (Air) (Drain):

Day	(Cmg/l)	Q(l/h)
5	11.4	327

Rinse (Air) (Drain), lower line:

Day	C(mg/l)	Q(l/h)
1	3.4	350
5	6.7	-

10% H_2SO_4 (Neutralisation) (D2), lower line:

Day	C(mg/l)
5	50.5

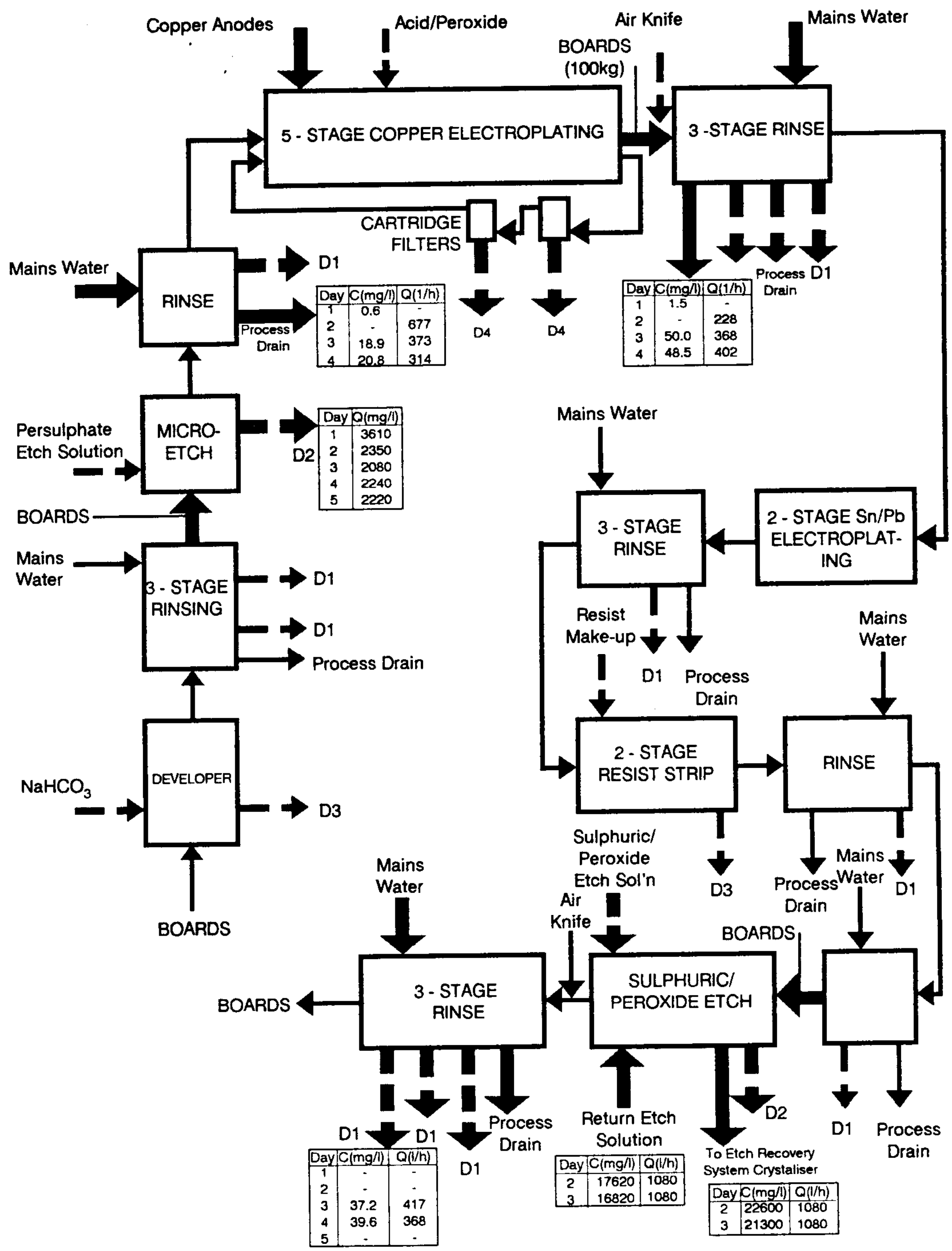
Rinse (Air) (Drain), lower line:

Day	C(mg/l)	Q(l/h)
1	7.4	-
2	8.7	-
3	4.8	556
4	7.3	979
5	10.8	-

Electroless copper plating bath (Drum Storage):

Day	C(mg/l)	Q(l/h)
1	10200	9
2	9080	9
3	10200	9
4	12400	9
5	13400	9

Figure 4: Process Flow Diagram for 9000 Line (Cu Electroplating Sn/Pb Electroplating, Resist Strip and Etching



Day	C(mg/l)	Q(1/h)
1	0.6	-
2	-	677
3	18.9	373
4	20.8	314

Day	C(mg/l)	Q(1/h)
1	1.5	-
2	-	228
3	50.0	368
4	48.5	402

Day	Q(mg/l)
1	3610
2	2350
3	2080
4	2240
5	2220

Day	C(mg/l)	Q(l/h)
1	-	-
2	-	-
3	37.2	417
4	39.6	368
5	-	-

Day	C(mg/l)	Q(l/h)
2	17620	1080
3	16820	1080

Day	C(mg/l)	Q(l/h)
2	22600	1080
3	21300	1080

KEY
C - Total Copper Concentration
Q - Flowrate

DUMPS
D1 - Daily to process sewer
D2 - Monthly to holding tank
D3 - Daily to holding tank
D4 - Change filters quarterly

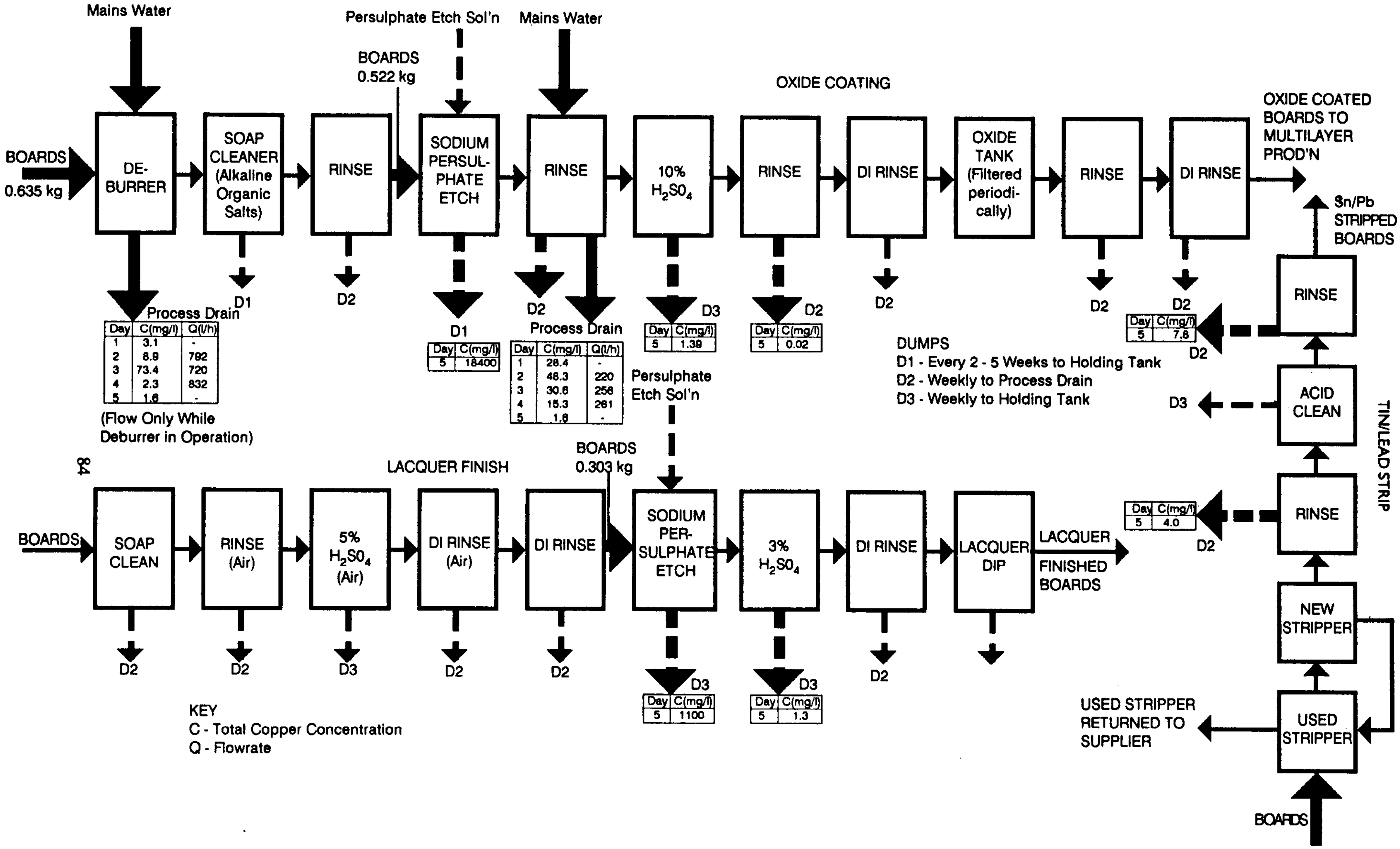
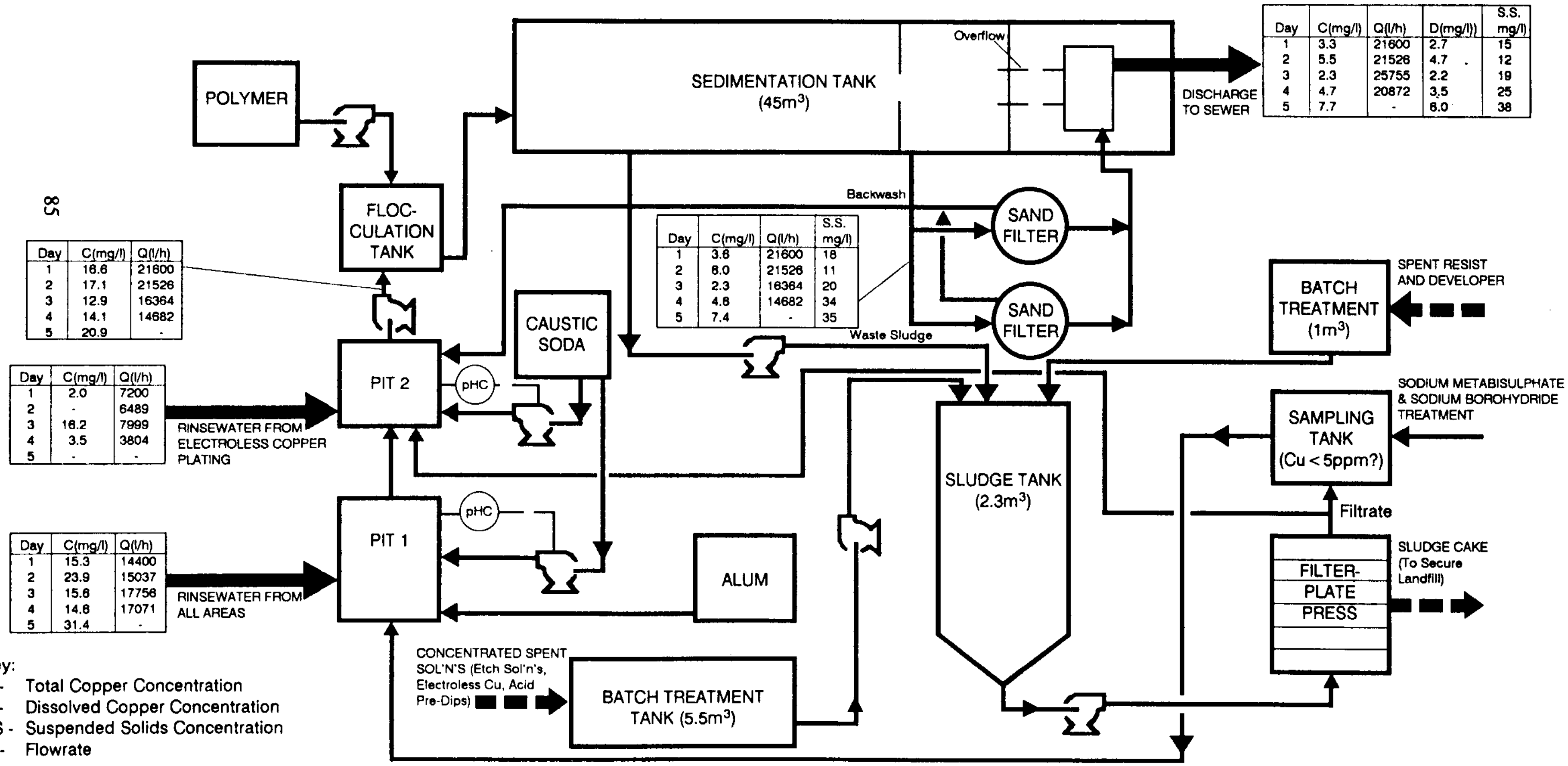


Figure 5: Process Flow Diagram for Oxide Coating, Lacquer Finish and Tin/Lead Strip

Figure 6: Process Flow Diagram for Wastewater Treatment Plant



Day	C(mg/l)	Q(l/h)	D(mg/l)	S.S. mg/l
1	3.3	21600	2.7	15
2	5.5	21526	4.7	12
3	2.3	25755	2.2	19
4	4.7	20872	3.5	25
5	7.7	-	8.0	38

Day	C(mg/l)	Q(l/h)	S.S. mg/l
1	3.6	21600	18
2	8.0	21526	11
3	2.3	16364	20
4	4.8	14682	34
5	7.4	-	35

Day	C(mg/l)	Q(l/h)
1	16.6	21600
2	17.1	21526
3	12.9	16364
4	14.1	14682
5	20.9	-

Day	C(mg/l)	Q(l/h)
1	2.0	7200
2	-	6489
3	16.2	7999
4	3.5	3804
5	-	-

Day	C(mg/l)	Q(l/h)
1	15.3	14400
2	23.9	15037
3	15.6	17756
4	14.8	17071
5	31.4	-

Key:
C - Total Copper Concentration
D - Dissolved Copper Concentration
SS - Suspended Solids Concentration
Q - Flowrate

PHASE 2: MATERIAL BALANCE: PROCESS INPUTS AND OUTPUTS

Due to the relative complexity of the printed circuit board plant the inputs and output information collected for the unit operations were recorded on the process flow diagrams based on Steps 4 - 10 of the waste audit manual. Any areas of inefficient operation and any opportunities for waste reduction were also noted. These opportunities are discussed later in Steps 15 -18.

Step 4: Determining Inputs

Input information was obtained from measuring chemical additions and water use and recording the area of copper circuit boards processed (etched);etching of the copper circuit boards involves acid treatment for surface conditioning, or finishing, and represents a significant copper input. In the case of the electroplating line the weight of copper anode used (the source of copper for electroplating) was estimated from past data. The wastewater treatment plant inputs were determined by measuring the total wastewater flows and concentrations.

Copper input information for the five processing areas was then recorded on the process flow diagrams in Figures 2 - 6.

Due to the nature of the copper raw materials (copper sulphate solutions and copper laminated boards) no handling losses were considered to occur prior to the processing operations.

Step 5: Recording Water Usage

The rinsewater flowrates were measured at the inlet to the rinse tanks by measuring the time to fill a known volume container or by draining down the rinse tanks and measuring the time to refill. The company had recently installed flow restrictors on the rinsewater feed pipes, a good water conservation measure, in order to limit the amount of water being used in the rinsing operations. In general, the flowrates measured were in accordance with the ratings for the flow restrictors.

The water usage data was also recorded on the process flow diagrams (Figures 3 - 6).

Step 6: Measuring Current Levels of Waste Reuse/Recycling

Copper-containing wastes were not generally reused at the plant. However, there was an on-line crystalliser on the sulphuric/peroxide etch stage of the electroplating line. The etch solution is pumped from the etch tank through the heat exchanger and into thecopper sulphate crystalliser where the spent etch solution is cooled to $16^{O}C$. Copper sulphate crystals are precipitated and then conveyed to storage tanks, drained and subsequently sold to a local plating shop. The recovered etch solution is returned to the etch feed tank. The quantity of etchant reused is described as an input in Figure 4.

Step 7: Quantifying Process Outputs

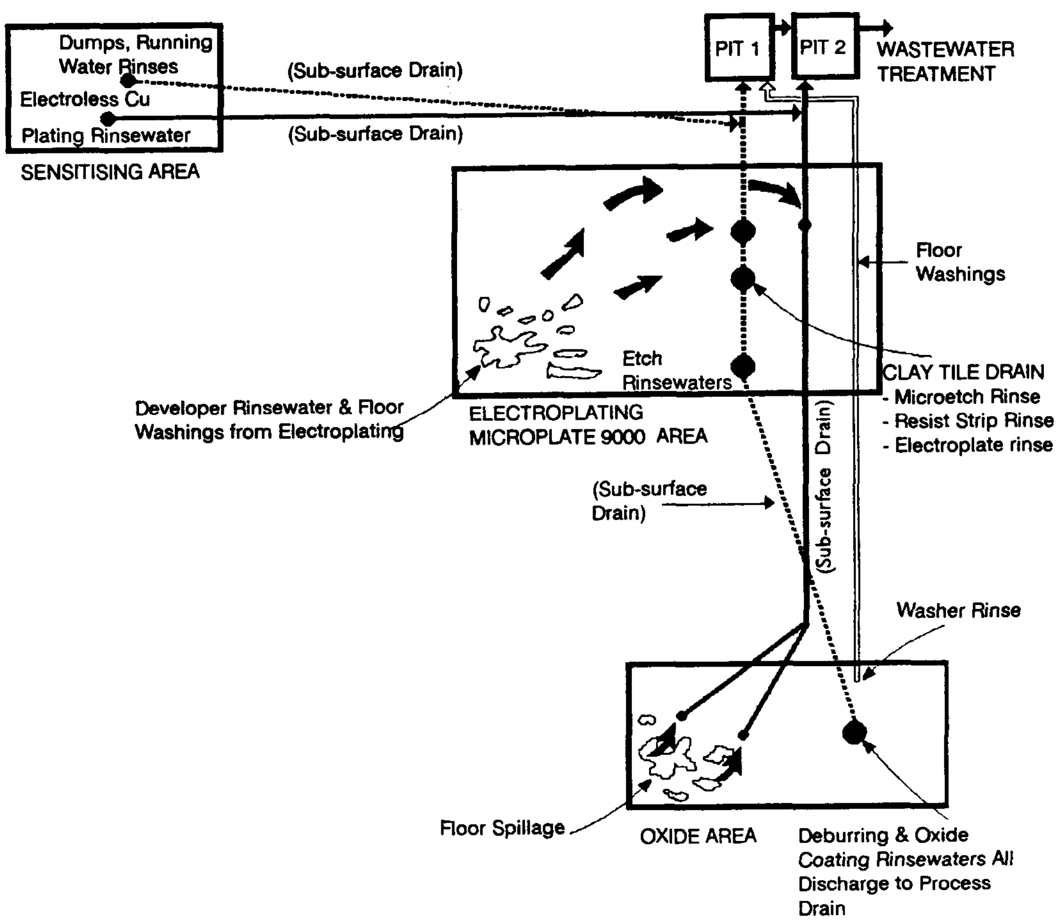
The copper-related process outputs were identified and then quantified from copper plating records and the measurement of waste masses, volumes and concentrations. Apart from the quantity of copper plated on to the printed circuit boards, which was determined from production information and plating thickness used, the process output information was obtained from measurements taken in the plant.

Step 8: Accounting for Wastewater

All the wastewater streams which were identified as containing copper (from Steps 1 and 7) were investigated in a thoroughly planned and conceived sampling programme. The sampling was performed over a production week in order to cover the full range of operating conditions and to ensure representative data. Composite samples were taken for all running wastewater streams whereas spot samples were obtained in the case of bath tanks and dumpings. Samples were also taken of the outputs from the wastewater treatment plant. The samples were carefully labelled, logged and sent out to an independent laboratory for copper and supporting analyses. Wastewater flows and tank volumes were also recorded. The wastewater information is described in Figures 2 - 6.

In addition, a process flow diagram describing the layout of the process drains was constructed (Figure 7). Dye tests were performed to determine the fate of the wastewater streams and the layout and interconnections of the surface drains. These studies highlighted some unnecessary and complex rinsewater piping arrangements which were subsequently modified by plant engineering staff.

Figure 7: Layout of Process Drains



Step 9: Accounting for Gaseous Emissions

The site investigations indicated evidence of a number of gaseous emissions. These were largely associated with forced-ventilated fume hoods to remove air-borne particulates from grinding operations and also acid and solvent fumes from subsequent process areas.

As wastewater issues were considered to be of priority concern for the current waste audit, it was decided that gaseous emissions would be a subject for further study at a later date.

Step 10: Accounting for Off-Site Wastes

The quantity of waste material stored on site and transported off-site for disposal was estimated from in-plant investigations and study of company records. The registerable wastes disposed of off-site included **copper** fines (270g/100m^2 of board), cartridge filters, and filter-press cake (1360 kg/week). The tin lead activator dump (0.7 m^3/annum) was stored on-site as registerable liquid waste.

Step 11: Assembling Input and Output Information for Unit Processes

The material balances were started by assembling the complete input and output data, converted to standard units, on the process flow diagrams (Figures 2 - 6).

Step 12: Deriving a Preliminary Material Balance for Unit Processes

From the collated information the preliminary balances were constructed for each processing area.

a) *Sensitising Deburrer*

The deburrer located in the sensitising area is operated in a recycle mode (see Figure 2). Return water is continuously filtered to remove copper fines before being fed back to the deburrer. Captured copper fines are subsequently backwashed from **the sand filter and collected in the bag filter. Essentially the copper inputs are from the brushed boards and the** outputs are from the sand filter backwash bag filter and the cartridge filter. An accurate mass balance could not be constructed from the available information as the thickness of copper removed from the boards could not be determined precisely. However, the company did plan to purchase a high-resolution microscope in the near future which would enable accurate determination and control of copper thicknesses removed.

b) Sensitising (Electroless Plating)

The preliminary material balance for the electroless plating line is shown below.

Copper Inputs (kg/week)

Copper fines from deburrer	0.040
Boards (microetch)	30.700
Etch solution	3.000
Electroless plating solution	25.000
Total	58.743

↓

Electroless Plating

↓

Copper Outputs (kg/week)

Boards (plated)	21.283
Rinsewaters	4.867
Dumps	0.261
Microetch dump	29.000
Electroless copper (storage)	4.400
Total	60.811

c) Electroplating Line (Microplate 9000 line)

Copper Inputs (kg/week)

Boards (microetch)	0.667
Boards (sulphuriclperoxide etch)	209.586
Copper anodes	124.500
Return etch solution	743.904
Total	1078.657

↓

Microplate 9000 tine

↓

Copper Outputs (kg/week)

Boards (plated)	100.078
Rinsewaters	1.474
Dumps	0.523
To etch recover (18 l/lmin) including 217.000 kg crystallised copper)	948.240
Total	1050.315

No make-up or dump of the sulphmic acid/peroxide etch tanks was made during the study period and as the crystalliser maintains a constant copper concentration in the etch tank these inputs and outputs were not considered in the material balance study.

d) Oxide coating area

Copper Inputs (kg/week)	
Boards (deburring)	0.653
Boards (microetches $10x10^{-6}$ inch)	0.825
Total	1.478

↓

Deburrer, Oxide Coating and Lacquer Finish

↓

Copper Outputs (kg/week)	
Rinsewaters	0.195
Dumps (drain)	0.003
Dumps (holding tank)	0.311
Copper fines (to drain)	0.632
Estimated copper increase in oxide Microetch bath	0.347
Total	1.488

e) Wastewater treatment

Copper Inputs (kg/week)	
Pit 1 Influent	12.493
Pit 2 Influent	12.893
*Concentrated spent solution	1.095
Total	26.481

↓

Wastewater Treatment System

↓

Copper Outputs (kg/week)	
Sewer discharge	5.239
Filter-plate press sludge (Estimated by difference)	21.242
Total	26.481

• No concentrated copper solutions treated in the study period

The volume of the filter-plate press sludge was estimated by difference as the sludge was withdrawn from the clarifier on an irregular and infrequent basis.

In addition, a material balance was constructed from all the rinsewaters and daily dumps to the process drains and the feed to the wastewater treatment system over days 1 - 4. (This map balance primarily represents the rinsewaters as most of the dumps are carried out on day 5.)

Copper Inputs (kg)	
Rinses	
Sensitising	
Alkaline cleaner rinse	0.014
Microetch rinse	4.404
Acid rinse	0.115
Electroless	0.259
Acid rinse	0.019
Electroplating Line	
Mircoetch	0.191
Floor capture	0.276
Electroplating	0.607
Etch rinse	0.600
Oxide Area	
Deburrer	0.653
Etch	0.025
Dumps	
Electroplating Line	
Mircoetch rinse	0.048
Electroplate rinse	0.235
Etch rinse	0.180
Total	8.346

↓

Drains

↓

Copper Outputs (kg)	
Treatment plant influent (total)	9.192

Step 13: Evaluating the Material Balance

Each material balance drawn up showed a good agreement considering the complexity of the printed circuit board manufacturing plant and the large number of waste copper sources. Approximately 91 percent of the copper loading into the treatment plant during production days 1 - 4 was accounted for by the measured wastewater sources. The extra 9 percent was probably due to copper being washed from contaminated floor areas and further minor sources of copper which were not included in the survey (eg gold plating line).

The following conclusions were made.

- The microetch rinse accounted for approximately 90 percent of the total sensitising area copper loading.
- The microetch rinse accounted for approximately 56 percent of the plant's total rinsewater copper loading on the treatment plant.
- Other major sources of rinse water contamination were electroplating rinse, sulphuric/peroxide etch rinse and the deburrer (oxide area) rinse.

Step 14: Refining the Material Balance

The preliminary material balance work, while giving very satisfactory results, had included a number of assumptions and estimates (by difference) had to be made; this particularly applied to the oxide-coating and wastewater treatment areas. A decision was therefore made to refine the material balance backing up the estimates by further monitoring and information gathering.

Step 15: Examining Obvious Waste Reduction Measures

From the information accumulated from the waste audit and observations which were made while investigating the plant in detail a number of obvious waste reduction and efficiency improving measures were identified. These again split into the four processing areas and the wastewater treatment plant.

a) Deburring operations (sensitising area)

It was noted that the sand filter associated with deburring operations was backwashed with return (dirty) water which would lead to entrainment of copper fines throughout the sand bed. This could lead to fines being released into the filtered water. The deburred spray water had a suspended solids concentration of 104 mg/l. This high concentration probably accounted for the fine powder layer which was observed on the printed circuit boards after the deburrer drier. While this only represented a small input of copper into the sensitising line (0.04 kg/ week), it created a potential adverse effect on product quality control.

The waste copper tines which were collected on the backwash bag filter system (2.6 kg per 3 days production) are transported to a secure landfill site together with sludge cake from the filter press. However, the fines are relatively pure copper and investigations confirmed them to have a value of approximately US$O.9/kg corresponding to a small potential income of US$275 per annum.

b) The sensitising line (electroless plating)

As discussed previously, the results of the wastewater characterisation showed that a very high copper loading was from the microetch rinse (90 percent of the sensitising rinsewater copper load). The sensitising line is a manually-operated plating line and it was observed that no drip time was used after the microetch. A one minute drip time was thus introduced and a monitoring programme initiated to record improved waste loadings. It was subsequently concluded that a static-rinse drag-out tank should be installed in the longer term to reduce further the running rinsewater loading from this source.

c) Electroplating line

It was noted that the recirculation pumps on the copper electroplating line had leaking mechanical seals leading to copper crystallisation on the pump shafts and surrounding floor areas. This copper material was subsequently picked up by the developer rinse, which flowed directly onto the floor, and discharged to the floor drain leading to Pit 12. The copper loading from this source at one floor drain closed to the electroplate rinse was approximately 70 g/d.

It was considered that although this pollution load passing to a drain was small, a satisfactory maintenance programme to prevent all such leaks and installation of drip trays and general cleanliness in the copper electroplating areas could reduce this source of waste loading on the treatment plant. Good housekeeping in all copper processing and handling areas could prevent copper waste loading from other areas (eg copper etch and crystallisation) from reaching the drain system.

d) Oxide coating area

The rinsewater from the deburrer in the oxide coating area was discharged directly to the process drain. A bag filter was attached to the pipe at the outlet to the drain but during the in-plant study the capturing device was inefficient leading to significant quantities of copper tines being released to the drain system. Contact with acid wastewaters would subsequently dissolve the tines in the process drains. Using existing equipment stocks, a closed-loop filtration system similar to the one in the sensitising area was added as a relatively simple control measure, eliminating this source of waste copper.

e) Wastewater treatment system

A number of inefficient operations in the wastewater treatment system were highlighted in the waste audit. First, alum was added to the pH corrected (pH 8.5) wastewater in Pit 1. Alum is an effective coagulant for colloidal material but is not necessary for metal hydroxide precipitation and increases the volume of sludge produced.

Second, the existing sedimentation basin was of poor design. Inadequate sludge removal capability and floating sludge were creating effluent discharge problems.

Third, in an effort to overcome the periodic high levels of copper being discharged to the public sewer, two sand filters were installed in parallel after the sedimentation tank. However, from the results in Figure 6 it can be seen that the sand filters were not effective in removing suspended solids or copper from the wastewater.

Assuming a 50 percent reduction of copper loading from the sensitising microetch rinse through improved rinsing, and elimination of the copper loading from the deburrers and electroplating area floor drain, a 40 percent reduction in rinsewater loading to the wastewater treatment plant could be achieved.

Step 16: Targeting and Characterizing Problem Wastes

From Figure 6 it can be seen that the sand filter input concentrations of suspended solids and copper are approximately equal to the output concentrations from the filter. Furthermore, the copper discharged to the public sewer was primarily dissolved (75 - 95 percent of total copper concentration) and in excess of the sewer discharge limits on days 2 and 5. Previous experience with the treatability of the printed circuit board wastewaters had established that the electroless copper wastewaters were particularly difficult to treat because of the presence of chelating agents in the electroless copper plating solution. In addition, chelating agents were present in the resist stripping solution. It was noted that when the treated resist strip was dumped to Pit 2 on days 2 and 4, significantly higher copper concentrations were observed in the discharge to the public sewer than on days 1 and 3. Day 5 (Friday) represents an atypical waste treatment day as weekly dumping of tanks in the sensitising and oxide areas occurs on this day.

The chelate containing copper wastewater and combinations of copper and chelate containing wastewaters were therefore considered to be 'problem wastes'.

Wastewater treatability tests using alum, sodium hydroxide, lime and a range of flocculants were conducted on samples from each individual pollutant source and on combined samples. The tests indicated that most copper containing wastewaters could be treated very successfully by metal hydroxide precipitation. However, the chelating agents in the electroless rinse and resist strip rinse affected copper hydroxide precipitation and should therefore be segregated and treated separately.

As indicated in Table 1, the tests on the influent wastewater treatment plant indicated that copper could be reduced from relatively high concentrations to less than the 5 mg/l standard using lime and anionic polymer flocculant. In general, lime produced a more dense and settleable precipitate than sodium hydroxide although it generated more sludge.

Table 1: Treatabtlity Tests using Lime and Anionic Polymer

Sample	Raw/Treated	Total Copper in Supernatant (mg/l)
Sensitising		
Microetch rinse	Raw	260.0
	Treated	0.3
Electroless rinse	Raw	9.1
	Treated	9.0
Electroplating Line		
Microetch rinse	Raw	22.0
	Treated	0.2
Copper electroplate rinse	Raw	33.0
	Treated	0.2
Copper electroplate rinse	Raw	19.0
Resist strip rinse (50:50)	Treated	20.0
Electroplate floor drain	Raw	44.0
	Treated	0.1
Solphuric/peroxide etch rinse	Raw	40.0
	Treated	0.1
Oxide Coating		
Microetch rinse	Raw	150.0
	Treated	1.1
Wastewater Treatment		
Influent	Raw	11 74 13 73 8.4
	Treated	0.4 0.6 0.4 4.0 0.7

*Hourly spot samples

Step 17: Segregation

It was clear from the findings of the waste audit investigations that waste segregation would form a necessary part of any long-term waste reduction programme in order to develop a technically satisfactory and cost-effective system. This aspect will be described in Step 18 below.

Step 18: Developing Long-Term Waste Reduction Options

While the waste reduction alternatives described in Step 15 will reduce pollutant loadings and result in significant cost savings, an efficiently designed and operated end-of-pipe treatment

section describes the **wastewater treatment** and recovery system design which was developed from the waste audit and treatability studies with the assistance of a consultant engineering company.

The major points for consideration in the system design were as follows.

- Segregation of all the chelate-containing wastewaters from the conventional metal hydroxide precipitation system.
- Segregation and separate treatment/recovery of all the chelate-containing rinsewaters and concentrated bath-dumps.
- Collection of all general bath dumps (non-chelate containing) in a holding tank for metering back to the conventional treatment system at a controlled rate (to prevent surges in copper loading).
- Upgrading of existing pH adjustment, polymer addition, clarification and sand filtration systems for efficient metal hydroxide precipitation and subsequent discharge of high quality effluent.

Information on the type of chelator or chelate concentration was not readily available from the chemical suppliers.

The sources of chelate containing wastewaters were as follows:

Source	Flowrate (l/h) or Volume (litres)	Copper Concentration (mg/l)
Mild Alkaline Cleaner Bath	400 litres	63.7
Mild Alkaline Cleaner Rinse	518 litres	0.8 (max 1.7 mg/l)
Electroless Plating Bath	588 litres	11000
Electroless Plating Bleed	10 l/h	11000
Electroless Plating Rinse	770 l/h	7.7 (max 10.3 mg/l)
Resist Strip Bath	920 litres	Less than 5.0
Resist Strip Rinse	390 l/h	

The proposed treatment system incorporates the following key elements.

- Collection of all non-complexed rinsewaters in a common sump for pH adjustment with caustic (or lime) to pH 9.0 - 9.5.
- Installation of a static-rinse tank after the electroless copper plating bath. The static-rinse tank will collect most of the drag-out loading from the electroless plating bath and will then be dumped daily for electrolytic recovery. The subsequent continuous-flow rinsewater (chelate-containing), operated on a counter-current principle, will then be discharged directly to the public sewer.
- Segregation, cartridge filtration and direct discharge of resist strip rinsewaters (chelate-containing) to the clarified water storage tank.
- Segregation and direct discharge of electroless plating running rinsewaters and cleaner rinsewaters (chelate-containing) to the clarified water storage tank.

- Segregation and collection of resist strip and developer dumps (or bleed) in a separate holding tank for pH adjustment and direct discharge.
- Segregation and collection of electroless copper (chelate-containing) bath dumps, controlled bleed and drag-out tank contents together with alkaline cleaner (chelate-containing) and microetch (sensitising) bath dumps in a separate batch recirculation tank for electrolytic copper recover. Possible alternatives involving sulphide precipitation or sodium borohydride treatment were also considered but discounted on technical and cost grounds.
- Polishing of electrolytically treated solutions in a chelating ion exchange resin bed prior to discharge to the clarified water storage tank.
- Segregation and collection of general bath dumps (eg microetches, predips, acids, alkalis, etc.) in a holding tank for subsequent metering into the pH adjustment sump.
- Modification of the existing sedimentation tank to incorporate a clarified water storage tank and provision for capture of accidental spills and emergency waste storage.
- Provision of an inclined-plate clarifier following existing pH control and flocculation units with sludge pumped to a sludge storage/thickening tank. Thickened sludge will then be periodically pumped from the storage tank for dewatering in the filter-plate press. The reduced volume of sludge cake will then be disposed of in a secure landfill site.
- Although it is considered that the effluent copper concentration from the proposed treatment system will comply with the existing discharge standard of 5 mg/l, it was recommended that the company's sand filters be upgraded and included in the treatment scheme in anticipation of the proposed lowering of the standard to 2 mg/l of copper. In this case, the clarified wastewater should be polished through a sand/anthracite dual-media bed to increase the solids loading capacity of the filters.

Step 19: Environmental and Economic Evaluation of Waste Reduction Options

As Company C was facing legal action from the local authority with respect to violation of discharge standards, the return on investment was not of prime concern in this case study; of more importance was the development of the most cost-effective reduction/waste treatment system available, and a quality of final effluent for sewer discharge compatible with the local authority's environmental pollution control requirements.

From Step 18 a number of waste treatment recovery alternatives were identified and a process design subsequently derived on the basis of technical considerations. However, through the waste reduction opportunities described and the segregation and recovery of copper from the chelate-containing and microetch (sensitising) wastes it was estimated that a cost saving of US$22,000 per annum on sludge transportation and secure landfill disposal costs could be realised. In addition, it was estimated that approximately US$3,500 per annum of copper could be recovered using the electrolytic recovery unit.

The total installed cost of the proposed system including the major equipment items (inclined-plate clarifier, sludge storage/thickening tank, filter-plate press, electrolytic copper recovery unit, ion exchange unit) segregation pumping and piping, instrumentation and control and 40 m^2 building was US$265,000. However, considering the company's history of pollution problems, the impending legal action and the amount of time being spent by senior personnel on day to day waste management problems, the implementation of the waste segregation and treatment/recovery system could be considered money well spent and an investment for the future.

Step 20: Developing and Implementing an Action Plan: Reducing Wastes and Increasing Production Efficiency

The results of the waste audit and the waste reduction/treatment studies were presented to the company's management and plans were made to implement the recommended waste reduction measures and the treatment/recovery system.

The waste audit-reduction approach achieved the following objectives.

- A sound understanding of all the sources of waste copper at the manufacturing plant.
- Identification and quantification of the major sources of waste copper.
- Evaluation of processing efficiencies from assembled information on unit processes, raw materials, water usage, products and waste generation.
- Identification of waste reduction opportunities.
- Elimination of some wastes and associated disposal problems.
- Identification of problem wastes requiring special attention.
- The development of a cost-effective, integrated waste segregation and wastewater treatment/recovery system.
- The development of a waste management system which would comply with discharge regulations and result in improved public relations.

CHAPTER 4
RESOURCE SECTION

APPENDIX 1: WASTEWATER FLOW AND GAS MEASUREMENT METHODS

Wastewater Flow Measurements

This section describes simple methods of measuring flows in open channels using triangular-notch (V-notch) or rectangular thin-plate weirs.

The discharge over thin-plate weirs is a function of the depth (head) of liquid on the weir, the size and shape of the discharge area, and an experimentally determined coefficient.

Thin-plate weirs should be vertical and perpendicular to the walls of the channel, constructed in steel, wood or similar smooth-surfaced robust material.

The intersection of the weir plate with the walls and floor of the channel should be watertight and firm, putty or other suitable material being used as a sealant as appropriate. Weirs are best installed under no-flow conditions to ensure that a good seal is obtained. Where wastewater flows normally arise 24 hours per day, 7 days per week, this can create problems unless production can be temporarily stopped. In such circumstances, the weir should at least be installed under low-flow conditions in order to facilitate the installation procedure and to minimise risk of leaks around or under the weir occurring.

In general, the weir should be located in a straight, horizontal, rectangular channel if possible. Ideally the length of the approach channel should not be less than 10 times the width of the jet (nappe) formed by the flow over the weir at maximum head.

The shape and size of the channel downstream from the weir is of no significance, but the level of the water in the downstream channel should be a sufficient vertical distance below the crest to ensure free, fully-ventilated discharges.

V-notch weirs permit the accurate measurement of much lower discharges than do rectangular weirs. Also, the discharge over a V-notch increases more rapidly with the head than in the case of a rectangular weir. Thus, where flow variations over a working day are large, use of a triangular-notch (V-notch) weir is preferable. For large flows however, a broad-crested rectangular weir may be necessary.

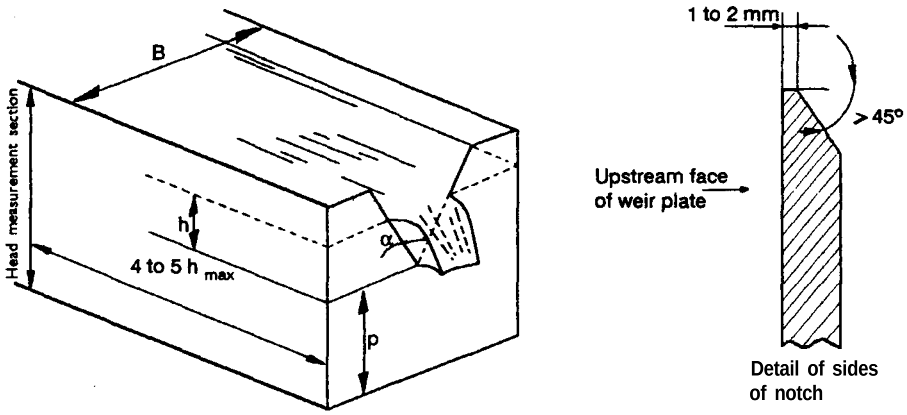
Where significant suspended solids are present, care should be taken to ensure that there is no accumulation of floating debris or settled solids behind the weir at the time of water level (head) measurement.

Triangular-Notch v-notch) Weirs

The triangular weir consists of a symmetrical V-shaped notch in a vertical thin plate. A diagrammatic illustration is shown in Figure A.

The bisector of the notch should be vertical and equidistant from the two walls of the channel.

Figure A: Triangular-notch, thin-plate weir



The plane surfaces of the notch should form sharp edges at their intersection with the upstream face of the weir plate. The width of the notch surfaces, measured perpendicular to the face of the plate, should be l-2 mm. The downstream edges of the notch should be chamfered if the weir plate is thicker than 2 mm, the maximum allowable width of the notch surface. The surface of the chamfer should make an angle of not less than 45^0 with the surface of the notch.

An appropriate formula, the Kindsvater-Shen formula, for all notch angles (a) between 20^0 and 100° degrees is:

$$Q = C_e \frac{8}{15}\sqrt{2g}\tan\frac{\alpha}{2}\, h_e^{5/2}$$

where Q = wastewater flow in cubic metres per second
C_e = coefficient of discharge (non-dimensional)
g = acceleration due to gravity, = 9.81 metres per second squared
a = the notch angle included between the sides of the notch, in degrees
h_e = the measured head over the weir, in metres
= h (measured head) + k_h (which compensates for the combined effects of viscosity and surface tension)

Also, p = the height of the weir crest above the upstream channel bed; and B = channel width at the weir section (ref. Figure A).

The factor k_h is small and can be ignored for all practical purposes with only minimal loss of accuracy; hence h_e can be assumed to equal h.

C_e is a function of the three variables - h/p, p/B and a. For most purposes, use of a standard value of 0.6 will give sufficient accuracy. For further information on the small variations of C_e under different weir conditions, reference may be made to the International Standard 'Water Flow Measurement in Open Channels using Weirs and Venturi Flumes', IS0 1438/l, 1980.

> The V-notch weir formula can therefore be simplified to:
>
> $Q = 1.42 \tan a/2 h^{5/2}$

For reasons related to measurement-error and lack of experimental data, limitations applicable to the use of this formula are:

- h/p limited to the range 0.1-2.0 for a 90^0 V-notch, and not greater than 3.5 for all other angles within the range 20°-100°;
- p/B limited to 0.1-1.0 for a 90° V-notch, and 0.1-1.5 for other values of a;
- h not less than 0.06 metres;
- p not less than 0.09 metres.

In the absence of continuous level recording equipment (which may be of a type which automatically records levels as flow for a given weir type and size), weir height readings may be taken using a calibrated dipstick positioned in the centre of the channel upstream of the weir, away from the immediate point of turbulence at the weir. The location of the dipstick will be satisfactory if it is at a distance equal to 4-5 times the maximum anticipated head (4-5 h_{max}) upstream from the weir.

With the bottom of the dipstick in contact with the base of the channel, the depth of immersion at any one point in time will equal h + p. Knowing p, h can then be calculated by difference and inserted into the weir formula to obtain the corresponding flow rate (Q).

Alternatively, it is recommended that a calibration curve be drawn up for any one weir size for a range of h values and corresponding Q values. This should be done before commencing flow measurement work so that Q values can be assessed quickly from the graph as soon as values of h are recorded.

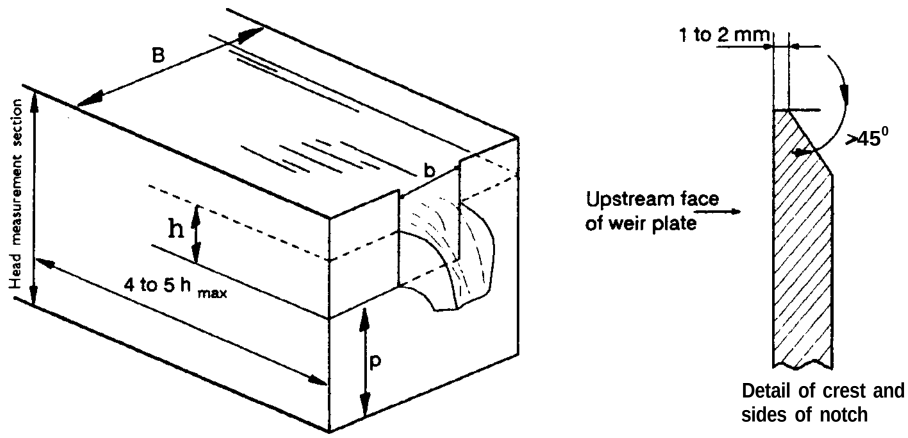
Level/flow rate measurements should be taken at least once per hour. More frequent measurements may be necessary depending on the pattern of flows experienced. The data can then be assessed to give an average daily flow (m^3/d) as well as an indication of minimum and maximum instantaneous discharge rates.

Rectangular Weirs

A rectangular thin-plate weir is a general classification in which the rectangular-notch weir is the basic form and the full-width weir is a limiting case.

A diagrammatic illustration is shown in Figure B with intermediate values of b/B and h/p. When b/B = 1, that is, when the width of the weir (b) is equal to the width of the channel at the weir section (B), the weir is a full-width weir type (also referred to as a 'suppressed' weir, because its nappe lacks side contractions).

Figure B: Rectangular-notch, thin-plate weir



A formula for rectangular weirs (the Kindsvater-Carter formula) is as follows:

$$Q = C_e \frac{2}{3} \sqrt{2g}\, b_e\, h_e^{3/2}$$

where Q = wastewater flow in cubic metres per second

C_e = coefficient of discharge (non-dimensional)

g = acceleration due to gravity, = 9.81 metres per second squared

b_e = the effective width in metres
= b (measured width) + k_b (which compensates for the combined effects of viscosity and surface tension)

h_e = the measured head over the weir, in metres
= h (measured head) + k_h (compensating factor similar to k_h)

Also, as for V-notch weirs, p = the height of the weir crest above the upstream channel bed; and B = channel width at the weir section (refer to Figure B).

The factors k_b and k_h are small and can be ignored for all practical purposes with only minimal loss of accuracy; hence b_e and h_e can be assumed to equal b and h respectively.

For rectangular weirs, C_e is a function of the two variables - h/p, p/B. As for V-notch weirs, use of a standard value of 0.6 will give sufficient accuracy in most cases.

> The rectangular weir formula can therefore be simplified to:
>
> $Q = 1.77\ b\ h^{3/2}$

For conservative practice, limitations applicable to the use of this formula are:

- h/p not greater than 2.5;
- h not less than 0.03 metres;
- b not less than 0.15 metres;
- p not less than 0.1 metres;
- either (B-b)/2 = 0 (weir full width of channel) or
  (B-b)/2 is not less than 0.1 metres (concentrated weir).

As in the case of V-notch weirs, the location of the head-measurement section will be satisfactory if it is at a distance equal to 4-5 times the maximum anticipated head (4-5 h,,) upstream from the weir.

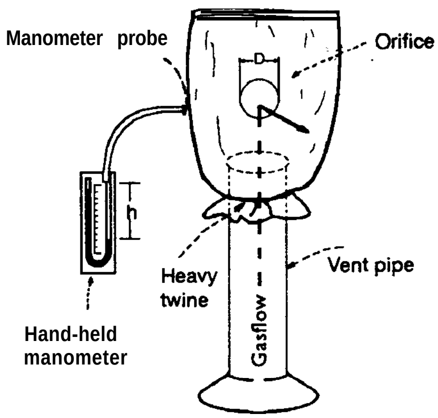
Gas Flow Measurements

In the course of gathering gas flow data for environmental control or a waste audit, flow measuring equipment is often lacking, or the velocity of the gaseous emission is too low for measurement. Even when the velocity is high enough for meter methods, the geometry of the system may make the measurement difficult or subject to error. Consequently, a method is needed for a quick and fairly accurate measurement of gas flow, that can be operated without the use of expensive or time-consuming installations.

In most cases the following method will work (or serve as a valid double-check) if only the gas can be made to flow through an accessible open-ended pipe or duct; it has been developed by the Chesapeake Corporation, Virginia, USA.

A plastic bag with a hole cut in it is placed over the end of the pipe or duct, causing a small resistance to the flow, depending on the size of the hole. Hence, a manometer reading of the pressure drop across the bag orifice accomplishes the purpose of an ordinary orifice. A diagram of the bag orifice is shown in Figure C.

Figure C: Measuring Gaseous Emissions Through a Vent Using a Bag Orifice



Since compressibility can be ignored for small pressure drops, the general orifice equation applies:

$$Q = KA\sqrt{2gh}$$

where Q = gas flow
- g = the acceleration due to gravity
- A = the orifice area
- h = the pressure drop
- K = the discharge coefficient including the velocity-of-approach factor

Where the bag size is large relative to the orifice diameter, the velocity-of-approach factor can be taken as 1.0. Experiments with different bag thicknesses, flow rates and air densities have then shown that the orifice equation can be rewritten, independently of bag thickness.

The simplified formula is as follows:

$$Q = 0.00257\, D^2 \sqrt{h/p}$$

where Q = gas flow in litres per second (to within +/- 4%)
D = the orifice diameter in millimetres
h = the pressure drop in millimetres
p = the gas density at the gas temperature *in* grammes per litre

In selecting a suitable orifice size, a pressure drop of 25-100 mm water gauge should be sought. Less than 25 mm is difficult to measure, and greater than 100 mm may make the bag slip off the pipe. If a rough estimate of the gas flow is known, the hole diameter (mm), necessary to produce a pressure drop of 63 mm, is approximately:

$$D = 7.65 \sqrt{Q}$$

Several features of the design can minimise error. These are as follows.

- The position of the manometer probe should project slightly through the bag wall, so that the axes of the vent pipe, the bag orifice and the probe end are all perpendicular (ref. Figure C), and so that a true indication of static pressure *can* be obtained.

- The bag should be large enough to minimise the effects of approach velocity and to prevent flapping or tearing.

- The orifice diameter should be measured during operation, so as to obtain true operating dimensions; if stretching causes an elliptical orifice, the area should be based on the product of the major and minor axes.

- Thin-walled bags, high temperatures and high velocities should be avoided since fluting outward of the orifice edges will tend to occur; when pronounced, the effect would be to increase the discharge coefficient as the shape of the orifice approaches that of a nozzle.

Finally, when members of the waste audit team make a bag orifice measurement, it is important to ensure that adequate steps are taken to prevent burns or fumigation.

APPENDIX 2: GLOSSARY

BOD_5: biochemical oxygen demand; a measure of the quantity of dissolved oxygen consumed by microorganisms as result of breakdown of biodegradable organic constituents. The standard test is carried out at 20°C over a 5-day period.

By-Product: a secondary *or* incidental product of a manufacturing process.

Catalyst: a substance that increases the rate of a chemical reaction without itself undergoing any permanent change.

COD: chemical oxygen demand; a measure of the quantity of dissolved oxygen consumed during chemical oxidation of wastewater with potassium dichromate.

Counter-Current Rinsing: the introduction of water or a solvent in the opposite direction to the product flow.

Discharge Points: this term refers to the points of exit for wastewater leaving the site. A discharge point may also refer to the place where an incoming tanker discharges a load.

Drainage: refers to the effluent collection system on a site.

Emission: an emission usually refers to fugitive or waste discharges from a process. Emissions are traditionally associated with atmospheric discharges. All such discharges are termed waste within the context of this manual.

Energy Audit: a quantitative account of the energy inputs and outputs to and from a unit operation, a process, a plant or an industry.

Gaseous Emissions: gaseous emissions can be classified into several categories; pure gases or vapours, combinations of gases and solids, combinations of gases and liquids and combinations of gases, liquids and solids. The last three categories are considered to be gaseous emissions because the gas is the carrier for the solid or liquid phase.

Material Balance: a precise account of all the inputs and outputs of a process, based on the law of conservation of mass.

Monitoring Programme: a monitoring programme that describes a timetable for regular sampling and testing of equipment, pumps, products, wastes and general operations to ensure that any deviations from the norm are noticed and can be rectified before problems result.

Operating Costs: also known as variable or running costs; they refer to costs which vary directly with the rate of output, for example labour costs, raw material costs, fuel, power, etc.

Plant: in the context of this manual a plant refers to the factory site. A plant may comprise a number of processes, administration buildings, site waste treatment facilities, site storage facilities, etc.

Pollution: the term describes the presence of harmful, hazardous or detrimental constituents in an environment. A polluted environment describes a state that occurs when the assimilative capacity of the environment is exceeded, resulting in undesirable ecological changes.

Process: in the context of this manual a process is taken to include all operations involved in production. Therefore, a process may begin with receipt of raw materials, storage and handling through process technology to product handling and waste treatment.

Process Flow Diagram (PFD): an essential tool in developing an organised diagrammatic presentation of a process.

Process Inputs: defined as one half of the material balance equation. Inputs to a process may comprise raw materials, water, energy, etc.

Process Outputs: the second half of the material balance equation. Outputs from a process may include a product, a by-product, wastewater, gaseous, liquid and solid wastes, heat, etc.

Product: the useful material output from a process.

Purchasing Records: documentation of invoiced purchases.

Raw Material: a material on which a particular manufacturing process is carried out.

Recovery: waste minimisation can be achieved by recovering valuable material from a waste. For example, cleaning solvent can be recovered from waste oil. Recovery often involves advanced technology such as ultrafiltration or reverse osmosis, although simple settlement can separate oil and water solutions.

Recycle: this term represents an important aspect of waste minimisation. The recycling of wastes within a process often reduces the fresh material input requirement. For example, a solvent used for cleaning engine parts can often be used twice before its cleansing power is exhausted.

Reuse: this is an important consideration in waste minirnisation. If a waste cannot be reduced can it be reused? Reuse represents a secondary line of action in a waste reduction plan.

Segregation: the term segregation refers to isolating hazardous and/or strong wastes from less polluting wastes. For example, uncontaminated surface drainage should be collected in a separate system from contaminated effluents from process areas. If the two wastes are not segregated the volume of wastewater requiring treatment is greater.

Services: in the context of this manual the term services is taken to mean supporting facilities such as a power supply.

Stockpile: refers to solid material such as coal or gravel stored outside on the ground. Stockpiling should comply with legislation to minimise pollution.

Stoichiometric Estimations: mass or concentration calculations based on the exact molecular relationship between constituent elements, taking into consideration atomic and molecular weights.

Unit Operation: a process will comprise a series of unit operations. A unit operation may be pulping or bark stripping in a pulp and paper mill, or distillation in a chemical manufacturing process. Unit operations may be intermittent such as tank washing and steam cleaning.

Waste: in the context of this manual waste is taken as a broad term to cover any non-product discharge from a process. Thus, it describes discharges in the gaseous, liquid and solid phases.

Waste Audit: a waste audit is a thorough account of the wastes from an industry, a plant, a process or a unit operation. A waste audit requires the derivation of a material balance for each scale of operation. The waste audit should result in the identification of wastes, their origin, quantity, composition and their potential for reduction.

Waste Reduction Plan: a waste reduction plan should include a series of scheduled actions to be undertaken with the overall aim of reducing the amount of waste generated.

Wastewater: the aqueous effluents from a process that pass to drain or to storage.

Wet Scrubber: pollution control equipment designed to treat off-gases. A wet scrubber will involve water or a chemical solution to strip certain gases from the gaseous phase before discharge to atmosphere. The wet component may be a once-through scrub or a recirculating solution (with a bleed to drain), the solution strength needing to be topped-up either continuously or periodically.

APPENDIX 3: REFERENCES

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(d) Training Materials

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'Money Down the **Drain,** video by Ontario Waste Management Corporation, Canada.

'Prepare **for Tomorrow',** video for the Prepare Project, NOTA, The Netherlands.

'Pollution Prevention - The Bottom Line', a video by Coastal Video Communications Corporation, USA.

'Pollution Prevention - Reducing Wastes in the Workplace', a video by Coastal Video Communications Corporation, USA.

(e) Information Systems/Bulletins/Newsletters

'Cleaner Production', a biannual newsletter of the Cleaner Production Programme of UNEP/IEO.

International Cleaner Production Information Clearinghouse (ICPIC), an on-line, computer-based information service, UNEP/IEO (see this manual, Appendix 4).

NETT, a network for environmental technology transfer, Ave Louise 207, BOX 10, Brussels, Belgium.

APPENDIX 4: UNEP/IEO CLEANER PRODUCTION PROGRAMME

Recognising the need to prevent pollution and minimise waste, the UNEP Governing Council, in May 1989, took Decision 37 urging UNEP 'to continue its catalytic role to promote, with govem-ments, industry, research organisations and other relevant institutions, the establishment of a network which will allow the transfer of environmental protection technology'.

To implement this decision, the UNEP Industry and Environment Office (IEO) convened a group of 23 senior level experts from various countries and international organisations for advice on the steps to be taken. Their recommendations led to the establishment of the UNEP/IEO Cleaner Production Programme. The Programme links existing sources of information on low and non-waste technologies and promotes cleaner production worldwide through four primiary activities: the International Cleaner Production Clearinghouse (ICPIC), expert working groups, a newsletter, and training activities.

(a) Working Groups

Working Groups are composed of experts who seek to identify cleaner production methods in specific industries (leather-tanning, textile, solvent, metal-finishing and pulp and paper industries), and to identify other experts and some working publications. Groups also cover wider issues, such as data networking, education and policies promoting cleaner production.

(b) Cleaner Production Newsletter

The newsletter includes news and information on cleaner technologies and products, and steps taken by governments and organisations to promote cleaner production.

The newsletter is available in English, French and Spanish.

(c) International Cleaner Production Information CIearighouse - ICPIC

This computer-based information exchange holds over 600 case studies and programme summa-ries, a directory of experts and an extensive bibliography. The system can be accessed by users in more than 100 countries.

(d) Training Activities

In order to support the initiation and development of national cleaner production programmes in different regions of the world UNEP/IEO organises workshops and seminars.

The International Cleaner Production Information Clearighouse - ICPIC

ICPIC contains information on cleaner production methods, and on industries using such technolo-gies. It also acts as a pointer to more detailed sources of information. ICPIC was established in cooperation with the US EPA and is based on their Pollution Prevention Information Exchange System PIES. Data are also contributed by users - either individuals or organisations - of the ICPIC system.

In addition to the main database, the ICPIC system incorporates an interactive message centre where users can leave information and questions for other network users. Also listed are bulletins concerning developments in the field of cleaner production, and subsidiary databases on individual subjects

The main databases contain:

Message Centre
An on-line feature allowing communication with other network members.

Bulletins
Latest news and announcements in the international clean technology community.

Calendar of Events
Listing of upcoming national and international conferences, training seminars and workshops.

Case Studies
A database of technical and programme case studies highlighting industry and waste involved, economic incentives and cost recovery time.

Programme Summaries
Descriptions of national and international programmes on cleaner production, as well as programmes adopted by industries.

On-line Bibliography
A bibliography of hundreds of clean technology documents, with information for ordering.

Directory of Contacts
An automated version of UNEP's Cleaner Production Directory.

ACCESSING ICPIC

Twenty-four hour access is free of charge to individuals and organisations with an Apple, an IBM-compatible computer or a terminal equipped with a modem (2400 baud or less) and appropriate communication software. The system can be connected either through direct telephone lines, or through Telenet data-packet switching network.

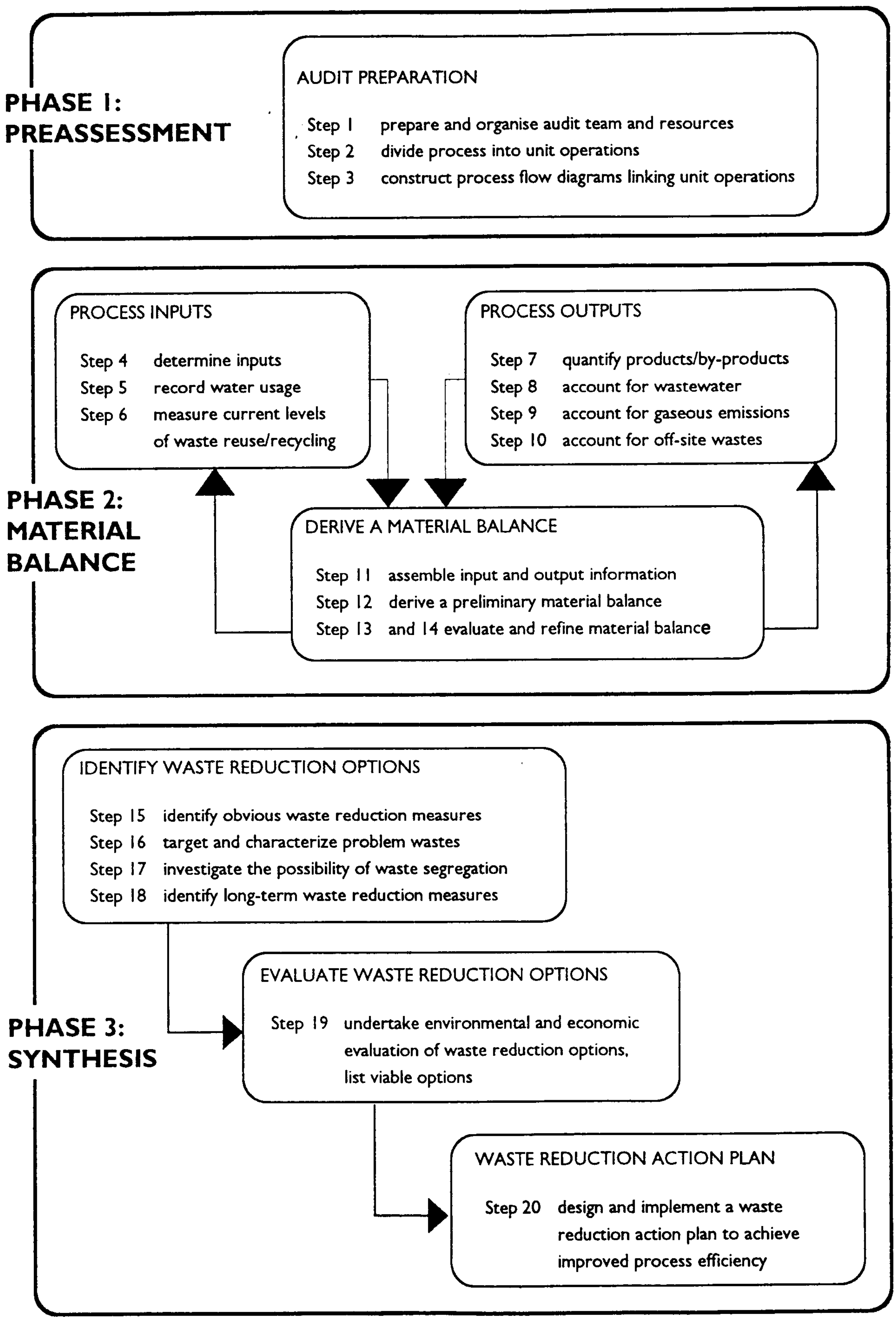
Different ways to access the system:

- via direct dial, set your software to 8 data bits, 1 stop bit, no parity and telephone number to 33-l-40 58 88 78 - omitting country and city code as appropriate if calling from France;
- directly via SPRINTNET (Telenet) by telephoning local Telenet access node and enter access code 762 006 04000,
- if connecting indirectly via another packet switching network, the Telenet and ICPIC access code is 3110 762 006 0400. In the latter case, the software settings may be different and dictated by the network being used.

Contact UNEP/IEO or US-Sprint to find out your local Telenet service address of national-packet switching networks appropriate to access ICPIC. A list of packet-switching networks which **allow** you to connect ICPIC via Telenet is also available in the ICPIC User Guide available from IEO.

Further information from UNEP/IEO by faxing 33-1 40 58 88 74.

QUICK REFERENCE AUDIT GUIDE



UNEP INDUSTRY AND ENVIRONMENT OFFICE

About UNEP/IEO

The Industry and Environment Office (IEO) was established by UNEP in 1975 to bring industry and government together to promote environmentally sound industrial development. The IEO is located in Paris. Its goals are:

(1) to encourage the incorporation of environmental criteria in industrial development plans;
(2) to facilitate the implementation of procedures and principles for the protection of the environment;
(3) to promote the use of safe and 'clean' technologies;
(4) to stimulate the exchange of information and experience throughout the world.

IEO provides access to practical information and develops co-operative on-site action and information exchange backed by regular follow-up and assessment. To promote the transfer of information and the sharing of knowledge and experience, IEO has developed three complementary tools: technical reviews and guidelines, 'Industry and Environment' review; and a technical query-response service. In keeping with its emphasis on technical co-operation, IEO facilitates technology transfer and the implementation of practices to safeguard the environment through promoting awareness and interaction, training activities and diagnostic studies.

Some recent UNEPIIEOpublications

Industry and Environment Review (quarterly), ISSN 03789993. Issues deal with topics such as: hazardous waste management, technological accidents, environmental auditing, industry specific problems, environmental news.

Environmental Aspects of the Metal Fishing Industry - A Technical Guide, Technical Report Series N^0 1, ISBN 92 807 12160,91 p, 1989.

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UNIDO AND THE ENVIRONMENT

As the lead agency for industrial development in the United Nations system, UNIDO is closely involved in the growing international co-operation on industry-related environmental matters. In mid-1990 UNIDO consolidated its various environmental activities under the umbrella of the UNIDO Environment Programme. UNIDO is well placed to transfer new technologies and cleaner production processes to developing countries in such important sectors as leather, cement, textiles, food processing, metal working, iron and steel, and others. Its assistance takes such forms as technical projects, provision of equipment and/or advisory services, investment promotion schemes, human resource development through training and fellowships.

The immediate emphasis of the UNIDO Environment Programme is on: (1) incorporating environmental considerations into the activities of UNIDO; (2) enhancing the awareness of developing countries of the need to include environmental considerations in their industrial plants and policies; and (3) assisting developing countries to prevent and cure the effects of environmental degradation attributable to industry through practical technical assistance projects and other activities such as cleaner technologies and processes, environmental audits, environmental impact assessments, energy efficiency, studies and technical reports, and provision of training and information. Specific support can also be given in design, installation and operation of industrial pollution abatement facilities.

Inquiries about UNIDO's programmes can be channelled through UNDP offices in developing countries, or sent directly to UNIDO headquarters, P 0 Box 300, A-1400 Vienna, Austria.