Reducing water and effluent costs in PCB manufacture
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This Good Practice Guide was produced by Envirowise

Prepared with assistance from:

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Printed Circuit Interconnection Federation (PCIF)
Printed circuit board (PCB) manufacturers use large quantities of water and generate equally large volumes of wastewater. Your company pays twice for this resource - once for the water as a raw material and again for its disposal as effluent. The vast majority of this water is used to rinse the boards between different processing stages.

In addition to ever increasing water supply and trade effluent charges, implementation of the Integrated Pollution Prevention and Control (IPPC) regime will increase the pressure on large PCB manufacturers to reduce water use and effluent generation.

This Good Practice Guide describes a range of cost-effective measures to help companies of all sizes to save money, while continuing to rinse boards just as effectively and without compromising quality standards. On average, PCB manufacturers that adopt a systematic approach to minimising water use can reduce their water and effluent bills by 15 - 20% at little or no cost to the business. If projects with a payback period of up to two years are included, savings of 30% or more can be achieved.

The Guide shows you how to achieve cost savings by adopting a systematic approach to reducing water use and effluent generation. This step-by-step approach is based on the answers to the following questions:

- What are the volumes and costs of your water and effluent?
- How should you go about making improvements?
- How can you:
  - Reduce drag-out from process baths?
  - Reduce rinse water consumption?
  - Recirculate and purify water for re-use?

Industry Examples throughout the Guide describe the cost savings and other benefits already achieved by companies without compromising board quality.
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Why worry about water?

In 2000, Envirowise carried out a survey of water use by UK printed circuit board (PCB) manufacturers with assistance from the Printed Circuit Interconnection Federation (PCIF). This survey revealed that the PCB manufacturing industry uses over 12 million m$^3$ of water each year at a cost of £13 million/year. The vast majority of this water is used to rinse the boards between different processing stages. The rinses are used to clean the boards, terminate chemical reactions and prevent contaminants entering subsequent process baths.

The survey findings are described in Benchmarking Guide (BG279) Benchmarking Water Use in PCB Manufacturing, available free of charge through the Environment and Energy Helpline on freephone 0800 585794.

PCB manufacturers will benefit from taking a closer look at their water use and effluent generation because:
- water and effluent charges are significant and rapidly-rising costs for PCB manufacturers;
- most companies are using more water than they need;
- simple measures can reduce volumes and costs significantly;
- of the requirement to comply with the new Integrated Pollution Prevention and Control (IPPC) Directive (larger companies only).

This Good Practice Guide describes cost-effective measures to help PCB manufacturers to use less water. The practical advice given in the Guide is based on a systematic approach to minimising water use and effluent generation, and is suitable for companies of all sizes.

1.1 Increases in water and effluent costs

Water consumption represents a significant cost for your company. Your company pays twice for this resource - once for the water as a raw material and again for its disposal as trade effluent. The Envirowise survey found that, in 2000, water purchase costs ranged from 46 pence/m$^3$ to £1.34/m$^3$ and effluent discharge costs from 11 pence/m$^3$ to 89 pence/m$^3$.

Water supply costs increased significantly during the 1990s and further steep rises are predicted in the future. For example, average costs in the four years after 1994/95 increased by 18% for water and by 28% for trade effluent$^1$.

There is a strong business case for improving your water efficiency, as water use in PCB manufacturing can be more than 1.5 m$^3$ per m$^2$ of board processed (see Fig 1). Many PCB manufacturers could reduce their water consumption by as much as 50%, which for a small to medium-sized facility can represent a cost saving of over £60 000/year.

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1.2 Are you using more water than is necessary?

Many companies are using - and paying for - more water than they actually need. Excessive use is generally due to:

- Lack of awareness of the volumes used and discharged, and the cost to the business.
- A wide ‘safety margin’ to ensure that board quality requirements are met. This factor is compounded by a lack of awareness of what can be achieved without compromising board quality.

The findings of the Envirowise survey\(^2\) show that water consumption varies greatly, with the least economical sites using up to 20 times more water than the most economical (see Fig 1).

The survey findings show that water efficiency (ie water use per surface area of board processed) is not linked directly to increased throughput (see Fig 2). Sites processing fewer boards were generally found to use more water per surface area of board processed than sites with higher throughputs. However, some of the smaller sites used water as efficiently as the larger sites.

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\(^2\) *Benchmarking Water Use in PCB Manufacturing* (BG279), available free of charge through the Environment and Energy Helpline on freephone 0800 585 794.
1.3 Cost savings from simple measures

On average, PCB manufacturing companies that adopt a systematic approach to minimising water use can reduce their water and effluent bills by 15 - 20% at little or no cost to the business. If projects with a payback period of up to two years are included, savings of 30% or more can be achieved.

The Envirowise survey found that the lower rates of water use achieved by the leading companies were due to:

- implementing simple drag-out reduction and rinse water reduction techniques (see Sections 4 and 5);
- recirculating cooling water and using ion exchange technology to purify wastewaters for re-use (see Section 6).

The company that achieved the highest water efficiency does not use sophisticated recycling technology. In addition to countercurrent rinsing, which is used by 93% of survey respondents, this company uses flow restrictors, rinse timer controls and low flow spray rinses (see Section 5). The survey findings also indicate that facilities that use ion exchange technology have a higher water efficiency than those that do not.

The two respondents with the highest rate of water use per surface area of board processed do not use ion exchange technology, but both stated that they employ countercurrent rinsing plus some other water saving measures. In such cases, unnecessarily high flow rates in the rinse tanks - particularly during periods of non-production - are probably wasting water.

1.4 Complying with IPPC

The IPPC Directive is being implemented in England and Wales by the Pollution Prevention and Control Regulations 2000 (SI 2000/1973)4. Under the IPPC Directive, any installation:

‘Surface treating metals and plastic materials using an electrolytic or chemical process where the aggregated volume of the treatment vats is more than 30 m³’

is classified as a Part A(1) (Part A in Scotland) installation and subject to stringent requirements to reduce its environmental impact. PCB manufacturers whose treatment vats exceed this threshold will need to demonstrate that they use Best Available Techniques (BAT) to control and reduce their water use and effluent generation.

To generate agreement on what constitutes BAT for each industry sector across all EU Member States, BAT reference (BREF) documents are being prepared for each industry sector by the European IPPC Bureau in Seville5. The IPPC Bureau is currently discussing with industry what BAT is in each sector. Work on the BREF document for the surface treatment of metals is planned to start in 2001.

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3 Available free of charge through the Environment and Energy Helpline on freephone 0800 585794.
4 The Regulations are separate for Scotland and Northern Ireland. For more information, contact the Environment and Energy Helpline on freephone 0800 585794.
5 Further information is available from the European IPPC Bureau website (at http://eippcb.jrc.es).
Existing PCB manufacturing facilities classified as Part A(1) installations should apply for a permit under the IPPC Directive by 31 July 2004\(^6\). New Part A(1) PCB installations and existing Part A(1) PCB installations that substantially change their operations must comply with the new Directive immediately. Scottish installations fall under the regime later\(^7\).

1.5 A systematic approach to waste minimisation

Using water more efficiently is just one way of reducing your operating costs. Taking a systematic approach to minimising all types of waste will also add to your company’s bottom line and help you to remain competitive.

The principles underlying good waste minimisation practice are based on the waste hierarchy (see Fig 3). This is the order of preference for reducing waste based on the fact that prevention is better than cure. The higher up the hierarchy that action is taken over waste, the greater the cost savings - so the closer to the first stage of ‘elimination’, the better the savings.

In UK businesses, the cost of waste is typically 4% of turnover - in some companies, it can be as high as 10%. Implementing waste reduction measures as part of a waste minimisation programme can reduce these costs by a quarter whatever the size of the company.

If you would like to know more about saving money through waste minimisation, there is a wealth of free material available from Envirowise. Some useful publications for PCB manufacturers are listed in Section 7.2. This list also contains publications with general advice on how to reduce water use and effluent generation. All Envirowise publications are available free of charge through the Environment and Energy Helpline on freephone 0800 585794 or via the Envirowise web site (www.envirowise.gov.uk).

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\(^6\) The Regulations for England and Wales can be downloaded from the web site (www.legislation.hmso.gov.uk/si). Information relevant for Northern Ireland can be obtained from the Environment and Heritage Service on 028 9025 1477.

\(^7\) The Regulations for Scotland can be downloaded from the web site (www.scotland-legislation.hmso.gov.uk).
1.6 How can this Guide help?

This Guide describes a step-by-step approach to help PCB manufacturers use less water and thus generate less effluent. Improved management of water and effluent will result in cost savings and improve your company’s image.

The Guide’s approach is based on the answers to the following questions:

- What are the volumes and costs of your water and effluent?
- How should you go about making improvements?
- How can you:
  - Reduce drag-out from process baths?
  - Reduce rinse water consumption?
  - Recirculate and purify water for re-use?

Practical advice is provided together with Industry Examples\(^8\) that illustrate how companies have already achieved significant cost savings without compromising quality standards. Table 1 summarises these cost savings and indicates the type of water-saving measures implemented.

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**Table 1 Summary of Industry Examples**

<table>
<thead>
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<th>Company</th>
<th>Benefits</th>
<th>Water-saving measure(s)</th>
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<td>APW Electronics Ltd</td>
<td>Cost savings of over £30 000/year.</td>
<td>Water efficiency measures including low-flow, self-cleaning spray nozzles for rinsing.</td>
</tr>
<tr>
<td>Comelim Circuits Ltd</td>
<td>Reduced drag-out.</td>
<td>Improved basket design.</td>
</tr>
<tr>
<td>DDI-Thomas-Walter Ltd</td>
<td>Rinse water and effluent volumes substantially reduced.</td>
<td>Switch to alternative oxide process.</td>
</tr>
<tr>
<td></td>
<td>Warm rinse water and reduced consumption of mains water.</td>
<td>Re-use of warm cooling water for non-critical rinsing.</td>
</tr>
<tr>
<td>Eurotech Group plc</td>
<td>Water use for rinsing reduced by 80%.</td>
<td>Switch to direct plating.</td>
</tr>
<tr>
<td></td>
<td>Reduced water consumption and wastewater generation.</td>
<td>Countercurrent rinsing.</td>
</tr>
<tr>
<td>Teknacron Circuits Ltd</td>
<td>Cost savings of £34 000/year.</td>
<td>Low-cost water-saving devices.</td>
</tr>
<tr>
<td></td>
<td>Cost savings of £10 000/year.</td>
<td>Wastewater purification using ion exchange.</td>
</tr>
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\(^8\) Wherever possible, examples are taken from PCB manufacturers. Where techniques are identical, some relevant examples are taken from metal finishing companies.
Measuring water use to identify opportunities to save money

Start by looking at recent water and effluent bills to find out how much your company pays annually in water and effluent costs.

The next step is to measure how much and where water is consumed on your site. This will allow you to:

- compare water use against benchmark values (see Section 1.2);
- identify which areas have the highest cost;
- focus your attention on areas with the greatest potential for improvement and cost savings;
- identify potential opportunities to reduce water use.

Simple estimates made as a ‘one-off’ exercise provide a good starting point and can allow you to identify ways of achieving initial savings through the introduction of good housekeeping measures.

A regular measurement routine and a systematic approach to water reduction are needed to sustain your early savings and achieve even more. It may be necessary to install permanent water meters on key parts of the process. The cost of taking regular measurements is usually more than justified by the typical 20 - 30% decrease in water use achieved by such a programme.

Remember: If you don’t measure it, you can’t manage it.

As a minimum, companies are advised to:

- read the water meters fitted to their incoming supply each month (or every four weeks depending on the accounting system used);
- check these readings against their water and effluent bills;
- fit water meters on each process line or on each water inflow point on a process;
- compare actual water use with expected water consumption based on equipment specifications and/or knowledge of the process.

Once you have gathered these data, use the step-by-step procedures described in Good Practice Guide (GG152) Tracking Water Use to Cut Costs and Good Practice Guide (GG67) Cost-effective Water Saving Devices and Practices to:

- construct a water balance to show where your water goes;
- calculate the cost of water use on each process line;
- identify cost-saving opportunities.

The results of water consumption measurements can:

- be used to identify where excessive amounts of water are being used;
- target priority areas for improvement;
act as a reminder to employees of the need to reduce water use;

- supply managers with information to help them ensure improved water efficiency is maintained.

### 2.1 Water meters

Details of different meters and their application are given in Good Practice Guide (GG67) *Cost-effective Water Saving Devices and Practices*. The technologies involved are simple and low-cost; water meters for 25 mm diameter pipes cost about £65 - £75 each (2001 prices). Little staff time is required to read the meters and record the findings.

Using water meters wisely allows you to:

- measure your actual water consumption accurately and thus improve management of water use;
- allocate water use between individual processes;
- detect serious leaks by highlighting discrepancies in water use calculated from meter readings of incoming water and effluent (after allowing for losses during processing).
A step-by-step approach to making improvements

Firstly, aim to reduce water use at source by looking carefully at your operation and processes. Then consider downstream measures and, ultimately, end-of-pipe effluent treatment.

The following Sections describe no-cost and low-cost measures to reduce water use and effluent generation. These involve simple changes to:

- reduce drag-out from process baths (see Section 4);
- reduce rinse water consumption (see Section 5);
- recirculate and purify wastewater for re-use (see Section 6).

The Action Plan in Section 7 summarises the advice given as a checklist of actions for different areas. Contact details for suppliers of equipment mentioned in the Guide are available from the PCIF.

3.1 Reduction at source

Always review your upstream operations before considering any changes to your effluent treatment plant. Small changes in operating procedures or process plant can often reduce the volume and/or strength of the wastewater significantly - thus reducing or even eliminating the need for expensive changes to your effluent treatment plant. Reducing the amount of water used and the effluent produced in the first place will reduce your operating costs and thus increase your profits.

Many water-saving measures require little or no capital investment. Water savings of 15 - 20% can often be achieved without cost, simply through good housekeeping, while limited investment can lead to savings of 20 - 30%.

To reduce water use by 30 - 40%, significant financial outlay is usually required - particularly for those techniques involving end-of-pipe treatment. For these more expensive options, a cost benefit analysis will help you to identify how much money you are likely to save and whether the savings are likely to arise in the short-term, medium-term or long-term. It is also important to consider indirect benefits such as lower environmental impact and compliance with existing and forthcoming legislation.

Before implementing any water-saving measure, carry out trials to ensure that board quality standards will be maintained.
Techniques to reduce drag-out

The first step to reducing waste at source is to reduce drag-out from process solutions. Drag-out and the subsequent contamination of rinse waters is the single largest factor leading to high water consumption and effluent generation in PCB manufacture.

The volume of process solution ‘dragged out’ when the board is removed from the process bath depends on the shape of the boards and the viscosity, surface tension and temperature of the solution. As the temperature of a process solution is increased, its viscosity and surface tension are reduced and, therefore, the drag-out volume is reduced.

Drag-out has costly implications:

- more water is needed to achieve adequate rinsing performance;
- contamination of subsequent process baths diminishes their capability, e.g., when alkaline drag-out enters an acid bath;
- chemicals are wasted, thus increasing the bill for raw materials;
- the additional chemical content of the wastewater increases the cost of operating the effluent treatment plant;
- more filter cake and sludge are generated and require disposal.

All of these factors have a direct impact on your company’s profits.

Although some drag-out will always occur, it is important to reduce this loss wherever possible. By reducing drag-out, less water is required to maintain clean rinses - thus reducing water and effluent costs.

You can reduce drag-out losses by up to 40% using simple no-cost and low-cost procedures.

4.1 Requirements when specifying new process chemistry

The chemical concentration and temperature of the process baths depend on the requirements of the process chemistry; both also have a direct effect on drag-out. For example, a process bath with a concentration of 300 g/litre clearly has drag-out with a 50% higher concentration than one with a concentration of 200 g/litre. Although many companies at present do not calculate the costs of rinsing and effluent treatment, it pays to consider drag-out/rinsing requirements when specifying new process chemistry.

Direct plating reduces rinse water consumption

Switching from electroless copper to direct through-hole plating on a horizontal process line reduced the amount of fresh water used for rinsing operations at Eurotech Group plc by about 80%. Eurotech aims to improve its competitiveness by moving to shorter processes with fewer steps and less chemistry. This will also result in reduced water use for rinsing and reduced loading on the company’s water recirculation systems and effluent treatment plant.
Research to improve the process efficiencies of low concentration solutions is on-going. Contact your chemical supplier to review the solution concentrations required in your process baths. Some larger PCB manufacturers have negotiated arrangements with their chemical suppliers whereby the company pays for its process chemicals as a fixed amount per m² of board produced. With this type of arrangement, chemical suppliers are likely to encourage you to change to a lower concentration process chemistry in order to reduce their costs. PCB manufacturers also benefit from reduced rinse water and effluent treatment requirements.

**Always assess the costs of rinse water and effluent treatment requirements when considering changing to a new process chemistry.**

### Oxide replacement technology reduces water and effluent costs

DDI-Thomas-Walter Ltd achieved substantial reductions in rinse water and effluent volumes following a switch from a black oxide vertical process line to an alternative oxide replacement horizontal process line. The black oxide process involved five main stages: clean, micro-etch, pre-dip, black oxide and reducer. The process produced a fragile board surface that did not lend itself to manufacture on a horizontal process line (the board surface would have been marked by the conveyor rollers). The boards were loaded into baskets to maximise throughput, but this meant that low-flow spray rinsing could not be used. The rinse tanks therefore consumed relatively large quantities of water.

The oxide replacement process is operated in a horizontal process line and involves only three main stages: clean, pre-dip and oxide replacement. The last stage combines the functions previously carried out in the micro-etch, black oxide and reducer stages. A major manufacturing benefit of the horizontal process line is that it can be used to process thinner panels.

Reducing the number of processing steps and associated inter-stage rinsing requirements has significantly reduced rinse water consumption and effluent generation. Furthermore, the use of squeegee rollers (see Section 4.3.1), proximity sensors (see Section 5.2.2) and low-flow spray rinsing (see Section 5.3.2) means that the horizontal process line uses considerably less rinse water and generates less effluent than the previous vertical process line.

### 4.2 Vertical process lines

#### 4.2.1 Optimise board withdrawal rate

The speed with which the board is withdrawn from the process bath has a major impact on drag-out volume. The faster the board is pulled out of the bath, the more drag-out there will be.

- To reduce drag-out, ensure your operating practices provide for smooth, gradual withdrawal of the board.

- The speed of board withdrawal used intuitively by a careful operator on a manual line - about 0.5 metre/second - provides an optimum level of board drainage without compromising the process time. Other operators may require training and management to ensure that they adhere to this withdrawal rate.

- On automatic lines, check that a withdrawal rate of about 0.5 metre/second has been programmed into the programmable logic controller (PLC) unit.
4.2.2 Allow sufficient drip times over process baths

- Allow sufficient drip time above the process bath to ensure effective drainage of the process solution from the boards. However, do not let the drag-out dry on the board as this can cause passivation and may prevent complete rinsing.

- Studies have shown that a drip time of 30 seconds is a maximum level beyond which minimal additional benefit is achieved. However, for most PCB manufacturers a drip time of about 15 seconds provides an optimum level of drainage set against increased process time. If the drip time is again reduced to only eight seconds, the amount of drag-out increases by 50%.

- On manual lines, the need to physically hold the boards above the process bath can make it difficult to extend drip times. There are two ways of overcoming this problem:
  - instruct the operator to balance the basket on the opposite rim of the tank (see Fig 4);
  - install a bar over the process tank on which the operator can hook the board.

![Fig 4 Draining the boards by balancing the basket on the opposite rim of the tank](image)

- Training and management are essential to ensure that operators adhere to the recommended drip times.

- On automatic machines, programme the unit to increase the dwell time above the process bath. You will need to balance the increase in process time against the cost savings associated with reduced process solution waste and lower rinse water consumption. You may be able to make up lost time at other stages in the process.

4.2.3 Reduce entrapment

Significant reductions in drag-out can be achieved by improving the design of the board separators and baskets used to transport boards between process baths on vertical lines.

- Design the equipment used to transport boards to avoid hollows and to minimise the amount of surface area. This will minimise the amount of process solution dragged out of the process bath by the basket and separator.

- Schedule work to ensure that the baskets are as full as possible and thus minimise the number of baskets used.
4.2.4 Agitate board to assist drainage

- A careful operator on a manual line intuitively carries out the agitation actions needed to minimise drag-out. Other operators may require training and management to ensure that they adhere to good practice.

- When processing a single board, ensure the operator gives it a slight shake over the process bath to dislodge drag-out.

- When processing a basket of boards, ensure the operator taps the basket against the side of the process bath.

- Most automatic vertical lines are designed to give smooth handling and are not designed to agitate the board once it has been withdrawn from the process bath. However, making the flight bar come to an abrupt halt when it reaches its highest point will induce sufficient movement. Programme this agitation into all existing process lines and specify it on all new process lines.

4.2.5 Angle boards to assist drainage

- Altering the position of boards as they are withdrawn from a process solution can also reduce drag-out. Studies have shown that boards drawn out at an angle to the solution surface drain faster than those drawn out perpendicular to the solution surface.

- For optimum manual drainage, withdraw boards at an angle of around 15° to the surface of the solution so that one corner hangs low and acts as the drainage point.

- Training and management may be required to ensure that operators do this.

- Design automatic lines to angle boards at 15° when they are fully withdrawn from the process by fitting a rod to the flight bar. The rod should be fitted to point vertically upwards from one side of the flight bar. When the bar reaches its highest point, the rod interferes with the hoist strap and causes one side of the flight bar to tip up. Fit this simple but effective modification to all existing process lines and specify it on all new process lines.
4.3 Horizontal process lines

4.3.1 Use squeegee rollers

- Position two pairs of polyvinylacetate (PVA) squeegee pinch rollers directly after each process spray bath. The spongy surfaces of these squeegee rollers are particularly effective at removing process solution from small holes and hollows on the boards. The squeegee roller sleeves cost about £75 to £100 each (2001 prices). It is important to check that the process chemistry is compatible with the roller material.

4.3.2 Use air knives

- Use an air knife to direct a curtain of low-pressure air against the board as it exits from the bath. This causes the drag-out to be blown back into the process spray bath.

- Use humidified air to ensure that the drag-out does not dry on the boards.

This technique is not widely used in the UK. However, it is expected to become more popular in the future as water and effluent costs continue to increase.
Techniques to reduce rinse water use

Having taken steps to reduce drag-out, the next step is to reduce the quantity of water consumed in rinsing. The key issue in reducing rinse water consumption is the required effectiveness of rinsing. Simply reducing the flow rate of water in a rinse system, without regard to rinsing effectiveness, may cause loss of product quality or contamination of the next bath in the processing sequence.

In most cases, a dilution ratio of 5 000:1 after a 200 g/litre process solution bath is considered to be the maximum level beyond which minimal additional benefit is achieved. In practice, a dilution ratio of 2 000:1 (based on concentration) is commonly used - particularly for inter-stage rinsing where a high rinsing efficiency is often not critical. Warm rinse water provides more effective rinsing than cold water. It is important to consult your chemicals supplier to ensure that adequate rinsing effectiveness is maintained.

Techniques to improve the efficiency of rinse water use can be grouped under three main headings:

- optimising rinse tank performance;
- improving the control of rinse water use;
- using alternative rinsing configurations.

5.1 Optimising rinse tank performance

The key objective for optimal rinse tank performance is to achieve fast and effective removal of process solution resulting from drag-out from the board. When this is achieved, the time necessary for rinsing is reduced and, for a given rinse water flow rate, the concentration of contaminants on the board when it leaves the rinse tank is minimised.

To maintain optimum performance, operate a preventative maintenance programme for process baths and rinse tanks that includes:

- checking and cleaning rollers and spray bars;
- checking and cleaning filters;
- inspection and repair of baskets and racks (focus particularly on loose fixtures that can increase drag-out);
- periodic inspection of tanks, tank linings, pipework and coupling to check for leaks.

5.1.1 Vertical process lines

- When specifying new rinse tanks for a vertical process line, optimise rinsing performance by:
  - selecting the minimum size of rinse tank in which the boards can be rinsed;
  - locating the water inlet and discharge points at opposite positions in the tank to avoid short-circuiting of the water flow;
  - using a flow distributor/eductor to feed the rinse water evenly;
  - using mechanical mixing or other methods of creating turbulence.
- Agitate individual boards in the rinse tank to ensure that process solutions are washed from the board surfaces.
For boards stacked into baskets, and particularly for boards with small holes where process solutions can become trapped, supplement the mechanical agitation or replace by air-enhanced diffusion. However, it is important to check that this is compatible with the process chemistry. For example, do not use air-enhanced diffusion in cases where drag-out surfactants would foam or after tin-lead process baths (where the drag-out would oxidise).

5.1.2 Horizontal process lines

- Optimise the rinsing performance of spray rinse units by:
  - boxing off each spray bar to prevent cross contamination (see Fig 5);
  - separating each spray bar with two pairs of squeegee pinch rollers to reduce drag-out (see Section 4.3.1).
5.2 Improving control of rinse water use

5.2.1 Flow restrictors

A flow restrictor is a washer that flexes under pressure to reduce the diameter of the pipe as the water pressure increases. The restrictor, therefore, maintains a relatively constant flow of water into the spray rinse under variable water pressures.

- Install flow restrictors in-line (see Fig 6) with the rinse tank water inlet pipes at sites where the pressure of the water supplied to spray rinse tanks can fluctuate.

![Fig 6 Flow restrictor fitted in-line with a rinse tank’s water inlet pipe](image)

To provide a constant flow of water irrespective of water pressure, an electroplating company installed meters and pressure-equalising flow restrictors on each spray rinse tank inlet. As the water pressure increases, a rubber controller expands and reduces the size of the orifice within the chamber. Each valve cost £15 - £35 (1995 prices), but in total saved 164 m³/day (a 42% saving in water consumption) and £36 000/year in water supply costs (61 pence/m³ in 1995)\(^\text{10}\). Such valves cost £30 - £65 in 2001.

\(^\text{10}\) For more details, see Case Study (GC22) Simple Measures Restrict Water Costs, available free of charge through the Environment and Energy Helpline on 0800 585794.
5.2.2 Rinse timer controls

Timer controls open the water inlet valve for a pre-set length of time. They can be operated either by pressing a switch (see Fig 7) or by using a photocell or proximity sensor to detect the presence of a board (see Fig 8). Fit a timer control to regulate the amount of dilution water added to the rinse tank.

**Fig 7 Rinse timer operated by a kick switch**

**Fig 8 Water valve on a spray rinse tank operated by a proximity sensor**
Proximity sensors tend to need less regular cleaning than photocell sensors, which are more likely to become blinded by the build-up of process chemicals on sensor surfaces. However, photocells are more able to cope with different surface finishes on the board; for example, proximity sensors can ‘miss’ the board if it contains only small areas of copper.

5.2.3 Conductivity controls

Conductivity controls monitor the concentration of metal ions in the rinse tanks and thus control the amount of dilution water added. As the concentration of metal ions rises, the conductivity of the rinse water rises. When a threshold level is reached, a solenoid valve opens to add the required amount of dilution water.

This technique is not widely used at present because it is not fully proven. Many companies have found that the probes currently available to measure conductivity in the rinse tank quickly become fouled by the process solutions. Calibration of the probes can also be a problem. At some companies, the variation in the conductivity of the incoming water supply can be greater than the threshold conductivity level that the probe is programmed to measure. However, further development should make the technology a viable method for controlling rinse water additions in the future.

5.3 Using alternative rinsing configurations

5.3.1 Countercurrent rinsing

Connecting two or more rinse tanks in a countercurrent arrangement reduces rinse water consumption significantly. This technique is common practice within the industry.

Fresh water flows into the rinse tank farthest from the process bath (ie the one with the lowest concentration of chemicals) and overflows in sequence into the other rinse tanks - even, perhaps, into the process bath as top-up water. With time, the first rinse tank becomes contaminated with drag-out and reaches a stable concentration that is lower than the process solution. The second rinse tank stabilises at a much lower concentration and requires only 2% of the fresh water flow to provide the same final rinsing ratio (eg 2 000:1 based on concentration) compared to using only one rinse tank. However, the total rinsing time is twice as long in order to give sufficient residence time and agitation to ensure complete mixing in the rinse tank.

Additional countercurrent rinse tanks (three-stage, four-stage, etc) further reduce the fresh water flow required to provide the same overall rinsing performance. However, the total time required for rinsing increases and space is needed for the extra rinse tanks. The example opposite shows the cost savings achievable with countercurrent rinsing.

- Incorporate countercurrent arrangements when specifying your requirements for new equipment.
- If possible, fit additional rinse tanks to existing equipment to provide countercurrent rinsing arrangements (see Fig 9).
- Two-stage countercurrent rinsing can reduce fresh water consumption by 98% and, given the space requirements for vertical rinse tanks, represents the optimum arrangement for most vertical process lines.
- Three-stage and four-stage countercurrent rinsing is generally used for spray rinse tanks on horizontal process lines as the tanks are much smaller.
Fig 9  Additional rinse tank fitted to a horizontal process line to provide two-stage countercurrent rinsing

A process bath in a vertical process line produces 2 litres/hour of drag-out and a rinsing performance of 2 000:1 (based on concentration) is required before the next process bath.

A residence time in the rinse tank of one minute is required to achieve complete mixing. To minimise drag-out, the company stipulates a withdrawal time of five seconds and a drainage time of 15 seconds.

The company pays 70 pence/m³ for water and 40 pence/m³ to discharge its effluent to sewer. The factory operates for 16 hours/day and 5 days/week.

Table 2 shows the cost benefits of using two-stage, three-stage and four-stage countercurrent rinsing compared to using single-stage rinsing.

**Example: Using countercurrent rinsing to reduce vertical process line rinse water consumption**

A process bath in a vertical process line produces 2 litres/hour of drag-out and a rinsing performance of 2 000:1 (based on concentration) is required before the next process bath.

A residence time in the rinse tank of one minute is required to achieve complete mixing. To minimise drag-out, the company stipulates a withdrawal time of five seconds and a drainage time of 15 seconds.

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Table 2 shows the cost benefits of using two-stage, three-stage and four-stage countercurrent rinsing compared to using single-stage rinsing.

<table>
<thead>
<tr>
<th>Number of rinse stages</th>
<th>Total time for rinsing</th>
<th>Water use with complete mixing (litres/hour)</th>
<th>Water use compared to single rinse</th>
<th>Cost of water (£/week)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 min 20 sec</td>
<td>4 000</td>
<td>100%</td>
<td>352.00</td>
</tr>
<tr>
<td>2</td>
<td>2 min 40 sec</td>
<td>91</td>
<td>2.3%</td>
<td>8.00</td>
</tr>
<tr>
<td>3</td>
<td>4 min</td>
<td>25</td>
<td>0.6%</td>
<td>2.20</td>
</tr>
<tr>
<td>4</td>
<td>5 min 20 sec</td>
<td>15</td>
<td>0.4%</td>
<td>1.30</td>
</tr>
</tbody>
</table>
5.3.2 Low-flow spray rinsing

Fig 10 shows the two main types of nozzle applicable to board rinsing operations. When selecting a nozzle for this application, you need to consider the flow rate, pressure drop, spray pattern, spray impact and droplet size. PCB manufacturers are, therefore, advised to consult an equipment supplier with an understanding of the technical aspects of their spray application.

- Use low-flow spray nozzles to direct or focus the water on horizontal process lines and vertical lines processing single boards. This will optimise rinsing efficiency and reduce water consumption.

- Use flat spray nozzles (see Fig 10) for spray rinse units on horizontal lines. Position the sprays as close to the board as possible to maximise the spray impact while still having about 30% overlap between spray patterns to ensure uniform coverage of the whole board. For most PCB applications, a nozzle-to-board separation of 75 mm provides optimum spraying performance.

- For spray rinse tanks on vertical lines, install flat spray nozzles nearest to the rim of the tank and full cone spray nozzles (see Fig 10) throughout the remainder of the tank. Installing full cone spray nozzles near the rim of the tank would result in the top half of the spray pattern being redundant when the flight bar was at its lowest point.

- To enable process solution to be flushed through small holes in the board, programme the spray bars to pulse spray alternate sides of the board as it is lowered into the tank, followed by both sides at once when the board is withdrawn from the tank.
Spray technologies have improved in recent years and the latest designs are less susceptible to blockage. New designs are also available which have improved water efficiency. Some nozzle suppliers claim that the best flat spray nozzles currently available can operate at a pressure of 240 kPa (2.4 bar) and use less than 1 litre/minute of water. Conventional flat spray nozzles are designed to operate at a pressure of 300 kPa (3 bar) pressure and use more than 2.5 litres/minute of water.

Typically, a reduction in water use of 20% can be achieved by:

- upgrading spray systems;
- installing and maintaining efficient directional nozzles for rinsing operations.

Replacement of existing full cone spray nozzles with low-flow, self-cleaning nozzles enabled APW Electronics Ltd to reduce the average water flow through the nozzles from 3 litres/minute to about 1.8 litres/minute, ie a 40% reduction in water consumption. Assessment of the board surfaces showed that the new low-flow nozzles provide superior rinsing performance.

APW Electronics also worked closely with the nozzle manufacturers to evaluate the application of new self-cleaning nozzles. The nozzle comprises an outer barrel and an internal insert that is free to move. When the valve supplying the nozzles is opened, the initial water pressure is not sufficient to close the insert and water flushes through the nozzle. As the water pressure in the nozzle reaches the working pressure, the insert closes and forms the water spray. This self-flushing action has virtually eliminated the incidence of nozzle blockages and has resulted in a considerable saving in maintenance time and costs.

5.3.3 Dual-purpose rinsing on vertical process lines

Some PCB manufacturers are able to use dual-purpose rinsing on vertical process lines to reduce the number of rinse tanks they operate. The technique involves using the same static rinse or recirculating spray rinse for rinsing operations following more than one process tank. Its use depends on the compatibility of the process chemistries and is generally applicable only in situations where the quality of rinsing is less critical.

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For details of the water efficiency measures implemented by APW Electronics Ltd, see Case Study (CS286) Copper Recovery Cuts Costs and Waste, available free of charge through the Environment and Energy Helpline on 0800 585794.
Recirculation and re-use techniques

Before considering recirculation and re-use techniques, assess all practical and cost-effective options to reduce the quantity of wastewater generated by your upstream operations.

6.1 Recirculating water for re-use

6.1.1 Cooling water

- Install a closed loop system to recirculate cooling water. In its simplest form, the cooling water is pumped to a storage tank for re-use and the tank is topped up with fresh water using a ‘feed and bleed’ system. Additional cooling of the recirculated water can be achieved by installing an in-line chiller unit.

- Use surplus cooling water from exothermic process baths in non-critical rinsing applications. Most etching processes give out heat and require cooling coils to be fitted to the process baths. Warm rinse water provides more effective rinsing than cold water; using warm cooling water avoids the need to heat fresh water for use in these rinses.

At DDI-Thomas-Walter Ltd, the water from cooling coils fitted to exothermic process baths is re-used for non-critical rinsing. The temperature of the cooling water increases, on average, from 10°C to 20°C on passing through the etch bath cooling system. A thermostatic valve is used to regulate the re-use of cooling water in the rinses; if the etching process is not operating, the valve switches the rinse water supply to mains water.

6.1.2 Water from brushing/surface preparation

- Use a filtration system to remove particulates from water used in brushing and surface preparation activities so that the water can be re-used. This is most commonly carried out using horizontal band filtration, a cyclone system and/or bag filtration (see Fig 11). A ‘feed and bleed’ system is used to top up the filtration system with fresh water.
6.2 Purifying wastewater for re-use

The technologies and treatment processes appropriate to purify wastewater for re-use at a particular site depend on several factors. These include:

- capital and operating costs of the proposed system;
- anticipated cost savings from reduced water use and effluent generation;
- estimated payback period;
- the budget available for the project;
- consent requirements for trade effluent discharge.

Before installing a wastewater treatment plant, it is important to consider first all options to reduce water consumption and effluent generation.

- It is generally easier and cheaper to reduce the quantity and strength of the wastewater at source than to treat the final waste stream.
- If you install a wastewater treatment plant and then reduce water use and effluent generation significantly, the plant is likely to be less cost-effective because it will not be operating under the conditions on which the cost-benefit analysis was based.

If you do not have sufficient expertise on-site to make decisions about wastewater treatment plant, seek professional assistance. Errors in specification or commissioning can be expensive to correct.
6.2.1 Ion exchange

Ion exchange reduces the concentration of ions in the wastewater to a level that enables the treated water to be re-used in the process. Companies can generally reduce their consumption of rinse waters by about 70% by introducing ion exchange and recirculating the treated water back into the process.

An ion exchange system usually has two columns, one containing a cation resin and one containing an anion resin. The metals in the wastewater bind to the cation resin and the salts to anion resin. The resin in each column gradually ‘fills up’ until it reaches capacity.

Ion exchange systems are most effective in treating rinse waters with relatively low total dissolved solids (TDS) and total organic carbon (TOC) levels. High levels of solids can generate high levels of precipitates, which cause the columns to become clogged. Organic materials bind to the resins, reducing their ability to attract metals and salts. A pre-filtration column may, therefore, be included in the system (see Fig 12).

Ion exchange resins require regular regeneration (also known as backwashing). Depending on the type of resin, the column is flushed with a weak acid and/or alkali solution to release the bound metals/salts as a concentrated solution. The columns are stabilised by rinsing with pure water and the ion exchange process is repeated. Depending on the rate of throughput and the size of the ion exchange column, regeneration may be necessary every 6 to 10 hours.

Regeneration takes 2 - 3 hours to complete. Unless this can be fitted in around normal working hours, the system must incorporate either a relief column or holding tanks for the wastewater.

The concentrated solution produced by the regeneration process also requires treatment, as illustrated by the following example.

The proposed concentration ratio is important in deciding whether it is cost-effective to use ion exchange to recycle a particular rinse water or to implement another water-saving option. For example, two-stage countercurrent rinsing will reduce rinse water consumption by 98% and increase the concentration of drag-out in the wastewater from the first stage tank by 50:1. This reduction in effluent volume and increase in concentration is far higher than those achievable using an ion exchange system.
6.2.2 Reverse osmosis

Reverse osmosis (RO) uses a semi-permeable membrane to separate water from dissolved salts. The solutions are forced against the membrane at pressures of 2 000 - 3 000 kPa (20 - 30 bar). The smaller water molecules pass through the membrane to form the permeate, leaving the larger metal and salt molecules behind in a concentrated effluent (the retentate). The purified water is of a high quality and can be re-used in the process.

An RO membrane system could remove all soluble contamination from rinse waters and theoretically enable 100% water recycling. However, the systems are expensive to buy and require filtration (to remove solids) and pH adjustment to avoid problems with membrane fouling. Further development is needed to make RO cost-effective for the purification of wastewater for re-use. However, it is likely to become a viable waste minimisation practice for PCB manufacturers in the longer term.

For more detailed information about reverse osmosis, see Good Practice Guides (GG37) Cost-effective Separation Technologies for Minimising Wastes and Effluents and (GG54) Cost-effective Membrane Technologies for Minimising Wastes and Effluents available free of charge through the Environment and Energy Helpline on 0800 585794.

Example: Ion exchange regeneration requirements

An ion exchange system capable of treating 10 m³/hour of wastewater requires about 500 litres of both anion and cation exchange resins. To treat wastewater with a TDS level of 200 ppm, the resins require regeneration after treating 100 m³ of wastewater. During regeneration, about 10 m³ of a concentrated effluent (or backwash) is produced. The ion exchange system requires regeneration every 10 hours and delivers an overall effluent concentration ratio of 10:1. If the wastewater input had a TDS level of 100 ppm, the system would run for about 20 hours before requiring regeneration. The regeneration effluent is treated as a normal concentrated outflow stream in the facility, usually with metal recovery or precipitation.

Ion exchange reduces water costs

Before Teknacron Circuits Ltd installed a water recycling facility, 80% of the water consumed by its Isle of Wight factory was used to wash boards in static rinse tanks. The contaminated rinse water was then treated in the on-site effluent treatment plant before being discharged to foul sewer.

The company began its campaign to reduce water consumption by installing several low-cost water management devices, eg flow restrictors and timer rinse controls. Implementation of these simple, low-cost measures reduced water use by 55% and reduced the site’s water costs from £60 000/year to £26 000/year.

In 1998, the company installed a state-of-the-art ion exchange plant to purify rinse waters for re-use. The ion exchange plant is equipped with both cation and anion resins, and the water is sufficiently purified to permit it to be recirculated within the process. The system operates by collecting rinse waters in a collection tank to ensure a continuous supply of rinse waters for treatment. The rinse waters are then pumped to a holding tank before being fed into the ion exchange system.

The ion exchange plant cost £55 000 to install and costs about £1 500/year to operate. In the first year of operation, about 60% of the rinse water was recycled and re-used in the process, giving cost savings of £10 000/year and a payback period of 6.5 years.
7.1 Summary of options

Table 3 summarises the advice given in this Guide as an ordered list of actions that you can consider to achieve cost savings by improving your water and effluent management. Please photocopy this checklist to use and give to others.

<table>
<thead>
<tr>
<th>Area</th>
<th>Action</th>
</tr>
</thead>
</table>
| What are your water volumes and costs (see Section 2)? | Examine your most recent water and effluent bills to find out how much water and effluent cost your company per year and per m$^3$.
| | Compare your water use against benchmark values (see Section 1.2). Investigate how much you could reduce your water consumption through improved management and control.
| | Install water meters to measure water use on each process line or on each water inflow point on a process.
| | Use these data to calculate the cost of water on each process line and to identify target areas with the greatest potential for improvement.
| | Compare the water use in target areas with the expected water consumption based on the equipment manufacturer’s recommended levels and/or knowledge of how the process is designed to work.
| | Identify and implement no-cost and low-cost measures, after ensuring that board quality standards will not be adversely affected.
| | Investigate other opportunities for reducing water and effluent costs. Assess which of these are economically, technically and practically feasible. Ensure that board quality standards will be met.
| | Assess the costs of rinse water and effluent treatment requirements when considering changing to a new process chemistry.
| | Consider opportunities to move to shorter processes with fewer steps and less chemistry.
| | Contact your chemical supplier to review the use of low concentration solutions in your process baths.
| | Ensure that operators on manual lines withdraw boards at a rate of about 0.5 metre/second and allow a drip time of 15 seconds above the bath.
| | Programme automatic process lines to withdraw boards at a rate of about 0.5 metre/second and allow a drip time of 15 seconds above the bath.

How can you reduce drag-out when specifying new process chemistry (see Section 4.1)?

How can you reduce drag-out on vertical process lines (see Section 4.2)?
Review the design of board separators and baskets used on vertical process lines to avoid hollows and minimise the surface area.

Ensure that when processing a single board the operator gives it a slight shake to dislodge drag-out and that when processing a basket of boards the operator taps the basket against the side of the process bath.

Incorporate mechanical agitation into automatic vertical lines by programming the flight bar to come to an abrupt halt when it reaches its highest point.

Ensure that operators withdraw boards at an angle of 15° to the surface of the process solution.

In automated systems fit a rod perpendicularly to one side of the flight bar to cause it to tilt at 15° when the flight bar reaches its highest point.

Position two pairs of PVA squeegee pinch rollers directly after each process spray bath.

Consider using air knives to blow drag-out back into the process spray bath.

Optimise rinse tank performance on a vertical line by:
- selecting the minimum size of rinse tank in which the boards can be rinsed;
- locating the water inlet and discharge points at opposite positions in the tank to avoid short-circuiting;
- using a flow distributor/eductor to feed the rinse water evenly;
- using mechanical mixing or other methods of creating turbulence.

For boards stacked into baskets, and particularly for boards which have small holes where process solutions can become trapped, supplement mechanical agitation or replace with air-enhanced diffusion (providing this is compatible with the process chemistry).

For spray rinse units on a horizontal line, box off each spray bar to prevent cross-contamination and separate them by two pairs of squeegee pinch rollers to reduce drag-out.

At sites where the water pressure can fluctuate, install flow restrictors in-line with spray rinse tank water inlet pipes.

As the technology improves, consider using conductivity controls to regulate fresh water additions to rinse tanks.
### Table 3 Checklist of actions to improve your water and effluent management (continued)

<table>
<thead>
<tr>
<th>Area</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>How can you improve rinsing efficiency (see Section 5.3)?</td>
<td><img src="image" alt="Install two-stage countercurrent rinsing on all vertical process lines." /> <img src="image" alt="Install three-stage countercurrent rinsing on all horizontal process lines. Consider the cost benefits of installing four-stage or five-stage countercurrent rinsing on some horizontal process lines." /> <img src="image" alt="Install low-flow spray nozzles on horizontal process lines and vertical process lines processing single boards. For horizontal lines, use flat sprays positioned about 75 mm from the board to provide about 30% overlap between spray patterns. For spray rinse tanks on vertical lines, use flat spray nozzles nearest the rim and full cone spray nozzles throughout the remainder of the tank. These should be programmed to pulse spray alternate sides of the board as it is lowered into the tank." /> <img src="image" alt="Consider using dual-purpose rinsing on vertical process lines." /> <img src="image" alt="Install a closed loop system to recirculate cooling water for re-use." /> <img src="image" alt="Recirculate cooling water from cooling coils fitted to exothermic process baths and re-use for non-critical rinsing." /> <img src="image" alt="Use a filtration system to remove particulates from water used in brushing and surface preparation activities so that the water can be re-used." /> <img src="image" alt="Consider all options to reduce water consumption and effluent generation before examining end-of-pipe measures." /> <img src="image" alt="Install an ion exchange system and recirculate the treated water back into the process." /> <img src="image" alt="As the technology develops and becomes more cost-effective, consider reverse osmosis as a potential alternative to ion exchange." /></td>
</tr>
<tr>
<td>How can you recirculate water for re-use (see Section 6.1)?</td>
<td><img src="image" alt="If necessary, obtain help." /> The Environment and Energy Helpline (0800 585794) can: <img src="image" alt="provide further advice and suggest other sources of information about the techniques described in this Guide;" /> <img src="image" alt="tell you about relevant environmental and other regulations that could affect your operations;" /> <img src="image" alt="send you copies of relevant Envirowise publications;" /> <img src="image" alt="arrange for a Fast Track visit, where a consultant visits your company if you employ fewer than 250 people (at the discretion of the Helpline Manager)." /></td>
</tr>
</tbody>
</table>
7.2 Useful Envirowise publications

Relevant Envirowise publications include:

- **Benchmarking Water Use in PCB Manufacturing** (BG279);
- **Saving Money Through Waste Minimisation: Reducing Water Use** (GG26);
- **Cost-effective Water Saving Devices and Practices** (GG67);
- **Tracking Water Use to Cut Costs** (GG152);
- **Choosing Cost-effective Pollution Control** (GG109);
- **Minimising Chemical and Water Waste in the Metal Finishing Industry** (GG160);
- **Electroplaters Plant Performance Optimisation Tool** (IT265);
- **Waste Minimisation Pays: Five business reasons for reducing waste** (GG125);
- **Cutting Costs and Waste by Reducing Packaging Use** (GG140);
- **Green Efficiency: Running a cost-effective, environmentally aware office** (GG256);
- **Profiting from Less Waste** (ET206) - a summary of the free advice and support material available from Envirowise to help you implement a successful waste minimisation programme;
- **Finding Hidden Profit: 200 Tips for Reducing Waste** (ET30);
- **Waste Mapping: Your route to more profit** (ET219);
- **Waste Account: Count the cost of waste for your business and measure your savings** (ET225);
- **Rinsing and Chemical Recovery System Achieves Large Savings** (NC11) - a Case Study at Goldrite Metal Finishing Ltd;
- **Simple Measures Restrict Water Costs** (GC22) - a Case Study at N T Frost Ltd;
- **Effluent Costs Eliminated by Water Treatment** (GC24) - a Case Study at Amphenol Ltd;
- **Copper Recovery Cuts Costs and Waste** (CS286) - a Case Study at APW Electronics Ltd.

All Envirowise publications are available free of charge through the Environment and Energy Helpline on freephone 0800 585794 or via www.envirowise.gov.uk

7.3 Sources of further assistance

In addition to contacting the Environment and Energy Helpline (freephone 0800 585794), you may find the following contact details useful:

- **PCIF**
  
The Printed Circuit Interconnection Federation (PCIF) is a division of the Federation of the Electronics Industry (FEI) representing the printed circuit board industry, its supply chain, and the Electronic Manufacturing Services (EMS) Industry. The PCIF provides technical support and training whilst representing its members at government level, both UK and European.

  PCIF
  Russell Square House,
  10-12 Russell Square,
  London WC1B 5EE
  Tel: 020 7331 2035
  Fax: 020 7331 2042
  E-mail: pcif-enquiries@pcif.org.uk
  Web site: www.pcif.org.uk
The Environment Agency, SEPA and the EHSNI

Depending on their location, UK businesses can gain environmental advice and information from the Environment Agency, the Scottish Environment Protection Agency (SEPA) or the Environment and Heritage Service in Northern Ireland (EHSNI). Call the Environment Agency’s general enquiries line (England and Wales) on 08459 333111 or SEPA (Scotland) on 0131 273 7258 or the EHSNI (N. Ireland) on 028 9025 1477. The environmental advice and information can include topics such as pollution prevention, water conservation and packaging.
Envirowise - Practical Environmental Advice for Business - is a Government programme that offers free, independent and practical advice to UK businesses to reduce waste at source and increase profits. It is managed by AEA Technology Environment and NPL Management Limited.

Envirowise offers a range of free services including:

- Free advice from Envirowise experts through the Environment and Energy Helpline.
- A variety of publications that provide up-to-date information on waste minimisation issues, methods and successes.
- Free, on-site waste reviews from Envirowise consultants, called Fast Track Visits, that help businesses identify and realise savings.
- Guidance on Waste Minimisation Clubs across the UK that provide a chance for local companies to meet regularly and share best practices in waste minimisation.
- Best practice seminars and practical workshops that offer an ideal way to examine waste minimisation issues and discuss opportunities and methodologies.