GOOD PRACTICE: Proven technology and techniques for profitable environmental improvement
COST-EFFECTIVE VESSEL WASHING

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Effective vessel washing is essential to the production of many speciality chemicals as it has a direct effect on product quality. However, vessel washing can be expensive, eg the total annual washing costs for one five-tonne vessel can range from £12 000 - £35 000. Furthermore, the washing process itself uses between 200 000 and one million litres of wash liquors, much of which leaves the site as effluent or in containers for treatment or disposal.

These financial costs, with the environmental impacts and regulatory requirements associated with vessel washing, therefore provide a strong commercial incentive for companies to improve the effectiveness of their vessel washing operations.

This Good Practice Guide shows that it is possible to cut washing costs by 20 - 50%, improve environmental performance by minimising waste and, at the same time, maintain or even enhance product quality.

The Guide describes tried and tested approaches that have been used successfully by different speciality chemicals manufacturers. All have reduced their vessel washing costs by more than 20%, and individual sites have achieved annual savings in excess of £80 000.

The techniques used involve a combination of common sense, good management practice and cost-effective technical change.

Effective management options range from questioning the need for vessel washing and improving staff awareness, to redesigning the process to minimise the washing requirement. Cost-effective technical options range from the use of simple spray balls and trigger hoses to the recovery and re-use of wash liquors and the installation of automated vessel washing control systems.

The Guide also includes a six-step approach to reviewing current practice and introducing appropriate changes to bring both environmental and cost benefits. This approach is suitable for companies that undertake vessel washing operations both within and outside the speciality chemicals sector.
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1. Introduction

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Appendix: Suppliers of vessel washing technologies and expertise
This Good Practice Guide aims to help companies save money and improve their environmental performance through managing vessel washing operations more effectively and, where appropriate, making technical improvements to the process.

The Guide is of particular relevance to the speciality chemicals sector, where the use of multi-product batch processing requires vessel washing between different product campaigns.

The technical and management options examined in the Guide have already been successfully adopted by companies from different parts of the speciality chemicals sector. Between them, these companies manufacture a broad range of products, including pigments and dyes, agrochemicals, pharmaceutical intermediates, drilling muds and deodorants.

Despite the diversity of products, processes and company sizes, the measures taken to improve vessel washing operations are broadly similar. They include a range of no-cost and low-cost solutions. The same approaches can help many other companies to achieve similar levels of commercial and environmental improvement.

The Guide:

- provides companies, and particularly those staff responsible for vessel washing operations, with practical advice on how to secure lasting improvements;
- demonstrates that cost-effective improvements really can be achieved with the right level of commitment and mostly without the need for major investment;
- is applicable to all washing techniques and wash liquors;
- includes a sequence of worksheets, checklists and real-life industry examples;
- gives advice that will ensure product quality is maintained.

**Effective washing**

In one year, Fine Organics on Teesside reduced the annual vessel washing costs in one section of its plant by more than 35%. Production downtime fell from 1,000 vessel hours to 700 vessel hours, while effluent disposal costs more than halved, from £51/m³ to £24/m³.

These improvements were achieved using a package of measures, including encouraging people to think about what they were doing, how they were doing it and why, logging vessel washing operations, targeting washing on difficult areas, using high pressure washing jets and recovering organic solvent wash liquors. As well as reducing wash liquor volumes and costs, these measures have contributed to product quality by controlling the risk of cross-contamination between different products.

“... better washing, not more washing.”

*Dr Geoff Richardson,*

*Head - Safety, Environment and Quality, Fine Organics*
The speciality chemicals production process uses vessels of a variety of designs for various purposes, including chemical reaction, mixing, blending, heating and storage. Mixing vessels typically range in size from 0.5 - 10 tonnes, while storage vessels are larger, with a typical capacity of 20 - 30 tonnes. They can be fixed or mobile, sealed or able to be opened, and they can incorporate features such as man-ways, heating jackets and internal apparatus such as heating coils, blades and baffles.

Most speciality chemicals companies produce a range of products using batch processes requiring some form of vessel washing between changeover of product.

### 2.1 VESSEL WASHING TECHNIQUES

The actual methods used for vessel washing vary with:

- the composition, viscosity and drying rate of the substance to be removed from the vessel;
- the standards set for product quality;
- vessel design;
- the level of automation involved;
- cost incentives for investment in vessel washing technology.
Common techniques include:

- drain-down;
- water jetting;
- manual scrub and washdown;
- spray balls, nozzles or cleaning robots;
- mechanical brush systems;
- fill-and-flush;
- boil-out;
- disassembly and manual cleaning.

Environmental regulations and cost incentives are driving companies to improve their production planning and product design to minimise the need for vessel washing. These factors also encourage the adoption of vessel washing techniques that reduce production downtime, increase the cleaning efficiency of wash liquor, reduce wash liquor and effluent volumes, and eliminate the release of gaseous emissions. As a result, techniques incorporating spray balls and wash recirculation are replacing less sophisticated fill-and-flush techniques, which take longer to complete and involve greater volumes of wash liquor and effluent.

2.2 VESSEL WASHING LIQUORS

The liquors that can be used for vessel washing include:

- water (aqueous);
- detergents and anti-foamants added to an aqueous wash to increase its effectiveness;
- organic solvents such as acetone, methanol, isopropanol and toluene (either virgin or reclaimed);
- alkaline solutions such as caustic soda;
- oxidising solutions such as sodium hypochlorite or hydrogen peroxide;
- acid solutions such as hydrochloric, sulphuric or acetic acid;
- neutralising agents such as ammonia;
- sterilising agents (particularly for pharmaceutical applications).

However, the choice of liquor for a particular wash will depend on a range of factors, including:

- compatibility of the liquor with the substance to be removed (substances may, for instance, be water-based or organic-solvent-based);
- compatibility of the liquor with the product subsequently entering the vessel;
- wash liquor and effluent disposal costs;
- health and safety issues (eg problems associated with solvent fumes, caustic burns and the risk of static build-up);
- customer standards, which sometimes specify the types of wash liquor to be used.

2.3 THE VALUE OF GOOD VESSEL WASHING PRACTICE

There are strong links between effective vessel washing and improved product quality, environmental performance, health and safety, and reduced cost. These links act as a powerful incentive to companies to minimise waste and improve their management of vessel washing operations.
2.3.1 Product quality

Effective vessel washing is essential to ensure product quality and prevent cross-contamination, particularly where batch plant is used for a range of different products. Furthermore, the number of customers setting high product quality standards is increasing, and these customers may require suppliers to maintain auditable records of their vessel washing operations.

This need to maintain product quality can lead to companies being over-cautious in their vessel washing. However, as this Guide shows, product quality can be protected by focusing on better washing techniques rather than on more washing. The result is often lower wash liquor consumption, reduced effluent generation, shorter downtime periods and fewer labour inputs.

2.3.2 Environmental impact

There are significant environmental impacts associated with vessel washing. These include:

- consumption of water or other wash liquors;
- generation of effluent;
- sludge generation;
- gaseous emissions, including volatile organic compounds (VOCs);
- consumption of energy during the vessel washing process.

Companies can minimise these impacts through the effective management of vessel washing. This will enable them to:

- Meet customer expectations of environmental good practice.
- Meet their own corporate objectives for environmental performance.
- Increase the efficiency of resource use by minimising waste.
- Ensure continued compliance with current environmental legislation concerning effluent discharge, solvent emissions and the disposal of wastes. Notable examples include the Environmental Protection Act (1990) and Integrated Pollution Prevention Control requirements.

The dangers of inadequate vessel washing

A large agricultural producer lost an entire crop of maize when the crop wilted in the field. Thorough investigation revealed that soil improvers applied to the crop had been contaminated with a defoliant. The agrochemical supply company undertook its own internal investigation and found that the contamination had occurred when traces of the defoliant were left in process vessels after a production line switch from defoliants to soil improvers. The incident resulted in costly litigation, paying compensation and the loss of a major customer - a powerful example of the commercial importance of good vessel washing.

Eliminating solvent emissions at source

Shipley Europe Ltd’s Coventry site manufactures organic and inorganic chemicals for use in the production of microchips. Acetone was used to wash the vessels on the organic production line, leading to gaseous emissions. To remove this problem, Shipley:

- introduced a closed-loop vessel washing system incorporating spray balls and wash liquor recirculation;
- replaced the acetone wash liquor with the base solvents used in the organic products.

Together these measures have helped to reduce solvent emissions at source and avoided the need for costly abatement plant, such as thermal oxidisers, which can cost in excess of £500 000.
2.3.3 Health and safety

Although this Guide does not specifically cover health and safety issues\(^1\), companies introducing changes to improve the effectiveness of vessel washing must meet the appropriate health and safety requirements. One important example is the earthing of spray systems to avoid the build-up of static and the increased risk of ignition.

2.3.4 Cost

Vessel washing imposes a range of costs associated with production downtime, labour requirements, the supply of wash liquor and effluent disposal which can be significant.

Based on a range of costs for alternative washing techniques (including fill-and-flush, manual scrub and spray ball) and assuming a twice-weekly aqueous wash (with downtime valued at £200/hour) the annual washing cost for a single five-tonne vessel would be £12 000 - £35 000, and for a ten-tonne vessel £25 000 - £64 000.

Although vessel washing costs may appear small in relation to the high product values that are characteristic of the speciality chemicals sector, they can still be significant to companies seeking to control their cost base and enhance profitability, particularly where sites have a large number of vessels.

Furthermore, the costs of vessel washing are rising. Industrial users have seen a substantial increase in mains water supply charges and trade effluent disposal costs since 1991 (Fig 1). In addition, although the price of organic solvents fluctuates in relation to their availability on the global chemicals market, the costs of disposal and recovery are rising because of stricter environmental controls.

Section 3 examines vessel washing costs in greater detail and provides a template that will allow individual sites to calculate their own costs.

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\(^1\) More information on health and safety requirements is available through the Health and Safety Executive (HSE) InfoLine on 0541 545500.
2.4 THE AIMS AND BENEFITS OF EFFECTIVE VESSEL WASHING MANAGEMENT

2.4.1 Aims

The effective management of vessel washing means better washing rather than more washing. The aims are to:

- reduce the frequency of vessel washing;
- reduce the time taken to wash the vessel;
- use smaller volumes of wash liquor;
- reduce the volume and contamination level of effluent generated;
- eliminate gaseous emissions from wash liquors;
- switch to less expensive and less environmentally harmful washing agents;
- meet health and safety regulations;
- maintain or enhance product quality.

2.4.2 Benefits

Good vessel washing management makes sound commercial sense. Many companies have already achieved significant cost savings and reduced the environmental impact of vessel washing using low-cost or even no-cost solutions. The emphasis in each case has been on good management practice combined with simple and cost-effective technical changes, rather than on complex configurations or technology. Examples of the benefits achieved by individual companies are summarised in Table 1.

An expensive weekend wash

At one large chemical plant operating 24 hours/day, 7 days/week, it is possible for cleaning operations to take place when full staff support facilities are not available, eg analytical labs at weekends. During one weekend clean-down, staff flushed the vessels 13 - 15 times using an expensive solvent. No samples were taken after the usual 5 - 6 flushes to check on remaining levels of contamination, and the clean-out stopped only when all the solvent on site had been used, the storage tanks were empty and the effluent tanks were full. The cost of the solvent used exceeded £20 000.

The cause of this avoidable and expensive incident was poor management of vessel washing. In the absence of full managerial and analytical support, the staff had been understandably cautious, preferring to over-clean rather than risk cross-contamination. Effective washing procedures had not been established and staff did not know when to stop washing. They were also unaware of the costs and environmental implications of their actions. Measures have now been taken to ensure that no similar incident occurs in the future.

Do you know how many of your vessels need to be washed out and how frequently this washing takes place in each case? Have you calculated the volume of wash liquor inputs and effluent output resulting from these vessel washing operations? Do you need to install effluent treatment or emission control systems? Are washing costs regarded as an unavoidable overhead?
<table>
<thead>
<tr>
<th>Company</th>
<th>Reduction in vessel washing costs (%)</th>
<th>Environmental and other benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bristol-Myers Company Ltd</td>
<td>60</td>
<td>60% reduction in vessel washing frequency, wash liquor inputs, effluent volumes and concentration.</td>
</tr>
<tr>
<td>Clariant UK Ltd</td>
<td>More than 80</td>
<td>85% reduction in water used and effluent volumes, plus savings in energy inputs.</td>
</tr>
<tr>
<td>Ellis and Everard</td>
<td>30 - 40</td>
<td>98% reduction in water use on 20-tonne vessels. 70% reduction in downtime.</td>
</tr>
<tr>
<td>Fine Organics</td>
<td>35</td>
<td>Reduction in total volume of wash liquors. 30% reduction in production downtime.</td>
</tr>
<tr>
<td>Hampshire Chemical Ltd</td>
<td>40 - 50</td>
<td>Reduced wash liquor volumes. Reduced effluent volumes.</td>
</tr>
<tr>
<td>Hodgson Specialities Ltd</td>
<td>25 - 30</td>
<td>20% reduction in aqueous wash use. 20% reduction in caustic wash use. 20% reduction in effluent volumes.</td>
</tr>
<tr>
<td>Seal Sands Chemicals Ltd</td>
<td>95</td>
<td>95% reductions in wash liquor inputs and effluent through the use of base solvents that are re-used in the products.</td>
</tr>
<tr>
<td>Shipley Europe Ltd</td>
<td>Saving of cost of gaseous abatement plant (which can cost in excess of £500 000)</td>
<td>Reduced gaseous solvent emissions. Avoided need for capital spend on solvent abatement.</td>
</tr>
</tbody>
</table>

**Table 1** Examples of vessel washing cost savings and benefits achieved

Are you aware of the savings in vessel washing costs that other companies in the speciality chemicals sector have made?  
Has their experience helped you to identify areas where you can make savings?  
Have you already taken steps to reduce vessel washing costs?  
If so, have you achieved savings of at least 20%?
3.1 THE COSTS OF VESSEL WASHING

Many of the costs associated with vessel washing are sometimes hidden or overlooked.

3.1.1 The main cost components

The ‘true’ costs include:

- the costs of plant downtime or lost production;
- labour costs;
- the cost of wash liquors;
- the cost of product losses;
- energy/heating costs;
- effluent treatment and disposal costs;
- the capital costs of abatement equipment.

While these costs obviously vary from site to site, depending on the number and size of the vessels involved and the range of products manufactured, information provided by companies contributing to this Guide has enabled a breakdown of typical costs to be established (Fig 2). This clearly shows production downtime as the largest cost component, followed by labour costs for the staff undertaking vessel washing activities (although the latter may be reduced by automation).

**Production downtime**

The value of production downtime depends on whether or not the plant is operating at full capacity. As many speciality chemicals producers do operate at full capacity, downtime is time which could be spent generating additional product or profit.

For example, if one tonne of product generates £500 profit, and a vessel produces one tonne of product per hour, the lost profit from a two-hour period of downtime for washing a vessel which is operating at capacity is £1 000.
Where companies are unaware of the duration and frequency of vessel washing, this information can be obtained by requiring operators to log vessel washing activities over an appropriate period - eg one month. Fig 3 shows a suggested template for logging production downtime and other aspects of vessel washing. The information should provide a clear picture of site vessel washing practices and indicate the scope for improvement.

<table>
<thead>
<tr>
<th>Name of operator:</th>
<th>Date:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vessel details:</td>
<td>Location:</td>
</tr>
<tr>
<td>Reference:</td>
<td></td>
</tr>
<tr>
<td>Product in vessel:</td>
<td></td>
</tr>
<tr>
<td>Materials used for washing eg water (including type), chemicals, detergent:</td>
<td>Amount of each material used:</td>
</tr>
<tr>
<td>Method of cleaning eg hose, spray ball, other:</td>
<td>Comments:</td>
</tr>
<tr>
<td>Overall duration of washing (hours):</td>
<td>Labour input (man-hour):</td>
</tr>
<tr>
<td>Reason for procedure:</td>
<td>Frequency of washing (per week or per month, as appropriate):</td>
</tr>
<tr>
<td>Materials for disposal:</td>
<td>Disposal location and cost:</td>
</tr>
<tr>
<td>Materials disposed of:</td>
<td>Disposal location:</td>
</tr>
<tr>
<td>Quantity in each case:</td>
<td>Disposal cost per unit:</td>
</tr>
<tr>
<td>Problems encountered:</td>
<td>Suggested improvements:</td>
</tr>
</tbody>
</table>

Fig 3 Template for vessel washing log sheet
**Labour costs**

Operators who undertake vessel washing will be able to detail the labour inputs for different vessel washing activities. The associated costs will depend on the hourly costs of the operators involved. In the speciality chemicals sector these are typically £12 - £25/hour. Details will be available from site managers or management accountants.

**Cost of wash liquors**

The cost of wash liquors can be calculated by multiplying the volumes used in each case by their respective unit costs. Where production records do not provide the necessary volume data, the amount of wash liquor used can be established without installing flow meters by:

- taking a visual reading from the side of the vessel;
- using vessel load cells where these are fitted;
- estimating flow rates from hoses by timing how long a hose takes to fill a vessel of known volume, e.g., a bucket, and then timing hose use during vessel washing.

The cost of organic solvents can be determined from supply invoices less any receipts for solvent recovery.

Indicative unit costs for a range of wash liquors are shown in Table 2.

<table>
<thead>
<tr>
<th>Wash solvent</th>
<th>Cost of wash solvent (£/tonne)</th>
<th>Disposal cost (£/tonne)¹</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aqueous</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Groundwater/surface water</td>
<td>0.30</td>
<td>1 - 3</td>
</tr>
<tr>
<td>Mains water</td>
<td>0.60</td>
<td>1 - 3</td>
</tr>
<tr>
<td>Demineralised/de-ionised water</td>
<td>1.10</td>
<td>1 - 3</td>
</tr>
<tr>
<td>Hydrogen peroxide/caustic</td>
<td>2.50²</td>
<td>50</td>
</tr>
<tr>
<td><strong>Organic solvents (bulk)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tetrahydrofuran (THF)</td>
<td>1 800 - 2 000</td>
<td>100</td>
</tr>
<tr>
<td>Dimethylfuran (DMF)</td>
<td>900 - 1 000</td>
<td>(250)³</td>
</tr>
<tr>
<td>Methyl-iso-butyl-ketone (MIBK)</td>
<td>800 - 900</td>
<td>100</td>
</tr>
<tr>
<td>Isohexane</td>
<td>700 - 800</td>
<td>150</td>
</tr>
<tr>
<td>Industrial methylated spirits (IMS) 99%</td>
<td>600 - 700</td>
<td>100</td>
</tr>
<tr>
<td>Ethyl acetate</td>
<td>600 - 700</td>
<td>100</td>
</tr>
<tr>
<td>Methylene dichloride (MDC)</td>
<td>450 - 550</td>
<td>(150)³</td>
</tr>
<tr>
<td>Methyl-tert-butyl ether (MTBE)</td>
<td>400 - 500</td>
<td>100</td>
</tr>
<tr>
<td>Isopropanol</td>
<td>350 - 450</td>
<td>100</td>
</tr>
<tr>
<td>Acetone</td>
<td>300 - 400</td>
<td>75</td>
</tr>
<tr>
<td>Hexane</td>
<td>250 - 350</td>
<td>100</td>
</tr>
<tr>
<td>Toluene</td>
<td>380 - 400</td>
<td>100</td>
</tr>
<tr>
<td>Methanol</td>
<td>350 - 400</td>
<td>100</td>
</tr>
<tr>
<td>Incineration of non-chlorinated solvents</td>
<td>300 - 400</td>
<td>1250 - 1 700</td>
</tr>
<tr>
<td>Incineration of chlorinated solvents (10% concentration)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

¹ Disposal costs vary according to level of contamination, presence of metals, water content, viscosity, etc.
² Excludes mixing costs.
³ Solvent recovery organisations may pay to receive these materials, so rather than a disposal cost, an income is possible.

**Table 2 Indicative wash liquor and solvent disposal costs**
The cost of product losses

Some product will be lost if washing commences before the vessel has been adequately drained down or if vessel design means that some product is retained in the vessel. The quantities involved can be determined from mass balance calculations, using data from production records. Product losses are typically 0.5 - 2.0% of vessel capacity. The associated cost is made up of the value of the lost product itself plus the cost of any additional effluent treatment and disposal required where the presence of product raises the chemical oxygen demand (COD) of the wash effluent.

Energy/heating costs

The cost of the energy used to heat the wash liquor can be calculated on the basis that an energy input of 1 kWh (costing 5p) raises the temperature of 1 000 litres of water by 1°C. The necessary temperature data should be available from site production records.

Effluent treatment and disposal costs

The costs of wash effluent treatment and disposal vary with the level of contamination and the costs of on-site effluent treatment or off-site treatment/disposal. Typical costs for aqueous effluent in the speciality chemicals sector are in the £1 - £3/m³ range. The disposal of organic solvents costs between £75 - £150/tonne (at least £300/tonne if sent for incineration). Other costs to be taken into account include tankering costs for transporting effluent for disposal (approximately £200/half-day for a 20-tonne tanker) and the costs of sludge disposal to landfill (£30 - £50/tonne, including landfill tax).

In many cases, details of effluent volumes and charges can be obtained from the invoices of water companies and solvent/liquid waste disposal contractors. Table 2 provides indicative unit costs for wash effluent disposal.

The capital costs of abatement equipment

Some companies may also need to take into account the major costs of capital investment in pollution abatement plant for controlling liquid and gaseous emissions from vessel washing.

Where the use of volatile substances such as acetone for vessel washing gives rise to gaseous solvent emissions, companies may need to install emission abatement plant such as condensers, carbon bed adsorption or thermal oxidisers. The capital costs involved are likely to be between £15 000 - £500 000, depending on gas flow volumes, concentration, etc. There are also operating and energy costs. Clearly, if the effective management of vessel washing can minimise these solvent emissions at source, companies will be able to avoid some or all of these substantial capital investments.

Tighter control of permitted discharges means that similar arguments apply to the discharge of some liquid effluents.

Overall costs

Taking account of all the above costs, and the type of washing procedure adopted, an overall cost of washing a single vessel can be calculated. For example, a ten-tonne vessel could be costing a company £64 000/year to wash, as shown in Table 3.

3.1.2 Cost calculations

The effective management of vessel washing can reduce vessel washing costs by 20 - 50%. To achieve this level of saving, companies must first be fully aware of their current annual vessel washing costs.

Fig 4 provides a template that individual companies can use to calculate these costs. Completing this template will help to strengthen the business case for examining, and subsequently introducing, appropriate cost-effective improvements in vessel washing management. The worked example is
based on a five-tonne vessel using a three-cycle fill-and-flush washing procedure, using the same approach as Table 3.

<table>
<thead>
<tr>
<th>Vessel washing techniques</th>
<th>Fill-and-flush</th>
<th>Manual scrub and wash-down</th>
<th>Spray ball with partial recirculation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Five-tonne vessel</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production downtime</td>
<td>0.75 hours</td>
<td>1.5 hours</td>
<td>0.5 hours</td>
</tr>
<tr>
<td>Value of downtime @ £200/hour</td>
<td>£150.00</td>
<td>£300.00</td>
<td>£100.00</td>
</tr>
<tr>
<td>Labour costs @ £15/hour</td>
<td>£11.25</td>
<td>£22.50</td>
<td>£7.50</td>
</tr>
<tr>
<td>Wash liquor costs (water) @ £0.066/1 000 litres</td>
<td>15 000 litres = £9.90</td>
<td>1 000 litres = £0.66</td>
<td>1 500 litres = £0.99</td>
</tr>
<tr>
<td>Wash liquor heating costs @ £0.05/kWh¹</td>
<td>£37.50</td>
<td>£2.50</td>
<td>£3.75</td>
</tr>
<tr>
<td>Lost product (1% of volume)</td>
<td>50 litres = £5.00</td>
<td>50 litres = £5.00</td>
<td>50 litres = £5.00</td>
</tr>
<tr>
<td>Effluent disposal costs @ £3/1 000 litres²</td>
<td>15 050 litres = £45.15</td>
<td>1 050 litres = £3.15</td>
<td>1 550 litres = £4.65</td>
</tr>
<tr>
<td>Total cost/wash</td>
<td>£258.80</td>
<td>£333.81</td>
<td>£121.89</td>
</tr>
<tr>
<td>Number of washes/year</td>
<td>104</td>
<td>104</td>
<td>104</td>
</tr>
<tr>
<td>Annual washing costs</td>
<td>£26 915.20</td>
<td>£34 716.24</td>
<td>£12 676.56</td>
</tr>
</tbody>
</table>

| **Ten-tonne vessel**      |                |                             |                                      |
| Production downtime       | 1.5 hours      | 1.75 hours                  | 1 hour                               |
| Value of downtime @ £200/hour | £300.00   | £350.00                     | £200.00                              |
| Labour costs @ £15/hour   | £22.50         | £26.25                      | £15.00                               |
| Wash liquor costs (water) @ £0.066/1 000 litres | 45 000 litres = £29.70 | 2 330 litres = £1.54 | 3 500 litres = £2.31                |
| Wash liquor heating costs @ £0.05/kWh¹ | £112.50         | £5.83                       | £8.75                                |
| Lost product (1% of volume) | 100 litres = £10.00 | 100 litres = £10.00 | 100 litres = £10.00                  |
| Effluent disposal costs @ £3/1 000 litres² | £135.30        | £7.29                       | £10.80                               |
| Total cost/wash           | £610.00        | £400.91                     | £246.86                              |
| Number of washes/year    | 104            | 104                         | 104                                  |
| Annual washing costs      | £63 440.00     | £41 694.64                  | £25 673.44                           |

¹ To raise the temperature of the wash liquor from 15°C to 65°C.
² Volume of effluent discharged = lost product + wash liquor.

**Table 3 Indicative vessel washing costs**
To raise the temperature of the wash liquor from 15°C to 65°C.

Volume of effluent discharged = lost product + wash liquor.

<table>
<thead>
<tr>
<th>Cost category</th>
<th>Enter data</th>
<th>Calculate</th>
<th>Worked example (five-tonne vessel)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production downtime</td>
<td>...........hrs</td>
<td></td>
<td>0.75 hours</td>
</tr>
<tr>
<td>Value of downtime (£/hour)</td>
<td>£...........</td>
<td></td>
<td>£200.00</td>
</tr>
<tr>
<td>1. Cost of downtime for vessel washing</td>
<td>£...........</td>
<td></td>
<td>£150.00</td>
</tr>
<tr>
<td>Labour input for vessel washing</td>
<td>...........man-hrs</td>
<td></td>
<td>0.75 hours</td>
</tr>
<tr>
<td>Labour costs of operators (£/hour)</td>
<td>£...........</td>
<td></td>
<td>£15.00</td>
</tr>
<tr>
<td>2. Labour costs of vessel washing</td>
<td>£...........</td>
<td></td>
<td>£11.25</td>
</tr>
<tr>
<td>Volume of wash liquor used</td>
<td>...........litres</td>
<td></td>
<td>15 000 litres</td>
</tr>
<tr>
<td>Wash liquor costs (£/1 000 litres)</td>
<td>£...........</td>
<td></td>
<td>£0.66/1 000 litres</td>
</tr>
<tr>
<td>3. Cost of wash liquor used</td>
<td>£...........</td>
<td></td>
<td>£9.90</td>
</tr>
<tr>
<td>Volume of product lost during washing</td>
<td>...........litres</td>
<td></td>
<td>50 litres</td>
</tr>
<tr>
<td>Value of product (£/litre)</td>
<td>£...........</td>
<td></td>
<td>£0.10/litre</td>
</tr>
<tr>
<td>4. Cost of product lost during washing</td>
<td>£...........</td>
<td></td>
<td>£5.00</td>
</tr>
<tr>
<td>5. Wash liquor heating costs @ £0.05/kWh¹</td>
<td>£...........</td>
<td></td>
<td>£37.50</td>
</tr>
<tr>
<td>Effluent volume/wash²</td>
<td>...........litres</td>
<td></td>
<td>15 050 litres</td>
</tr>
<tr>
<td>Effluent disposal costs (£/litre)</td>
<td>£...........</td>
<td></td>
<td>£3.00/1 000 litres</td>
</tr>
<tr>
<td>6. Cost of effluent disposal/wash</td>
<td>£...........</td>
<td></td>
<td>£45.15</td>
</tr>
<tr>
<td>Total costs per wash (1+2+3+4+5+6)</td>
<td>£...........</td>
<td></td>
<td>£258.80</td>
</tr>
<tr>
<td>Number of washes/year</td>
<td>...........</td>
<td></td>
<td>104</td>
</tr>
<tr>
<td>Total annual washing costs</td>
<td>£...........</td>
<td></td>
<td>£26 915.20</td>
</tr>
</tbody>
</table>

¹ To raise the temperature of the wash liquor from 15°C to 65°C.
² Volume of effluent discharged = lost product + wash liquor.

Fig 4 Template for establishing site vessel washing costs
3.2 QUESTIONING THE LEVEL OF WASHING NEEDED

In some companies, vessel washing operations owe more to the ‘we’ve always done it that way’ principle than to a proper understanding of the levels of cleanliness required to avoid contamination of the next product entering the vessel. This increases the risk of over-washing, thereby using more wash liquor and generating more effluent than is necessary to achieve the level of cleanliness required. A structured approach to examining your current processes is detailed in Section 5.

To establish when a washing process has achieved the levels of cleanliness required (allowing for a sufficient margin of safety), companies will need to analyse the contaminant concentrations in the effluent from each wash, using techniques such as gas chromatography and visual inspection. The data obtained, combined with in-house data on the levels of product X that can be tolerated in product Y, should help to establish the need for and level of vessel washing in any particular case.

3.3 ESTABLISHING WASHING PROCEDURES AND GUIDANCE

The next step is to identify the most cost-effective method of meeting vessel washing needs. Consideration can be given to alternative washing techniques, and the performance of each can be recorded in terms of wash duration, labour inputs, wash liquor inputs, gaseous and liquid effluent, and capital and operating costs. It may be appropriate to establish a vessel washing matrix that operators can refer to before initiating a washing process (Fig 5).

Vessel washing instructions help to reduce costs and environmental impact

Hampshire Chemical Ltd, a manufacturer of speciality chemicals, has analysed concentrations of contaminants remaining in the wash liquor. The results were used to identify the wash techniques, durations and volumes necessary for the Company to meet customer quality standards. The plant manager has used the findings to prepare instructions for vessel washing, and these are followed by those who operate the vessel washing process. This approach has avoided unnecessary over-washing, and has contributed to a 40 - 50% reduction in the Company’s vessel washing costs, wash liquor consumption and effluent volumes discharged.
A vessel washing matrix application

The vessel washing procedures established by Ellis and Everard, a manufacturer of a range of aqueous and organic products, depend to a considerable extent on the nature of the next product entering the vessel. The site production team first identified the levels of cleanliness required between different products and translated them into appropriate washing procedures. These procedures were then summarised in a matrix.

Site operators responsible for vessel washing refer to the matrix to identify the appropriate cleaning procedures. This approach helps to ensure the correct level of cleaning, protects product quality and guards against over-cautious washing episodes, eg such as those that can occur when the site manager is on holiday.

Furthermore, whenever there is sufficient production flexibility, the matrix allows the Company to identify product sequences that can minimise the cost of washing operations.

<table>
<thead>
<tr>
<th>Preceding product</th>
<th>Subsequent product$^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td>A</td>
<td>No washing required</td>
</tr>
<tr>
<td>B</td>
<td>2 toluene rinses then flush with product A base solvent</td>
</tr>
<tr>
<td>C</td>
<td>No washing required</td>
</tr>
<tr>
<td>D</td>
<td>No washing required</td>
</tr>
</tbody>
</table>

$^1$ Matrix uses invented washing procedures.

Fig 5 Example of a vessel washing matrix

In some instances, the matrix can be simplified by classifying the washing procedures into categories, eg:

- **Mild** = a quick rinse with cold water
- **Moderate** = 2 cycle cold wash
- **Severe** = 2 cycle hot wash
- **Critical** = 2 cycle hot wash followed by steam drying

The matrix information can be transferred to vessel washing instruction cards (Fig 6). These specify the type and volume of the various wash liquors to be used and the wash duration. They also include tips, eg the need to concentrate on ‘difficult’ areas such as the ‘splash zone’, the inside of vessel lids, baffles and vessel bottoms.
It is most important to involve operators in the preparation of washing instructions. They are the ones who will actually undertake the washing and they must be able to implement the instructions. Once instructions have been prepared they will need to be piloted and operators may require appropriate guidance and staff training.

3.4 IMPROVING STAFF AWARENESS

The effective management of vessel washing depends on improving staff awareness of the environmental and financial implications of these activities. It is the operators who are most familiar with the plant and who ultimately determine the effectiveness of vessel washing operations. If the procedures devised are not practical, then the required levels of cleaning will not be achieved.

Furthermore, raising awareness is an effective way of generating practical ideas for improvement as well as helping to ensure that procedures are followed. Many of the cost-effective changes introduced by the companies contributing to this Guide have been identified by operators.

“Over 50% of our improvements came from staff suggestions.”

Dr Ken Lee, Works Manager, Hampshire Chemical Ltd

Staff motivation can be improved by:

- providing information about the environmental implications and costs of vessel washing and the potential savings of more effective vessel washing management, eg using posters (Fig 7);
- emphasising to staff that their actions directly affect these environmental impacts and costs;
creating an atmosphere in which staff can make suggestions for improvement, eg through brainstorming sessions;

- rewarding staff for good ideas that they have identified;
- providing summaries of performance and improvements achieved, eg using eye-catching graphics (Fig 8).

It is important to promote ownership of the procedures by:

- assigning responsibilities to operators as well as to management;
- brainstorming to identify options and ideas;
- encouraging suggestions, flexibility and innovation.

---

**The costs of vessel washing**

**Q:** Three types of water are used on this site. Do you know what they are?

**A:** Demineralised (DMWO), townswater, borehole.

**Q:** Do you know the supply cost of each type?

**A:** Water from a borehole costs 5p/m³ (1 000 litres).

- Townswater bought from the water company costs 78p/m³.
- DMWO (and townswater further treated on-site) costs 140p/m³.

**Q:** Do you know how much it costs to treat effluent on site?

**A:** Operating costs for our effluent treatment plant are £250 000/year. This is equivalent to £2.50/m³ of water treated.

**Q:** Do you know how much it costs to dispose of our effluent to the water company?

**A:** Our effluent bill from the water company was £180 000 last year. This was for the disposal of 220 000 m³ of effluent and is equivalent to about 82p/m³.

**Q:** Do you know the value of the production that is lost during vessel cleaning?

**A:** Vessel production time is valued at £200/hour. This means that vessel washing operations currently cost us £250 000/year in terms of downtime and lost production.

Our aim is to improve the cost-effectiveness of vessel washing operations by looking at:

- the water supply we choose;
- the amount of water we use and the way in which we use it;
- whether we are cleaning to higher standards than are strictly necessary;
- whether washing equipment will help;
- whether we have minimised the effluent and waste we produce;
- whether we can reduce production downtime during vessel washing.

You can help:

- by coming up with bright ideas for improving the cost-effectiveness of vessel washing;
- completing vessel washing logs to provide the data we need to make improvements;
- asking questions if you are unsure of anything in the vessel washing process;
- identifying areas where we need to provide better vessel washing instruction cards.

---

*Fig 7 Example of a noticeboard campaign for raising staff awareness*
3.5 PRODUCTION SCHEDULING TO REDUCE WASH FREQUENCY

Production scheduling to minimise the need for vessel washing between product batches depends primarily on the experience and knowledge of the production manager. The inherent variability of production patterns for many companies in the speciality chemicals sector means that scheduling cannot always be planned far in advance. In general, the longer the lead time the easier it is to schedule effectively: providing four days’ notice to the production team rather than two can make a significant difference where companies are scheduling to minimise washing.

Companies can improve opportunities for production scheduling in several ways:

- Where there are good communications between producer and customer, it may be possible to obtain long lead times for forward orders and to negotiate product delivery dates. This creates greater flexibility within the production process.
- Good communication between the sales and production departments ensures that the sales department provides as much notice as possible of forthcoming orders, allowing the production department more time to schedule production effectively. This can be achieved through production planning meetings or through the use of internal e-mail and open-access ‘bulletin boards’. Company computer networks can be used very effectively to summarise and disseminate forthcoming contracts, delivery dates and production campaigns. Sales staff need to be made aware of the need for more effective vessel washing management, and of the implications that this has for their own work.
- Although improved scheduling is not necessarily a prime reason for purchasing a new vessel (which can cost more than £1 million), companies have found that having extra vessels can help to reduce the number of wash-outs by allowing them to earmark certain vessels for compatible product runs.

Production scheduling is easier to achieve with own-brand products (as long as accurate information on stock levels is available) or where firms are fortunate enough to have a monopoly over product supply and are able to say to the customer when a batch will be produced.

Producing larger batches over longer periods can also reduce the need for vessel washing. However, inventory costs are higher as more resources are tied up in stock.
3.6 ENHANCING INSPECTION AND MONITORING

Effective management of vessel washing depends on learning from experience. Changes need to be based on accurate data provided by systematic inspection and monitoring, i.e., learning by logging.

Inspection and monitoring is used to identify efficient vessel washing practice. It is also important when developing and piloting new, improved washing procedures. One approach is to analyse the chemical composition, colour, turbidity or viscosity of the wash liquor, as this can indicate when the wash procedure has achieved the required level of cleanliness with a sufficient safety margin.

A number of firms, with particularly high-value products and potentially long vessel wash times, take periodic samples of the wash liquor every 10 - 30 minutes during a two-hour wash cycle. This allows the operator to identify the exact point at which the required level of vessel cleanliness has been achieved. Training is often required before the operators can undertake the necessary analysis effectively. It is also important to have management staff available to advise on questions arising from the monitoring and analysis.

"If you can’t measure something, you can’t hope to control it."

Kathy Rogerson, Quality Assurance and Environmental Manager, Bristol-Myers Company Ltd

3.6.1 Analysing operational variations

One way of encouraging an improvement in the management of vessel washing is to compare the actual performance of each wash operation with the targeted performance. Target levels are set for each variable, and operators then record the actual values (Fig 9). Variations between the two are investigated, and the findings are used as the basis for subsequent improvements. The data can also be used to calculate the actual cost of each wash. The initial actual values provide a baseline against which subsequent improvement can be monitored.
<table>
<thead>
<tr>
<th></th>
<th>Target</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Solvent type</td>
<td>No of flushes</td>
</tr>
<tr>
<td>Solvent use</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total volume:</td>
<td>Total cost:</td>
</tr>
<tr>
<td>Waste generated</td>
<td>Type</td>
<td>Volume</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total volume:</td>
<td>Total cost:</td>
</tr>
<tr>
<td>Duration</td>
<td>Start time:</td>
<td>Finish time:</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Production downtime</td>
<td>Vessel size (tonnes)</td>
<td>Hours/vessel</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total number of hours:</td>
<td>Total cost:</td>
</tr>
<tr>
<td>Parts</td>
<td>£</td>
<td></td>
</tr>
<tr>
<td>Labour</td>
<td>£</td>
<td></td>
</tr>
<tr>
<td>Total cost</td>
<td>£</td>
<td></td>
</tr>
<tr>
<td>Reasons for deviation from target</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.7 PROCESS/PRODUCT REDESIGN TO REDUCE THE NEED FOR VESSEL WASHING

Changes to the production process can sometimes reduce or eliminate the need for vessel washing. Various options include:

- switching to water-based solvents, thereby reducing the need for washing with organic solvents and minimising the risk of gaseous solvent emissions;
- adding colours or odorants to the base product outside the main mixing vessel rather than within the vessel, thereby avoiding the need for washing after each sub-product;
- using the same base solvent in a range of different products to enhance their chemical compatibility, thereby reducing the need for washing between products.

An effective process and product change

Ellis and Everard, a manufacturer of aqueous and organic products, uses a range of dyes in its products. The variety of product colours and perfumes employed increases the need for vessel washing. However, for one antifreeze product, the Company has switched from a powder to a liquid dye. This dye is now added to the product in the road tanker, as the product leaves the site, rather than in the mixing vessel. This reduces the need for vessel washing.

Adapting the process to reduce vessel washing

The various colours and perfumes used by Bristol-Myers Company Ltd, a toiletries manufacturer, in its deodorant products were traditionally added in the mixing vessels. These vessels then had to be washed between batches to prevent colour or perfume contamination. The Company has now refined its production process so that a single, base deodorant product, unperfumed and uncoloured, is manufactured in the vessels: fragrance and colour are added at the bottle filling line. This has reduced washing on the product line by 80% as well as making production more flexible.

Have you examined whether your washing operations are over-specified?

Are your staff aware of the costs and environmental implications of vessel washing?

Have your operators been involved in identifying and introducing improvements to reduce these costs and impacts?

Are your sales staff aware of the implications of their own activities for production scheduling and vessel washing costs?

Have you considered whether the management options described are appropriate to your plant?

Have you implemented those options that are cost-effective?
4 TECHNICAL IMPROVEMENT OPTIONS

As well as good management techniques there are technical developments which can help improve vessel washing practices. These can be adopted mostly without the need for high capital outlay.

4.1 SPRAY NOZZLES/BALLS

Spray nozzles, balls and rotating heads produce dense sprays and jets of wash. Units are available in several configurations: fixed, lance-mounted, rotating in a single plane around a central axis or oscillating through the vertical plane. They offer a relatively simple technique for reducing the amount of wash liquor used and, when fitted with partial recirculation, they can increase washing efficiency by 90%. Spray balls are suitable for vessels ranging in capacity from less than one tonne to more than 20 tonnes. More sophisticated equipment is available for cleaning much larger tanks.

Costs depend on the complexity of the tank cleaning devices and range from less than £100 for a single spray ball to more than £3,000 for a more complex system. However, the savings associated with reduced use of wash liquor and lower effluent volumes result in paybacks that are frequently less than six months.

Several factors need to be taken into account by companies considering the use of spray balls for vessel cleaning:

- whether the requirement is for permanently fixed spray ball(s) or for temporary units installed via the man-way or other inlets;
- the need for careful alignment and movement of spray head(s) to avoid ‘shadows’ caused by internal vessel apparatus such as baffles and mixing shafts;
- the need to target problem areas such as the ‘splash zone’ or ‘scum line’, baffles and the vessel bottom;
- an appropriate vessel design to ensure that it can withstand the impact of the spray jet without leaking - one approach is to test out new pressure systems using water rather than other potentially hazardous solvents;
- the impact of vessel size and shape on wash pressure requirements - ‘odd’ (non-round) shapes and very large vessels require higher-pressure units;
- the need for effective measures to prevent the build-up of static where there is the risk of explosion - options include earthing, using a conductive wash, eliminating all oxygen prior to washing by charging the vessel with nitrogen, and using spray pressures of less than 20 bar;
- the possible need for external expertise from, for example, process engineers, chemical and equipment suppliers, and health and safety specialists;
- the need to incorporate filtration and spray nozzle maintenance to avoid blockages with product residues and to prevent the build-up of scale;
- the impact on energy use - smaller volumes of wash liquor require less energy to heat them.
4.2 RECOVERY AND RE-USE OF WASH LIQUORS

Recovering or re-using vessel washing liquors can bring significant reductions in effluent volumes and discharge costs and can also reduce product loss. Procedures may involve:

- recovering solvent from the wash liquor;
- re-using the wash liquor by returning it to the next product;
- re-using the wash liquor for other purposes, such as general cleaning.

Recovering product from the wash effluent is particularly appropriate in the case of organic compounds and can be achieved using methods such as ‘air stripping’.

Re-using the wash liquors in the subsequent product is appropriate for both aqueous and organic solvent-based washes, as long as the wash liquor is compatible with the second product’s base solvent. It is normal to re-use the second or final rinse: the first rinse is often too highly contaminated.

In practice, re-using the wash liquor for other washing activities (cleaning) or returning it to a subsequent product usually requires storage in drums or tanks until the next product or washing campaign. In some circumstances there may be space constraints and, while it may be possible to use existing tanks to avoid any further investment, storage may prove to be impractical, particularly where relevant product campaigns are intermittent. Furthermore, for some products, wash liquor cooling and the possible danger of microbiological growth increases the risk of product contamination, thereby ruling out this option.
A reliable system for classifying and labelling solvent containers is a prerequisite for wash liquor storage and re-use. The labelling needs to indicate solvent type (e.g., toluene) and product type (e.g., product x). This should avoid the accidental mismatching of solvents and products that can result in cross-contamination.

Any company assessing the costs and benefits of wash liquor re-use will need to take into account possible increases in labour costs and the value of the storage space, as well as benefits such as reduced effluent volumes and waste disposal costs.

### Effective wash liquor recovery and re-use
Ellis and Everard has successfully used the base solvents of its products for vessel washing. The wash solvent is recovered and, after storage, is returned to the product during the next campaign. The Company believes that this practice could eventually be extended to 80% of its product range, reducing by 90% the quantities of solvent leaving the site as trade effluent.

### Re-using the wash-out
Hodgson Specialities Ltd, a manufacturer of speciality liquids, esters and oil field products, uses a caustic alkali wash for cleaning the vessels in which surfactants and drilling muds are manufactured for use in the off-shore oil industry. The wash-out is frequently re-used for cleaning out the bulk storage tanks or for general housekeeping (e.g., for cleaning bunded areas where fatty acid oils have accumulated).

### Cost reduction of 95% by re-using the wash liquor and production scheduling
Seal Sands Chemicals Ltd, Teesside, is a manufacturer of industrial chemicals, and specialised chemicals and intermediates for the pharmaceutical and agrochemical industries. The Company used to wash reaction vessels with methanol, which was then disposed of. A site operator then suggested re-using the methanol in the subsequent crude product after passing it through a filter to remove particulates. With the wash liquor now recovered as product, Seal Sands has effectively reduced vessel downtime from 24 hours to two hours. The vessel line now operates continuously and at capacity. The change has achieved substantial financial savings. It has also significantly reduced both wash liquor use and effluent discharge volumes.

In addition, ongoing dialogue with customers to plan product delivery has allowed the site to reduce the number of its product campaigns from eight/year to four.

The combination of these two approaches has reduced the cost, inputs to and emissions from vessel washing by 95%.

### 4.3 SWITCHING TO ALTERNATIVE WASH LIQUORS
Using an alternative solvent as a wash liquor can have a number of potential benefits. These include:

- A reduction in the cost of washing and effluent disposal;
- Less damage to the environment;
- Improved health and safety.
When selecting an alternative wash liquor, companies may consider the potential of the following options:

- switching from expensive demineralised or treated water to mains or borehole water;
- using a process filtrate or distillate as the wash liquor;
- using different solvents for different stages of a vessel wash;
- re-using solvent flushes until they become ‘saturated’;
- diluting an organic wash solvent with water before the washing process;
- using a neutralising reagent before the washing process to render difficult contaminants or hazardous residues less harmful.

It is important to confirm the suitability of any new wash liquor for the process and product concerned. Fig 10 provides a checklist of the questions that need to be asked.

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is the wash liquor compatible with the substance to be removed (eg water- or organic-solvent-based)?</td>
<td></td>
</tr>
<tr>
<td>Does the wash liquor dissolve all raw materials, intermediates, products and by-products?</td>
<td></td>
</tr>
<tr>
<td>Would any contaminants react with the wash liquor?</td>
<td></td>
</tr>
<tr>
<td>Is the wash liquor compatible with the subsequent products entering the vessel?</td>
<td></td>
</tr>
<tr>
<td>Is the wash liquor compatible with the construction materials of the vessel and its associated equipment (eg pipework)?</td>
<td></td>
</tr>
<tr>
<td>What is the cost of the wash liquor?</td>
<td></td>
</tr>
<tr>
<td>What is the cost of recovering or disposing of the waste wash liquor?</td>
<td></td>
</tr>
<tr>
<td>Are there any health and safety issues (eg fumes, burns, static build-up)?</td>
<td></td>
</tr>
<tr>
<td>When opening vessels after washing, are difficulties likely to occur because of the hazardous nature of the wash liquor (eg chlorinated solvents)?</td>
<td></td>
</tr>
<tr>
<td>By what means will the wash liquor be charged to and discharged from the vessel?</td>
<td></td>
</tr>
<tr>
<td>Will the wash liquor comply with customer standards?</td>
<td></td>
</tr>
</tbody>
</table>

Fig 10 Questions to be asked when assessing the suitability of alternative wash liquors

4.4 ENSURING COMPLETE VESSEL DRAIN-DOWN TO IMPROVE WASH EFFECTIVENESS

The opportunities for using vessel design to enhance drainage are limited. Such opportunities really arise only during the design of a new process or when plant is being refurbished. Furthermore, vessels are designed primarily to enhance mixing or blending performance: vessel washing and drainage are usually only secondary concerns within the design process. Nevertheless, it is important for companies to be aware of good practice so that they can take advantage of opportunities when they arise.
Various aspects of a vessel's design will affect drainage, and therefore the effectiveness of vessel washing. These include:

- Vessel construction materials. A high specification, finely polished stainless steel (e.g., US Grade 316) has a smoother, less pitted surface than lower grade stainless steel (e.g., Grade 304). As a result, it drains down more effectively and is easier to clean. The extra costs of a high grade, highly polished steel vessel can be recovered through reduced product loss and lower effluent concentrations. Furthermore, because the higher grades of steel contain less carbon than the lower grades, they are less prone to corrosion if aqueous washes are used.

- Positioning the drainage valves to assist complete drain-down. The remains of the product or wash liquor can simply drain to buckets placed below the valves and then be poured either into the next batch or into a drum for liquid waste disposal or solvent recovery. Valves need to be locked shut before the vessel is filled again for washing or production purposes.

- Replacing flat-bottomed vessels with cone-shaped units that drain down more effectively. This may require redesign of the agitator.

- Minimising distances between valves and joints to reduce dead-leg problems and improve cleaning performance.

- Designing all new pipes so that they drain down to the lowest point. It may also be possible to reroute existing pipework to ensure effective drain-down.

- Using diaphragm or butterfly valves to avoid localised clogging and deposits.

- Designing vessels to withstand high-pressure cleaning systems (up to 50 bar).

4.5 CLOSED-LOOP AND HIGH-PRESSURE WASH SYSTEMS

4.5.1 Closed-loop wash systems

Closed-loop vessel washing systems minimise the release of gaseous emissions, contain any liquid for disposal, allow recirculation of the solvent to maximise its use, and protect the operator from contact with or inhalation of the wash liquors. The system consists of a wash tank linked by pipework and pumps to spraying devices in the vessel. Wash liquor is returned from the vessel to the wash tank via a filter and is then recirculated back to the vessel. When the wash liquor is ‘saturated’, it is drained from the wash tank into a drum for recovery and re-use or for disposal. Although the costs of a closed-loop wash system range from £10 000 - £40 000, reductions in wash liquor use and avoiding the need for abatement equipment can give significant financial benefits.

Closing the loop

Shipley Europe Ltd’s site near Coventry manufactures chemicals for the production of microchips. The Company has piloted changes to its vessel washing operations that indicate future cost savings of £600 000. The changes involve:

- a closed-loop, recirculating vessel washing system;
- using wash solvents that are compatible with the base solvent of the subsequent products.

The investment required is less than £10 000 - for a new pump, pipework, a new filter and the installation work. The £600 000 saving stems from avoiding the capital cost of a thermal oxidiser and a 10% reduction in effluent costs because of recirculation.
4.5.2 High-pressure wash systems

Increasing wash pressure improves the efficiency of cleaning and helps to reduce the volume of wash liquor required. The equipment available for this purpose ranges from individual pressure guns attached to hoses, which cost less than £100, to larger pressure-wash systems costing up to £20 000. The former provide a low-cost but highly effective means of waste minimisation, reducing wash liquor volumes and increasing the cleaning efficiency of water at standard mains pressure by up to 20 times. However, it is important to remember that pressure guns should not be used with non-aqueous wash solvents because of the risk of static build-up and ignition.

Triggered hoses, which eliminate unattended hose use, are also an effective and inexpensive method of reducing unnecessary water consumption during vessel washing. Typical costs are £20 - £60, and payback periods are frequently less than six months.

The use of brush systems for vessel washing reduces gaseous and liquid effluent problems: it also reduces the risks associated with static build-up and ignition. However, brushes are not suitable for oddly shaped (eg square) or large vessels (greater than 1.5 tonnes).

High pressure, triggered hose for vessel cleaning

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High-pressure cleaning cuts water use and effluent by 88%

Clariant UK Ltd, a manufacturer of dyestuffs, has introduced high-pressure cleaning to replace boil-outs in its dye-manufacturing vessels. This has reduced water use and effluent volumes from 4 m³ to 0.5 m³/batch. Water supply and disposal costs have fallen by nearly £4/batch and the Company is achieving higher standards of cleaning than with previous practice.
4.6 AUTOMATED VESSEL WASHING CONTROL SYSTEMS

Automated vessel washing techniques, particularly when used in enclosed vessels, can incorporate remotely controlled inflow and outflow valves, flow meters, concentration meters and spray balls. Supervisory control and data acquisition (SCADA) systems and programmable logic control linked to PC-based control suites are used to control these automated systems. The systems can be programmed with pre-tested washing procedures for exact washing performance. Automatic monitoring of wash-out concentration levels helps to ensure that the required cleaning standards have been met.

These automated systems offer a number of key advantages:

- they provide repetitive, reliable control of the vessel washing processes;
- they include on-line monitoring facilities which help to ensure that the required levels of cleanliness are met;
- they generate and record data that can be used to monitor performance and costs;
- they provide auditable washing records if required by customers for quality control purposes;
- they can be used for multi-product batch plant.

However, system cost is high - generally in the £35 000 - £100 000 range - and higher still for extensive systems covering many vessels. Furthermore, output data still have to be validated manually at intervals.

Have you considered installing spray nozzles/balls, closed-loop wash systems or high-pressure wash systems to reduce your vessel washing costs?

Have you investigated options for recovering and re-using wash liquors or switching to alternative wash liquors that are less costly and/or less damaging to the environment?

Have you considered adapting the design of your vessels to improve drain-down?

Have you looked into the installation of automated vessel washing control systems?

Have you implemented those options that are cost-effective?
This Section outlines a six-step approach (Fig 11) that you can adapt and develop to achieve the environmental and commercial benefits of effective vessel washing management on your site. Vessel washing is a key area in which companies can achieve cost-effective environmental improvements.

The approach is based on tried and tested methods developed by other companies and is suitable for application throughout the speciality chemicals sector as well as in other industries. Furthermore, it can be incorporated into your company’s environmental management system (eg Eco-Management and Audit Scheme (EMAS) or ISO 14001). Further information on environmental management systems for speciality chemicals companies can be obtained through the Environmental Helpline on 0800 585794.

The approach emphasises the importance of staff involvement and their ‘ownership’ of actions to improve vessel washing performance.

“Management-imposed solutions simply don’t work; operators need to ‘own’ the improvements and see the benefits of their own actions.”

Mr Barry Haynes, Environmental, Health and Safety Manager, Shipley Europe Ltd

5.1 REVIEW CURRENT PRACTICE

Your first step is to acquire a clear understanding of your site’s vessel washing operations by asking the questions: What? Where? Why? How? How often? At what cost? Asking operators to complete vessel washing log sheets (see Section 3.1.1) will provide the necessary data.
Data collected over a period of, say, one month can be entered into a spreadsheet and analysed to identify:

- the costs of vessel washing, broken down into the key cost components;
- the amounts and types of wash liquor used and effluent generated;
- any problems encountered which affect costs and environmental performance;
- suggested solutions.

Use these findings:

- to raise management and staff awareness of the costs and impact of vessel washing;
- to establish key objectives associated with the improvement of vessel washing management which might include:
  - reduced production downtime;
  - lower wash liquor inputs and costs;
  - a reduction in effluent volumes and disposal costs;
  - lower solvent emissions;
  - a reduction in product loss;
  - controlling the risk of cross-contamination.

### 5.2 OBTAIN COMMITMENT TO ACTION

Use the information obtained from your review of current practice to generate a business case for action. You will need to obtain both the commitment of senior management to cost-effective improvements in vessel washing management and the necessary resources (finance and staff) for taking the first steps. Make sure that you highlight the levels of improvement already achieved by companies featured in this Guide. These provide an indication of the savings that could be achieved at your own site. For example, you should be able to reduce vessel washing costs and production downtime by at least 20%.

Having obtained the commitment of senior management, set up a team to carry out the improvements. This team will, ideally, include vessel washing operators, site process engineers, production managers, chemists, health and safety personnel and quality control personnel. Consider involving sales staff: they may not realise the implications of their actions for product scheduling and washing costs.

Make sure that the team is given full responsibility for identifying and implementing the improvements and that it recognises the benefits of its actions. Responsibility will help to provide the sense of ‘ownership’ that is essential for achieving lasting improvement.

### 5.3 REVIEW OPTIONS FOR IMPROVEMENT

Table 4 provides an example of how the various improvement options examined in Sections 3 and 4 of this Guide might be used to meet some of the objectives defined in Section 5.1.

Hold a ‘brainstorming’ session with the team to identify and explore suitable options for meeting your site’s objectives.

Use the same approach to prioritise options, using criteria such as ease of implementation, implications for product quality and estimated cost of implementation. Fig 12 provides a template for assessing the likely effects and benefits of options such as production planning to reduce wash frequency, the introduction of spray ball techniques or wash liquor re-use. Remember that it is less easy to assess the likely effects of some measures, eg those designed to increase staff awareness.
### Aims of Questioning

<table>
<thead>
<tr>
<th>Aims of improving the effectiveness of vessel washing</th>
<th>Management options</th>
<th>Technical options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced wash frequency</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Reduced wash duration</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Reduced wash volumes</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Reduced effluent discharge</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Reduced product loss</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

✓ = Option can help to meet the aim.

Table 4  Matching options and aims
5.4 INVESTIGATE PROMISING OPTIONS

Having identified and prioritised the various options, investigate the most promising in more detail. This will require:

■ careful attention to product quality;
■ visual inspection of the vessel;
■ chemical analysis of the wash liquor to assess the effectiveness of new wash procedures;
■ detailed ‘what if’ analysis to assess the performance of the proposed options across the range of possible operating conditions and scenarios;
■ an investigation into all associated health and safety issues, e.g., ensuring that spraying systems are correctly earthed to prevent the build-up of static charges and the risk of ignition.

Undertake trials with the full involvement of operators, site process engineers, production managers, chemists, health and safety personnel and quality control personnel. It is they who will have to put the new procedures into practice.

Write up instruction cards for all successfully trialled options (Section 3.3 provides an example).

Where the option involves a technical change to the vessel washing process, make plans for staff training.

Set up a procedure for monitoring the continued effectiveness of the option. Actual targets will depend on the company’s objectives for improving its management of vessel washing (Section 5.1).

Other initiatives - programmes to raise staff awareness and production scheduling to reduce the need for washing - can be introduced via phased implementation plans.

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**Fig 12 Template for assessing the effects and benefits of vessel washing improvement options**

<table>
<thead>
<tr>
<th>Current vessel washing practices</th>
<th>Proposed vessel washing practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brief description of practice</td>
<td></td>
</tr>
<tr>
<td>Time taken</td>
<td></td>
</tr>
<tr>
<td>Production downtime</td>
<td></td>
</tr>
<tr>
<td>Labour requirements and costs</td>
<td></td>
</tr>
<tr>
<td>Washing liquor volumes and costs</td>
<td></td>
</tr>
<tr>
<td>Effluent volumes and disposal costs</td>
<td></td>
</tr>
<tr>
<td>Wash liquor heating costs</td>
<td></td>
</tr>
<tr>
<td>Other costs</td>
<td></td>
</tr>
<tr>
<td>Total costs/wash</td>
<td></td>
</tr>
<tr>
<td>Annual washing costs</td>
<td></td>
</tr>
<tr>
<td>(costs/wash x no of washes/year)</td>
<td></td>
</tr>
</tbody>
</table>
5.5 IMPLEMENT SUCCESSFUL OPTIONS

The effective implementation of successful options will involve:

- establishing responsibilities;
- ensuring that washing instructions are understood - with a supervised pilot scheme and training if appropriate;
- ensuring that analytical results and observations are maintained and interpreted correctly by management and operators;
- providing adequate technical support;
- selecting a practicable start-time;
- monitoring.

Don’t lose sight of your original purpose. Abandon the option if washing is not effective.

5.6 PROVIDE FEEDBACK ON PERFORMANCE

Monitor the effectiveness of the changes introduced. Ensure that operators log actual performance against targeted performance using a version of Fig 9 in Section 3.6.1.

Provide site staff with performance reports. These are essential for motivation. Use progress charts (eg Fig 8, Section 3.4) and other forms of communication (eg Fig 7) to summarise the financial and environmental benefits. These are powerful means of communicating the improvements achieved by site personnel.

Once the first round of improvements has been completed (typically six months after project start-up), initiate a repeat review of vessel washing performance and try to identify additional cost-effective improvements that might be introduced in the future. Remember that circumstances change: eg charges may increase and staff will become more experienced. Remember, too, that the management changes that have been implemented at little or no cost will have generated savings. This can help to justify subsequent investment in more capital-intensive measures.

Do you have an environmental management system, and is vessel washing part of that system?
Do you know how much vessel washing costs your company each year?
Is your management committed to improving vessel washing performance in terms of its environmental impact and cost?
Is it clear exactly who is responsible for identifying options for improvement, implementing changes and reporting on subsequent performance?
Can your company afford to ignore the opportunities in this area? Other companies in your sector have already cut their vessel-washing costs by 50% or more while maintaining or enhancing product quality.
Do you know where you can get more information that will help you to improve your performance?
Have you gained management support to explore the potential cost savings of improved vessel washing management?
Have you set a date for action?
5.7 FURTHER HELP

The Environmental Technology Best Practice Programme can provide further help.

- Speciality chemicals manufacturing sites with specific environmental queries can contact the Environmental Helpline on 0800 585794.
- Sites employing fewer than 250 people can ask for a counselling visit to advise on any aspect of waste minimisation, including water use.

The list below is not exhaustive and has been compiled from information currently available to the Environmental Technology Best Practice Programme. The listing of an organisation should not be regarded as an endorsement of its services or products by the Programme. Similarly, the Programme makes no claim for the competence or otherwise of any organisation not listed.

Further advice may be obtained from the Environmental Helpline on 0800 585794.

Breconcherry Ltd
Lower Road Trading Estate
Ledbury
Herefordshire
HR8 2DH
Tel: 01531 636143

Hughes Pumps Ltd
Highfield Works
Spring Gardens
Washington
Pulborough
West Sussex
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Tel: 01903 892358

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CDN Systems Ltd
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Steel Fab Ltd
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Cardiff
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CF2 2XL
Tel: 01222 498212

Silotank
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The Environmental Technology Best Practice Programme is a joint Department of Trade and Industry and Department of the Environment, Transport and the Regions programme. It is managed by AEA Technology plc through ETSU and the National Environmental Technology Centre.

The Programme offers free advice and information for UK businesses and promotes environmental practices that:

- increase profits for UK industry and commerce;
- reduce waste and pollution at source.

To find out more about the Programme please call the Environmental Helpline on freephone 0800 585794. As well as giving information about the Programme, the Helpline has access to a wide range of environmental information. It offers free advice to UK businesses on technical matters, environmental legislation, conferences and promotional seminars. For smaller companies, a free counselling service may be offered at the discretion of the Helpline Manager.

For further information, please contact the Environmental Helpline

0800 585794

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world wide web: http://www.etsu.com/etbpp/