CASE STUDY 1: BEER PRODUCTION

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

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

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

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

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

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

PHASE 1: PREASSESSMENT

Step 1: Audit Focus and Preparation

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

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

With the help of the brewery’s engineering staff, a V-notch weir was then installed in a manhole where all the various effluents combined so that the flow could be monitored continuously using an available ultrasonic level/flow meter and associated chart recorder.
Since an automatic sampler was not readily available, it was decided that composite samples would be taken daily by combing manually-taken samples in proportion to flow. It was also established that the brewery’s laboratory was well-equipped to carry out the required wastewater analyses.

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

- water usage aspects (rather than attempt to obtain a complete materials balance);
- investigate methods of reducing COD and SS loads discharging to drain.

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

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

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

**Table 1: Waste Contributions from Beer Production**

<table>
<thead>
<tr>
<th></th>
<th>Company A</th>
<th>Typical Brewery (a)</th>
<th>Old Brewery (b)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wastewater Flow (m³/m³ beer)</td>
<td>2</td>
<td>7</td>
<td>7.5</td>
</tr>
<tr>
<td>BOD Load (kg/m³ beer)</td>
<td>4.1</td>
<td>4.5</td>
<td>7.5</td>
</tr>
</tbody>
</table>

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

Another factor in favour of Company A is that most of the beer is transported from the brewery in road tankers rather than bottles or kegs, both of which give rise to more waste being produced. This simplifies the brewery operations and makes for more efficient and economical operation in terms of water consumption.
Step 2: Listing Unit Operations

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

The various unit operations were listed as in Table 2.

<table>
<thead>
<tr>
<th>Unit Operation</th>
<th>Brief Functional Description</th>
<th>File No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brewhouse</td>
<td>Processing of malt, hops and sugar to produce ‘wort’</td>
<td>1</td>
</tr>
<tr>
<td>Fermentation</td>
<td>Fermentation of chilled ‘wort’</td>
<td>2</td>
</tr>
<tr>
<td>Product Treatment</td>
<td>Centrifugation, filtration, carbonation, colouring and final polishing and pasteurising</td>
<td>3</td>
</tr>
<tr>
<td>Dispatch</td>
<td>Bottling, kegging and bulk tanker filling</td>
<td>4</td>
</tr>
</tbody>
</table>

Step 3: Constructing Process Flow Diagrams

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

Once all the unit operations had been identified and described, the audit team proceeded to gather data on water usage, wastewater output and waste recovery.
Figure 1: General Flow Diagram for the Brewery
Step 4: Determining Inputs

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

Step 5: Recording Water Usage

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

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

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

Step 6: Measuring Current Levels of Waste Reuse/Recycling

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

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

Step 7: Quantifying Process Outputs

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

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

The audit team then proceeded to quantify these outputs.
Step 8: Accounting for Wastewater

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

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

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

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

Step 9: Accounting for Gaseous Emissions

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

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

The audit team also observed that pockets of carbon dioxide in the fermentation areas could cause problems of drowsiness amongst the brewing staff and that improved ventilation would help to ensure their general health and safety.
Step 10: Accounting for Off-Site Wastes

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

Step 11: Assembling Input and Output Information for Unit Operations

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

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

Step 12: Deriving a Preliminary Material Balance for Unit Operations

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

<table>
<thead>
<tr>
<th>Inputs</th>
<th>m³/d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>2,750</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Overall Brewery -Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outputs</td>
</tr>
<tr>
<td>Domestic Sewage</td>
</tr>
<tr>
<td>Product</td>
</tr>
<tr>
<td>Wastewater</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>
Case Study 1: Beer Production

Step 13: Evaluating the Material Balance

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

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

Step 14: Refining the Material Balance

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

The waste audit team then proceeded to build up material balances for all the major unit operations within the brewery. When this work had been completed, they felt that they had gained considerable knowledge about the various production activities, their inputs, outputs, wastes and operational problems.
PHASE 3: SYNTHESIS

Step 15: Examining Obvious Waste Reduction Measures

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

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

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

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

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

a) Brewhouse

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

Study of the flow and analytical data obtained indicated that the Lautertun drain contributed 3.5% of the flow, 23% of the COD and 4% of the SS load. Discussions with the company indicated that it should be possible to store this waste flow for use as make-up water for the subsequent brew and that this should be possible without detriment to brewing standards. A 15 m³ stainless-steel storage tank with associated pumps, valves and pipework would need to be installed with the advantage that the system would:

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

The hot water tank overflow accounted for nearly 9% of the total wastewater flow. Since this water was clean and hot, continual reuse was the obvious possibility. Unfortunately this proved to be impossible owing to the spasmodic production of this water.
proved to be impossible owing to the spasmodic production of this water. As the 75% tank was very large however, it was considered that its inherent balancing capacity could be utilised if the supply for reuse was taken part way down the tank rather than from the overflow when it occurred.

Reuse of this water would be preferable in a process that consumed hot water at approximately the same rate as the 75°C hot water production, that is 150 m³/d. The only process in the brewery which utilised this quantity of hot water was the pasteurising machine which had a water consumption of some 170 m³/d. However, all of this flow was not hot water since a temperature gradient had to be maintained within the pasteuriser to ensure that bottles were not warmed up or cooled down too rapidly.

It was considered that the 75°C hot water should be injected directly into the pasteuriser to replace the heating of cold water to 60°C. In addition, the hot water could be blended with the supply of cold water that already existed to give the required temperature profile throughout the pasteuriser. It was estimated that such a system would enable at least 75 m³ of the excess hot water to be reused each day.

b) Fermentation Cellar

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

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

Gauging Vessels

Possibilities for reducing the pollution load from this source of CIP effluent were limited as no yeast was present which could be filtered out. However, reuse of the relatively-clean final rinse as the initial rinse for the next CIP wash would reduce the effluent flow to drain by a total of 26 m³/d from 8 vessels.

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

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

**Fermentation Tanks**

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

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

**Storage Tanks**

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

**Yeast Recovery Plant**

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

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

Therefore, instead of treating each of the fermentation cellar discharges separately which would be uneconomic, the audit team considered that the proposed filter-press installation for the yeast recovery area should be arranged to filter the initial rinses from fermentation tanks, storage vessels and yeast recovery equipment. This would not only prevent the majority of yeast from flowing to drain but would enable its recovery for resale to a food manufacturer.
In addition, any other liquor containing yeast that had to be dumped to drain, such as the initial drop from the storage tanks when the yeast storage vessels were full, could be filtered and the yeast and beer recovered. The expected increase in flow to the proposed filter press was estimated at 50 m$^3$/d containing 100 kg SS/d, well within the unit’s design capacity.

c) Treatment Cellar

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

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

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

**Step 16: Targetting and Characterizing Problem Wastes**

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

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

<table>
<thead>
<tr>
<th>Unit Operation</th>
<th>Waste Description</th>
<th>Existing Composition</th>
<th>Recommendation</th>
<th>Predicted Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>m³</td>
<td>kg COD</td>
<td>kg SS</td>
</tr>
<tr>
<td>Lautertun</td>
<td>Final run to Drain</td>
<td>60</td>
<td>1392</td>
<td>60</td>
</tr>
<tr>
<td>75°C Hot Water Tank</td>
<td>Overflow</td>
<td>150</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Brewhouse Vessels</td>
<td>Caustic and acidic wash at weekends</td>
<td>36</td>
<td>152</td>
<td>16</td>
</tr>
<tr>
<td>Gauging Vessels</td>
<td>CIP wash</td>
<td>26</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Fermenting Vessels</td>
<td>CIP wash</td>
<td>65</td>
<td>248</td>
<td>166</td>
</tr>
<tr>
<td>Storage Tanks</td>
<td>CIP wash</td>
<td>17</td>
<td>89</td>
<td>13</td>
</tr>
<tr>
<td>Yeast Storage and recovery</td>
<td>CIP wash</td>
<td>2</td>
<td>17</td>
<td>1</td>
</tr>
<tr>
<td>Pasteuriser</td>
<td>Process water</td>
<td>100</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Total: 456 1898 278 129 88 47.2

For flow, COD and SS load savings of 327 m³/d, 1,810 kg COD/d and 230 kg SS/d (ref. Table 3), the predicted reductions on the total wastewater discharges assessed in Step 8 were approximately 19%, 30% and 15% respectively.

Step 17: Segregation

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

The proposals were discussed with the management who, in principle, were in agreement that the various measures put forward were sensible and practicable, subject to the audit team being able to demonstrate that the likely long-term cost savings to be achieved would be appreciable.
Step 18: Developing Long-Term Waste Reduction Options

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

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

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

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

Step 19: Environmental and Economic Evaluation of Waste Reduction Options

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

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

<table>
<thead>
<tr>
<th>Unit Operation</th>
<th>Waste Description</th>
<th>Estimated Current Charges US$/annum</th>
<th>Estimated Reduced Charges US$/annum</th>
<th>Estimated Savings in Charges US$/annum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lautertun</td>
<td>Final run to drain</td>
<td>56,000</td>
<td>0</td>
<td>56,000</td>
</tr>
<tr>
<td>75°C Hot Water Tank</td>
<td>Overflow</td>
<td>7,000</td>
<td>3,500</td>
<td>3,500</td>
</tr>
<tr>
<td>Brewhouse Vessels</td>
<td>Caustic and Acidic Wash at Weekends</td>
<td>7,800</td>
<td>0</td>
<td>7,800</td>
</tr>
<tr>
<td>Gauging Vessels</td>
<td>CIP Wash</td>
<td>1,200</td>
<td>0</td>
<td>1,200</td>
</tr>
<tr>
<td>Fermenting Vessels</td>
<td>CIP Wash</td>
<td>25,000</td>
<td>7,000</td>
<td>18,000</td>
</tr>
<tr>
<td>Storage Tanks</td>
<td>CIP Wash</td>
<td>5,000</td>
<td>1,500</td>
<td>3,500</td>
</tr>
<tr>
<td>Yeast Storage and Recovery</td>
<td>CIP Wash</td>
<td>800</td>
<td>200</td>
<td>600</td>
</tr>
<tr>
<td>Pausteriser</td>
<td>Process Water</td>
<td>4,300</td>
<td>0</td>
<td>4,300</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>109,100</strong></td>
<td><strong>12,200</strong></td>
<td><strong>96,900</strong></td>
</tr>
</tbody>
</table>

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

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

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

The audit team appreciated that in addition to savings in trade effluent charges, there would be other cost benefits which were difficult to quantify during the time-frame of the consultant’s brief but which included costs associated with raw water, energy and the probable elimination of combined wastewater treatment which would otherwise be required to meet discharge consent conditions consistently.
It was also recognised that some capital expenditure would be required to implement the proposed waste reduction programme. It was agreed with the brewery management that this aspect was best costed by their own engineering staff but that since the capital sums involved would be relatively small compared to the company’s capital expenditure budget for the current year, and related to progressive improvements in the brewery production operations, the company would be likely to accept the waste savings proposals on the basis of the significantly reduced trade effluent charge savings alone.

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

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

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

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