GG175
GUIDE

ENVIRONMENTAL
TECHNOLOGY
BEST PRACTICE
PROGRAMME

IMPROVING THE PERFORMANCE OF EFFLUENT TREATMENT PLANT

GOOD PRACTICE: Proven technology and techniques for profitable environmental improvement

IMPROVING THE PERFORMANCE OF EFFLUENT TREATMENT PLANT

This Good Practice Guide was produced by the Environmental Technology Best Practice Programme

Prepared with assistance from:

Hyder Consulting

SUMMARY

Most companies operate effluent treatment plants to reduce the potential for pollution of receiving waters and to comply with discharge consent conditions. Effective management and control of the processes used for effluent treatment will help you to:

- reduce your operating costs and thus increase profits;
- achieve more effective compliance with legislation;
- improve your company's public image.

This Good Practice Guide aims to help companies reduce the costs associated with effluent treatment plant operation by at least 5%. As illustrated by the four Industry Examples at the back of the Guide, some companies have achieved significantly greater cost savings by improving the performance of their effluent treatment plant (ETP). Although the Guide is aimed particularly at the speciality chemicals industry, the advice given is applicable to many other companies operating an effluent treatment plant.

Before reviewing the operation of their ETP, companies are urged to take action to minimise the amount and strength of the effluent created by production processes. Producing less effluent in the first place will reduce the demands made on the ETP and thus save both money and effort.

A thorough understanding of the nature and properties of your company's effluents is essential for cost-effective pollution control. The Guide describes how to characterise your effluent streams and identifies key control parameters. It describes how to improve the performance of the most common treatment processes, including neutralisation, equalisation and activated sludge treatment. Advice on how to reduce sludge management costs is also given.

Improving the performance of the ETP will reduce your site's operating costs and make it easier for your site to comply with its discharge consent conditions. Sites discharging to sewer will also reduce their trade effluent charges.

The five steps to effective effluent management are:

- characterise all effluents produced on-site;
- implement a waste minimisation programme to reduce the volume and strengths of effluents;
- incorporate in-process conditioning and treatment, where appropriate;
- determine and install segregation facilities to tailor treatment options;
- optimise performance of ETP.

CONTENTS

1 WHY OPTIMISE YOUR EFFLUENT TREATMENT PLANT?

To comply with discharge consent conditions and reduce the environmental burden of their discharges, companies often need to modify their processes and/or install an effluent treatment plant (ETP). Effective management of an ETP has a number of benefits, including:

- reduced operating costs;
- improved company image;
- more effective compliance with the law.

This Good Practice Guide emphasises the importance of good effluent analysis and management, and describes how companies can achieve the benefits above by improving the performance of existing on-site effluent treatment plants. Although the Guide is particularly concerned with the control of plants treating effluent from batch production processes in the speciality chemicals industry, the advice given is applicable to other sectors.

The four Industry Examples (see Table 1) on the loose-leaf sheets in the back of this Guide illustrate the cost savings that can be achieved by taking action to improve the performance of your ETP. **Companies that adopt good practice can achieve cost savings of at least 5%, and often considerably more.** For example, BIP Ltd has reduced its ETP operating costs from £260 000/year to £80 000/year and avoided the need for significant capital expenditure on upgrading its existing ETP.

Industry Example	Company	Title
1	BIP Ltd	Internal charging for effluent treatment minimises waste
2	Hickson & Welch	Effluent characterisation highlights benefits of separate treatment
3	Nipa Laboratories	Out-sourcing effluent treatment produces significant benefits
4	Pentagon Chemicals Ltd	Team approach achieves significant reductions in effluent flow and strength

Table 1 Industry Examples

The information given in the Guide, which is of a technical nature, is aimed at plant managers and operators in all sizes of company. The Guide will also be of interest to environmental and production managers, as the production plant is ultimately responsible for determining the amount and characteristics of the effluent to be treated.

1.1 THE PURPOSE OF THIS GUIDE

This Guide seeks to provide guidance that will help plant managers and operators to make the most of their existing treatment facilities. The Guide will help you to:

- understand the need for better effluent control;
- characterise your effluent;
- minimise effluent flow and strength;
- improve the performance and reduce the cost of your existing treatment plant.

For advice on how to select the most appropriate process or effluent treatment plant, see Good Practice Guide (GG109) *Choosing Cost-effective Pollution Control*. This Guide is available free of charge through the Environment and Energy Helpline on 0800 585794.

1.2 THE BENEFITS OF EFFECTIVE EFFLUENT MANAGEMENT

1.2.1 Reduced costs

The true cost of effluent can be over six times greater than the cost of effluent disposal, because it includes:

section 1

- the value of raw materials and product lost in the effluent;
- the costs of lost production due to wasted product;
- the use of water and treatment chemicals;
- the operating costs of pollution control equipment;
- waste disposal costs, including trade effluent charges and pumping costs;
- costs associated with non-compliance with legislation, including fines, legal fees, the cost of remedial work following pollution incidents, staff time and increased insurance premiums;
- loss of potential sales to customers that refuse to trade with a company possessing a poor environmental record.

In addition, the costs of effluent treatment and waste disposal continue to increase. Between 1991 and 1998, average charges to industrial users increased by approximately 70% for trade effluent discharge and by 44% for mains water supply[1]. Waste disposal costs are also increasing as environmental standards become more stringent and the landfill tax increases.

Experience has shown that companies could save typically up to 1% of turnover by implementing a waste minimisation programme.

1.2.2 Improved public image

Public interest in companies' environmental performance has increased significantly in recent years. Poor environmental performance can affect your company by:

- reducing sales opportunities;
- reducing the stock market value of the company;
- increasing advertising and marketing costs to recover from poor public perception;
- increasing the cost of public relations activities.

Stakeholders with direct or indirect interest in your company's environmental performance may include:

- **Customers.** Many retailers and product users now request information on a company's environmental performance. Implementation of environmental management system standards such as ISO 14001 is putting increasing pressure on suppliers to demonstrate responsible manufacturing.
- **Shareholders and investors.** Some large institutional investors have a policy of not investing in companies with a poor environmental record. This could ultimately affect the company share price due to restrictions on potential sales.
- **Employees.** A good environmental record can improve your employees' perception of their workplace, improve morale and increase commitment.
- **Local community.** The general public is now more aware of environmental issues and more likely to complain if they believe a local company is polluting the environment. Public debates take up staff effort and affect how the company is viewed by other stakeholders.

[1] OFWAT 1998/1999: *Report on Tariff Structure and Charges.*

- **Environmental pressure groups and the media.** Negative publicity tarnishes a company's image in the eyes of its stakeholders, even if the criticism later proves to be incorrect. Many companies spend significant amounts of money and staff time on public relations to prevent, or counter, poor reports in the media.

1.2.3 Cost-effective compliance with legislation

Environmental legislation is the main reason why companies operate effluent treatment plants. Table 2 summarises the main environmental legislation affecting effluent discharge by speciality chemicals companies in England and Wales[2]. Companies should also be aware of the regulations and statutory guidance applicable to their processes and operations, eg Integrated Pollution Control Guidance Notes issued by the Environment Agency. Companies discharging trade effluents to sewer must comply with the consent conditions imposed by their local water company/authority and pay trade effluent charges.

Responsible body	Legislation	Coverage
Environment Agency	Environmental Protection Act 1990, Part I: Part A Processes* for Integrated Pollution Control (IPC)	Discharges to controlled waters and sewers
	Environmental Protection Act 1990, Part II: Waste on Land	Duty of Care. Waste management licensing
	Water Resources Act 1991	Discharges to controlled waters
	Water Industry Act 1991	Discharges to sewer of special category effluents
Water companies	Water Industry Act 1991	Discharges to sewers
	Urban Waste Water Directive	Discharges to controlled waters

* As defined by the Environmental Protection (Prescribed Processes and Substances) Regulations 1991 and subsequent amendments.

Table 2 Key environmental legislation affecting effluent discharges by the chemicals industry in England and Wales

1.2.4 Minimise toxic effects

Direct Toxicity Assessment (DTA) is a monitoring tool that attempts to determine the actual effect of an effluent on the receiving water rather than relying on an arbitrary measurement of potential pollution such as biochemical oxygen demand (BOD), chemical oxygen demand (COD) or specific chemical concentrations. The main aim of DTA is to protect the aquatic environment through the reduction of toxic releases.

There is still some debate over the most appropriate technique for measurement. Possible techniques range from measuring the effect of toxic materials on photoluminescent bacteria to tests with living organisms such as algae, crustacea and higher vertebates. A number of demonstration programmes are being undertaken to test the suitability of these methods for a range of effluent types.

DTA is likely to have a significant impact on the management of the effluent treatment process.

> For advice and information about current and forthcoming environmental legislation affecting your company, including DTA, contact the Environment and Energy Helpline on 0800 585794.

[2] For information on environmental legislation applicable in Scotland and Northern Ireland, contact the Environment and Energy Helpline on 0800 585794.

2 REDUCING THE EFFLUENT LOAD

section 2

Waste minimisation will save you money - typically up to 1% of turnover, either as extra profit or in reduced operating costs. In terms of pollution control, it will minimise - or even eliminate - the waste streams requiring treatment.

An effluent treatment plant will cost less to run if the site produces less effluent in the first place. Significant cost savings can be achieved by reducing both the amount and strength of the raw effluent entering the plant. Considering the effluent treatment plant as an integral part of the company's operations, and not just as an end-of-pipe necessity, will help to maximise savings. This approach also offers greater opportunities for chemical and water re-use within the site.

Investigating where and how effluent arises, and its composition, will give you a more detailed understanding of how your process affects the operation of effluent treatment plant. However, the first stage is to take action to reduce the site's water consumption and effluent generation. Don't forget that effluent can be lost product or raw materials.

A waste minimisation programme to reduce waste and prevent pollution will result in:

- increased production and sales;
- reduced operating costs;
- reduced effluent generation;
- reduced water consumption;
- lower energy consumption;
- improved efficiency;
- better use of resources;
- improved company image;
- more effective compliance with legislation.

An ongoing culture of waste minimisation and control is the best way of reducing effluent generation. Everyone concerned with the manufacturing processes - operators, supervisors, scientists, engineers and managers - needs to be aware of their environmental responsibilities and involved in the waste minimisation programme. To maintain commitment, staff should be kept informed of the benefits to the company of achievements in reducing waste and preventing pollution.

Waste minimisation team achieves significant savings at Pentagon Chemicals Ltd

Pentagon Chemicals Ltd found that implementing a team approach to waste minimisation that involved people from all levels has raised awareness of waste and produced a culture change. Each production process is being reviewed in turn to identify opportunities for reducing effluent quantities and strength. For example, diversion of high strength effluents from reactor boil-outs and phase separation processes has reduced the COD load discharged to sewer by 50%. Trade effluent volumes have been reduced by installing cooling towers to reduce water consumption. For more details, see Industry Example 4.

Practical advice on setting up and managing waste minimisation programmes and reducing your effluent volumes is available free of charge through the Environment and Energy Helpline on 0800 585794. The Helpline can also suggest other sources of information and advice.

Guides of particular relevance to effluent reduction include:

- Environmental Performance Guide (EG105) *Water Use in the Manufacture of Speciality Chemicals;*
- Good Practice Guide (GG120) *Cost-effective Vessel Washing;*
- Good Practice Guide (GG26) *Saving Money Through Waste Minimisation: Reducing Water Use*;
- Good Practice Guide (GG101) *Reducing Vacuum Costs;*
- Good Practice Guide (GG67) *Cost-effective Water Saving Devices and Practices.*

Significant savings from reducing effluent flows and strength at BIP Ltd

BIP Ltd, based in the West Midlands, has reduced the operating costs of its ETP by encouraging the different business areas on site to reduce their effluents.

Application of the 'polluter pays' principle, together with a range of measures to improve control of its ETP, has allowed BIP Ltd to reduce operating costs by £180 000/year. The six business areas of BIP are now charged individually for the effluent they discharge to the ETP. Charging is on the basis of effluent quantity and load. Effluent volumes, strength and treatment costs have all fallen significantly since this internal charging mechanism was introduced. For more details, see Industry Example 1.

3 WHAT IS YOUR EFFLUENT?

In speciality chemicals plants, effluent characteristics generally fluctuate widely due to variations in raw materials, batch process operating conditions and product range. Unexpected events also add to the variations. **For cost-effective pollution control, a thorough understanding of the nature and properties of your company's effluent is essential.** As well as having information about the type and concentration of pollutants present, it is important to appreciate pollutant flows and loadings under all possible scenarios.

You need to know what you are dealing with to ensure that the correct technology and appropriate control measures are used. This applies to all types of ETP, from simple plant where the effluent is neutralised before discharge to sewer, to more complex facilities employing physical and biological processes. For example, measures to segregate or mix particular waste streams may make them easier to treat.

The effluent treatment plant should be considered at least as important as any other production unit. Understanding the science of the plant will help to optimise its operation, as with any reaction process. Understanding why an existing plant is not working properly will help you to improve its performance and can often eliminate the need to upgrade or replace it with new plant.

Effluent characterisation identifies the need for separate treatment systems at Hickson & Welch

A comprehensive sampling and analytical programme helped Hickson & Welch to identify the need for two separate new processes when planning the upgrading of the Company's existing ETP. High strength effluents will be pre-treated by a low pressure, wet oxidation process before being combined with other effluents and treated in an oxygen-activated sludge plant. The measurements identified a high strength and colour effluent which is now segregated and treated by high rate biofiltration. Separate treatment has reduced the COD load of this effluent by over 90%, thus contributing to a 16.5% reduction in the site's trade effluent charges. For more details, see Industry Example 2.

3.1 CHARACTERISING YOUR EFFLUENT

Begin by establishing the source and nature of effluents on your site. When characterising your effluents, it is important to establish and then monitor regularly the level of pollutants in:

- effluent arriving at the treatment plant;
- effluent arising from individual production areas;
- effluent from individual product manufacturing procedures;
- effluent discharged from site;
- surface run-off water.

Each effluent stream should be characterised in terms of:

- total quantity;
- physical and chemical properties, eg temperature, flow rate, pH, COD and colour;
- the type and concentration of pollutants present;
- concentration range and variations with time and operating conditions.

To do this, you may need to carry out a detailed survey and develop a programme of regular monitoring. The data you collect will help you to understand your effluent characteristics and to decide which parameters you need to measure.

Remember:

If you don't measure it, you can't manage it.

3.2 COLLECTING EXISTING INFORMATION

An important initial stage is to collect existing data and information on your processes and the chemicals used on-site. Possible sources of information include:

- the operating manuals for the process plants and the ETP;
- Control of Substances Hazardous to Health (COSHH) Regulations files;
- IPC authorisations;
- discharge consents to sewers or controlled waters;
- on-line instrument and laboratory analysis records.

Some data on your final effluent should be available from samples taken by the regulator to compare with your discharge consents. Volume and concentration data for trade effluent discharges should be available from water company invoices held by the accounts department.

To identify potential pollutants, eg toxic or non-biodegradable substances, you will need to develop a database of the significant chemicals used on-site and which may be present in the effluent. You may need to identify chemicals that arise as products of reaction. By cross-referencing the chemicals to specific processes you will be able to identify particular processes which may be the main causes of your most polluting effluents. Remember to amend the database when changes are made to production.

3.3 SURVEYING YOUR EFFLUENT STREAMS

The next step is to carry out a survey to establish variations in the composition of the effluent streams arriving at the ETP. Although carrying out a survey may appear expensive and time-consuming, installing an ETP or modifying your ETP or production process on the basis of inadequate monitoring could prove expensive to correct later. The survey could be carried out on a site-wide basis, or focus initially on the processes identified as being potentially the most polluting.

Combining a survey of effluent inputs to the ETP with a survey of specific effluents from different production areas may highlight opportunities for segregation of different effluents.

Remember, the survey needs to include 'non-routine' discharges such as vessel wash-outs, eg solvents or acids, and annual cooling tower clean-outs which may contain anti-bactericides.

A survey involves:

- planning;
- flow measurement;
- sampling;
- analysis.

It is important to plan surveys so that they span periods of different process activities on-site, including product changeovers and process shutdowns.

Use site drainage system drawings to:

- determine how effluent streams arrive at the ETP;
- establish where effluent streams combine.

You can then identify the best places to measure flow and collect the most representative samples. Flow measurement, sampling and data analysis are discussed in the Appendix.

3.4 IMPLEMENTING A REGULAR MONITORING REGIME

Set up a permanent monitoring system to provide routine data on flows, loads and plant performance. Daily collection and recording of data are recommended, at least initially. Once satisfactory operating experience is obtained, it may be possible to reduce the frequency.

Data should be recorded in a simple table and updated regularly. The information should be used by plant operators, supervisors and managers to monitor and control the performance of the ETP to promote treatment efficiency and waste minimisation. Deviations from the norm should be recorded and corrective action taken on the same principle as when a product fails on quality.

Continuous on-line monitoring ensures consent compliance

A regular monitoring programme at Nalco Ltd, Northwich, gives the Company confidence that its effluent always remains within consent limits.

The treated effluent is continuously monitored for pH, turbidity, flow rate, total oxygen demand and temperature, and the data are entered into a Distributed Control System (DCS). The DCS has a trending capability that allows the operator to anticipate changes in performance. Plant problems are easily identified through the DCS.

The system also has alarmed on-line monitors to enable the operator to recycle the treated effluent to the equalisation system should it not be suitable for discharge to sewer.

4.1 MAIN TECHNIQUES IN THE UK SPECIALITY CHEMICALS SECTOR

The main effluent treatment techniques used by the UK speciality chemicals industry can be divided into three categories: pre-treatment, physical/chemical and biological processes. Measures to improve the performance of these different processes are discussed in Sections 5 - 7 respectively. Section 8 describes how to achieve cost-effective sludge management.

A survey of 30 speciality chemicals companies, carried out on behalf of the Environmental Technology Best Practice Programme, found that the most commonly used effluent treatment techniques are neutralisation, equalisation and biological treatment using an activated sludge process. Fig 1 overleaf summarises the survey findings, and links these to the relevant Section in the Guide where measures to improve each technique are outlined.

Technologies, such as adsorption, ion exchange, reed beds, biofiltration, membrane bioreactors and electrochemical technologies, are not covered in this Guide due to their current limited use in the speciality chemicals industry. For information on these processes, see:

- Good Practice Guide (GG37) *Cost-effective Separation Technologies for Minimising Wastes and Effluents*;
- Good Practice Guide (GG54) *Cost-effective Membrane Technologies for Minimising Wastes and Effluents*;
- Good Practice Guide (GG109) *Choosing Cost-effective Pollution Control*;
- Future Practice Profile (FP200) *A Novel Membrane Bioreactor for the Recovery of Valuable By-products.*

These publications are all available free of charge through the Environment and Energy Helpline on 0800 585794.

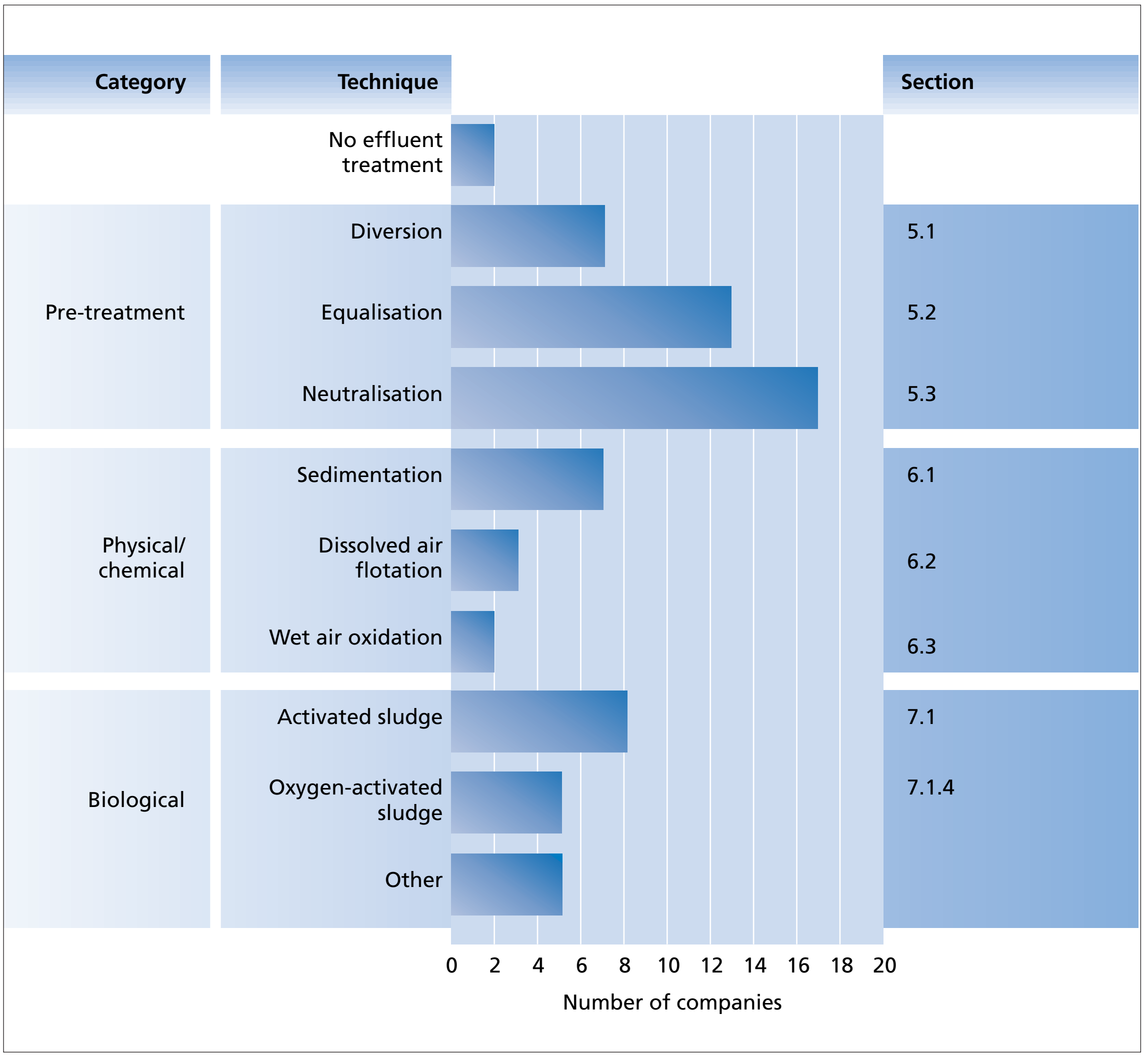

Fig 1 Effluent treatment techniques used and the associated Section where each is covered in this Guide

4.2 CONTRACTING OUT EFFLUENT TREATMENT

As demonstrated in Industry Example 3, contracting out your effluent treatment requirements can have a number of business benefits, including:

- phasing investment costs for the ETP;
- use of staff fully trained and experienced in running ETPs;
- greater confidence in being able to respond to changing legislative requirements;
- long-term operational security.

Business benefits of out-sourcing

The ETP at Nipa Laboratories was designed and financed by an out-sourcing company. This company now operates and maintains the ETP for Nipa, ensuring that the effluent is treated to approved quality standards and allowing Nipa to phase financial investment. In addition, changing from landfill disposal to land application has saved £79 000/year. For more details, see Industry Example 3.

5.1 DIVERSION

For most chemicals plants, diversion facilities to which effluents can be redirected quickly and easily are essential as a temporary storage facility. An informed decision can then be made on how to deal with the contents. Diversion facilities (see Fig 2) are used to control occurrences that could put the ETP or the site's discharge consent at risk, eg:

- unexpected peaks in the strength, flow and/or pH of process effluent;
- unexpected events such as spillages or tank overflows;
- firewater run-off.

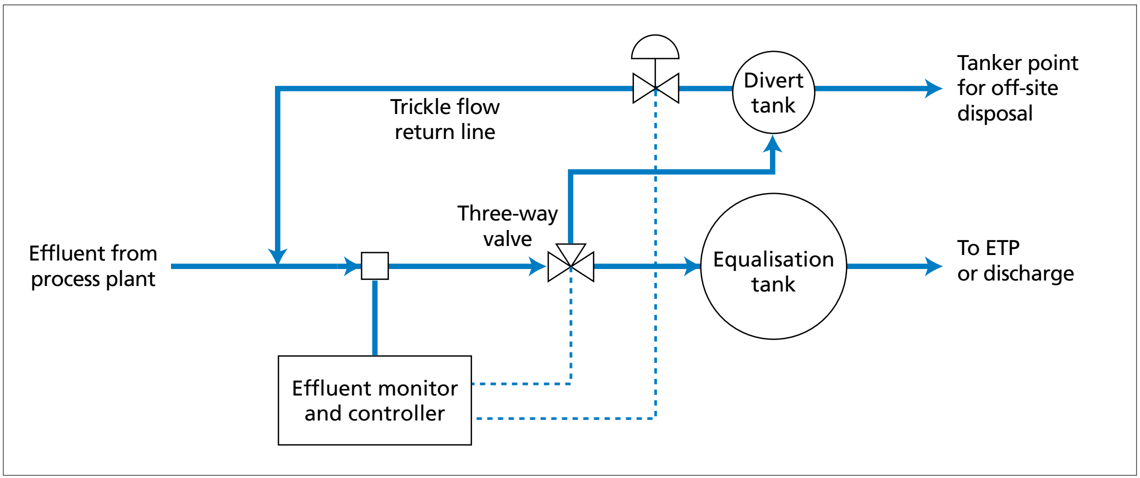

Fig 2 Example diversion facility

For effective use of diversion facilities, check that they are controlled:

- automatically by:
  - an on-line pH or total organic carbon (TOC) monitor;
  - an emergency signal from the production area which controls stop valves and/or pumps;
- manually by an operator in accordance with site emergency procedures.

Make sure that process and ETP operators know which effluent streams can be diverted and at what point.

It is sometimes possible to divert final effluent that does not meet consent limits back to the inlet of the ETP. However, most diversions are to a pit or tank. Several diversion units may be necessary to handle different streams and/or provide sufficient capacity.

Consider isolating high-strength or highly toxic vessel wash-out or boil-out water produced during product changeover into a diversion tank. You can then decide whether this wastewater is suitable for re-use in the process on product start-up or for disposal by an appropriate method.

A procedure for dealing quickly with the contents of a diversion unit is essential. Options for dealing with the contents of a diversion tank include:

- arranging for off-site disposal or recovery by a licensed waste contractor;
- using a trickle return of the effluent at a suitable point for treatment in the ETP;
- re-using or reprocessing the contents of the tank in the manufacturing process;
- modifying the contents of the tank for re-use, trickle return to the ETP or another disposal route, eg by phase separation or pH adjustment.

5.2 EQUALISATION/BALANCING

Equalisation controls fluctuations in the effluent characteristics arising from batch manufacturing processes, thus ensuring optimum conditions for subsequent downstream treatment processes.

Equalisation systems include mixed tanks, basins and lagoons. They seek to:

- smooth out fluctuations in organic load and thus prevent shock loading;
- smooth out flow surges to provide a reasonably constant flow of effluent to the ETP;
- minimise the need for chemical additions for pH control by combining compatible acidic, neutral and alkaline effluents;
- provide a uniform temperature of effluent entering the ETP;
- minimise toxic shocks on downstream biological treatment from concentrated batches or spillages to drain.

The most important control on an equalisation or balancing unit is the level of mixing. It should be kept well mixed to achieve constant conditions throughout the effluent volume.

Review your balancing facilities. Check that:

- the capacity is sufficient to provide a constant or near constant flow rate based on a flow and load survey;
- mixing is adequate to promote blending and prevent solid deposits;
- the location of the tank inlet and outlet prevents short-circuiting of the effluent;
- the strength of the effluent leaving the balancing tank is no more than twice the average daily value;
- the normal operating volume leaves adequate spare capacity to handle flow surges.

Balancing units can be operated either in a constant volume (variable outflow) or variable volume (constant outflow) mode. If the effluent flow rate remains reasonably constant with time, a constant volume unit will provide adequate load equalisation. For batch production processes with rapid changes in both flow and organic load, a variable volume unit with a controlled withdrawal rate should be used. This normally requires a flow control valve in the pipeline from the balance unit to the downstream treatment plant or variable speed pumping of the effluent.

5.3 NEUTRALISATION

Most speciality chemicals manufacturers carry out some form of neutralisation or pH control.

Many effluents contain acidic or alkaline materials and require the pH to be adjusted either before discharge or prior to treatment by biological processes. Physical/chemical processes often require pH control to optimise the performance of treatment chemicals, remove toxic metal ions or specific dissolved solids, or to crack emulsions.

At sites with both acidic and alkaline effluents, consider using these streams to neutralise each other in a diversion facility. This minimises the need for chemical additions for pH control.

5.3.1 Acid use

Any strong acid can be used to neutralise an alkaline effluent subject to chemical compatibility, safety and cost considerations. The main acid reagents used for neutralisation are listed below.

- Hydrochloric acid. Chloride discharge may be limited in the consent conditions as it causes poor settling in the treatment plant and may cause corrosion problems.
- Sulphuric acid. This tends to form insoluble precipitates, especially when calcium is present, and to increase sulphate levels. Sulphate discharge may also be limited in the consent conditions to avoid sewer damage (due to hydrogen sulphide) and downstream biotreatment problems.
- Carbon dioxide. This is applied as a gas stream through a submersible mixer and is relatively easy to handle. Although carbon dioxide is generally more expensive, more accurate neutralisation is achieved since overdosing to below pH 6 is unlikely.

section 5

5.3.2 Alkali use

Various carbonates and hydroxides, eg calcium, sodium and magnesium, are used as alkaline reagents for neutralising acidic wastes. Alkalis used for pH control include:

- hydrated or slaked lime (calcium hydroxide);
- quicklime (calcium oxide);
- limestone (calcium carbonate);
- sodium carbonate;
- caustic soda (sodium hydroxide);
- magnesium hydroxide.

Calcium-based alkalis

Lime is the cheapest alkali and comes as a fine powder in bags or bulk. Lime needs a carefully designed handling and dosing system. It is generally stored as a dry powder and normally made up into a 10 - 15% slurry with water immediately before dosing. However, some sites add powdered lime directly to the wastewater with good mixing. Lime is now available in a non-settling suspension which makes it more convenient to handle, especially for low-volume users.

The disadvantages of lime for pH control include:

- The formation of insoluble precipitates with anions such as sulphates, phosphates and fluorides.
- Low solubility in water, with scale formation.
- The need for agitation to avoid the slurry settling to form a deposit in pumps and pipelines. Careful pump selection is important.

Use of a pressurised ring main system for the continuous recirculation of lime slurry is recommended. Such a system is effective for controlled dosing directly to the neutralisation tanks.

Sodium-based alkalis

Convenience makes sodium hydroxide a widely used alkali. The advantages of using sodium hydroxide compared to lime for pH control are that it is highly soluble and available as a liquid in various strengths. Subject to appropriate health and safety considerations, it is relatively easy to store and meter into an effluent stream or tank, making control of final pH easier. The sodium salts formed during neutralisation are also soluble.

Magnesium-based alkalis

Magnesium hydroxide can be used as a neutralising agent for acid effluents, including those containing metals.

The advantages of suspensions of magnesium hydroxide over lime and caustic soda include:

- lower sludge volumes;
- less material is required for neutralisation;
- no need for pre-mixing, eg preparing a slurry of powdered lime;
- in the event of overdosing there is a natural buffering capacity at pH 9 - 9.5, which prevents the discharge of highly alkaline effluents.

5.3.3 Controlling neutralisation

Controlling pH can be difficult unless pH sensors and control systems are designed and maintained properly.

The relationship between pH and acid or alkali concentration can change rapidly. This means that a poorly controlled pH system may result in overdosing with neutralisation reagents and increased operating costs.

The example titration curve in Fig 3 for lime and a strong acid effluent shows the point of inflexion where the rapid change in pH occurs. The graph shows clearly that a small increase in concentration of lime addition increases the pH of the effluent significantly. Therefore, it is recommended that neutralisation is carried out as a two-stage process to limit overdosing.

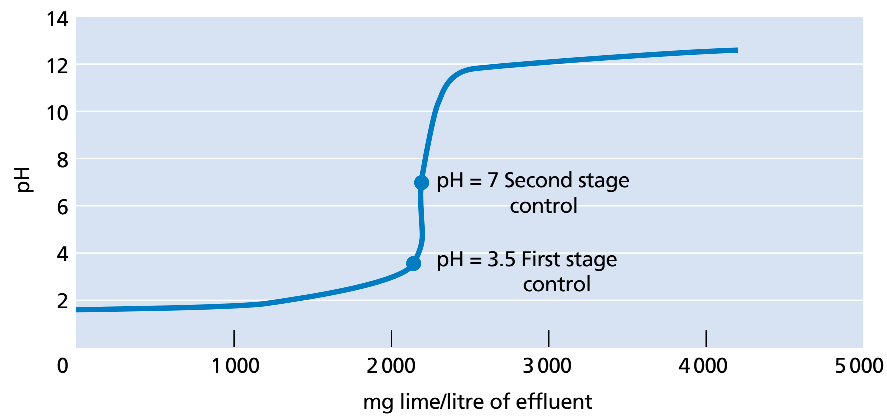

Fig 3 Lime titration curve for a strong acid effluent

To ensure effective pH control:

- Implement a regular programme of sensor inspection and cleaning. Consider automatic sensor cleaning systems, especially chemical cleaning. For example, the use of lime may require sensors to be inspected and cleaned twice daily.
- Ensure adequate back-up sensors are available in case of faults occurring.
- Use on-line validation systems.
- Conduct regular calibration checks, ie daily manual readings.
- Ensure that the balancing and diversion capacity available prior to neutralisation is adequate to avoid rapid fluctuations in flow rate and pH.
- Use automatic dosing to add diluted reagents to small volumes of effluent. NB Great care is needed when diluting strong acids prior to dosing.
- For large volumes of effluent, ensure continuous agitation when adding acid or alkali to achieve uniform distribution throughout the whole volume.
- Consider using a two-stage or three-stage neutralisation process, with the effluent remaining for a minimum of five minutes at each stage.

An example of a two-stage neutralisation process is shown in Fig 4.

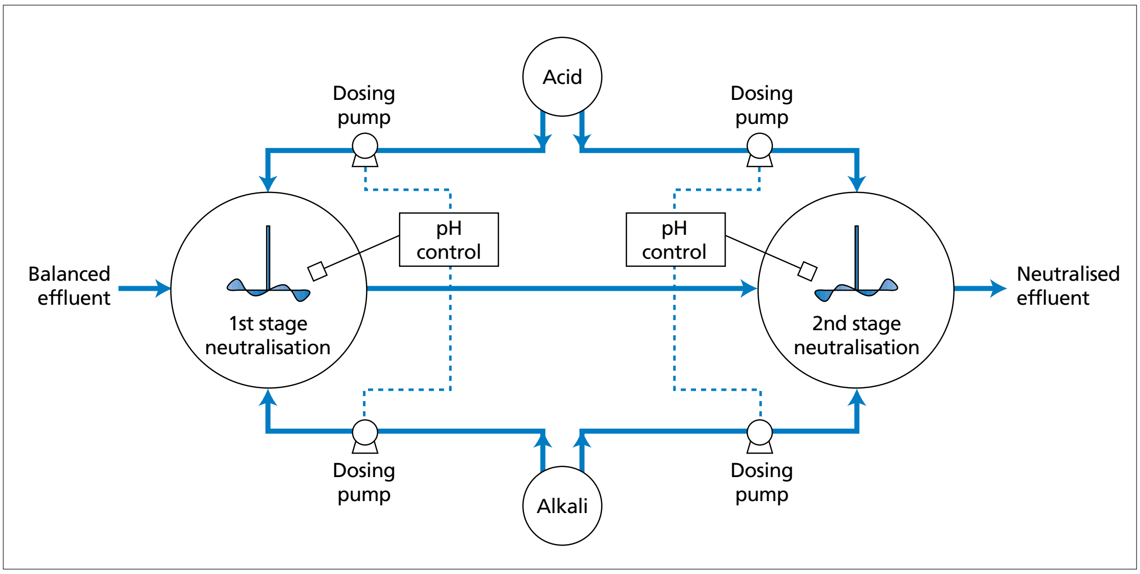

Fig 4 Example two-stage neutralisation process

6 PHYSICAL/CHEMICAL PROCESSES

6.1 SEDIMENTATION

Sedimentation is used at both the pre-treatment and main treatment stages to remove suspended solids through gravity settlement in a settlement tank or basin.

The performance of settlement tanks is affected by a number of parameters, including:

- effluent flow and sedimentation time;
- the nature of the solids;
- sludge build-up.

6.1.1 Flow rate and sedimentation time

Wide variations in flow rate due to the intermittent discharge of effluent from batch operations have a significant impact on the performance of sedimentation tanks. Elimination of suspended solids' formation is essential as carry over of suspended solids may lead to a breach of the site's discharge consent or a deterioration in the performance of downstream treatment plant.

- Ensure that adequate balancing of the effluent (see Section 5.2) is available upstream to minimise variations in flow rate and thus maintain efficiency.
- The effectiveness of separation depends on the time allowed for settlement at the specific flow into the tank. As a general rule, the retention time (RT) in the settlement tank should not be less than two hours at maximum flow. RT is calculated as follows:

  $$\text{RT (hours)} = \frac{\text{Tank volume (m}^3\text{)}}{\text{Effluent flow rate (m}^3\text{/hour)}}$$

- The upward flow rate (UFR) of the effluent through the settlement tank should also be restricted. UFR is calculated as follows:

  $$\text{UFR (m/hour)} = \frac{\text{Effluent flow rate (m}^3\text{/hour)}}{\text{Tank surface area (m}^2\text{)}}$$

  – When settlement tanks are used for clarification and separation, ensure that the UFR does not exceed 1.8 m/hour. At average flow, the UFR should be less than 1.0 m/hour.

  – When settlement tanks are used to remove activated sludge, the UFR should not exceed 1.5 m/hour. However, specialist advice should be sought as other factors are important.

To produce denser flocs and thus reduce settlement time, it may be necessary to add a coagulant and/or a polymeric flocculant. Adding chemical coagulants, eg iron or aluminium salts, or polyelectrolytes, promotes the formation of large, rapid-settling flocs. This is essential for colloids and fine suspended particles which do not settle out on standing.

Sedimentation can remove heavy metals, phosphates and some organic materials from effluents. However, metals are usually precipitated as their hydroxide; minimum solubility is achieved by adjusting the pH through additions of lime or caustic. Pre-treatment may be necessary to remove substances, eg cyanides, that could interfere with metal precipitation. Flocculant addition may be needed to improve solids separation.

Adding these chemicals will result in additional costs, however, optimising their use will reduce the overall costs of effluent treatment.

- Optimise precipitation processes by conducting laboratory tests to determine the pH and chemical dosage that give good settlement of solids and a clear supernatant.

6.1.2 Nature of the solids

Discharging high concentrations of inorganic and organic solids into the settlement tank can increase the density of the settled sludge so that it becomes difficult to remove.

- Encourage the production team to report abnormal discharges of suspended solids so that measures can be taken to increase the rate of sludge removal from the settlement tank.

6.1.3 De-sludging programme

Accumulation of large quantities of sludge in the settlement tank should be avoided as it affects the quality of the final effluent.

- Do not use settlement tanks as a regular means of storing quantities of sludge prior to dewatering. If the dewatering plant requires the sludge to be processed in batches rather than a continuous feed, install an intermediate sludge storage tank or thickener.
- Prevent sludge accumulating in the bottom of the settlement tank to:
  - avoid the development of septic conditions, problems with floating sludge, and the subsequent release of odorous gases such as hydrogen sulphide;
  - maximise the settlement depth and volume.
- Carry out regular and frequent de-sludging of the tank, eg two to four times daily. Little and often is the key to efficient sludge removal. This can be achieved by:
  - using an automated, timed programme, eg an automated valve or a close coupled pump (this avoids the potential for odour release);
  - installing an ultrasonic sludge level detector that sets off an alarm if the sludge reaches a preset level.

6.2 DISSOLVED AIR FLOTATION

Dissolved air flotation (DAF) is generally used to remove suspended solids and part of the organic load prior to biological or other treatment.

In the DAF unit, part of the effluent flow is pressurised in the presence of air to approach saturation. This 'white water' is then released to atmospheric pressure in the flotation tank. The very fine air bubbles that are formed rise to the surface, becoming enmeshed in particles of flocculated sludge, suspended solids, oil and grease. Specialised chemicals are added to the effluent prior to flotation to produce the flocculated sludge. The resultant sludge is skimmed off at the surface of the flotation tank and the treated effluent is removed at the bottom. Some of the treated effluent is recycled to produce the pressurised white water.

To maximise the performance and final effluent quality from a typical DAF plant, it is necessary to:

- control coagulant and/or flocculant dosing rates;
- operate at the correct degree of air saturation;
- operate at a constant flow rate;
- maintain equipment in a good condition.

6.2.1 Controlling the addition of coagulants and/or flocculants

Adding coagulants and/or flocculants, eg iron or aluminium salts, or polyelectrolytes, will encourage the formation of larger, more voluminous flocs. This will accelerate rise rates and encourage particle adsorption at the air/effluent interface. The increased solids removal would generally offset the cost of adding these chemicals as long as the chemical addition in closely controlled.

- Monitor chemical additions to ensure that only the amounts sufficient to do the job are used.
- Check the dose rate regularly by carrying out jar tests. Jar tests involve adding chemicals to effluent samples to determine the optimum type, dose and mixing conditions to achieve strong floc formation. (The chemical supplier usually offers this service free of charge.)
- Allow floc formation to proceed for 5 - 20 minutes.
- Avoid any shearing forces, eg pumping or high-flow in-line mixing, after addition.

6.2.2 Maximise the efficiency of air saturation

- Operate the air saturators producing the pressurised white water at 400 - 700 kPa (4 - 7 bar). This should produce up to 90% air saturation. Air saturation can be determined by using measured values of dissolved oxygen and temperature in standard saturation tables.
- Check the white water system regularly to ensure optimum operating conditions are maintained.

6.2.3 Maintain a constant flow rate

- Keep the surface loading rate to the preferred rate of 6 m/hour, and at a maximum of 10 m/hour to avoid carry over of solids into the effluent. The surface loading rate is calculated as follows:

$$\text{Surface loading rate (m/hour)} = \frac{\text{Flow received by the flotation tank (m}^3\text{/hour)}}{\text{Tank surface area (m}^2\text{)}}$$

- As DAF plants work best under steady operating conditions, maintain constant flow using balancing facilities.

6.2.4 Implement a regular maintenance programme

Inadequate pumping capacity, insufficient air saturation and leakage from pumps and valves associated with the DAF unit can reduce the efficiency of solids separation as described in the following example. This could cause problems in complying with consent limits.

Significant improvement in COD removal following low-cost repairs to faulty valves

Recurring problems in the ETP at a company manufacturing water treatment chemicals led to higher than predicted COD loading in the final effluent. Visual plant checks revealed that non-return valves on the pumps feeding the DAF unit were faulty. This caused about 20% of the effluent to bypass the treatment stage, resulting in a high COD in the final effluent. Repair work at negligible cost, together with improvements to the operation of the DAF unit, resulted in a significant increase in the percentage of COD removed from the effluent.

- Provide schedules for regular checks and maintenance of mechanical plant items.
- Check that the skimmer unit is removing all the floated sludge, but is not collecting excess water. This can adversely affect sludge dewatering.

6.3 WET AIR OXIDATION

Pre-treatment of certain high COD effluents and sludge (including COD which is not readily biodegradable) can be achieved by oxidation of organic pollutants at high temperature and pressure using air, hydrogen peroxide or oxygen.

Depending on the system and the effluent characteristics, temperatures of 120 - 300°C and pressures of 300 - 20 000 kPa (3 - 200 bar) are typically required for sub-critical oxidation. To destroy persistent and toxic organic substances, supercritical wet air oxidation operates at temperatures above 370°C and pressures above 22 000 kPa (220 bar).

Depending on the conditions, wet air oxidation can be used to convert organic compounds to carbon dioxide, water and nitrogen, or to break down complex structures into more degradable compounds prior to secondary biological treatment.

Optimisation of wet air oxidation processes is outside the scope of this Guide. These processes should be operated and controlled within limits established under guidance from specialist suppliers.

The Environment and Energy Helpline on 0800 585794 can provide details of suppliers of wet air oxidation technology.

7.1 ACTIVATED SLUDGE

The activated sludge process is an aerobic biological treatment in which bacteria and other micro-organisms feed on biodegradable organic material in the effluent and degrade it. Nutrients such as nitrogen and phosphorus are required to support good growth. Activated sludge is the term used to describe the active mass of micro-organisms. The bacteria and other micro-organisms - the biomass - are maintained in suspension, with oxygen transfer occurring directly - as dissolved oxygen - from the aqueous phase to the biomass. Under different conditions, two processes can occur:

- Carbon oxidation to remove BOD and COD.
- Conversion of ammonia to nitrate and nitrite. This is known as nitrification.

An activated sludge plant (see Fig 5) for the treatment of effluent from speciality chemicals manufacture includes balancing (see Section 5.2), biological action in the aeration tank, activated sludge recycle and sedimentation (see Section 6.1). Activated sludge plants are suitable for effluents with a COD value up to 12 000 mg/litre.

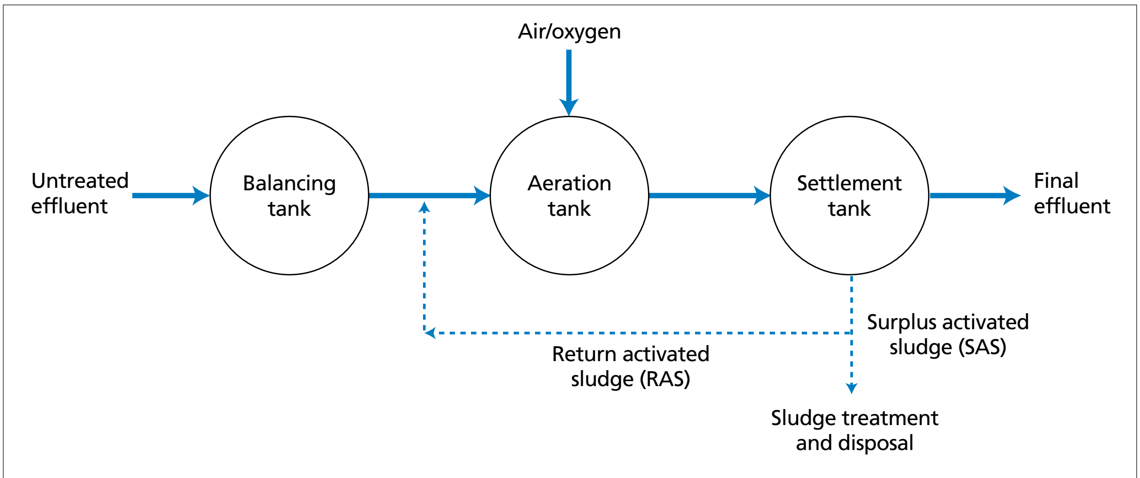

Fig 5 The main elements of an activated sludge plant

7.1.1 The importance of regular monitoring

A healthy activated sludge process can accept and adapt to minor changes in flow, load and chemical composition. However, the operator needs to predict or detect these changes and make the necessary process adjustments, as it can be days before the effects of some changes are observed. This is an important consideration when operating the plant on a daily basis. Regular monitoring is therefore essential to maintain microbial activity and maximise final effluent quality.

For efficient operation and control of an activated sludge plant, a range of parameters should be monitored daily for untreated effluent and final effluent. This will allow you to:

- identify performance trends and deviations from optimum conditions;
- take remedial action according to defined procedures.

Key parameters are considered in more detail below. A suggested routine monitoring programme for an activated sludge plant is described in Section 7.1.11.

7.1.2 Microscopic examination

Microscopic appearance is an excellent indication of the sludge's general condition and an experienced eye can deduce a great deal about the plant's overall health.

Microscopic examination requires certain skills. With training, a simple assessment can be made of:

- the size and structure of the biomass;
- the diversity of micro-organisms;
- the number and types of protozoa (unicellular organisms that feed upon bacteria; common in activated sludge; beneficial to the activated sludge process as they 'polish' the effluent);
- the number and types of filamentous bacteria or fungi which prevent the sludge from settling;
- the clarity of the surrounding liquor.

Microscopic examination of sludge samples is an important monitoring tool and should be performed regularly.

Fig 6 shows the difference in appearance between a healthy sludge (left) and sludge containing filamentous bacteria.

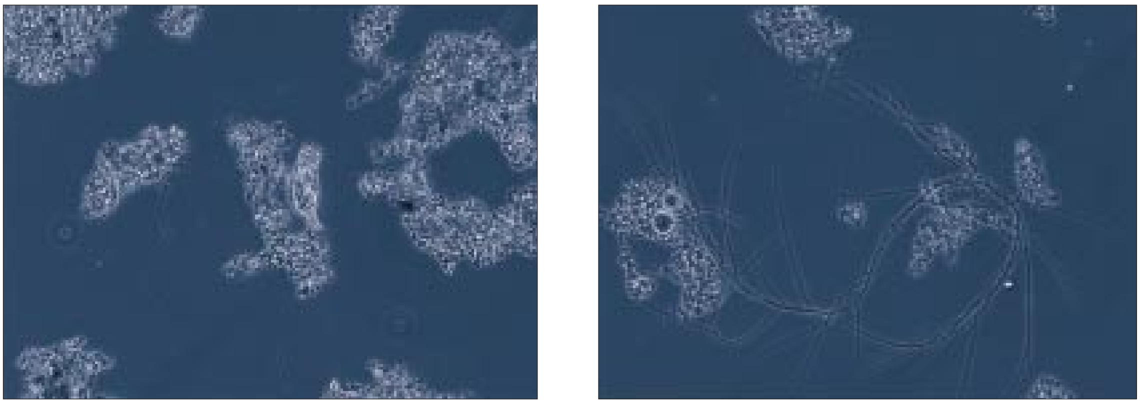

Fig 6 Microscopic examination of activated sludge:
(left) healthy sludge (right) sludge containing filamentous bacteria

7.1.3 BOD and COD

The COD:BOD ratio provides an indication of how well the effluent will be treated by the activated sludge process. If the ratio is 2:1 to 3:1, the effluent should be highly amenable to biological treatment (provided that no highly toxic substances are present).

BOD and COD values are also used to calculate the amount of nutrients required (see Section 7.1.6) and the organic load that the system can accept (see Section 7.1.7).

7.1.4 Dissolved oxygen

The oxygen requirement of activated sludge depends on:

- the organic strength of the untreated effluent;
- the operating temperature;
- the need for nitrification.

For degradation of organic compounds, the dissolved oxygen (DO) concentration in the activated sludge system needs to be kept between 1 - 2 mg/litre. For satisfactory nitrification, the DO needs to be kept at around 4 mg/litre. Over-aeration wastes energy, while under-aeration kills a large proportion of the microbial population leading to a failure to comply with the site's discharge consent limits.

Air or oxygen can be used to aerate the effluent, although more oxygen systems are used for treatment of chemical effluents. While oxygen is more expensive than air, its advantages over air include:

- a fast response to changing effluent character;
- reduced size of plant due to more concentrated biomass;
- increased oxygen transfer rate to biomass;
- reduced VOC/odour emissions.

Dissolved oxygen control

- Monitor the DO levels using probes in the aeration tank, adjusting the controls on the air/oxygen supply to provide a DO level of between 1 - 2 mg/litre.
- With automatic control systems, signal time lags may mean that the aeration system starts to hunt for the correct level of aeration and may begin to drift from the desired range. Calibrate DO probes regularly to avoid drift. Have at least two probes in each aeration tank in case of problems.
- Manually measure the DO level with a portable probe on a regular basis to check the automatic control.

The DO level can be controlled using either on-off sensors or proportional control sensors. Proportional control sensors have two main advantages compared with on-off sensors:

- There is much less fluctuation in the DO level in the aeration tank. When the sensors detect a slight increase or decrease in the DO level, they compensate by decreasing or increasing the amount of air/oxygen supplied, as required.
- Less air or oxygen is used.

7.1.5 pH and alkalinity

Efficient performance of an activated sludge plant requires effluent with a constant pH and sufficient buffering capacity to allow for loss of alkalinity due to nitrification. The optimum pH is 6.5 - 9.5 for the breakdown of organic matter and 7.0 - 8.5 for nitrification.

- Carry out the main pH adjustment before the untreated effluent enters the aeration tank - ideally at the equalisation or neutralisation stage (see Sections 5.2 and 5.3).
- Fine-tune the pH by limited direct addition of chemicals to the aeration tank.

If the carbon dioxide produced by the activated sludge process is not stripped out of the mixed liquor, a build-up of soluble carbon dioxide will decrease the pH. This is more of a problem in pure oxygen plants than in conventional air plants. Removal of ammoniacal nitrogen during nitrification also reduces the pH, due to the requirement for alkalinity.

- Monitor the pH in the aeration tank and adjust the pH control system gradually to fine-tune the observed pH range.
- To avoid measurement drift, calibrate pH probes at least every three days. Have at least two probes in each pH adjustment tank for security and back-up.
- Measure the pH manually on a regular basis to check the automatic control.
- For nitrification systems, measure the alkalinity in the effluent entering and leaving the aeration tank.

7.1.6 Nutrient addition

The biological activity of sludge flocs and their settling characteristics are affected by the composition of the untreated effluent and particularly by the presence of nutrients such as ammoniacal nitrogen and phosphorus.

- Maintain a BOD:nitrogen:phosphorus ratio of approximately 100:5:1 to provide the optimum nutrient balance for microbial growth. Exact nutrient ratios are site-specific and may differ in practice.
- Monitor nitrogen and phosphorus levels in the effluent entering and leaving the activated sludge plant to ensure that sufficient nutrients are present. Ensure an excess of at least 1 mg/litre of ammoniacal nitrogen and phosphorus in the effluent leaving the plant.
- Review nutrient addition levels regularly and adjust dose rates to optimise the use of chemicals.

7.1.7 Food:mass ratio

A certain 'mass' of micro-organisms in the aeration tank is required to treat the BOD load - the bacterial 'food' - in the untreated effluent. The ratio of the food (BOD load) to the biomass weight (M) is known as the food:mass ratio (F:M ratio) or sludge loading rate (SLR). The weight of dry solids within the activated sludge plant is known as the mixed liquor suspended solids (MLSS). The biomass is sensitive to fluctuations in the organic strength of the untreated effluent, leading to serious effects on sludge characteristics and settleability. The F:M ratio is an important parameter in controlling the activated sludge process.

The F:M ratio is usually based on BOD and is calculated as follows:

$$F{:}M_{(BOD)}\ (\text{day}^{-1}) = \frac{\text{Effluent flow rate (m}^3\text{/day) x Effluent BOD (mg/litre)}}{\text{MLSS (mg/litre) x Volume of aeration tank (m}^3\text{)}}$$

For activated sludge plants, the optimum F:M value depends entirely on the type of effluent being treated. However, COD is easier and quicker to measure than BOD. Once a steady COD:BOD ratio has been established, the operational F:M can be based on effluent COD and calculated as follows:

$$F{:}M_{(COD)}\ (\text{day}^{-1}) = \frac{\text{Effluent flow rate (m}^3\text{/day) x Effluent COD (mg/litre)}}{\text{MLSS (mg/litre) x Volume of aeration tank (m}^3\text{)}}$$

- Calculate the F:M loading daily. Collect data in a spreadsheet format and plot graphs to monitor the trend.

Maintaining the correct F:M ratio

To maintain the F:M ratio at the design value, it is necessary to adjust the amount of sludge recycled as return activated sludge (RAS) or wasted from the system as surplus activated sludge (SAS).

For example, from the equation for calculating for $F{:}M_{(BOD)}$, it can be seen that increasing the BOD of the effluent entering the system increases the F:M ratio. If the flow is constant and the volume of the aeration tank is fixed, the only parameter that can be adjusted is the MLSS. The MLSS can be altered as required by adjusting the RAS and SAS as shown in Table 3. Changing from an air system to an oxygen system will increase the MLSS by at least a factor of two. Sludge age is linked to the F:M ratio and is considered in Section 7.1.8.

	MLSS	F:M ratio	Sludge age
Alter RAS/keep SAS constant			
Increase RAS	Increases	Decreases	No change
Decrease RAS	Decreases	Increases	No change
Alter SAS/keep RAS constant			
Increase SAS	Decreases	Increases	Decreases
Decrease SAS	Increases	Decreases	Increases
Alter both RAS and SAS			
Increase RAS/decrease SAS	Increases	Decreases	Increases
Decrease RAS/increase SAS	Decreases	Increases	Decreases

Table 3 Effects of changing RAS and SAS on key parameters

7.1.8 Sludge age or solids retention time

Sludge age or solids retention time (SRT) is another important plant control parameter and gives control over sludge activity. Sludge age, which is linked to the F:M ratio, is defined as the time in days that the biomass remains in the system. SRT affects both the character and condition of the activated sludge flocs in the aeration tank. It is calculated by dividing the total mass of solids in the aeration tank by the mass of settled solids lost from the tank. The latter includes both the mass of solids lost as SAS and the mass of solids lost in the final effluent. SRT is calculated as follows:

$$\text{SRT (days)} = \frac{\text{Mass of solids in aeration tank (kg)}}{\text{Mass of solids (SAS and final effluent) (kg/day)}}$$

Sludge age can be altered by:

- changing the MLSS concentration by wasting more or less sludge (see Table 3);
- adjusting the rate of effluent discharge.

A short SRT, ie less than half a day, indicates a sludge with a high growth rate and a system operating at the higher end of the F:M range. A long SRT, ie longer than five days, indicates a low growth rate sludge and a system operating at the lower end of the F:M range.

A long SRT is desired as this results in less production of new bacterial cells and smaller volumes of excess sludge to be wasted. A long SRT also allows the development of slow-growing bacteria that may be needed to break down certain constituents, eg phenols, and the conversion of ammonia to nitrate by nitrification. However, as the SRT increases, the DO needs to increase.

7.1.9 Settleability

Good sludge settleability is a key factor in producing a high quality final effluent. All activated sludge plants have the potential to produce bulking and foaming activated sludge. The poor settling characteristics of bulking activated sludge can result in foam formation and sludge being carried over the settlement tank weirs into the final effluent. By contrast, a foaming sludge may have good settlement characteristics, but generate a viscous, brown foam which is also carried over the weir. This may lead to a breach of the suspended solids consent limit.

Settleability is influenced by any or a combination of the following factors:

- under-aeration or over-aeration;
- shock loading affecting the composition of the effluent;
- nutrient deficiency;
- sulphides in the untreated effluent;
- temperature inconsistency;
- pH fluctuation.

Improved settleability can be achieved by structured control procedures to deal with insufficient DO, unusual pH values, excessive biomass and inappropriate nutrient balances. Such procedures will also help to prevent the development of filamentous bacteria - the cause of bulking activated sludge.

7.1.10 Controlling bulking activated sludge

Although prevention is better than cure, this is not always practicable. A variety of short-term and long-term control methods are available if filamentous bacteria become dominant in the activated sludge. However, it may be necessary to seek advice from specialists, who can advise on a structured approach to tackling more deep-rooted problems.

Short-term measures to address the symptoms of bulking sludge include:

- Killing the filamentous bacteria using biocides such as chlorine, hydrogen peroxide or ozone.
- Adding flocculating agents, eg organic polymers, to help bind the sludge solids together and improve the settling rate.
- Restricting the effluent flow into the plant to reduce the solids load on the settlement tanks. This measure only works if adequate balancing facilities are available.
- Increasing the rate at which activated sludge containing bulking sludge is recycled to the settlement tank. This measure can only be used for a short time due to the associated increase in flow to the settlement tanks.

When sludge bulking occurs frequently, long-term measures that concentrate on improving the growth of flocculating bacteria are required. One such measure is the installation of a selector at the inlet to the aeration tank. This provides a contact zone where return activated sludge (RAS) can be mixed with untreated effluent prior to aeration. The high loading rate promotes the formation of flocculating bacteria rather than filamentous bacteria.

7.1.11 Suggested routine monitoring programme

Once normal operating conditions have been established, it is important to monitor key parameters regularly. This will allow you to detect any changes in conditions early and investigate the reasons for them. Plants with recurring problems may require a more detailed assessment of the plant inputs and outputs to establish the source of problems.

Table 4 shows a suggested monitoring programme for a seven-day period for a typical activated sludge plant.

- Use these data to calculate the F:M ratio and the sludge age.
- Examine how these parameters differ from normal or designed values.
- Investigate the causes of operational problems and seek solutions.

Once an initial detailed survey has been completed, a monitoring programme to provide regular data on flows, loads and plant performance should be established. Daily collection and recording are recommended, at least initially.

Parameter	Balancing tank effluent	Contents of aeration tank	Final effluent
Record			
Flow	Continuous	Continuous	Continuous
pH	Continuous	Continuous	Continuous
Temperature	Continuous	Continuous	Continuous
Sample/analyse			
BOD	24-hour composite sample		24-hour composite sample
COD	24-hour composite sample		24-hour composite sample
Total suspended solids (TSS)	24-hour composite sample		24-hour composite sample
Ammonia	24-hour composite sample		24-hour composite sample
Total Kjeldahl nitrogen (TKN)	24-hour composite sample		24-hour composite sample
Nitrate	24-hour composite sample		24-hour composite sample
Nitrite	24-hour composite sample		24-hour composite sample
Phosphate	24-hour composite sample		24-hour composite sample
Mixed liquor suspended solids (MLSS)		Daily spot sample	
Measure			
Stirred sludge volume index ($SSVI_{3.5}$)		Daily	
Oxygen uptake rate (OUR)*		Daily	

* The rate at which micro-organisms consume oxygen. Indicates the relative level of microbial activity, eg a high OUR means high activity. Measured by recording the rate of fall of DO with time in a fresh sample of mixed liquor from the activated sludge plant.

Table 4 Suggested routine monitoring programme for an activated sludge plant

Most effluent treatment processes used in the speciality chemicals industry either generate a sludge from a solids-liquid separation process or produce a sludge as a result of chemical precipitation, coagulation or a biological reaction.

Sludge treatment and disposal costs often form the major part of the operating costs of an ETP. Sludge treatment to reduce the volume of sludge requiring disposal will produce savings through reduced transport and other costs, eg landfill charges. **However, sites that take action to reduce the amount of sludge produced in the first place will save much more money.**

To prevent nuisance, sludge odour control measures should be considered. These can include passing the off-gases from the treatment process through activated carbon, sand, soil or peat beds or through scrubbing towers containing chemical agents.

8.1 SLUDGE THICKENING AND DEWATERING

Sludge thickening and dewatering are mechanical operations used to produce a more concentrated sludge by reducing the volume, ie removing water.

Thickening processes generally increase the sludge concentration to 6% dry solids, while dewatering processes can concentrate the sludge to 40% dry solids.

8.1.1 Thickening

Currently used methods include gravity thickeners, decanters and drum thickeners. The easiest method of thickening is simple consolidation of the sludge in thickening tanks.

Sludges from primary and secondary settlement tanks are generally about 0.5 - 1.0% dry solids. Sludges from dissolved air flotation units have higher values - up to 4% dry solids.

Optimisation of the thickening process can be achieved by:

- Mixing pre-treatment sludges with biological sludges (the exact ratio will depend on the site and the relative volumes of sludge requiring disposal).
- Using tall and narrow tanks rather than low tanks with a large surface area. The efficiency of thickening depends on the height of the sludge layer and not on the volume of sludge above it.
- Providing gentle agitation to help reduce 'banding' of the sludge and promote the release of entrained gases. The most common method is a picket fence within the tank.
- Minimising residence time in the thickening tank to avoid the formation of septic conditions, with associated odour and corrosion problems.
- Adding sludge to the thickener at the rate of 20 - 30 m^3 of feed/m^2 of surface area/day.

8.1.2 Dewatering

Dewatering is typically carried out using a centrifuge, belt press or plate and frame press.

Some form of chemical conditioning is generally required to help separate the entrained water from the sludge flocs before the sludge is pressed or centrifuged. A wide range of flocculants are available, which are very effective but expensive. It is therefore essential to perform regular tests to optimise dose rates and sludge cake quality.

If you want to reduce the cost of effluent treatment:

- Identify the benefits of improved control, eg reduced operating costs, improved public relations and effective compliance with environmental legislation.
- Calculate your current effluent treatment costs and identify potential savings. Include water, chemical, energy, labour, maintenance, discharge and sludge disposal costs.
- **Adopt a site-wide view of pollution control as an integral part of the manufacturing process. Implement a systematic approach to waste minimisation to reduce the amount and variability of effluent requiring treatment.**
- Assess the performance of your existing ETP by carrying out a flow and load survey.
- **Define your effluent problem by characterising your effluent streams. Implement a programme of sampling and analysis for all production effluents.**
- Review the performance of each process unit in your ETP. Identify areas to reduce costs and improve performance, eg:
  - monitor key parameters regularly;
  - control flow balancing and diversion facilities;
  - fine-tune pH control systems;
  - maintain optimum dose rates for chemical additions;
  - monitor trends in performance and identify reasons for deviations.
- Review and optimise your sludge management strategy.
- Monitor cost savings associated with changes in the operation of your ETP.
- Publicise your achievements and successes to all stakeholders. This will help to ensure commitment to further improvements.

If necessary, obtain help.
The Environment and Energy Helpline (0800 585794) can:

- Send you copies of relevant Environmental Technology Best Practice Programme publications.
- Suggest other sources of information.
- Provide free, up-to-date information on a wide range of environmental issues, legislation, technology and equipment suppliers.
- Arrange for a specialist to visit your company if you employ fewer than 250 people, at the discretion of the Helpline Manager.

FLOW MEASUREMENT, SAMPLING AND DATA ANALYSIS

Flow measurement

The intermittent nature of effluent streams from batch processing requires the use of flow measurement techniques capable of making accurate continuous measurements and recording variable flow rates over every 24-hour period. Spot measurements made over short periods of time generally give inaccurate and misleading data. Suitable flow meters cost from £300 to £3 000.

When selecting and operating a flow measurement device specific to your needs, it is essential to take into account:

- the maximum flow rate expected;
- the optimum location to minimise restrictions to normal flow;
- accurate operation according to the manufacturer's instructions;
- specified calibration and checking procedures;
- potential problems from deposits of suspended solids and interference from foam, oil and grease, and corrosion.

Sampling and analysis

Representative and accurate sampling is critical. Collection and analysis of effluent samples during an effluent survey provides information on:

- the daily concentration of pollutants;
- peak concentrations and their duration;
- the concentration range.

Use of autosamplers

The variable composition of effluent from batch processes means that grab or spot samples are inaccurate for determining effluent strengths. Composite samples, ie material composed of individual sub-samples combined together, are usually required.

Composite samples are best taken using autosamplers, which can be programmed to take regular sub-samples into a common bottle or series of bottles. For example, sub-samples taken every 15 minutes for two hours into one container provide a two-hour composite sample for analysis. Sub-samples continue to be taken and are directed into another bottle for two hours, and so on. For a daily composite sample, the sub-samples are all directed into one large bottle over a 24-hour period.

Autosamplers cost from £1 200 for a basic portable sampler to £7 500 for a portable sampler designed for use in hazardous environments. Autosamplers can also be hired for £150 - £300/week.

Autosamplers operate as either:

- time proportional for sampling at fixed time intervals (most widely used); or
- flow proportional for sampling after a certain volume of effluent has been measured - this requires a signal from a flow meter.

To enable flow and concentration data to be linked, autosamplers should be placed on the same effluent streams as flow meters. It may be necessary to collect the samples into refrigerated containers and for the samples to be kept cool until they arrive at the laboratory for analysis. Your laboratory chemist should be able to advise on sample handling and analytical methods.

Table A1 shows a basic survey programme for a single effluent stream.

Parameter	Sample frequency and type
Record	
Flow	Continuous record*
pH	Continuous record*
Sample/analyse	
Biochemical oxygen demand (BOD)	4-hour composite sample
Chemical oxygen demand (COD)	4-hour composite sample
Total suspended solids (TSS)	24-hour composite sample
Ammoniacal nitrogen (NH_3-N)	24-hour composite sample
Total Kjeldahl nitrogen (TKN)	24-hour composite sample
Phosphate	24-hour composite sample
Temperature	Daily spot sample

* Log for statistical analysis.

Table A1 Basic survey programme for a single effluent stream

Recording and assessing data

Draw up a table of your survey data in time and date order, listing the parameters and values of relevance to your type of operation. If possible, use a computer spreadsheet. Fig A1 shows an example table from a fictitious company.

- Collate the flow information into four-hour and daily intervals to identify short-term variations and determine the effluent storage capacity required at the ETP.
- If you use biological treatment, calculate the COD:BOD ratio.
- Calculate the BOD, COD and TSS daily load using the formula given below. This provides a measure of the strength of the effluent.

  $$\text{Load (kg/day)} = \frac{\text{Flow (m}^3\text{/day) x Concentration (mg/litre)}}{1\,000}$$

- For each parameter in the table, calculate the minimum, average (or mean) and maximum values. These values show the variation in load.

Sample point	Plant A effluent pit: 24-hour composite sample										
	Flow		Concentration (mg/litre)					COD:BOD	Load(kg/day)		
Date	m^3/day	pH	BOD	COD	TSS	NH_3-N	PO_4	ratio	BOD	COD	TSS
20/07/99	1 882	7.1	236	660	123	20	14	2.8	444	1 242	231
21/07/99	1 896	7.3	240	789	152	19	12	3.3	455	1 496	288
22/07/99	1 920	7.6	260	756	120	13	11	2.9	499	1 452	230
23/07/99	2 011	7.5	253	730	110	13	11	2.9	509	1 468	221
24/07/99	2 515	7.3	520	830	190	16	15	1.6	1 308	2 087	478
25/07/99	2 670	7.6	180	470	91	12	13	2.6	481	1 255	243
26/07/99	2 012	7.1	200	440	85	14	12	2.2	402	885	171
27/07/99	2 145	7.8	150	520	74	10	11	3.5	322	1 115	159
28/07/99	2 256	7.5	164	560	99	11	10	3.4	370	1 263	223
Minimum	1 882	7.1	150	440	74	10	10	1.6	322	885	159
Average	2 145	7.4	245	639	116	14	12	2.8	532	1 363	249
Maximum	2 670	7.8	520	830	190	20	15	3.5	1 308	2 087	478

Fig A1 Example of data collection and assessment

appx A1

INTERNAL CHARGING FOR EFFLUENT TREATMENT MINIMISES WASTE

BIP Ltd manufactures a range of speciality plastics and resins for use as raw materials in the production of items ranging from electrical sockets to tissue paper. Products include thermoplastics, urea formaldehyde, moulding plastics and amino and polyurethane resins.

The benefits of initiatives to improve the operation of the effluent treatment plant (ETP) at BIP Ltd include:

- Total savings of £280 000/year
- Elimination of the need to upgrade the existing ETP
- Number of tanker journeys significantly reduced

Effluent Treatment at BIP Ltd

Effluent from the production plant is treated on-site and discharged to sewer. The site consists of six separate business areas, each with its own effluent pit. Before material is transferred from the pits to the site's effluent treatment plant, the flow is measured and samples taken for analysis.

The existing effluent treatment plant consists of two balancing tanks, two activated sludge reactors operating in series, and two final settlement tanks. Both reactors have surface aeration. New facilities to accommodate regular increases in production capacity were planned when a management buy-out occurred in 1995.

Measures to Improve Performance

Following the management buy-out, a review of the site's water use and effluent generation was undertaken and internal charging for effluent treatment introduced. Each business area is now charged for the effluent it discharges to the effluent treatment plant. Internal charges are made on the basis of the Mogden Formula. A system of fines for spillages and incidents has also been developed. This has helped to encourage a responsible approach to environmental performance in each business area.

The site effluent review identified a number of potential improvements in the operation of the effluent treatment plant. Changes have included:

- segregation of some high strength effluents in the balancing tanks;
- re-routing of low strength effluents to the second stage of the activated sludge process;
- segregation of liquid streams contaminated with solvents (now sent off-site for incineration);
- adding phosphoric acid as a nutrient and for pH control of the activated sludge process;
- upgrading of the monitoring system for pH and total oxygen demand (TOD);
- responsibility for effective operation of the ETP has been given to the operators of the chemical plant with the most polluting effluent.

Sludge from the biological treatment process was originally tankered off-site by a waste disposal contractor to a sewage treatment works. This disposal route involved a round trip of 100 miles. Following negotiations with the local water company, surplus activated sludge is now discharged direct to sewer for treatment at a large sewage treatment works. As part of the agreement with the water company, discharge is limited to certain times of day.

Savings and Benefits

Even though production has increased, application of the 'polluter pays' principle within the site and implementation of various waste minimisation initiatives have significantly reduced flows and loads to the ETP. As a result, BIP's trade effluent charges have decreased. The ETP currently costs £80 000/year to operate compared with £260 000/year in 1994.

These ongoing measures to reduce flows and costs have increased the efficiency of the existing ETP and avoided major capital expenditure. Without this improvement in performance, a larger plant would have been needed to manage the site's effluent.

The change in the sludge disposal route has produced cost savings of £100 000/year. In addition, there are environmental benefits through the reduction of tanker movements and exhaust emissions.

Host Company:

BIP Ltd,
Tat Bank Road,
Oldbury,
Warley,
West Midlands B69 4PG

FOR FURTHER INFORMATION, PLEASE CONTACT THE ENVIRONMENT AND ENERGY HELPLINE

0800 585794

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

e-mail address:
etbppenvhelp@aeat.co.uk

THE ENVIRONMENTAL TECHNOLOGY BEST PRACTICE PROGRAMME IS A JOINT DTI AND DETR PROGRAMME MANAGED BY AEA TECHNOLOGY PLC THROUGH ETSU AND THE NATIONAL ENVIRONMENTAL TECHNOLOGY CENTRE

ENVIRONMENTAL TECHNOLOGY BEST PRACTICE PROGRAMME

EFFLUENT CHARACTERISATION HIGHLIGHTS BENEFITS OF SEPARATE TREATMENT

Hickson & Welch operates 18 IPC-authorised processes, producing products based on hydrogenation, chlorination and optical brightener chemistry. Up to four new processes are implemented each year on a campaign basis. Effluent treatment currently costs about 2.5% of turnover.

The benefits of initiatives to improve the operation of the effluent treatment plant (ETP) at Hickson & Welch include:

- 16.5% reduction in trade effluent treatment charges
- Increased confidence of compliance with consent conditions
- Greater production flexibility and capacity

Effluent Treatment at Hickson & Welch

The existing ETP at Hickson & Welch consists of a neutralisation and precipitation system using lime and waste sulphuric acid, a balancing tank with diversion facilities, and high rate filtration. The Company currently discharges its effluent to sewer, accounting for 30% of the volume entering the local sewage treatment works. Because this discharge does not meet the requirements of the Urban Waste Water Treatment Directive 91/271, the water company is expected to double trade effluent charges over the next six years and impose restrictions on what can be discharged.

Following a review of available treatment options, Hickson & Welch decided to upgrade the existing ETP. The Company plans to install a low-pressure, wet oxidation process to pre-treat high strength effluent streams before they combine with general effluent for treatment by a new oxygen-aerated biological process. A pilot-scale plant was operated at the site for several months to verify the performance of the selected processes.

Measures to Improve Performance

To maximise the effectiveness of the new plant, Hickson & Welch has implemented a number of measures in the existing ETP.

- One process effluent with a very high strength and colour is segregated for separate treatment by a high-rate biofiltration process.

- New process effluents are subject to extensive analysis to assess their toxicity, nutrient content and organic load.
- Effluents can be diverted at several points on the ETP if there is loss of pH control, a volume overload, a chemical spillage or a high-level alarm from the on-line total organic carbon (TOC) monitoring system.
- To produce an optimum clarified effluent, the pH system on the two-stage neutralisation and precipitation system has been fine-tuned to control to within 0.1 of a pH unit.
- Flow monitoring data from all the effluent lines are collated at a control centre and checked for changes. The control centre can initiate effluent diversion if an overload occurs due to excessive rainfall collection.
- The input and output from the high-rate filter are monitored for various parameters to ensure adequate nutrients are available and to assess the load to the high-rate filter.
- Staff from the site's environmental team take it in turns to manage the ETP on a 24-hour manning programme.

Savings and Benefits

Operational changes to the existing plant have resulted in significant benefits.

- Segregation and pre-treatment have reduced the COD load of the high strength effluent by over 90%. The reduced COD has contributed to a reduction in effluent treatment charges of 16.5%.
- On-line monitoring of effluent parameters ensures compliance with consent conditions.
- Site staff are more aware of the effects of production on the operation of the ETP. For example, spillages are now handled effectively through management plans and the need to implement production shutdown procedures has been avoided.

Hickson & Welch expects the new plant extension to:

- allow all wastes to be treated on-site, thus eliminating the need to discharge to sewer and permitting direct discharge to river;
- provide greater control of effluent treatment costs;
- improve the flexibility and manufacturing capacity of the production plant for both existing and new products;
- contribute to the improvement of the local river quality and confirm the Company's responsibility to the environment.

Host Company:

Hickson & Welch,
Wheldon Road,
Castleford,
West Yorkshire WF10 2JT

FOR FURTHER INFORMATION, PLEASE CONTACT THE ENVIRONMENT AND ENERGY HELPLINE

0800 585794

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

e-mail address:
etbppenvhelp@aeat.co.uk

THE ENVIRONMENTAL TECHNOLOGY BEST PRACTICE PROGRAMME IS A JOINT DTI AND DETR PROGRAMME MANAGED BY AEA TECHNOLOGY PLC THROUGH ETSU AND THE NATIONAL ENVIRONMENTAL TECHNOLOGY CENTRE

ENVIRONMENTAL
TECHNOLOGY
BEST PRACTICE
PROGRAMME

OUT-SOURCING EFFLUENT TREATMENT PRODUCES SIGNIFICANT BENEFITS

Nipa Laboratories, a subsidiary of BTP plc, produces fine and speciality chemicals for the pharmaceuticals industry. The North Wales site produces pharmaceutical intermediates and bulk active medicines.

The benefits of initiatives to improve the operation of the effluent treatment plant (ETP) at Nipa Laboratories include:

- Consistent quality of the final effluent
- Cost savings of £79 000/year from switching to land injection for sludge disposal
- Phasing of financial investment

Effluent Treatment at Nipa Laboratories

To achieve compliance with Nipa's internal standards and IPC authorisation conditions, Nipa needed to upgrade its effluent treatment and disposal methods. Since the site discharges to an estuary, improving the quality of the final effluent would also benefit the environment.

Nipa commissioned a new ETP through a partnership approach with a company specialising in effluent treatment. The out-sourcing experts were responsible for the design, construction and financing of the project and now operate and maintain the ETP. An open, team-based relationship between Nipa and the out-sourcing company ensures that the effluent is treated cost-effectively and to approved quality standards.

Measures to Improve Performance

The ETP has been designed to provide even flows and loads to the oxygen-activated sludge process and to cope with surges and unexpected events. On-line monitors provide automatic measurements of key parameters.

Effluent from the production plant flows initially into an equalisation tank. An associated diversion tank provides extra storage capacity for handling speciality effluent and rainwater collection. Material from the diversion tank can be bled back into the ETP in a controlled fashion. Effluent leaving the equalisation tank is monitored for flow, pH and total organic carbon (TOC) before nutrients are added in a dedicated dosing tank.

The effluent is then split between two bioreactors. Dissolved oxygen levels in the bioreactors are controlled by an automatic system which operates between two set points. Settlement of the mixed liquors from the bioreactors is carried out in two clarifiers, allowing separation of the biomass from effluent. Settled sludge is recycled to the bioreactors or when essential to plant operation, diverted to a sludge tank. This allows thickening of the sludge before being sent off-site as a fertiliser.

The final effluent is monitored automatically for pH and suspended solids, thus providing the option to send back the effluent for further treatment should it prove unsuitable for discharge.

- Changing from gravity feed to pumped flow from the equalisation tank improved performance considerably.
- Initially, the equalisation tank was operated at full capacity. It now normally operates half full, thus providing capacity for both flow and load balancing. The flow to the bioreactors can thus be maintained at a constant rate for most of the time.
- Nipa staff are trained to be aware of the effects of the production processes and spillages on the performance of the ETP. Procedures are in place to report incidents to the ETP operators so that effective action can be taken.
- Nitrogen and phosphorus are added to the effluent to aid biological treatment. However, one of the production effluents has a high nitrogen content. When this is available, it is used instead of the pre-blended mixture to provide the necessary nutrient balance.

Savings and Benefits

- Out-sourcing of the funding for the ETP allowed Nipa to phase financial investment to the benefit of the Company's core business activities.
- Out-sourcing the operation and maintenance of the plant safeguards Nipa against unforeseen expenditure on effluent treatment and provides long-term operational security.
- Initiatives to increase production yield and improve resource use have led to a continuous reduction in the organic load entering the ETP.
- Operational changes have resulted in an increase in the amount of sludge produced by the ETP to 100 m^3/week. Continued disposal to landfill would have cost approximately £113 000/year. Alternative options were evaluated and land injection chosen, saving £79 000/year. Future initiatives to reduce disposal costs further include investigating a sludge thickening system.

Host Company:

Nipa Laboratories,
Sandycroft,
North Wales

FOR FURTHER INFORMATION, PLEASE CONTACT THE ENVIRONMENT AND ENERGY HELPLINE

0800 585794

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

e-mail address:
etbppenvhelp@aeat.co.uk

THE ENVIRONMENTAL TECHNOLOGY BEST PRACTICE PROGRAMME IS A JOINT DTI AND DETR PROGRAMME MANAGED BY AEA TECHNOLOGY PLC THROUGH ETSU AND THE NATIONAL ENVIRONMENTAL TECHNOLOGY CENTRE

ENVIRONMENTAL TECHNOLOGY BEST PRACTICE PROGRAMME

TEAM APPROACH ACHIEVES SIGNIFICANT REDUCTIONS IN EFFLUENT FLOW AND STRENGTH

Pentagon Chemicals Ltd manufactures speciality organic and contract chemicals for use in the pharmaceuticals, oil, textiles, paper and food industries.

The benefits of initiatives to improve the operation of the effluent treatment plant (ETP) at Pentagon Chemicals include:

- Reduction in COD load to sewer of approximately 50%
- Reduced flow to the plant and to sewer
- COD discharges consistently well below consent limits

Effluent Treatment at Pentagon Chemicals

The effluent from Pentagon Chemicals Ltd is discharged to sewer after pre-treatment in two holding tanks with a continuous overflow. To comply with the Urban Waste Water Treatment Directive 91/271, the local water company proposes to install secondary treatment facilities at the sewage treatment works and recover its costs by increasing trade effluent charges. To reduce costs and comply with its environmental policy, Pentagon Chemicals has reduced the load on the ETP considerably by minimising effluent generation and improving effluent quality control. Concerns over pH fluctuations, high flow, high strength and the potential for carry over of oils also led Pentagon to upgrade the ETP.

Measures to Improve Performance

A team approach to waste minimisation involving people from all levels of the Company - managers, supervisors, process operators and maintenance engineers - is producing a culture change at Pentagon Chemicals. Each production process is being reviewed in turn to identify opportunities for avoiding waste and implementing cost saving measures.

Operational and other changes at the ETP

- Diversion of alkaline process streams to a diversion tank, where acid is added to the effluent before it is bled back to the ETP in proportion to the main flow.
- Reduction of the flow to the ETP by installing cooling towers to reduce water consumption.
- Using two diversion tanks to segregate high-strength streams from reactor boil-outs and phase separation processes. These streams are recycled to the process, where possible, or sent off-site for disposal, thus reducing the COD load discharged to sewer.
- Installation of skimming units on the holding tanks. Oil is collected by absorbent ropes passing through rollers and sent off-site for disposal.
- Modification of the holding tanks to incorporate an emergency diversion tank for control of any spillages. This will help to ensure that consent limits are met consistently.
- Improved production planning, reactor efficiency and re-use of reactor boil-outs have reduced COD levels and increased production efficiency.

Savings and Benefits

- Segregation of high-strength effluent has reduced the COD load to sewer by approximately 50%, thus reducing trade effluent charges.
- Increased production efficiency has further reduced the COD loading to sewer to approximately 33% of the consent limit.
- Diversion of uncontaminated cooling water to the river has significantly reduced the volume of trade effluent and hence trade effluent charges.
- Installation of a cooling tower to allow re-use of process water eliminated the need to invest several hundreds of thousands of pounds to increase the capacity and treatment capability of the existing non-potable water extraction system. Pentagon has also saved around £115 000/year in non-potable water supply costs.

Host Company:

Pentagon Chemicals Ltd,
Northside,
Workington,
Cumbria CA14 1JJ

FOR FURTHER INFORMATION, PLEASE CONTACT THE ENVIRONMENT AND ENERGY HELPLINE

0800 585794

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

e-mail address:
etbppenvhelp@aeat.co.uk

THE ENVIRONMENTAL TECHNOLOGY BEST PRACTICE PROGRAMME IS A JOINT DTI AND DETR PROGRAMME MANAGED BY AEA TECHNOLOGY PLC THROUGH ETSU AND THE NATIONAL ENVIRONMENTAL TECHNOLOGY CENTRE

Printed on paper containing 75% post-consumer waste.

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 Environment and Energy 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 ENVIRONMENT AND ENERGY HELPLINE

0800 585794

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

e-mail address: etbppenvhelp@aeat.co.uk