2.1.5 Biological treatment processes

2.1.5.1. Anaerobic biological treatment processes

General information

Anaerobic digestion is a process for degrading organic matter in closed vessels in the absence of air. Biogas comprising methane and carbon dioxide is a product of the process, which may be used to generate electricity at very large treatment plants, but is more commonly used to provide heating of the reactor, the process requiring temperatures in excess of 30ºC for optimum performance.

The process has been very successfully applied to the digestion and conditioning of sludges from sewage treatment works, to facilitate their final disposal to land, and has also been used for high strength organic wastewaters, for example form the food industry. The process must be used with care in industrial applications, a range of compounds having potential to inhibit digestion, including some metals (chromium, copper, etc), and commonly-encountered organic compounds (e.g. dichloromethane, PCP, carbon tetrachloride) (see Environment Agency, 1990).

Effluent after anaerobic treatment is in a reduced state, and will generally contain relatively high concentrations of dissolved methane, ammoniacal-N, sulphides, and amines, that will make it unsuitable for discharge to surface waters. Discharge to sewer may entail risks of methane gas or sulphide in the sewer, and subsequent aerobic treatment processes are widely applied.

Main benefits of anaerobic treatment usually relate to reduction of high COD values, with consequent reductions in trade effluent charges, or to conditioning of sludges, with typical applications being for treatment of wastewaters from dairies, breweries, and paper mills.

Applications for leachate treatment have been rare in the UK, and we are unaware of any full-scale plants being operated, although several have been operational in the Netherlands. Nevertheless, pilot-scale studies have been undertaken, financed for research purposes by the UK DoE/EA (see Blakey et. al., 1992; 1987; Reynolds and Nedwell, 1992).

Process overview

Process reactor tanks may have fixed media, onto which anaerobic bacteria attach, or may be of the fluidised bed type, which uses either granules of sand, or sometimes activated carbon, to allow the formation of “bacterial granules” which move around in the reactor. A common form of such a process in the “Upflow Anaerobic Sludge Blanket”, or UASB reactor.

Although relatively uncontrolled anaerobic lagooning of leachates has had some success in warmer climates, for example Italy (reported by Blakey et. al., 1992), this is unlikely to be either successful, or environmentally acceptable, at UK landfill sites.

Heaters fuelled by the biogas being generated will usually be needed, but supplementary gas must also be available (possibly landfill gas may be used), for occasions when the reactor is not working fast enough to be self-sufficient in biogas, for example when flows are being increased. Blakey et. al. (1992) calculated from a small laboratory-scale unit that about 500 litres of gas, containing 70-80 percent methane, could be produced for each kg of COD removed.

Anaerobic digestion naturally generates hydrogen sulphide from biological reduction of sulphate, if this is present in leachate. This provides an efficient precipitant for most toxic metals, which accumulate as inert solids within the sludge, but release of H_2S gas must be managed safely. Surplus inorganic and organic sludge must be periodically removed from the reactor.

Accessories include a methane gas vacuum pump, solids mixing/recycle pumps, influent pumps, flow meters, and chemical dosing systems to allow for precise pH-value control. Because of the relatively long hydraulic retention times required, (Blakey et. al., 1987, estimated that a hydraulic retention time of about 70 days would be needed to achieve 90 percent COD removal in a leachate containing upto1 50,000 mg/l of COD) relatively large reactors are required.

The main problems for anaerobic digestion of leachate can be summarised as follows:

- The process does not remove ammoniacal-N at all, and indeed is more likely to increase concentrations of this main contaminant of landfill leachates. Secondary aerobic biological and other processes will generally be essential;
- A COD value in raw leachate in excess of about 10,000 mg/l is essential if the anaerobic treatment process is to be self-sufficient in energy. At most modern landfills, the acetogenic phase where this is the case for leachates is relatively short-lived;
- The anaerobic processes being used are far more efficiently provided within the landfill body itself, where optimum and stable temperatures are likely to be present. Recirculation of acetogenic leachates in a controlled way may well enable this to be carried out successfully, with resulting landfill gas collected by the existing systems. However, this activity is beyond the remit of this document and should be considered as part of the overall landfill process.

On this basis, it is unlikely that anaerobic digestion as a leachate treatment system, will find successful or widespread application at UK landfills.

2.1.5.1.1 Upflow anaerobic sludge blankets (UASB)

General information

The liquid waste to be treated enters the reactor at the base and is passed up through a sludge blanket. This blanket consists of anaerobic bacteria that have formed into granules that have a high settling velocity and are therefore retained in the reactor. The liquid waste flows up through the sludge blanket and effluent is discharged from the top of the reactor. Mixing in the reactor is aided by the production of anaerobic gases and the upward flow of liquid waste. As with other anaerobic activities this treatment is unlikely to be applied to leachate.

Indicative BAT for anaerobic biological treatment processes
1. It is unlikely that anaerobic biological leachate treatment will be successfully employed, because of the high COD levels required and the inability to remove ammoniacal-N. Consequently any proposal to use anaerobic digestion must be considered carefully and full justification provided for its selection as an appropriate technique.

2.1.5.2 Aerobic biological treatment processes

Introduction

The great majority of leachate treatment systems that have been installed and have operated successfully, in the UK and elsewhere in the World, have incorporated an aerobic biological treatment stage. The main benefits of aerobic biological processes are that many contaminants are actually degraded and treated, rather than concentrated to appear in another form (e.g. in sludge, or a concentrated “brine”).

During aerobic biological treatment, organic compounds can be largely oxidised to carbon dioxide and water, and ammoniacal nitrogen (ammoniacal-N) can be removed by oxidation (nitrification) to nitrate. Nitrification is a widely adopted biological treatment process for domestic and industrial effluents, although relatively high concentrations of ammoniacal-N (often greater than 1000 mg/l) in leachates can require specific process designs, if treatment efficiency is not to be inhibited by toxic effects.

In some instances, at an increasing number of locations, concern about the impacts of releases of high concentrations of nitrate in effluents (e.g. eutrophication, potable waster concerns etc), require these to be reduced before discharge. The process of denitrification can be combined within the treatment process, within an anoxic reactor or as part of anoxic stage of a reaction. In an anoxic environment, absence of either oxygen molecules or other chemically bound oxygen, means that bacteria instead use the oxygen in the nitrate compound to oxidise organic compounds. Simple organic compounds such as methanol are often added at this stage of treatment, to provide a readily degradable oxygen demand. The nitrate is thereby reduced to nitrogen gas, which is safely released into the atmosphere (which comprises 80 percent by volume of nitrogen gas).

Aerobic biological treatment plants are therefore designed to be able to perform the following main treatment processes:

- Denitrification of organic carbon compounds
- Nitrification of ammoniacal-N
- Full or partial denitrification of nitrate-N.

Each of the treatment processes is effected by communities of bacteria, which metabolise the contaminants. A well-designed treatment process must ensure that the bacteria are provided with optimal growth conditions, and are mixed intimately with the leachate to be treated, with oxygen, nutrients as necessary, and at appropriate temperatures and pH-values. Issues related to this control are discussed in general terms below, and apply to a variety of different aerobic biological treatment systems.

General overview of aerobic biological treatment processes

Aerobic biological processes have been demonstrated to be able to provide effective treatment of leachates from landfills in early, acetogenic stages of decomposition, and also to leachates from older sites, in methanogenic stages. Treatment can readily reduce high concentrations of COD and BOD in acetogenic leachates, and effect nitrification of high concentrations of ammoniacal-N in both acetogenic and methanogenic leachates, from a wide variety of landfills receiving household, commercial, and industrial wastes.

In addition, a variety of trace organic compounds often present in leachates, are also readily treatable.

Because a range of different aerobic biological treatment systems, when appropriately designed, have many common features in terms of treatment processes, key issues have been considered below in more detail, with respect to:

(i) Treatment of COD and BOD;

(ii) Treatment of ammoniacal-N;

(iii) Treatment of trace organic and other compounds.

(i) Treatment of COD and BOD

From the point of view of aerobic biological treatment of leachates, the 5-day biochemical oxygen demand (BOD_5) test is rarely an adequate measure of the extent to which organic compounds can be degraded within a well-designed treatment plant, containing an acclimatised bacterial population. The BOD_5 test uses a standard (sewage-based) bacterial seed, and is limited to a 5-day incubation period. Although the 20-day BOD test (BOD_{20}) may be more helpful, generally the COD value is used for design purposes.
Most, if not all, successful aerobic biological leachate treatment plants, achieve far higher removal of organic compounds than is predicted by even 20-day BOD results. Table 2.10 below presents typical UK examples.

Experience has demonstrated that levels of residual, non-degradable, “hard” COD in effluents from aerobic biological treatment of leachates, are not closely related to concentrations of organic materials in raw leachate, but rather to influent concentrations of ammoniacal-N. This is likely to be the result of associated release during the degradation of the landfilled wastes, or possibly (to some extent), their generation during the process of nitrification. Figure 2.5 below presents data to demonstrate this, from a wide variety of leachates treated in full-scale and pilot-scale aerobic biological systems.

Table 2.10: Typical performance of aerobic biological leachate treatment schemes in removal of COD and BOD (in mg/l, concentrations of ammoniacal-N provided for comparison)

Site	Ref	Determinand	Influent	effluent	removal
Arpley	(a)	COD	5990	1470	4520
		BOD_{20}	1720	67	1653
		BOD_5	688	20	668
		NH_4-N	1460	3.7	1456
Pitsea	(b)	TOC	365	337	28
		BOD_5	28	19	9
		NH_4-N	281	0.4	281
Bryn Posteg	(c)	COD	5518	153	5365
		BOD_5	3670	18	3652
		NH_4-N	130	9	121
Llanddulas	(d)	COD	3400	1310	2090
		BOD_{20}	682	15	667
		BOD_5	88	5	83
		NH_4-N	1330	<0.3	1330

References: (a) Robinson et. al., 2003a, (b) Knox, 1991, (c) Robinson and Grantham, 1988, (d) Howard Robinson, unpublished data

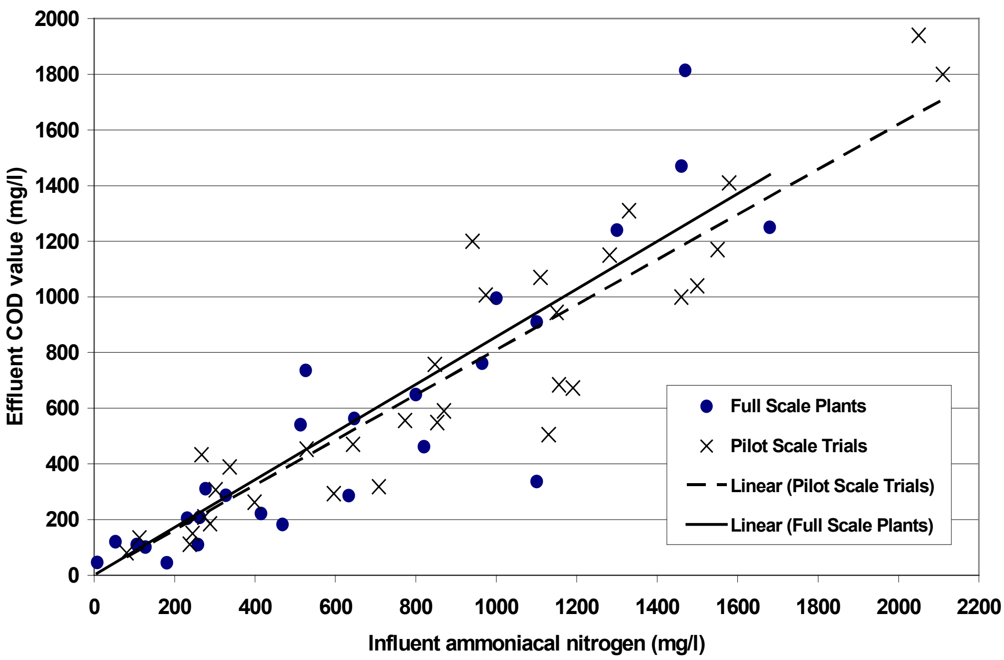

Figure 2.5: Relationship between ammoniacal-N in raw leachate, and COD values in effluents from aerobic biological treatment (after Carville et. al., 2003)

A proportion of organic compounds in leachate are used by bacteria in cell synthesis, as new bacteria grow. In treatment of methanogenic leachates, with low organic content, this will be balanced by death and lysis of bacteria, or by gradual loss of some bacteria in effluent, and generally little net increase in bacterial populations (sludge growth) takes place.

In treatment of acetogenic leachates, containing higher concentrations of degradable organic substances (COD values of 5000 mg/l or much greater), cell synthesis becomes much more important, for two reasons. First, production of biological sludge is significantly increased, requiring removal of ammoniacal-N into biomass. Detailed laboratory studies by Robinson and Maris (1983) demonstrated that nitrogen uptake in cell growth amounted to about 3.6 percent of COD reduction, a value that is typical of data reported by other workers. Although significant (reduction of 10,000 mg/l of COD would consume 360 mg/l of ammoniacal-N), this will rarely be adequate to account for complete removal of ammoniacal-N, even in acetogenic leachates, and some degree of nitrification will be needed to reduce remaining concentrations of ammoniacal-N to low levels in effluent.

The nature of relatively inert residual COD in treated leachates has been studied to some extent. Of greatest importance is the fact that, although relatively high COD values may be present in effluent, a number of studies have demonstrated no detectable toxicity to the Microtox® test (e.g. Robinson et. al., 2003a), or to fish (e.g. Robinson et. al., 2003).

(ii) Treatment of Ammoniacal-N

Nitrification

Nitrification is the biological oxidation of ammoniacal nitrogen to nitrate nitrogen by autotrophic bacteria, which derive energy from the oxidation reaction, and utilise inorganic carbon as their principal food source. The nitrification reaction is a two-stage oxidation, each stage being performed by a distinct group of bacteria. The first stage, oxidation of ammoniacal nitrogen to nitrite nitrogen, is performed by bacteria of the genus *Nitrosomonas*. The second stage, where this nitrite nitrogen is further oxidised to nitrate nitrogen, is performed by species of Nitrobacter. The reactions are shown empirically below:

1st stage $55\ NH_4^+ + 76\ O_2 + 5\ CO_2 \rightarrow 54\ NO_2^- + 109\ H^+ + 52\ H_2O + C_5H_7O_2N$

2nd stage $115\ NO_2^- + 52.5\ O_2 + 5\ CO_2 + NH_4^+ + H_2O \rightarrow C_5H_7O_2N + H^+ + 115\ NO_3^-$

From the above empirical reactions it may be calculated that for one kilogram of ammoniacal nitrogen that is nitrified:

- 4.27 kg of dissolved molecular oxygen is consumed,
- 7.14 kg of alkalinity, as $CaCO_3$, is destroyed,
- 0.22 kg of new cells are synthesised.

Both groups of bacteria are relatively sensitive to environmental conditions (compared with those groups which oxidise organic substrates), and either one or both stages can be easily inhibited by:

- Low pH-values (below about 6.5);
- Insufficient dissolved oxygen (below about 2 mg/l);

- Low temperatures (below 5°C), or high temperatures (above 35°C);
- Toxic inhibition.

A wide range of chemicals are known to inhibit nitrification by toxic effects, although enough work has now been carried out on nitrification in European leachates to show that such inhibition is rare in the UK, and treatment can be readily achieved, particularly in methanogenic leachates. However, the range of toxic chemicals includes both ammoniacal nitrogen itself, and the intermediate oxidation product, nitrite nitrogen, both of which can potentially inhibit the second stage of the reaction, leading to a build up of nitrite nitrogen in effluent.

The optimum pH-value for biological nitrification is typically between 7.5 and 8.0 (often quoted as 8.4), and nitrification rates decrease very sharply at pH values below 5.5. Nitrifying bacteria can, however, sometimes adapt to acidic environments, but rarely operate efficiently within them. Therefore, unless the wastewater being treated contains sufficient alkalinity, the nitrification reaction will ultimately prove to be self-inhibitory as it releases hydrogen ions and depresses pH-values. This process, together with maintenance of insufficient concentrations of dissolved oxygen, is the most common cause of failure in full-scale treatment plants trying to accomplish nitrification.

Many previous pilot-scale studies undertaken (e.g.: Robinson and Luo, 1991) and experiences at many full-scale leachate treatment plants in the UK, have looked in great detail at alkalinity requirements for nitrification, and availability in leachates. In strong methanogenic leachates it has routinely often been found necessary to add alkalinity, at rates up to 50 percent of that originally present in raw leachate. Lower concentrations of ammoniacal nitrogen may also require addition of alkali, albeit in lesser amounts. Nutrient requirements in leachate treatment are well understood, for example the need to add phosphorus (e.g.: Robinson, 1990; Robinson and Grantham, 1988).

Denitrification

Biological denitrification is the reduction of nitrate nitrogen to nitrogen gas by facultative heterotrophic organisms that use organic carbon for energy and as a carbon source. These organisms can use molecular oxygen as the electron acceptor under aerobic conditions, but are also able to use nitrate nitrogen as the electron acceptor under anoxic conditions. An anoxic stage is a zone where only chemically combined oxygen is available, and can be used by bacteria, in the form of nitrate nitrogen and nitrite nitrogen. It should not be confused with “anaerobic”, which describes conditions where a complete absence of available oxygen exists.

Denitrification can sometimes be incorporated into a treatment process for reasons other than a need to reduce nitrate levels, one example can be as a means of reducing requirements to add external alkalinity, and the process is described in detail below.

Denitrification of nitrate nitrogen to nitrogen gas occurs in many wastewater treatment plants, and has become the most widely-used nitrogen removal process in municipal wastewater treatment. It has also been reported to be a significant process at full-scale landfill leachate treatment plants (Robinson, 1990). A large number of bacterial species which occur naturally in the activated sludge process, or in extended aeration treatment systems, are capable of denitrification, making use of the oxygen contained in the nitrate ion. These organisms are termed heterotrophic bacteria, and are capable of using either molecular oxygen, or nitrate nitrogen and nitrite nitrogen oxygen, when they oxidise organic compounds. Under anoxic conditions, in the absence of available molecular oxygen, nitrate nitrogen dissimulation occurs through a complex series of reactions catalysed by enzymes. Facultative bacteria which are oxidising organic carbon compounds in a single sludge process are therefore able to switch easily from oxygen to nitrate for respiration.

In a treatment plant where nitrification is the main process being achieved, it is generally necessary to add an organic substrate to allow denitrification to proceed. A variety of organic substrates are suitable. Methanol (CH_3OH) is widely used. The overall reaction, including cell synthesis, may be expressed by the following equation:

(a) $NO_3^- + 1.08\ CH_3OH + 0.24\ H_2CO_3 \rightarrow 0.06\ C_5H_7O_2N + 0.47\ N_2 + 1.68\ H_2O + HCO_3^-$

The N_2 gas is released to air. From this empirical reaction it may be calculated that for one kilogram of nitrate nitrogen that is denitrified:

- At least 2.47 kg of methanol are used,
- 0.45 kg of new cells are synthesised,
- 3.57 kg of alkalinity are formed.

The presence of dissolved oxygen inhibits the denitrification process, concentrations of more than 0.2 to 0.5 mg/l have been shown to significantly reduce denitrification activity. Denitrification activity is reduced at low temperatures and enhanced by an increase in temperature up to an optimum of 40°C. Temperatures above this level prevent denitrification.

As alkalinity is formed during denitrification, the addition of an acid such as sulphuric acid to maintain the pH-value within a narrow optimal range of 7 to 7.5 may possibly be needed. It has been shown that for pH-values less than 6 and greater than 8 there is a rapid decrease of denitrification activity.

(iii) Treatment of trace organic and other compounds

Recent work on behalf of the Environment Agency (Robinson and Knox, 2001; 2003), based on an extensive programme of sampling at landfills and aerobic biological leachate treatment plants in the UK and Ireland, has obtained data on presence of a wide range of trace organic compounds and heavy metals in leachates, and on their removal by a variety of treatment processes. This work has provided indicative median removal rates for those trace compounds that were detected in more than 5 percent of leachates tested, where it has been possible to obtain these (for some compounds, no removal data were available, and it was not possible to provide indicative results).
Table 2.11 below presents results for the range of compounds and metals investigated during the study.

It is important to emphasise that all of these data relate to well-designed and operated aerobic biological leachate treatment plants, generally achieving full nitrification of all ammoniacal-N.

Aerobic biological treatment of leachate

Although aerobic biological treatment processes have been widely applied to the treatment of domestic wastewaters, and of industrial effluents, there are several specific characteristics of leachates that must be recognised in the design of appropriate facilities. These are considered in turn below:

- High concentrations of ammoniacal-N, generally >500 mg/l and regularly in excess of 1000 mg/l at modern landfills, are many times stronger than levels of 25-30 mg/l typically encountered in domestic wastewaters.

Although direct toxicity of ammoniacal-N to nitrification processes is not a significant issue in sewage treatment, wide experience in leachate treatment systems has demonstrated that (at typical pH-values in the range 7-8), concentrations of 80 mg/l of ammoniacal-N or above significantly inhibit the nitrification process. A number of full-scale leachate treatment plants in the UK have failed as a result of lack of knowledge about this process. Actual levels of toxicity are related to presence of free ammonia, which in turn is a function of concentration of ammoniacal-N and pH-value (at higher pH-values, a higher percentage of total ammoniacal-N is present as free ammonia).

Leachate treatment designs must take account of these issues for example, direct application of 1000+ mg/l of ammoniacal-N to bacteria on the surface of an attached growth system will lead to serious toxic inhibition. Several designers have failed to recognise the significance of this. Furthermore, acidity produced during nitrification will often require very large additions of alkalinity to buffer pH-values, requirements to add between 10-15 litres of 32% w/v NaOH to every cubic metre of leachate treated are not uncommon. Kalic lime has also been used for additional alkalinity. Additionally there is occasionally sufficient alkalinity, measured as $CaCO_3$ present in the leachate to neutralise the acid reaction of nitrification.

- High concentrations of other contaminants can lead to problems not generally encountered in treatment of domestic or other weaker wastewaters. Degradation of high (>5000 mg/l) BOD and COD values can generate high volumes of organic sludge, which may clog attached growth systems and require routine removal from suspended growth systems. High concentrations of iron, calcium and other metals may lead to similar problems with inorganic sludges or deposits. High salinity may require that bacteria being used to effect treatment are gradually acclimatised to the leachate being treated, and this may take several months before optimum treatment rates are achieved.
- Variability of quality and quantity of leachate to be treated, both over timescales of years and seasonally, have been discussed earlier, and remain key issues.

Table 2.11: Median concentrations of a range of trace organic compounds and heavy metals detected in more than 5 percent of UK landfill leachates, and median percent removal during aerobic biological treatment (after Robinson and Knox, 2001; 2003)

Substance	% detected	LOD (µg/l)	Median concentration (µg/l)	% removal
Chromium	33	20	50	30
Nickel	86	10	60	20
Copper	60	5	11	50
Zinc	100	5	135	70
lead	8	20	<50	no data
arsenic	94	1	8	70
aniline	17	1	<1	80
AOX	97	<8	177	no data
biphenyl	51	0.1	0.1	60
DEHP	25	1	<1	90
ethylbenzene	15	10	<10	80
MCPA	12	0.1	<0.1	95
MCPP (mecoprop)	98	0.1	11	99
methylene chloride	12	1	<1	no data
MTBE	8	1	<1	90
naphthalene	70	0.1	0.46	95
nonyl-phenol	83	0.2	1.0	95
organotin	50	0.02	0.20	no data
pentachlorophenol	8	0.1	<0.1	50
Phenols (mono)	54	20	0.03	99
PAH (Borneff 6)	29	5	<5.25	50
Toluene	54	10	21	80
Xylenes	35	10	35	60

Notes: Limit of detection (LOD) represents typical levels obtained by a normal commercial laboratory in leachate samples

Percent removal data relate to median values for well-designed and operated aerobic biological leachate treatment plants, of various sorts

All concentrations in microgrammes per litre (µg/l)

Higher percent removals have been demonstrated to be possible for a number of substances where subsequent polishing processes (e.g. reed beds) are applied

Aerobic biological treatment processes can be divided broadly into two categories, namely:

- Suspended (or dispersed) growth systems, or
- Attached growth systems.

2.1.5.2.1 Aerated lagoons

General overview

First attempts to treat leachates, during the 1970s and 1980s, used simple aerated lagoons, and achieved some successes. Lagoons were often large, typically 1-2m deep, and usually designed to look like natural lakes, with vegetation around their perimeter. A small, sub-surface aeration system has generally been used to provide oxygen inputs and slow circulation of the lagoon, but is rarely adequate to provide turbulent mixing of biological solids, which generally settle out in more quiescent areas of the lagoon.

Outline of the process

Biodegradable organic matter is stabilised by a combination of aerobic and anaerobic processes. The lower part of the lagoon is generally anaerobic, as sludge and solids settle there to be converted to carbon dioxide and methane. The upper portion of the lagoon is aerobic, oxygen being provided by a combination of the aeration system, passive surface aeration across the water/air interface, and also to a significant extent in some locations, by algal growth during daylight hours. The aerobic upper layers act as a “cap” to oxidise reduced compounds from the underlying anaerobic zone, minimising odour releases.

Effluent is withdrawn from the upper aerobic zone, generally over an overflow arrangement, although a secondary settlement lagoon, or reed bed filtration system, is normally required where a discharge to surface waters in envisaged. The main technical installation is the aeration system of the lagoon.

Although algal growth may be promoted by constructing lagoons as shallow basins, algae do not settle well, and often pass into effluent where they contribute biodegradable organic matter and suspended solids. In most Central and Northern European climates, as in the UK, water temperatures routinely fall below 5 or 10°C for extended periods, and strongly influence treatment rates. At low water temperatures, below such values, nitrification of ammoniacal-N stops completely, and may take several weeks to recover. Only at average temperatures of 15°C or above, with volumetric loads of less than 20g of BOD per m^2/d, can BOD_5 values be reduced to below 25 mg/l, and full nitrification be expected (Albers, 1985; Maehlum, 1997).

Aerated lagoons may be provided with increased oxygen inputs, to improve treatment rates, but nevertheless will typically have hydraulic retention times of many weeks. They have generally proved effective only for relatively diluted leachates (ammoniacal-N <300 mg/l), and overall are unable to provide consistent degrees of treatment.

During the 1980s, aerated lagoons increased in sophistication, being shaped and provided with additional power for mixing and aeration. This meant that active biomass could be maintained in suspension at all times, and although the synergistic relationship with a deeper anaerobic zone was lost, the more intensive and controlled process, generally operated as a Sequencing Batch Reactor (SBR – see later), provided more reliable and more consistent treatment.

Environmental issues and concerns

The main concern with use of simple aerated lagoons for treatment of leachates is the ability of designers to provide a robust system, capable of providing consistent and reliable treatment of a specified leachate to a required standard. Although any aeration of leachate will undoubtedly provide some degree of improvement in leachate quality, whether this can be provided efficiently and consistently is doubtful.

Environmental impacts and concerns, apart from inefficient use of energy, include large land requirements, indeterminate requirements for de-sludging of the lagoon, sensitivity to temperature, and potential for odours. The main concern is inability to provide a design that is able to consistently meet specified effluent discharge limits, especially when treating stronger leachates during winter months.

2.1.5.2.2. Activated sludge

General information

The most widely used aerobic biological processes for treatment of domestic wastewaters are based on the activated sludge process. The activated sludge system provides far more intensive treatment than achieved within an aerated lagoon, by operating with greatly increased populations of acclimatised bacteria, and far more intensive and vigorous aeration.

Process overview

The aeration tank is completely mixed, generally by use of a vigorous aeration system, and receives controlled and steady inflows of raw leachate continuously. Mixed liquor overflows continuously from the aeration tank, into a sludge separation stage, generally comprising a settlement reactor. Here, biomass/sludge is settled, to be returned into the aeration reactor, and a clarified effluent is decanted from the surface, for discharge or further treatment (see Figure 2.6).

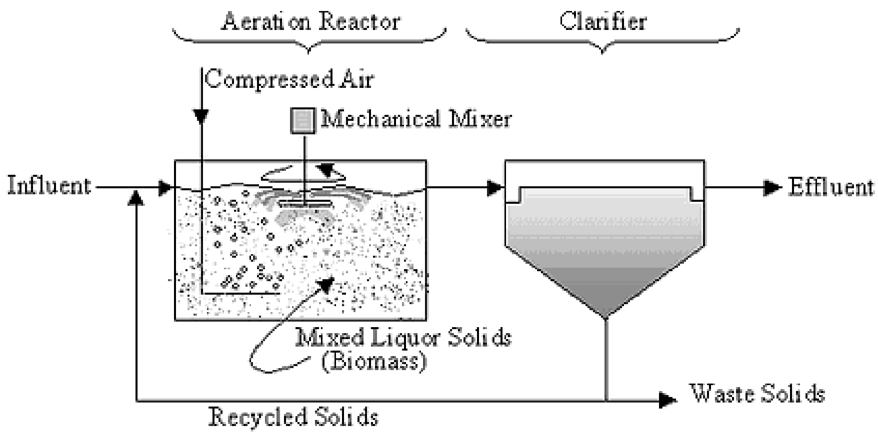

Figure 2.6: Typical activated sludge process

Although in treatment of domestic wastewaters, the process can be intensified such that mean hydraulic retention times (HRTs) in the order of 8-12 hours may be achieved, the much greater strength of leachates, and increased oxygen transfer requirements for full treatment, mean that greater periods of treatment are needed. Plate 2.11 below shows a typical application of the activated sludge process to leachate treatment in Germany during the early 1990s.

Plate 2.11: Typical application of the activated sludge process to leachate treatment, showing sludge settlement in the foreground, and aeration reactor in the background, Germany, 1990

Additions of nutrients (primarily phosphorus) and of alkalinity to buffer acidity generated during the nitrification process, are required routinely, and biological sludge must be wasted from the process, and disposed of on a regular basis, especially while treating leachates containing substantial levels of biodegradable organic materials.

The weakness of the activated sludge process for leachate treatment lies primarily in the intensive nature of the continuous sludge separation/effluent clarification process. Any short-term variations in ability of biomass to flocculate and settle, are rapidly exhibited by poor effluent quality. In particular, for a wastewater such as leachate, where treated effluent may contain in excess of 1000 mg/l of nitrate-N, the development of slightly anoxic conditions within the settlement tank at any time, can lead to uncontrolled denitrification, with bubbles of nitrogen gas attaching themselves to sludge flocs, causing these to rise to the surface and impact on final effluent quality (see Plate 2.12).

Plate 2.12: Rising sludge as a consequence of denitrification within the settlement phase of an activated sludge system treating leachate, Germany, 1990

Rising sludge may be reduced by the use of plate separators. A more recent development has been the use of specialised membranes for separation of sludge and effluent, instead of conventional settlement tanks. This can be a microfiltration or an ultrafiltration process. In countries such as Germany, many domestic wastewater treatment plants now incorporate such processes. Biomass separation using ultrafiltration has a number of advantages (Ehrig, 2003);

- The process can separate much higher concentrations of biomass in mixed liquor;
- Ultrafiltration reliably retains all biomass, allowing effluent quality to be stabilised and improved;
- Ultrafiltration destroys biomass sludge flocs, increasing the available surface area of the biomass, with potential to increase treatment efficiency – especially during the nitrification process.

One specific potential disadvantage of an ultrafiltration membrane activated sludge plant is that the ultrafiltration process may experience problems with the high concentrations of inorganic components of landfill leachate, precipitation of these substances can damage membranes, and reduce flux rates through them.

During coming years it is likely that ultrafiltration technologies will increase, and their use in combination with activated sludge processes will find increased application for leachate treatment. Recent developments in Membrane Bioreactor (MBR) processes are essentially similar (see separate MBR section).

The activated sludge process can be modified to include a denitrification stage, for the reduction in concentrations of nitrate in effluent, using either predenitrification (Pre-DN) or postdenitrification (Post-DN), and these two processes are discussed in detail later.

Environmental issues and concerns

Potential environmental impacts and concerns regarding the operation of a well designed and well operated activated sludge process for leachate treatment have much in common with those applicable to a range of other aerobic biological treatment systems. Odour generation can be much less than at a domestic sewage works but may still require control, see Section 2.2.6. Noise emissions may be an issue because of the need to vigorously aerate and are considered in Section 2.9.

Standard practice for storage, handling and dosing of chemicals used in treatment should be adopted as a matter of course – routine use of 82% w/v phosphoric acid (which has a s.g. of 1.6), and of 32% w/v sodium hydroxide solutions, for example. The latter has a freezing point of between 7 and 9°C, so full thermal protection, trace heating of pipework etc is essential, to prevent crystallisation within automated dosing systems.

As in all biological treatment systems, well-designed and appropriate safeguards, fail-safe interlocks, alarm and telemetry systems, and operator training are fundamental to safe operations.

Although few, if any, traditional activated sludge systems are presently being used for treatment of leachates in the UK, future developments in sludge separation, and overseas experiences, may lead to more such systems being proposed in future.

2.1.5.2.3 Sequencing Batch Reactors (SBRs)

General information

The Sequencing Batch Reactor (SBR) treatment process has been developed as a readily-automated, extended aeration system, that is particularly well-suited to the higher organic strength and concentrations of ammoniacal-N in landfill leachates. The larger volume of the main SBR tank makes for efficient aeration, high rates of dilution of incoming leachates, and high resistance to shock loading. The great majority of well-engineered aerobic biological leachate treatment systems successfully installed in the UK make use of SBR technologies.

Process overview

An SBR is a cyclically operated, suspended growth, activated sludge process. The only conceptual difference between the SBR and a conventional activated sludge system is that each SBR tank carries out functions such as aerobic biological treatment, equalisation, settlement of solids, effluent clarification and decanting, over a time sequence rather than in spatially separate tanks. The ability to vary the time sequence, (compared to the inflexibility of specific volumes of separate tanks) enables a very robust and flexible treatment system to be provided. SBR systems that have been designed for particular loading rates, of ammoniacal-N or of organic contaminants, will have considerable flexibility to receive this as either small volumes of strong leachate, or as larger volumes of weaker leachate. This can be important as leachate character changes over time to ensure that optimum treatment performance is maintained.

The operating cycle of a typical SBR system comprises four main phases, nominally:

FILL, REACT, SETTLE, DECANT

Although in treatment of domestic and other relatively dilute wastewaters, the fill stage (when wastewater feed is pumped into the SBR) may be a relatively rapid stage, for leachate treatment feeding of leachate generally takes place throughout the REACT stage, in order to balance oxygen demand and oxygen supply, to avoid shock loadings to micro-organisms and to avoid toxic inhibition from contaminants such as ammoniacal-N.

In leachate treatment, the process is readily automated, and generally operated within a 24-hour cycle, in a tank which provides a typical mean hydraulic retention time (HRT) of ten days or longer when treating strong leachates. In general terms, for such leachates, selection of a shorter HRT does not reduce operational costs at all, and may only result in marginal reduction in capital costs. A significant benefit of a 24-hour cycle, is a standard time of day (or night) when a discharge of clarified effluent is made from the SBR.

A typical* cycle of operation for SBR treatment of landfill leachate is therefore:

(1) FILL AND REACT: During a period of from 18-20 hours, leachate is gradually fed into the SBR, during which time the reactor is aerated, and pH-value is controlled;

(2) SETTLE: Aeration is stopped for between one and two hours, during which period sludge flocculates and settles, and supernatant liquor is clarified;

(3) DECANT: Effluent is decanted from the surface of the SBR, by means of one of a number of options (bellmouth overflow, floating decant – either gravity or pumped, etc), typically during a period of one or two hours depending on volume involved. Decanting stops and the treatment cycle then recommences.

In many instances, where the relatively high flow rate from the SBR cannot be fed directly to the disposal route (e.g. to sewer, surface water, or for further treatment such as in a reed bed), then an effluent balance tank is generally used to balance flows, and allow discharges to be made evenly at lower rates, over a 24 hour period.

SBR treatment systems adopted in the UK have comprised either lagoon systems, or tank-based plants, and these are considered separately below.

Supervisory Control and Data Acquisition (SCADA) systems, are reliable and simple to install and operate, and provide a high level of protection and safety, as well as the maintenance of detailed operating records. Consideration should be given to installing SCDA systems. It is unlikely that manually operated systems will provide adequate safeguards and protection, or even optimal treatment efficiency. Remote monitoring of the operation of the leachate treatment plant should consider the use of GSM dial out alarms.

Lagoon-based SBR systems

In the UK, initial SBR leachate treatment systems began to be designed and constructed during the early 1980s, that were based on engineered HDPE-lined lagoons (e.g. Robinson, 1984; 1985; 1987; Robinson and Davies, 1985). The term “SBR” was not generally used, although in hindsight this is exactly the process that was being applied.

Treatment plants were characterised by oval lagoons, with shallow sloping

* This is a commonly adopted operating cycle in the UK. Many other cycles are possible, including operation with 2 or more complete cycles each day. At some UK sites (eg Robinson, 1999) such operations have been beneficially adopted

sides, a concrete base slab, and an operating depth of typically 3m (see Plate 2.13). Two or more slow speed floating surface aerators provided efficient oxygen transfer, and re-suspension and turbulent mixing of solids at appropriate times in the operating cycle. In addition to surface aerators diffused air was used in the mid 1990s.The lagoon configuration encouraged optimum mixing patterns, and when needed, additions of phosphoric acid as a nutrient were made manually. Addition of alkalinity was only occasionally required, often because these plants were either installed at new landfills where significant volumes of acetogenic leachate were available, or at sites where leachates were relatively diluted (ammoniacal-N from 300-600 mg/l).

Plate 2.13: Typical lagoon-based SBR leachate treatment scheme – Summerston LTP, Glasgow, commissioned 1990

Often, treatment was required to enable discharges of treated effluent to be made into small sewage treatment works, which were unable to accept untreated leachates. Treatment objectives involved provision of an effluent similar in quality to domestic wastewater (e.g. BOD <100 mg/l, ammoniacal-N <30 mg/l). Up to twenty such plants were constructed during the 1980s, and most, if not all, continue to operate successfully, automatically and reliably, using simple adjustable timers to control settings of the cycle. These plants were typically operated by weighbridge or similar staff, requiring less than an hours attention each day to maintain performance.

Very reliable treatment has nonetheless been achieved and maintained, over extended periods, by many such treatment systems. Table 2.12 below presents typical operating data.

Table 2.12: Typical performance data from lagoon-based SBR leachate treatment schemes

	Bryn Posteg 1983 – Robinson & Davies, 1985		Chapel Farm 1990 – Robinson et. al, 1992		Harewood Whin 1990 - Last et. al, 1993	
Determinand	**Leachate**	**Effluent**	**Leachate**	**Effluent**	**Leachate**	**Effluent**
COD	9750	210	10600	491	33800	292
BOD_5	7000	37	4100	3.0	21800	4.0
ammoniacal-N	175	0.9	412	0.3	603	4.3
nitrate-N	-	-	<0.2	27.2	0.2	<0.2
nitrite-N	-	-	0.3	<0.1	<0.1	<0.1
Notes: All results in mg/l						

Lagoon-based SBRs, while providing reliable treatment of a wide range of leachates, suffer from two drawbacks. A minor limitation is that where a single SBR lagoon is being used, provision must be made for short-term storage of leachate being generated during the period in which the cycle is in "settle" and "decant" phases. This represents at most only 4-6 hours of production. Simple blending of leachates from different tipping cells, of different ages, is preferable to give a more consistent feed quality.

The most important constraint in UK applications is that during winter months, water temperatures within the lagoon will fall, often down to 3 or 4°C or less, and these low temperatures will limit rates of treatment, especially rates at which ammoniacal-N can be nitrified. Use of floating surface aerators, although extremely energy efficient for provision of oxygen and mixing, will encourage cooling during very cold weather.

Nevertheless, significant rates of nitrification have been achieved and observed at temperatures down below 10°C, and many operators have been able to adjust treatment rates on a seasonal basis. Storing leachate during colder winter months, often within landfilled wastes, and maximising treatment rates during warmer summer months, to "catch up" any backlogs. Although this is only practical when flow rates at the point of discharge are adequately flexible and compliance with the leachate head requirements of the landfill can be met.

Environmental issues and concerns for SBR lagoons

It is recognised that there are health and safety issues related to safe handling of chemicals – phosphoric acid, alkalis, etc and issues for staff who are required to work in close proximity to the lagoon, for example to take samples, clean monitoring probes etc. The provision of lifejackets, adequate steps, and handrails, etc is outside the scope of this document. A further issue which, requires consideration relates to the slippery nature of the slopes of an HDPE lined lagoon. This can make it difficult, or impossible, for animals or humans falling in, to climb out. (Similar issues must be considered for HDPE-lined raw leachate storage lagoons.) On several occasions, animals such as foxes and rabbits have drowned in such facilities. Therefore there should be provision of "escape mats" up the side of lagoons, and of readily available lifebelts etc. In addition to security fencing, small mesh fencing should be used to exclude wildlife from the area of the SBR lagoon, with particular provision being made beneath entry gates etc.

Servicing of floating surface aerators, which may each exceed 500 kg in weight, may involve using a crane to lift them from the lagoon, or engineers using a boat to access them within the lagoon. In either instance, appropriate measures should be used to prevent accidents which, could result in an environmental impact.

The potential to release odours from a well designed well operated SBR plant should be minimal and there should be no detectable odour at a well designed and operated leachate treatment installation. Emission of noise from floating surface aerators can be a problem. Noise from diffused air blowers can be attenuated by enclosure of the blowers and it may be necessary to consider the mechanism of aeration in order to minimise noise emissions.

Production of significant quantities of foam within an aerobic biological treatment process generally reflects stressing of the treatment system (e.g. shock loadings, sudden changes in temperature or leachate nature), but may also be a feature of treatment of particularly strong leachates (e.g. ammoniacal-N >1500 mg/l). In an SBR lagoon, to prevent windblown foam loss, and also to maximise oxygen transfer rates, routine addition of small quantities of an appropriate antifoam solution may occasionally be carried out.

Biological sludge may gradually accumulate when treating acetogenic leachates, and occasionally require removal to prevent concentrations of biological solids from exceeding optimum values. This is easily effected by provision of simple desludging pipework within the lagoon base, allowing controlled extraction of thickened sludge (typically 3-5 percent dry solids) using a vacuum tanker, after settlement of solids within a settlement phase. Sludge is generally either disposed of back into the landfill typically without dewatering, or to a local sewage treatment works. In practice, few leachate treatment plants (<20 percent) **ever** require to be desludged, the extended aeration mode of operation encouraging auto-digestion of the dead biomass.

Tank-based SBR systems

As leachate treatment experience increased in the UK, during the late 1980s and early 1990s, and as venturi-type high efficiency aerators became more widely available and more reliable, increasingly SBR leachate treatment plants were designed with treatment taking place within a circular or other tank. The main benefits of such systems, compared with lagoon SBRs, include;

- Maintenance of optimum temperatures,
- Reduced land requirements,
- Increased structural strength,
- Energy efficiency, and
- Management of environmental accident hazards

A tank-based SBR system costs little more than a lagoon-based SBR, once issues such as adequate secondary containment and leak detection are provided for the lagoon.

Treatment is generally carried out in circular tanks, of depth 5 to 6 metres, with a simple roof structure. Use of high efficiency venturi aerators, means that all energy consumed by the aerators, and all heat energy generated during biological treatment, can be retained and used to ensure that treatment takes place within a temperature range of 20 to 30°C, at all times. Burial of SBR tanks (generally applicable only where concrete structures are used) can improve insulation further, and also reduce visual impact. Experience has demonstrated that even in extremely exposed locations (e.g. Robinson, 1999) very stable temperatures and treatment rates can be maintained at all times.

Reinforced concrete is generally the preferred material for tank-based SBR systems, having a long life expectancy and better structural integrity.

Alternative materials such as epoxy-coated steel have sometimes proved inadequate to prevent corrosion in some instances. Glass coated steel tanks require annual emptying, steam cleaning, inspection and repair if a warranty is to be provided, which may not be practicable if an increasingly acclimatised biological population is to be maintained.

Use of fully buried Glass Reinforced Plastic (GRP) “interceptor-type” tanks as SBRs has resulted in variable degrees of success. There are concerns about leak detection and long-term abrasion resistance, to grit etc passing through the powerful venturi aerators. These issues have to be considered when establishing BAT.

Typical examples of tank-based SBR treatment system are shown below in Plates 2.14 and 2.15.

Plate 2.14: Typical example of a buried tank SBR leachate treatment system: Arthurstown Landfill, Dublin, 300 m^3/d, 1998- (see Robinson and Harris, 1999)

Plate 2.15: Typical example of an above-ground SBR leachate treatment system: Llanddulas Landfill, Abergele, 150 m^3/d, 2002- (see Robinson and Last, 2003)

Very large tank-based SBR leachate treatment plants can now be designed and operated reliably, treating large volumes of very strong leachate from large landfills. Often representing contaminant loads equivalent to those in domestic wastewaters from populations of several hundred thousand people (e.g. see Plate 2.16).

Plate 2.16: Large tank-based SBR System: Arpley Landfill, Warrington, 450 m^3/d (COD 10,000 mg/l, ammoniacal-N 2500 mg/l), 2001- (see Robinson and Last, 2003)

Very high treatment efficiencies can be achieved by such SBR systems for very strong leachates – typical examples are presented in Table 2.13 below.

Table 2.13: Typical performance data from tank-based SBR leachate treatment schemes

	Efford 2003- Robinson & Last, 2003		Llanddulas 2002- Robinson & Last, 2003		Arpley 2001- Robinson et. al, 2003	
Determinand	**Leachate**	**Effluent**	**Leachate**	**Effluent**	**leachate**	**Effluent**
COD	942	462	3410	762	5990	1060
BOD_5	72	22	1520	9	688	<1
Ammoniacal-N	820	1.59	965	1.2	1460	3.2
nitrate-N	0.21	423	<0.3	668	1.9	1238
nitrite-N	0.04	0.56	<0.1	<0.1	<0.1	0.1

Notes: Results in mg/l

NB – effluents at Efford and Arpley subjected to additional polishing before discharge

The warmer and more stable operating temperatures within a tank-based SBR system generally result in higher rates of treatment, although as in a lagoon SBR, short-term storage and blending of influent leachates is beneficial with one or two days flow typically being stored within a raw leachate balance tank.

Venturi aerators have proved to be efficient and reliable, and are readily installed to provide flexibility in optimising mixing patterns for optimum treatment. Only when installed at excessive power (greater than about 80 watts per m^3 of aeration volume) have any adverse effects on floc formation been observed in leachate treatment applications.

Diffused air systems have been used instead of venturi aerators. They require regular cleaning to ensure there is no problem with inorganic precipitation. The oxygen transfer efficiencies of well maintained diffused aerators may prove better than venturi aerators and they may prove more energy efficient.

Successful operation of any dispersed biomass/activated sludge biological treatment system requires development and acclimatisation of a biomass that will flocculate well, settle rapidly, and compact well in the base of the SBR during the settlement/clarification stage. These features are generally assisted in a leachate SBR by the fact that sludge may contain up to 40 or 50 percent of inorganic solids, primarily iron and calcium, which are also beneficial to flocculation.

Effluents from tank-based SBR systems may typically contain between 50-200 mg/l of suspended solids in effluent, and are not likely to be suitable for direct discharge to surface waters. Simple polishing processes such as Dissolved Air Flotation (DAF), or reed beds (each discussed elsewhere) can readily provide effluents suitable for discharge into surface watercourses. About half of all tank-based SBR systems presently treating leachate in the UK, discharge effluents into surface watercourses.

Smaller, tank-based SBRs typically handling throughputs of up to 50 m^3 per day of leachate can readily be constructed more simply, for application at small rural landfills (e.g. see Plate 2.17), where glass-coated steel tanks may be more appropriate.

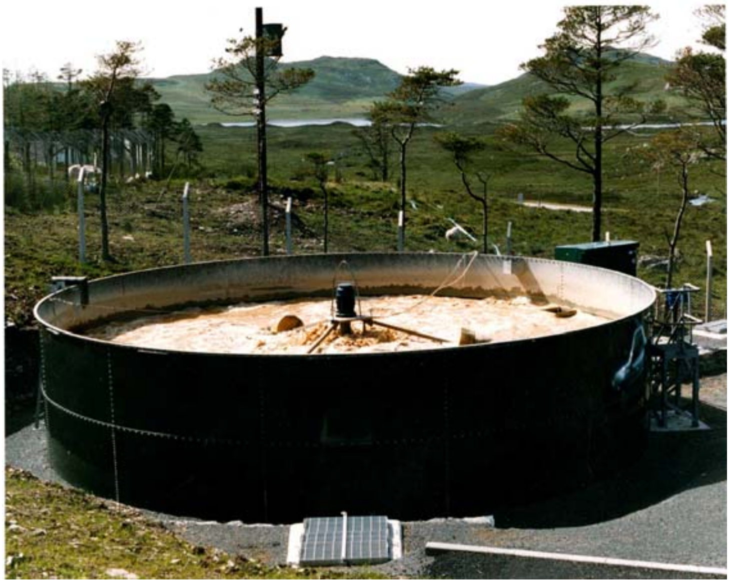

Plate 2.17: Smaller tank-based SBR treating leachate at Gairloch Landfill, Ross and Cromarty (30 m^3/d, 1993-)

Environmental issues and concerns for tank-based SBRs

Such systems, in combination with well-designed and engineered process designs, allow a high level of automation to be adopted, and to incorporate safety measures such as fail-safe procedures, interlocks, alarms, telemetry, and emergency dial-out systems.

Odours should not be an issue, in well-operated and designed SBR. Noise is less likely to be significant when venturis are used as they operate at a depth of 5 to 6m for optimum oxygen transfer efficiencies. There may be minor noise as air is entrained within delivery pipes at surface level that requires attenuation.

It is possible to use alternative means of oxygenating water within an SBR tank. In particular, compressed air and liquid oxygen have been used occasionally in the UK. Main issues are ability of compressed air systems to re-suspend biological solids, to handle inorganic precipitation, and to provide oxygen cost-effectively. Liquid oxygen is generally relatively expensive, but may be required to deal with transient peaks in loading. Such use requires appropriate safety measures to be adopted.

As for lagoon SBR systems, production of foam, especially when treating stronger leachates (e.g. ammoniacal-N >1500 mg/l) may require routine addition of small quantities of an appropriate antifoam solution. This can be automated simply, by monitoring of foam levels, to optimise dosing rates.

Although SBR leachate treatment systems can effectively treat very strong leachates indeed, (successful treatment of leachates with concentrations of ammoniacal-N up to 6000 mg/l has been reported (see Chen et al, 1997). Levels of ammoniacal-N in effluents will rarely exceed 5 mg/l in a well designed and well operated system, further simple effluent polishing may often be required to meet stricter surface water discharge standards. In particular, levels of suspended solids (often 50-200 mg/l in SBR effluent) and of ammoniacal-N, may require additional treatment. Horizontal flow reed beds are often used for this purpose (see separate section).

2.1.5.2.4 Membrane bioreactors (MBRs)

General overview

The Membrane Bioreactor (MBR) process is essentially an advanced form of the traditional activated sludge process, where the biological part of the process is combined with ultrafiltration membrane technology, for separation of return sludge from a clarified/filtered effluent. This replaces the need for a separate settlement tank, which is often the rate-limiting step in conventional effluent treatment.

Process overview

The separation of biomass from a clarified and treated effluent is accomplished by a cross flow filtration process, within an efficient ultrafiltration (UF) system. This retains all biomass, and all suspended solids typically larger than about 0.02 µm, including all bacteria. The concentrated sludge separated out by the system is continually returned to the bioreactor as return sludge, as in a conventional activated sludge system. However, because of the improved efficiency of the solids separation stage much higher concentrations of biomass can be maintained within the bioreactor, where Mixed Liquor Suspended Solids (MLSS) values of up to 20,000 mg/l are typical. This allows more intensive treatment to take place, reducing the size of plant required for a given loading of contaminants. The bioreactor stage of treatment is also often operated at increased pressure, to further increase treatment rates. Pressurised aeration tanks allow a reduction in the volume of air utilised because of greater oxygen transfer efficiency. This in turn leads to greater control with regard to foaming and the emission of VOCs and other odorous substances.

The key part of the process is the membrane filtration stage, an area in which rapid progress has been made in recent years. Processes such as turbulent and directed air flows along membrane surfaces have also improved control of membrane clogging, and have minimised the size of ultrafiltration units required for a given application. Recent developments use automatically controlled sequences of forward and back flushing of the UF modules to maintain the flux rate. The mounting of cross flow modules externally to the aeration tank can greatly facilitate the cleaning process.

Over 500 MBR treatment systems have been commissioned at full-scale, to treat both industrial and municipal wastewaters, and rapid advances and improvements to the process continue to be made, as experience is gained (e.g. van Dijk and Roncken, 1997, Robinson AH, 2003, and Robinson AH 2005).

A number of leachate pilot trial have been conducted in the UK where full scale cross flow MBRs have been operating in the food industry for several years. Two full scale MBR leachate treatment plants are due to become operational in the UK in 2006. More than 50 full-scale plants have been constructed in Germany, France, Spain and other countries and typical performance data are included in Table 2.14 below.

Denitrification reactors can readily be added, to achieve anoxic removal of nitrate-N, generally using methanol as a carbon source, in a pre-denitrification configuration.

The use of UF membranes rather than sedimentation for liquids/solids separation generates an effectively 'solids free' effluent. Also bacteria are retained both for nitrification and oxidation of hard to degrade COD. The 'solids free' effluent is suitable for further treatment if necessary by reverse osmosis, activated carbon or wetland.

The heat generated by the UF feed pump together with the exothermic nature of the process and the compact nature of the plant means that the MBR process tends to operate at 30 –35 °C, an optimum temperature range for nitrification.

Table 2.14: Typical performance data from MBR leachate treatment schemes

	a		b		c		d	
Determinand	Leachate	Effluent	Leachate	Effluent	Leachate	Effluent	Leachate	Effluent
COD	2340	15	2800	10	2700	71	5120	51
BOD_5	-	<5	-	<5	-	<5	-	<5
Ammonia	980	1.5	844	0.2	1250	0.2	1800	1
Nitrate	-	34	-	3.5	-	0.15	-	45
Nitrite	-	0.12	-	0.12	-	0.01	-	1

	e		f		g		h	
Determinand	Leachate	Effluent	Leachate	Effluent	Leachate	Effluent	Leachate	Effluent
COD	3470	65	1060	237	9500	41	22000	51
BOD_5	-	<5	97	3	-	<5	2700	<5
Ammonia	1000	0.1	920	0.2	3600	0.1	2330	0
Nitrite	-	12.5	70	90	-	150		23
Nitrate	-	<0.1	-	0	-	0		0

Key :

a – Freiburg, Germany (1999 -), Flow 129 m^3/d, MBR volume 98 m^3, Membrane area 88 m^2

b – Loerrach, Germany (1997 -), Flow 331 m^3/d, MBR volume 240 m^3, Membrane area 226 m^2

c – Lueneburg, Germany (1996 -), Flow 120 m^3/d, MBR volume 114 m^3, Membrane area 160 m^2

d – Biberach, Germany (2002 -), Flow 119 m^3/d, MBR volume 200 m^3, Membrane area 68 m^2

e – Karlsruhe, Berg Germany (1997 -), Flow 60 m^3/d

f – Bilbao, Spain (2004 -), Flow 2200 m^3/d, MBR volume 1260 m^3, Membrane area 972 m^2

g – Sloius, Spain (2002 -), Flow 115 m^3/d, MBR volume 206 m^3, Membrane area 32 m^2

h – Qingdao, China (2003 -), Flow 284 m^3/d, MBR volume 760 m^3, Membrane area 162 m^2

Notes:

Treatment data in mg/l

The data shown are results obtained when the plants are operated to produce the best effluent.

The data is courtesy of Wehrle Environmental

Environmental issues and concerns

Like the SBR process, treatment of leachate in an MBR is readily automated, with process control achieved through a programmable logic control (PLC) and operator interface PC. Again, the process is readily fitted with a telemetry system, allowing the plant to be remotely monitored for alarms and optimisation.

The more intensive nature of the process, with relatively short hydraulic retention times, higher concentrations of solids in mixed liquor, and pressurised reactors, demands a higher degree of monitoring than is required for an SBR, and failsafe controls and auto shut-down facilities are essential.

Replacement and cleaning of UF modules is a relatively straightforward manual process, which can be carried out by trained staff with minimal disruption. Similar chemicals are used to the SBR process, and require similar degrees of control and management. The two most common chemicals used as a carbon source for denitrification are methanol and acetic acid. Methanol is generally less expensive than acetic acid, but requires a delivery, storage and dosing system which takes account of its flammable and explosive nature. Foam control is generally more important than in other aerobic biological processes, as a result of the more intensive treatment, and it is important to ensure that antifoam reagents selected are compatible with the UF membranes being used. Biodegradable compounds are generally preferred to silicone reagents because of this, and operating costs may be increased as a result.

The contained nature of the process minimises potential for odour and other emissions, and a typical MBR plant has an external vertical bioreactor vessel, with all membrane stages etc carried out within an adjacent building. The height of the glass-coated steel bioreactor vessel may typically be 10m or more, to optimise aeration efficiency, and may have planning implications, but because it generally comprises a silo-like unit, which is readily moveable, this may reduce concerns. This may also allow portable MBR units to be constructed, and operated on a temporary basis to deal with transient leachate problems at some landfill sites. Larger installations are usually equipped with reinforced concrete tanks.

Sludge will be generated, and may require removal and disposal in a similar manner to an SBR unit. In a MBR system all of the solids are retained and must be periodically wasted, in a SBR process it is likely that some solids will be discharged in the effluent.

Attached growth systems

Introduction

In an attached growth, or fixed film, system of aerobic biological treatment, bacteria grow attached to the surface of an inert media, generally plastic support material, or the rotating rotor of a RBC system. A number of alternative processes, each with specific benefits and disadvantages are available.

Bacteria which effect nitrification can become strongly fixed to suitable media, providing that high concentrations of degradable COD are not present, and so very stable nitrification can be achieved, if all other conditions are optimal. However, a common problem can be that because most attached growth systems are not completely mixed reactors, then they do not have the same capacity to rapidly dilute high incoming concentrations of ammoniacal-N in particular. Moving Bed Bioreactors (MBBR) have been used to treat leachate and because the media is kept in suspension using coarse bubble aeration.

Since free ammonia is toxic to nitrifying bacteria, and is a function of pH-value and concentration of total ammoniacal-N, if high concentrations of ammoniacal-N come into direct contact with the bacteria, then rates of nitrification will fall rapidly, and this failure will move rapidly through the full depth of the attached growth system (this does not necessarily apply directly to MBBRs or to Rotating Biological Contactor systems, which can be encouraged to behave more like completely mixed reactors, to some extent).

Consequently, design of a fixed film reactor must ensure that a high nitrification rate is achieved in the initial part of the treatment bed. In suspended growth systems treating leachate, operating at typical pH-values in the order of 7.5 to 8.0, significant toxic effects have been noted at concentrations of ammoniacal-N as low as 60 mg/l, and these values are likely to also apply to bacteria operating in attached growth reactors. If concentrations of ammoniacal-N cannot be achieved in leachate initially contacting bacteria on the media, then it may be possible to recirculate a proportion of treated effluent to dilute the incoming raw leachate. Nevertheless, for leachates with concentrations of ammoniacal-N in excess of 300-400 mg/l, this is likely to prove to be impractical. Although MBBRs may be more robust to toxic shock than suspended growth systems.

A second fundamental issue in the design of fixed bed attached growth systems, is control of pH-values to optimum levels throughout the full depth of the bed. Rapid rates of nitrification locally, can quickly reduce pH-values in parts of the bed to inhibitory acid levels (below about 6.5). Unlike a completely mixed suspended growth reactor or MBBR, where the relatively large volume of the reactor provides buffering of pH-values, and where a single pH probe can be used to control alkali addition and pH-values for the whole treatment reactor, this is not possible through the whole depth of a fixed bed system.

In a fixed bed system, additions of sufficient alkalinity to raw leachate, to adequately buffer all acidity produced by nitrification through the depth of the fixed bed, is likely to raise initial pH-values to levels at which free ammonia toxicity is enhanced as discussed above. It can therefore prove extremely difficult, if not impossible, to provide alkalinity at appropriate doses, and at the point of need, within an attached growth fixed bed reactor, treating stronger landfill leachates.

If there is a high hydrocarbon content in the leachate there is a danger that this will ‘blind’ the media preventing the development of a biomass. In suspended growth systems the hydrocarbons are emulsified and metabolised.

2.1.5.2.5 Percolating filters

General information

A percolating filter is an aerobic, fixed film biological treatment system, which comprises a fixed bed of media, to which bacterial films are attached, and over which wastewater to be treated percolates downwards under gravity.

Media may typically be between 2-4m deep, and can comprise a variety of materials, from blast furnace slags, or gravels, to specialised plastic units designed to have a high ratio of surface area: volume. The media itself plays no part in treatment, acting only as a surface to which the biological films that effect treatment are attached.

Wastewater is irrigated evenly onto the surface of the percolating filter, often in a manner similar to that employed in the traditional “sewage filter bed”. Effluent that emerges from the bottom of the bed is generally passed through a clarifier, to remove biological solids that slough off from the media surfaces before final effluent is discharged.

Process overview

Although a limited number of very weak leachates (ammoniacal-N < 50mg/l) have been treated with some success, often on a seasonal basis, using simple percolating filters, application of this technology to stronger leachates has failed on many occasions. Typical reasons for failure have included:

- Scaling/clogging of filter media with organic and inorganic sludges
- Short hydraulic retention times leading to vulnerability to short-term shock loading of the system.
- Inhibition of nitrification due to colder temperatures, either diurnally (at night) or seasonally (in winter).
- Inability to provide additional alkalinity required for sustainable nitrification (see earlier) evenly through the filter, leading to either local scale formation, or unstable pH-volumes in the filter causing process inhibition.

- Direct bacterial inhibition of nitrifiers, as the top layers of the filter receive leachate feed containing concentrations of ammoniacal-N well in excess of those at which significant inhibition will take place (e.g. typically >80mg/l).
- Inability to supply adequate oxygen to the media.

Few, if any, technical papers have provided details of successful applications of percolating filters to landfill leachates in the UK. Although the relatively simple process may contribute to the treatment of very weak leachates, it is unlikely to provide successful applications at most modern landfills. There are many instances where percolating filters have been installed at landfills, and have failed.

2.1.5.2.6 Rotating biological contactors

General information

A rotating biological contactor (RBC) is an aerobic, fixed-film biological treatment system, which comprises a series of closely spaced, plastic (polystyrene, PVC, or polyethylene) circular discs on a horizontal shaft. Discs are often large, up to 3 or 4m in diameter, and provide a very large surface area on which bacteria can grow.

Process Overview

A typical unit of 6m in length, of 3.5m diameter, can have a surface area that approaches 10,000 m^2, based on up to 200 m^2 of surface per m^3 of rotor volume.

The rotor system is mounted in a contoured basal tank, to partially immerse (typically 40 percent) of the discs in the leachate, which flows at right angles to the discs, through the basal tank. The discs develop a slime layer of attached bacteria across their entire wetted surfaces, as they rotate slowly through the wastewater, generally at between 1.5 and 2 rpm. This means that bacteria alternatively contact contaminants within the wastewater, and then the atmosphere for adsorption of oxygen. Excess growth of biomass is sheared off during rotation of the system, and the stripped solids are carried with the effluent to a clarifier, where they are separated from the final effluent.

In order to maintain adequate temperatures for treatment, in the order of 20°C, in UK climatic conditions the rotors are sometimes buried in the ground, or enclosed within a roof system, which must be ventilated for optimum oxygen transfer. To minimise the area of rotor required, incoming leachate is generally heated.

RBCs provide a greater degree of flexibility for treatment of leachate than do trickling filters. In particular, by adjustment of the configuration of the basal tank and rotor, the mixing characteristics of the system can be modified, to reduce the degree of “plug flow”, and encourage the system to operate more like a completely mixed reactor. This provides some of the benefits of rapid dilution of incoming leachates that are provided by extended aeration processes such as SBRs.

Nevertheless, RBCs are generally most effective for methanogenic leachates. Since high concentrations of degradable COD found in acetogenic leachate can result in excessive sludge growth, and clogging of interstices within rotors. RBC systems are also most effective for concentrations of ammoniacal-N below 500 mg/l, although because of their modular construction, they can be operated in series to optimise nitrification efficiency.

Factors affecting the treatment efficiency of RBC systems include the type and concentrations of organics present, hydraulic residence time, rotational speed, media surface area exposed and submerged (which is readily modified by adjusting the depth of water in the basal tank), and pre- and post-treatment systems added.

RBCs were first developed in Europe during the 1950s and 1960s, and have the advantage of relatively low energy use to provide aeration; when compared with suspended growth systems, energy consumption may be only 20 percent as great.

RBC systems have occasionally treated methanogenic leachates at German landfills, sometimes after chemical oxidation has been used to reduce biodegradable COD to low levels. Ehrig (1983) reported detailed laboratory trials, and Wittek et al (1985) gave results from a full-scale RBC plant, which both indicated optimum loadings of between 1-2 gN/m^2 of media surface per day, at ambient temperatures, in methanogenic leachates.

The most detailed studies of RBC treatment of leachate have been carried out at the Pitsea Landfill in the UK. The Pitsea leachate is extremely well suited to RBC treatment, the landfill being strongly methanogenic. Leachate has also initially been treated by passage through an extensive, shallow perimeter ditch system, and recirculated through wastes, such that BOD_5 values in leachate to be treated by the plant rarely exceed 60 mg/l. Concentrations of ammoniacal-N are typically in the range 200-500 mg/l, and average about 350 mg/l.

Knox (1983) carried out detailed treatability studies on the leachate, providing design data for construction of the full-scale plant (see Table 2.15 below).

Table 2.15: Loading criteria used for design of the Pitsea RBC Plant (Knox, 1983)

Temperature (°C)	Loading rate ($g/N/m^2.d$)
<5	1.4
5-10	1.9
10-15	3.2
15-20	4.6
>20	5.6

A full-scale RBC plant was constructed at Pitsea in 1985, having 30,000 m^3 of media, with the intention of discharging up to 150,000 m^3 of fully nitrified leachate per annum into a tidal creek. The plant has been described in great detail (Knox, 1989; 1991), and a full evaluation of its performance during the first 5 years of operation was prepared on behalf of the UK Department of the Environment (Knox, 1992).

The plant comprised 3 RBC units, each of 10,000 m^2 (increased in later years by addition of further units), with a settling tank with traditional bridge and scraper, and is shown in Plates 2.18 and 2.19 below.

Plate 2.18: Pitsea RBC Plant

Plate 2.19: Growth of biofilm on RBC media at Pitsea RBC Plant

Operation of the plant has demonstrated the suitability of the design for the treatment of the methanogenic leachate at Pitsea, full nitrification having been achieved at loadings of up to 5 $gN/m^2.d$, when temperatures could be maintained at 20°C. Occasional build up to nitrite has been observed at higher loading rates, as noted by Ehrig (1991).

Work confirmed the reduced power demand needed for a RBC system, roughly one sixth of the power that would be required by an equivalent suspended growth treatment system. A strong correlation between effluent suspended solids and BOD_5 values indicated the presence of solids that were neither trapped within the biofilm or removed by the settlement stage. For highest quality effluent, a second stage of treatment such as DAF, sand filtration, or a reed bed would be valuable.

The plant was very vulnerable to heating failure in winter, from the landfill gas system, and this was supplemented with a more reliable propane based system. Scale formation as a result of both leachate heating, and localised alkali dosing points, was also an occasional problem. The use of a more-sophisticated pH control system would be beneficial, to optimised dosing at NaOH solutions. At most landfills that produce only methanogenic leachates, such as Pitsea, changes in leachate composition take place gradually, which will assist this.

Table 2.16 below shows typical treatment performance achieved at optimum temperatures.

Table 2.16: Loading criteria used for design of the Pitsea RBC Plant (Knox, 1983)

Determinand	Leachate	Effluent
Suspended solids	55	66
pH-value	8.00	8.93
TOC	365	337
BOD_5	28	19
Ammoniacal-N	281	0.4
Nitrate-N	3.0	4.4
Nitrite-N	1.0	4.4
Iron	6.3	4.4
Notes: Results in mg/l except pH-value		

The extent to which a RBC process could successfully treat leachates containing higher BOD values than were present in Pitsea leachate is not known. To some extent, slightly higher BOD_5 value may prove beneficial to biofilm growth. Work would be needed to assess whether higher leachate BOD_5 values would result in a thicker biofilm, which might lead to clogging of a high density (180 m^2/m^3) media such as was used at Pitsea, a lower density media, with greater spacing may prove more appropriate.

Environmental issues and concerns

As in most aerobic biological systems treating leachates, issues related to handling of chemicals such as high strength alkalis (e.g. NaOH), phosphoric acid etc apply. Since dosing of these will generally be automated at larger plants, risks will be reduced. Provision of facilities such as emergency eyewash baths, and emergency showers adjacent to areas at risk is good practice. Use of removable clear Perspex sheets in front of dosing pumps, to provide additional protection, is often recommended.

Odours are unlikely to be an issue in a well-operated and designed RBC, and noise levels will be very low. Production of foam during treatment has never been reported to be an issue.

A high level of automation of a RBC is possible and appropriate, to incorporate safety measures such as fail-safe procedures, interlocks, alarms, telemetry, and emergency dial-out systems.

Indicative BAT for biological treatment
General
1. Storage and handling of chemicals is covered in section 2.1.2. 2. The principles of containment are covered in section 2.1.1. 3. Plant should be operated using automated process controls. 4. Failsafe controls and an auto shut down facility should be employed. 5. Adequate storage must be provided to accommodate allow for maintenance, flow balancing and blending where applicable.
Simple aerated lagoons
1. When considering simple aerated lagoons the following key points should be demonstrated as a priority but regard should also be given to all other aspects of this document: ▪ The containment principles outlined in Section 2.1.1 are being achieved and can be achieved throughout the operational life of the lagoon, with regard to the potential for lining system degradation. ▪ The principles of energy efficiency outlined in Section 2.7 are being achieved. ▪ Odour is managed in accordance with requirements of Section 2.2.6. ▪ Sludge can be effectively removed from the lagoon, with regard to the potential for lining system damage. ▪ The lagoon design provides consistent effluent quality that can cope with the seasonal fluctuations in ambient temperature. Failure to demonstrate the key points above will compromise the selection of simple aerated lagoons as BAT. 2. All lagoons shall: ▪ have safe means of access for taking samples and maintenance of equipment; ▪ be secured to prevent unauthorised access including preventing animals from entering the lagoon; and ▪ have appropriate escape mats and lifebelts.
Lagoon based SBR systems
1. When considering lagoon based SBR systems the following key points should be demonstrated as a priority but regard should also be given to all other aspects of this document: ▪ The containment principles outlined in Section 2.1.1 are being achieved and can be achieved throughout the operational life of the lagoon, with regard to the potential for lining system degradation. ▪ The lagoon design can provide treatment that can cope adequately with seasonal fluctuations in ambient temperature. The use of floating surface aerators is likely to encourage cooling during cold weather and the replacement of these may be necessary, however this should only be done after considering the energy efficiency of the alternative aeration system and comparing this against the benefits of tank based treatment. ▪ Odour is managed in accordance with requirements of Section 2.2.6. ▪ Sludge can be effectively removed from the lagoon using de-sludging pipe

work that does not compromise the containment system of the lagoon. ▪ Windblown can be prevented without excessive use of antifoam solution. Failure to demonstrate the key points above will compromise the selection of lagoon based SBR systems. 2. The safety principles outlined in point 2 above should be complied with. 3. Remote monitoring systems should be installed on SBR systems where practicable. These may include SCADA systems but should as a minimum include telemetry systems such as GSM alarms.
Tank based SBR systems
1. The selection of the material used to construct the tank should take account of the containment principles in Section 2.1 and the following specific points: ▪ Life expectancy ▪ Structural integrity ▪ Corrosion resistance, especially significant for epoxy coated and glass coated steel tanks. This may determine the need for maintenance and inspection and impact on the ability to maintain an acclimatised biological population. ▪ Abrasion resistance, particularly for GRP tanks. 2. The selection of the mechanism to aerate and mix leachate should take account of: ▪ Energy efficiency ▪ Oxygen transfer efficiency ▪ Reliability and maintenance requirements ▪ Ability to re-suspend biological solids ▪ Noise impact. 3. Remote monitoring systems should be installed on SBR systems where practicable. These may include SCADA systems but should as a minimum include telemetry systems such as GSM alarms.
Membrane bioreactors (MBRs)
1. Anti-foam agents have to be compatible with the membrane.
Percolating filters
1. When considering percolating filters the following key points should be demonstrated as a priority but regard should also be given to all other aspects of this document: ▪ The design can withstand scaling and clogging. ▪ The design can provide treatment that can cope adequately with seasonal fluctuations in ambient temperature. ▪ The design can withstand fluctuations in leachate quality and can cope with the likely ammoniacal-N concentrations. ▪ Odour is managed in accordance with requirements of Section 2.2.6.

Rotating biological contactors (RBCs)
1. The plant should be operated using automated process controls 2. Failsafe controls and an auto shut down facility are essential. 3. Leachate quality, especially COD and ammoniacal-N concentrations, should be assessed to ensure the suitability of the treatment.

2.1.6 Constructed wetlands

General information

Constructed wetlands and reed beds are designed and man-made systems which attempt to simulate treatment that has been observed to take place when polluted water passes through natural wetlands. In the UK these systems tend to be called “reed beds” or “reed bed treatment systems” (RBTS), but internationally they are usually called constructed wetlands (CW).
Systems are able to treat wastewaters by degrading organic matter (BOD and COD) and oxidising ammoniacal-N, removing suspended solids, and to a lesser extent reducing concentrations of nitrate and phosphorus. Treatment mechanisms are complex and involve bacterial oxidation, filtration, nitrification and chemical precipitation.

During the last 20 years, reed bed systems or “constructed wetlands” have been employed in the UK for treatment of a variety of wastewaters, often being used for polishing of effluents that have previously received initial treatment using a separate process. The process first came to prominence in 1985, following a visit by a group of Water Industry personnel to see several systems that had been constructed and operated in Germany (Boon, 1985).

The first UK systems began operation in late 1985. Now, there are well over 600 systems in the UK. Severn Treat Water plc alone operates about 200 systems for treatment of domestic wastewaters, generally after pre-treatment has been undertaken using processes such as RBCs, and mainly at relatively small STW’s (typically treating sewage from less than about 2000 people).

Constructed wetlands have become popular in the UK, and across Europe, because they are seen to have the following advantages:

- Relatively low capital and operating costs.
- Simplicity of operation (low requirement for operator supervision).
- Suitable treatment for low flows, previously untreated.
- Seen as a natural and therefore “green” process.
- They are attractive and provide wildlife habitat.
- As a polishing stage they can improve and enhance performance of initial treatment processes.

The treatment technology generally relies on processes similar to those used extensively in gravel “filter beds”, enhanced by the extensive rhizomatous root system of the reed plants (*Phragmites australis*) which can transfer limited quantities of oxygen into the surrounding media, stimulating bacterial communities. Other constituents of the effluent can be immobilised, or absorbed by the plants themselves (on some occasions alternative plants such as bulrush (*Typha latifolia*) have been used successfully). Although aerial growth of the reed plants (which can reach 2-3m high) dies down during the winter months, treatment has been demonstrated to continue effectively. In situations where effluent from a previous treatment process, such as an SBR, may be warm (20-25°C), the dead reed stems typically mat down on the gravel surface of the bed, providing heat insulation and maintaining adequate temperatures within the root zone of the reeds at all times.

The European Water Pollution Control Association (EWPCA, 1990) concluded that nitrification of ammonia to nitrate has not generally occurred in temperate reed bed treatment systems, because of oxygen limitations, but noted that it has been reported in some “polishing” treatment schemes. In a summary of UK reed bed performance, Findlater et al (1990) concluded that neither soil beds or beds containing coarse granular media, removed significant amounts of nitrogen, and individual authors (e.g. Christian, 1990) have discounted their use as a sole treatment process for domestic sewage, in cases where an ammonia standard must be met to protect a receiving watercourse. However, recent developments in constructed wetland technology have indicated that high nitrification rates can be achieved when suitable oxygenating plant species are employed.

A variety of basic constructed wetland designs have been used, and performance varies significantly from one design type to another. The two basic design types are:

- Horizontal flow, and
- Vertical flow.

For both design types, most successful applications involve subsurface flow within the (generally gravel and sand) media in which the reeds are planted – avoiding surface flow, which would bypass the main treatment surfaces.

A constructed wetland has the potential advantage of long-term, sustainable treatment, with very low costs of operation and maintenance, whether used alone for treatment of leachates from older landfills, or for polishing of stronger leachates that have been pre-treated by other biological processes. This is especially important for leachate control, where (unlike sewage treatment works) large landfill sites may be remote and unmanned, and require indefinite treatment timescales. Passive constructed wetlands can offer very long lifetimes, with minimal need for equipment replacement.

2.1.6.1 Horizontal flow reedbeds / constructed wetlands

The majority of all of the constructed wetlands that have been built in the UK for sewage treatment have been subsurface, horizontal flow systems (e.g. Cooper and Green, 1994). Such systems typically comprise lined beds, containing depths of gravel between 0.6-0.9 metres, with a horizontal top surface, and are longer than they are wide.

Wastewaters are introduced along one of the shorter edges of the bed, and discharge from the bed at the far end, generally via buried pipework. Liquid level in the bed is adjusted by a simple overview mechanism outside the bed – usually this will be maintained at or close to the gravel surface, but the horizontal surface of the bed allows intermittent flooding to be effected, for control of weeds (e.g. nettles) as necessary.

Figure 2.7 below shows a typical arrangement for a horizontal-flow reed bed treatment system.

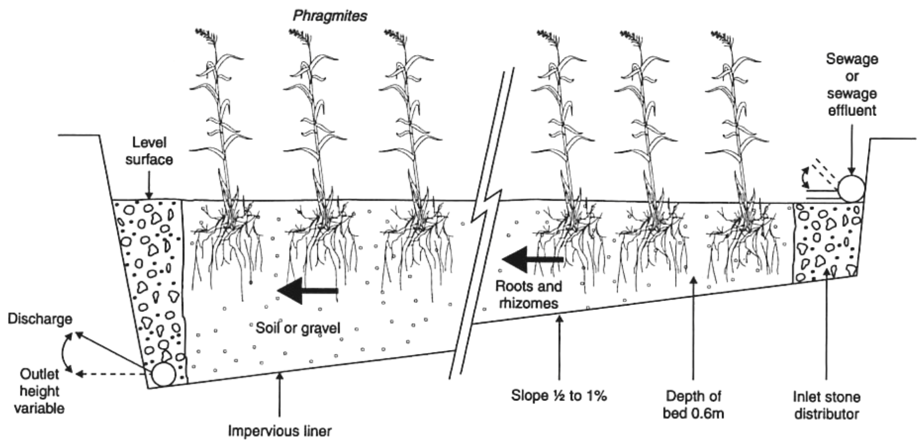

Figure 2.7: Typical arrangement for a horizontal-flow reed bed treatment system (after Cooper et.al., 1996)

For leachate treatment, single-sized gravel of up to 10mm in size has most commonly been used, and is commonly placed to a depth of 600mm. Provision of a basal slope can assist in draining of the bed, but maximum gravel depth should not exceed 1m. Horizontal-flow reed beds have been used with success for the direct treatment of relatively weak leachates – for example, from very old closed landfills, where low concentrations of ammonia, and remoteness of sites, may make this a simple and ideal solution. Increasingly, however, horizontal flow reed beds are being used as a second stage of polishing for stronger leachates, following a biological first treatment stage, before discharge of effluents to watercourses. More than 20 such combined systems have been constructed in the UK since 1990. Taking these 2 applications for horizontal flow reedbeds in turn:

Direct treatment of weak leachates/contaminated groundwaters.

At several UK sites, horizontal-flow reed beds have been used with success for treatment of weak leachates (ammoniacal-N <25mg/l). At old closed sites, their ability to reduce concentrations of residual BOD, suspended solids, iron, and also trace organic compounds such as mecoprop, can prove to be an ideal solution. The Monument Hill Landfill site near to Devizes in Wiltshire is a good example (see Robinson and Harris, 2001).

The site is an unlined valley, filled during the 1970s, which was draining between 100-400m^3/d of weak leachate (COD~50mg/l, iron~20mg/l, ammoniacal-N 15-30mg/l) into a small stream. An 1800m^2 reed bed provided a rapid improvement in water quality, in terms of iron and suspended solids (>95 percent removal), of ammoniacal-N (30-50 percent removal), although only about 15 percent reduction in COD values was achieved (see plate 2.20 below).

At Monument Hill, reduction in concentrations of ammoniacal-N to below 15mg/l was adequate, together with dilution available in the receiving watercourse, to allow a satisfactory discharge to be made. In other situations, limitations with regard to removal of ammoniacal-N will generally prove to be the factor that determines whether horizontal reed beds can provide an adequate solution.

In situations where large volumes of groundwater have become slightly contaminated with leachate, horizontal flow reedbeds can also provide a suitable solution – at the WRG Judkins Landfill in Nuneaton, a 0.9Ha reed bed reduces concentrations of ammoniacal-N from 5 and 10mg/l, to below detection limits which allow discharge into a canal – between 1000-200m^3/d having been treated over extended periods.

Plate 2.20: View of the Monument Hill Landfill horizontal flow reed bed system for direct treatment of weak leachate, 1993.

Polishing of biologically pre-treated leachates

Polishing of biologically-pre-treated leachates using horizontal flow reed beds is becoming a common feature of many leachate treatment schemes at operational landfills, where effluents are being discharged into surface watercourses. The Efford Landfill leachate treatment scheme operated by Hampshire County Council is a typical example. An SBR system treats up to 150m^3/d of strong leachate, effluent being polished by passage through a reed bed, before being discharged into a small, rural STW (see Plate 2.21).

Plate 2.21: Efford Leachate Treatment Plant, Hampshire, showing horizontal flow reed bed used to polish SBR effluent.

The reed bed is able to provide excellent removal of residual solids, ammoniacal-N and BOD in SBR effluent, as well as up to 35 percent removal of residual COD (see Figures 2.8 and 2.9 below, from Robinson and Olufsen, 2004).

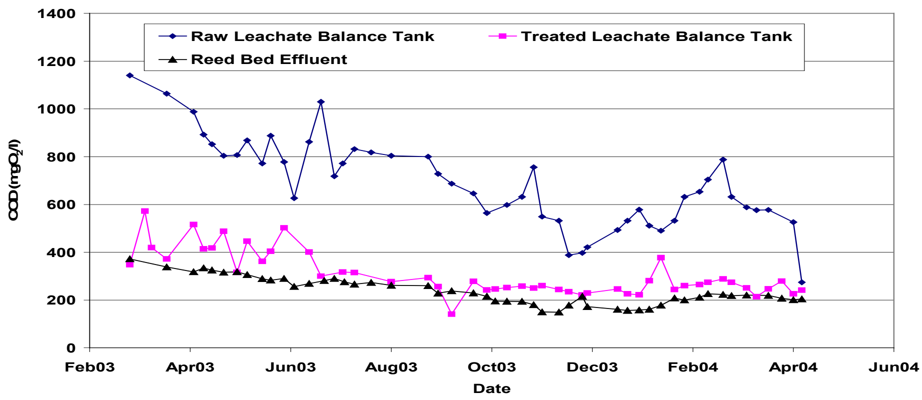

Figure 2.8: Removal of COD at Efford LTP, March 2003 – May 2004 (mg/l)

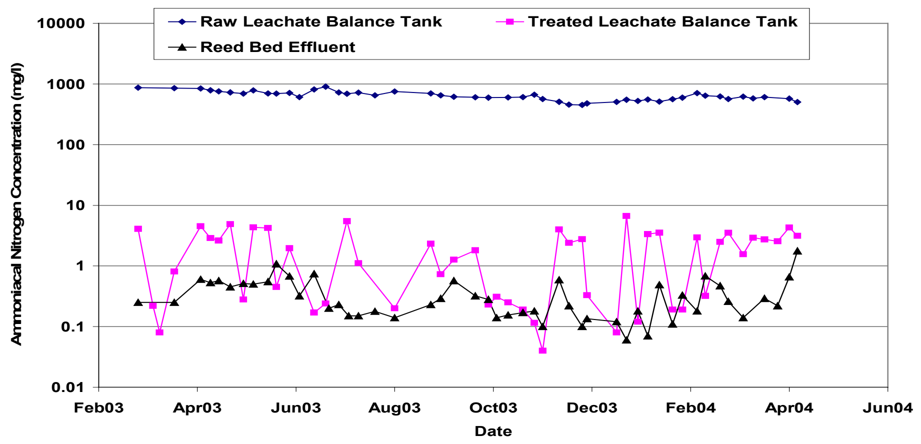

Figure 2.9. Removal of ammoniacal-N at Efford LTP, January 2003 – May 2004 (mg/l as N)

Many other case studies have been reported, where horizontal flow reed beds have successfully been applied as effluent polishing systems (e.g. Robinson et.al., 2003a; 2003b).

2.1.6.2 Vertical flow reedbeds / constructed wetlands

Vertical-flow reed bed systems differ from horizontal-flow systems in two fundamental ways (see Figure 2.10). They also comprise a flat bed of uniform depth, typically 0.5 to 0.6m, with reeds growing at similar planting densities. The main differences are:

(i) the bottom half of the bed generally comprises much larger stones, typically to 30mm smooth washed gravel size or larger, on top of which lies smaller diameter pea gravel (<6mm), and a surface depth of 80-100mm of sharp sand, into which the reeds are planted.

(ii) the bed is fed with wastewater or leachate intermittently, as a large batch, which initially floods the surface of the bed, and then gradually percolates downward through it, to the coarser stone drainage network in the base. The bed is then completely drained, allowing air to refill it, and the next slug dose of liquid traps this air – leading to much improved oxygen transfer.

Vertical-flow systems were originally developed to address concerns about the limited ability of early horizontal-flow systems to nitrify ammoniacal-N – probably as a result of the limited ability of the reed rhizomes to transfer oxygen, which had generally been greatly overestimated (Cooper et. al. 1996). Vertical-flow systems have been shown to greatly increase oxygen transfer rates, acting more as a crude biological filter, but are much less good at solids removal than horizontal-flow systems – often they will be followed by a horizontal-flow reed bed system for polishing.

Many vertical-flow systems comprise several beds in series or in parallel – some parallel beds being sequentially fed in rotation for 1 or 2 days, then being rested for several days. Reeds growing in the bed provide limited oxygen transfer, having the primary purpose of assisting in maintenance of the required hydraulic conductivity within the bed.

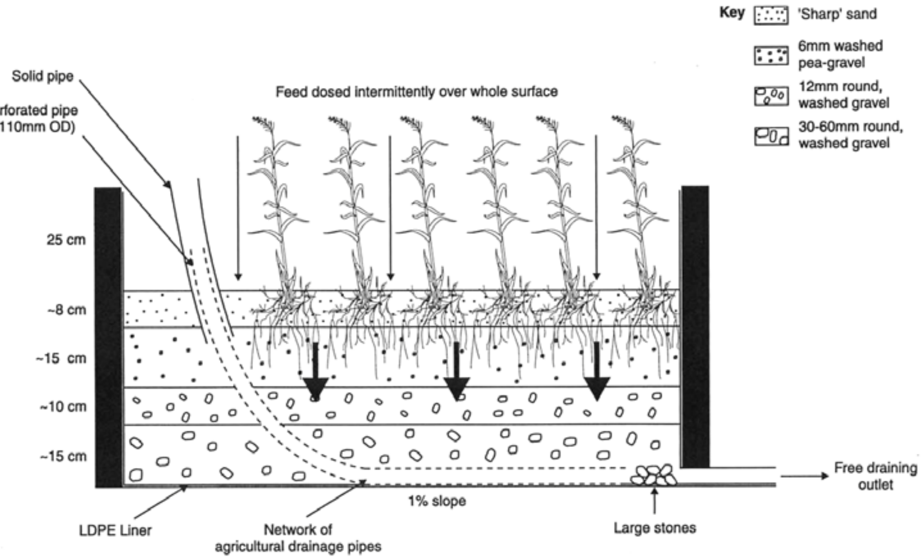

Figure 2.10: Typical arrangement of a vertical-flow reed bed system (after Cooper, 1996)

Design information and published case studies of successful application for treatment of leachates in the UK, are lacking for vertical flow reedbed systems, and data regarding the loadings of ammoniacal-N that can be treated reliably and consistently remain the greatest uncertainty. Nevertheless, such schemes have potential to achieve improved rates of nitrification per m^2 of reed bed area, compared to traditional horizontal flow systems, as a result of the extra oxygen inputs which this mode of operation provides. Recent work has indicated that soil/plant vertical flow wetland systems, utilising salt marsh plant species evolved to liberate oxygen to sediments have the ability to remove significant quantities of ammonium from influent leachate, principally through nitrification. Large oxygen inputs from the plants and surface diffusion into the sediments, combined with large nitrifying bacterial populations may allow nitrification of leachates containing relatively high levels of ammonium. The ability of such systems to provide adequate primary treatment of stronger leachate has yet to be proved with a full scale plant.

Indicative standards for engineered wetlands

1. Engineered wetlands shall have a lined base that prevents leachate and effluent from leachate treatment escaping and groundwater ingress.
2. The top surface of substrate must be level to allow flooding of the reedbed to occur for control of weed growth.
3. Although a low level of supervision is required wetlands must be managed if they are to operate as designed. Through out the operational life of a wetland the following shall be managed
   - Water depth, including acceptable ranges of fluctuation
   - Cleaning and maintenance of inlet and outlet structures
   - Inspection and maintenance of structures
   - Depth of sediment accumulation and removal when required
4. Careful consideration must be given to the quality of leachate and effluent from leachate treatment that the wetland can treat. Selection of plant species and support media may allow a range of leachate types to be treated.

2.2 Emissions control

2.2.1 Point source emissions to air

Nature of the emissions

The nature and source of the emissions expected from each activity is given in previous sections and will be confirmed in detail in the application. In general they comprise those tabulated below in Table 2.17.

Point source emissions relate to those emissions that result from the collection of gas from a vessel or area and are passed either via abatement or direct to a stack or vent.

More detailed information on odour control in given in section 2.2.6.

Table 2.17: Point source emissions to air

Activity	Abatement options			
	VOC	**Odour**	**Ammonia**	**Methane**
Air Stripping	Ad,To, Ab	Ad, To, Bo	Ab, To	To
See Table 2.17 for air abatement options key.				

Table 2.18: Air abatement options key

Key	Name	Comment
Ab	Absorption	Suitable for high flow, low concentration (e.g.. 1-200 mg/m^3 VOCs), low temperature gas stream, where the pollutant is chemically reactive (or soluble in the case of VOC contaminants). One possible use is the absorption of ammonia gas in sulphuric acid to produce ammonium sulphate. Monitoring provisions include: • PH, flow rate and level of scrubber liquors scrubber pressure drop • pressure drop monitoring with
Ad	Adsorption	Carbon adsorption is appropriate abatement technology for gas streams containing low concentrations of organic compounds.
To	Thermal oxidation	Used for the ammonia gas control where ammonia gas is fed into high temperature enclosed landfill gas flares.
Bo	Biological oxidation	Biofilter is a generic term applied to any biological oxidation process taking place in a packed system. This includes the conventional trickling filters, bioscrubbers (microbial population supported in scrubber liquor) or biobeds (packed system using soil, peat and bark). Biobeds have been installed on waste treatment sites for abatement of odours. Operational conditions include:

		• Incoming air must have a relative humidity of >90% (this may require the use of a humidifier). • Particulates must be removed • Hot gases may need to be cooled closer to the optimal activity temperature for aerobic micro-organisms, generally 25 to 35^{o}C, and the potential temperature rise across the bed of up to 20^{o}C should be taken into account. • The major operating parameters such as off gas temperature and back pressure should be checked daily. • The moisture content in the filters should be monitored regularly. • A low temperature alarm should be fitted to warn of freezing, which may damage the filter and may affect the growth of the microbial population. • The packing medium must be supported to allow a fast, even airflow without pressure drop. • The medium should be removed when it starts to disintegrate, affecting airflow. • Choice of medium and supporting system affects the power requirement to maintain airflow. Power to overcome bed resistance is the largest operational cost. • Biofilters and bioscrubbers have lower operating costs than many other air pollution control techniques for treating low concentrations of biodegradable organic pollutants. Bioscrubbers have higher maintenance costs of the two. Environmental benefits include low energy requirements and the avoidance of cross media transfer of pollutants. • Consideration should be given to the loss of biomass due to the introduction of toxic compounds, and a standby procedure should be developed for such an event.

Indicative BAT requirements for the control of point source emissions to air

1. Abatement is used to clean what could be termed incidental emissions from the leachate treatment process. Emphasis should be placed on the prevention of the production and displacement of pollutants. Abatement can be readily overloaded and become ineffective. Abatement techniques should not be used as an inline proceed tool as part of the treatment process.
2. Correctly operate and maintain the abatement equipment, including the handling and disposal of spent scrubber medium or spent carbon.
3. The benchmark values in Section 3 should be achieved unless alternative values are justified and agreed with the regulator in the permit.
4. The operator should identify the main chemical constituents of the emissions and assess of the fate of these chemicals in the environment.

5. Vent and chimney heights should be assessed (see Section 4).
6. Although unlikely to be a significant issue at the majority of leachate treatment plants, the operator should consider the need to minimise water vapour. In order to address local visual amenity issues which in severe cases can include loss of light, fogging, icing of roads etc. and which can also adversely affect plume dispersion. Ideally, therefore, the exhaust should be discharged at conditions of temperature and moisture content that avoid saturation under a wide range of meteorological conditions.
7. The use of **prime energy** to reduce a plume simply because it is visible should be avoided. However, it may be appropriate to use **waste heat**. For example heat could be used from the utilisation or destruction of landfill gas. Nevertheless, the use of energy for re-heat should be balanced against the benefits gained.
8. Generally, the volume of air involved determines the degree of difficulty in dealing with air emissions. The volume of air has implications not only for the final size of abatement plant but also for the associated equipment such as fans, ducting, pressure losses, etc. Optimum containment of odorous or polluted air is therefore important in either eliminating the need to treat the air or minimising the amount (and consequently cost) of the abatement technology.
9. Enclosure of specific units identified as being a source of pollution should be implemented to reduce air volumes requiring abatement.
10. The operator should maintain a plan for the reduction of emissions to air.

2.2.2 Point source emissions to surface water and sewer

The nature and source of the emissions to surface water or sewer expected from each activity is given in previous sections and the inventory of emissions should be confirmed in detail in the application. Earlier sections of this document deal in detail with the techniques employed for treating leachate prior to discharge to sewer or surface water. This section covers the general principles when consider the discharge from the leachate treatment plant.

The primary consideration should always be to prevent releases of harmful substances to the aquatic environment, whether releases are direct or via a sewage treatment works, and only where prevention is not practicable should the release be minimised or reduced to the point where the emission is incapable of causing significant harm.

In addition to the substances that give rise to COD leachate may contain persistent organic pollutants, some of which are poorly biodegraded, and which can be particularly toxic.

For emissions to controlled waters, the use of whole effluent bioassays for the assessment of the complex effluent should be considered.

The use of direct toxicity assessment (DTA) for environmental assessment is included in the document IPPC Environmental Assessments for BAT and can be used to:

- Supplement chemical-specific assessments according for the effects of substances that might otherwise go undetected
- Provide an alternative to chemical-specific assessment when there are insufficient ecotoxicological data on the chemicals of concern

A tiered approach is advocated which might involve not using DTA or using cost-effective high-throughput methods.

A DTA approach should be used as a trigger for action to investigate and reduce known ecotoxicity problems rather than applied as a pass/fail permit condition, although there may be occasions where this is needed to deliver environmental improvements or gains and maintain public confidence.

For discharges to sewer it is important to note that, whereas a trade effluent consent for discharge to sewer allows the release of a stated level of pollution, this does not necessarily mean that this is BAT for the treatment process. BAT requires that pollution should be prevented or reduced, within the cost and benefit framework of BAT.

The primary consideration should be to prevent releases of harmful substances to the aquatic environment, whether releases are direct or via a sewage treatment works.

Indicative BAT requirements for the control of point source emissions to water and sewer

1. Where prevention is not possible, the emissions benchmarks given in Section 3 should be achievable.
2. Where effluent from the leachate treatment plant is treated off-site:

- The treatment provided at the off site treatment works is as good as would be achieved if the emission was treated on-site, based on reduction of load (not concentration) of each substance to the receiving water (using the IPPC Environmental Assessments for BAT software tool will assist in making this assessment).

- Action plans should be in place for discharges to sewer that in the event of sewer bypass, (via storm/emergency overflows or at intermediate sewage pumping stations) prevent direct discharge of the pre-treated leachate during these periods, e.g. knowing when bypass is occurring, rescheduling activities such as cleaning or even shutting down when bypass is occurring
- A suitable monitoring programme is in place for emissions to sewer.

3. There must be an understanding of the main chemical constituents of the treated leachate (including the make-up of the COD) and assessment of the fate of these chemicals in the environment.
4. All emissions should be controlled, as a minimum, to avoid a breach of water quality standards (see Section 3.2 and Section 4.1), but noting that where BAT can deliver further reduction at reasonable cost it should do so (see Section 1.1). Calculations and/or modelling to demonstrate this will be carried out in the application.
5. The primary objective of leachate treatment operations has been to produce an effluent that can be transferred to the sewage undertaker under the terms of a trade effluent discharge consent. It must be emphasised that, if emissions can be reduced further than the treatment provided by the undertaker, or prevented altogether, at reasonable cost, then this should be done irrespective of the requirement a trade effluent consent. BAT therefore can go further than existing consents. Furthermore, irrespective of the receiving water, the adequacy of the plant to minimise the emission of specific persistent harmful substances must also be considered.

2.2.3 Point source emissions to groundwater

The Groundwater Regulations for the UK came into force on 1 April 1999, and an IPPC permit will be subject to the following requirements under these Regulations.

i. The permit shall not be granted at all if it would allow the *direct discharge* of a List I substance (Regulation 4(1)) – except in very limited circumstances (see Notes 1 and 2, below).

ii. If the permit allows the disposal of a List I substance or any activity that might lead to an *indirect discharge* of a List I substance then *prior investigation* (as defined in Regulation 7) is required and the permit shall not be granted if this reveals that indirect discharges of List I substances would occur. In any event, conditions to secure the prevention of such discharges must be imposed (Regulation 4(2) and (3)).

iii. In the case of List II substances, permits allowing direct discharges or possible indirect discharges, cannot be granted unless there has been a prior investigation and conditions must be imposed to prevent groundwater pollution (Regulation 5)

iv. The Regulations contain further detailed provisions covering *surveillance* of groundwater (Regulation 8); conditions required when direct discharges are permitted (Regulation 9); when indirect discharges are permitted (Regulation 10); and review periods and compliance (Regulation 11).

The principles, powers and responsibilities for groundwater protection in England and Wales, together with the Environment Agency's policies on this, are outlined in the Environment Agency's document *Policy and Practice for the Protection of Groundwater*. This outlines the concepts of vulnerability and risk and the likely acceptability from the regulator's viewpoint of certain activities within groundwater protection zones. These are categorised as:

A Prior investigation of the potential effect on groundwater of on-site disposal activities or discharges to groundwater. Such investigations will vary from case to case, but the regulator is likely to require a map of the proposed disposal area; a description of the underlying geology, hydrogeology and soil type, including the depth of saturated zone and quality of groundwater; the proximity of the site to any surface waters and abstraction points, and the relationship between ground and surface waters; and the composition and volume of waste to be disposed of; and the rate of planned disposal.

The Environment Agency has produced a series of maps for England and Wales, which provide a guide to potential groundwater vulnerability. Source Protection Zones are intended to aid protection by defining annular zones around each major potable source, including springs, boreholes and wells, based on travel times.

B Surveillance – This will also vary from case to case, but will include monitoring of groundwater quality and ensuring the necessary precautions to prevent groundwater pollution are being undertaken.

Note 1 The Regulations state that, subject to certain conditions, the discharges of List I substances to groundwater may be authorised if the groundwater is "permanently unsuitable for other uses". Advice must be sought from the regulator where this is being considered as a justification for such discharges.

Note 2 List I and List II refer to the list in the Groundwater Regulations and should not be confused with the similar lists in the Dangerous Substances Directive.

Indicative BAT requirements for application Question B2.4 Identify if there may be a discharge of any list II substances and if any are identified, explain how the requirements of the Groundwater Regulations 1998 have been addressed.
1 In general, there should be no permitted releases to groundwater of either a direct or indirect nature. 2 If there are releases to groundwater and they are to continue, the requirements of the Regulations, as summarised above, must be complied with.

2.2.4 Fugitive emissions to air

Examples of common sources of fugitive emissions are:

- Open storage vessels, lagoons and tanks
- Accidental loss of containment or failed plant and equipment
- Displacement air on filling of tanks, vessels and tankers

As part of the application the operator should identify and, where possible quantify, significant fugitive emissions to air from all the specific relevant sources listed above, estimating the proportion of total emissions that are attributable to fugitive releases for each substance. Where there are opportunities for reductions, the permit may require the updated inventory of fugitive emissions to be submitted.

Indicative BAT requirements for control of fugitive emissions to air
1. When transferring volatile liquids, the following techniques should be employed – subsurface filling via (anti-syphon) filling pipes extended to the bottom of the container, the use of vapour balance lines that transfer the vapour from the container being filled to the one being emptied, or an enclosed system with extraction to suitable abatement plant. 2. Vent systems should be chosen to minimise breathing emissions (for example pressure/ vacuum valves) and, where relevant, should be fitted with knock-out pots and appropriate abatement equipment. 3. Maintenance of bulk storage temperatures as low as practicable, taking into account changes due to solar heating etc. from storage tanks at atmospheric pressure: – Tank paint with low solar absorbency – Temperature control – Tank insulation – Inventory management – Floating roof tanks – Bladder roof tanks – Pressure/vacuum valves, where tanks are designed to withstand pressure fluctuations – Specific release treatment (such as adsorption condensation) 4. For information on odour, see Section 2.2.6.

2.2.5 Fugitive emissions to surface water, sewer and groundwater

As part of the application, the operator should identify and, where possible, quantify significant fugitive emissions to water, sewer or ground from all relevant sources, and estimate the proportion of total emissions that are attributable to fugitive releases for each of the main substances releases. Some common examples of sources of fugitive releases to waters and their preventive measures are given in the BAT box below.

Indicative BAT requirements for control of fugitive emissions to water

1 **For subsurface structures**:

- establish and record the routing of all installation drains and subsurface pipework;
- identify all sub-surface sumps and storage vessels;
- engineer systems to minimise leakages from pipes and ensure swift detection if they do occur, particularly where hazardous (i.e. Groundwater-listed) substances are involved;
- provide secondary containment and/or leakage detection for sub-surface pipework, sumps and storage vessels;
- establish an inspection and maintenance programme for all subsurface structures, e.g. pressure tests, leak tests, material thickness checks or CCTV

2 **All sumps should**:

- be impermeable and resistant to stored materials;
- be subject to regular visual inspection and any contents pumped out or otherwise removed after checking for contamination;
- where not frequently inspected, be fitted with a high level probe and alarm, as appropriate;
- be subject to programmed engineering inspection (normally visual, but extending to water testing where structural integrity is in doubt).

3 **For surfacing**:

- design appropriate surfacing and containment or drainage facilities for all operational areas, taking into consideration collection capacities, surface thicknesses, strength/reinforcement; falls, materials of construction, permeability, resistance to chemical attack, and inspection and maintenance procedures;
- have an inspection and maintenance programme for impervious surfaces and containment facilities;
- unless the risk is negligible, have improvement plans in place where operational areas have not been equipped with:
  - an impervious surface
  - spill containment kerbs
  - sealed construction joints
  - connection to a sealed drainage system

4 **All aboveground tanks** containing liquids whose spillage could be harmful to the environment should be bunded. Bunds should:

- be impermeable and resistant to the stored materials;
- have no outlet (that is, no drains or taps) and drain to a blind collection point;
- have pipework routed within bunded areas with no penetration of contained surfaces;
- be designed to catch leaks from tanks or fittings;
- have a capacity greater than 110 percent of the largest tank or 25 percent of the total tankage, whichever is the larger;
- be subject to regular visual inspection and any contents pumped out or otherwise removed under manual control after checking for contamination;
- where not frequently inspected, be fitted with a high-level probe and an alarm, as appropriate;
- where possible, have tanker connection points within the bund, otherwise provide adequate containment;
- be subject to programmed engineering inspection (normally visual, but extending to water testing where structural integrity is in doubt).

5 **Storage areas for IBCs, drums, bags, etc,** should be designed and operated to minimise the risk of releases to the environment. In particular:

- Storage areas should be located away from watercourses and sensitive boundaries, (e.g. Those with public access) and should be protected against vandalism.
- Storage areas should have appropriate signs and notices and be clearly marked-out, and all containers and packages should be clearly labelled.
- The maximum storage capacity of storage areas should be stated and not exceeded, and the maximum storage period for containers should be specified and adhered to.
- Appropriate storage facilities should be provided for substances with special requirements (e.g. flammable, sensitive to heat or light) and formal arrangements should be in hand to keep separate packages containing incompatible substances (both “pure” and waste).
- Containers should be stored with lids, caps and valves secured and in place. This also applies to emptied containers.
- All stocks of containers, drums and small packages should be regularly inspected (at least weekly).
- Procedures should be in place to deal with damaged or leaking containers.

2.2.6 Odour

This section will detail the potential for different leachate treatment process to cause odour and consideration of how this can be managed to prevent its becoming an annoyance at sensitive receptors.

The level of detail supplied should be in keeping with the risk of causing odour related annoyance at sensitive receptors.

Where an installation poses no risk of odour related environmental impact because the activities undertaken are inherently non-odorous, this should be justified and no further information relating to odour need normally be supplied.

Where odour could be a problem, the operator will be required in the application to supply the information as indicated below:

- Information relating to sensitive receptors, in particular the type of receptor, location relative to the odour sources and an assessment of the impact of odorous emissions on the receptors. This should normally be available before a permit is issued, but where very detailed information has to be obtained the operator may be able to secure an agreement to supply this as part of an improvement programme.
- An overview of any complaints received, what they relate to (source/operation) and remedial action taken.
- The types and source of odorous substances used or generated, intentional and fugitive (unintentional) release points and monitoring undertaken.
- Actions taken to prevent or minimise
  - A description of the actions taken to prevent and/or minimise odour annoyance for each odour source.
  - A demonstration that the indicative BAT requirements are being complied with.
  - Identification of any circumstances or conditions which might compromise the ability to prevent or minimise odour annoyance, and a description of the actions that will be taken to minimise the impact.

There may be a requirement placed upon the operator to provide some or all of this information in the form of an odour management statement.

The use of appropriate sections of *H4 Horizontal Guidance for Odour – Part 1(Regulation and Permitting) and Part 2 (Assessment and Control)* is advised.

The definition of pollution includes “emissions which may be harmful to human health or the quality of the environment, cause offence to human senses or impair or interfere with amenities and other legitimate uses of the environment”. Odour emissions can constitute “offence to human senses” and are associated with point source and fugitive emissions.

Further guidance on odour can be found in the Environment Agency’s guidance note IPPC H4 Horizontal Guidance for Odour Parts 1 and 2.

Indicative BAT requirements for odour control
1. The requirements for odour control will be installation specific and depend on the sources and nature of the potential odour. 2. Odour emission from contained and fugitive sources shall be free from offensive odour at any location at or beyond the site boundary. 3. Any odour abatement equipment shall be maintained to ensure that adequate odour removal efficiency is retained throughout its operational life. 4. Where odour can be contained, for example within buildings, the operator should maintain the containment and manage the operations to prevent its release at all times. 5. Where odour releases are expected to be acknowledged in the permit, (i.e. contained and treated prior to discharge or discharged for atmospheric dispersion): ▪ For existing installations, the releases should be modelled to demonstrate the odour impact at sensitive receptors. The target should be to minimise the frequency of exposure to ground level concentrations that are likely to cause annoyance. ▪ For new installations, or for significant changes, the releases should be modelled and it is expected that the operator will achieve the highest level of protection that is achievable with BAT from the outset. ▪ Where there is no history of odour problems then modelling may not be required although it should be remembered that there can still be an underlying level of annoyance without complaints being made. ▪ Where, despite all reasonable steps in the design of the plant, extreme weather or other incidents are liable, in the view of the regulator, to increase the odour impact at receptors, the operator should take appropriate and timely action, as agreed with the regulator, to prevent further annoyance (these agreed actions will be defined either in the permit or in an odour management statement). 6. Where odour generating activities take place in the open, (or potentially odorous materials are stored outside) a high level of management control and use of best practice will be expected. 7. Where an installation releases odours but has a low environmental impact by virtue of its remoteness from sensitive receptors, it is expected that the operator will work towards achieving the standards described in this note, but the timescales allowed to achieve this might be adjusted according to the perceived risk. 8. The objective is to prevent emissions of odorous releases that are offensive and detectable beyond the site boundary. This may be judged by the likelihood of complaints. However, the lack of complaints should not necessarily imply the absence of an odour problem. 9. Assessment of odour impact should cover a range of reasonably foreseeable odour generation and receptor exposure scenarios, including emergency events and the effect of different mitigation options. 10. The significance of releases from leachates from relatively-recently emplaced wastes should be assessed by use of pilot-scale stripping trials, involving collection of gas samples for formal testing using odour panels (see Environment Agency Horizontal guidance H4 (parts 1 and 2)). Where such odour effects occur, biofilters e.g. brushwood or heather filters, or equivalent, should be employed.

11. Confined spaces in leachate treatment plants shall be constructed and equipped in such a way as to prevent the formation of an explosive atmosphere. If it is not possible to prevent the formation of an explosive atmosphere, the ignition of explosive atmospheres shall be prevented by additional protective means, e.g. ventilation or permanent installation of gas warning devices to initiate emergency procedures.

2.3 Management

It is a requirement that the management of the installation site is controlled by a person who is a “fit and proper person”. This includes a component whereby the management of the Specified Waste Management Activity (SWMA) that is to be carried out is in the hands of Technically Competent Management (TCM).

Effectively, biological treatment processes will be subject to Environment Agency assessment and physico-chemical treatment processes will be subject to WAMITAB certification. Further information can be found in the Environment Agency Guidance document *Technical Competence for Operators of Authorised Waste Facilities July 2004*. It should be noted that “deemed” and “pre-qualification” competence does not apply for the purpose of PPC.

A relevant treatment award will always be an acceptable way to demonstrate TCM for a leachate treatment plant, alternatively, as a landfill award encompasses leachate treatment, a landfill award is also acceptable where the leachate treatment plant forms part of a landfill (whether unregulated, licensed under the Waste Management Licensing regime or PPC permitted).

Within PPC, an effective system of management is a key technique for ensuring that all appropriate pollution prevention and control techniques are delivered reliably and on an integrated basis.

The regulators strongly support the operation of formal environmental management systems (EMSs). An operator with such a system will not only find it easier to meet the BAT requirements for management of the installation but also many of the technical/regulatory requirements listed in other sections of this guidance.

The regulators recommend either certification to the ISO 14001 standard or registration under EMAS (EC Eco Management and Audit Scheme) (OJ L114, 24/04/01). Both certification and registration provide independent verification that the EMS conforms to an auditable standard. EMAS now incorporates ISO 14001 as the specification for the EMS element, and the regulators consider that overall EMAS has a number of other benefits over ISO14001 - including a greater focus on environmental performance, a greater emphasis on legal compliance, and a public environmental statement. For further details about ISO 14001 and EMAS contact British Standards Institute (BSI) or the Institute of Environmental Management and Assessment (IEMA), respectively.

Whilst an effective EMS will help the operator to maintain compliance with specific regulatory requirements and manage all significant environmental impacts, this section of the guidance identifies only those EMS requirements that are not specifically covered elsewhere in the document. This section should not, therefore, be taken to describe all of the elements of an effective environmental management system. The requirements below are considered to be BAT for IPPC, but they are the same techniques required by a formal EMS and so should be capable of delivering wide environmental benefits.

The European Commission has also set out its views on BAT and Environmental Management Systems in the form of standard text which will be included in all new and updated BREFs.

Indicative BAT requirements for management

Operations and maintenance

1. Effective operational and maintenance systems should be employed on all aspects of the process whose failure could impact on the environment, in particular there should be:
   - documented procedures to control operations that may have an adverse impact on the environment
   - a defined procedure for identifying, reviewing and prioritising items of plant for which a preventative maintenance regime is appropriate
   - documented procedures for monitoring emissions or impacts
   - a preventative maintenance programme covering all plant, whose failure could lead to impact on the environment, including regular inspection of major 'non productive' items such as tanks, pipework, retaining walls, bunds ducts and filters
2. The maintenance system should include auditing of performance against requirements arising from the above and reporting the result of audits to top management.

Competence and training

3. Training systems, covering the following items, should be in place for all relevant staff which cover
   - awareness of the regulatory implications of the permit for the activity and their work activities;
   - awareness of all potential environmental effects from operation under normal and abnormal circumstances
   - awareness of the need to report deviation from the permit
   - prevention of accidental emissions and action to be taken when accidental emissions occur
4. The skills and competencies necessary for key posts should be documented and records of training needs and training received for these posts maintained.
5. The key posts should include contractors and those purchasing equipment and materials;
6. The potential environmental risks posed by the work of contractors should be assessed and instructions provided to contractors about protecting the environment while working on site.
7. Where industry standards or codes of practice for training exist (e.g. WAMITAB) they should be complied with.

Accidents/incidents/non-conformance

8. There should be an accident plan as described in Section 2.8 which:
   - identifies the likelihood and consequence of accidents;
   - identifies actions to prevent accidents and mitigate any consequences.
9. There should be written procedures for handling, investigating, communicating and reporting actual or potential non-compliance with operating procedures or emission limits.
10. There should be written procedures for handling, investigating, communicating and reporting environmental complaints and implementation of appropriate actions.

11. There should be written procedures for investigating incidents, (and near misses) including identifying suitable corrective action and following up

Organisation

12. The following are indicators of good performance which may impact on the regulator's resources, but not all will necessarily be insisted upon as permit conditions:
13. The company should adopt an environmental policy and programme which:
    - includes a commitment to continual improvement and prevention of pollution;
    - includes a commitment to comply with relevant legislation and other requirements to which the organisation subscribes; and
    - identifies, sets, monitors and reviews environmental objectives and key performance indicators independently of the permit.
14. The company should have demonstrable procedures (e.g. written instructions) which incorporate environmental considerations into the following areas:
    - the control of process and engineering change on the installation;
    - design, construction and review of new facilities and other capital projects (including provision for their decommissioning);
    - capital approval; and
    - purchasing policy.
15. The company should conduct audits, at least annually, to check that all activities are being carried out in conformity with the above requirements. Preferably, these should be independent.
16. The company should report annually on environmental performance, objectives and targets, and future planned improvements. Preferably, these should be published environmental statements.
17. The company should operate a formal Environmental Management System. Preferably, this should be a registered or certified EMAS/ISO 14001 system (issued and audited by an accredited certification body).
18. The company should have a clear and logical system for keeping records of, amongst others:
    - policies;
    - roles and responsibilities;
    - targets;
    - procedures;
    - results of audits;
    - results of reviews.

2.4 Raw materials

This section covers the use of raw materials and water, and the techniques for both minimising their use and minimising their impact by selection. (Energy and fuels are covered under **Section 2.7** on Energy).

As a general principle, the operator will need to demonstrate the measures taken to:

- reduce the usage of all raw materials and intermediates (Section 2.4.2)
- substitute less harmful materials, or those which can be more readily abated and when abated lead to substances that are more readily dealt with
- understand the fate of by-products and contaminants and their environmental impact (Section 2.4.2).

2.4.1 Raw Materials selection

This section looks at the selection and substitution of raw materials and Section 2.4.2 describes the techniques to minimise their use.

It should be recognised that the process of selecting raw materials can present an opportunity to control emissions at source. In this regard it is suggested that operators closely examine the range of possible raw material options available to them.

The operator should supply in the application a list of the materials used which have potential for significant environmental impact, together with the following associated information:

- the chemical composition of the materials, where relevant;
- the quantities used;
- the fate of the material in the installation (i.e. approximate percentages to each environmental medium and to the products);
- the environmental impact potential, where known (e.g. degradability, bioaccumulation potential, toxicity to relevant species);
- any reasonably practicable alternative raw materials that may have a lower environmental impact (including, but not limited to any alternatives described in the BAT requirements below) on the substitution principle;
- and justification for the continued use of any substance for which there is a less hazardous alternative (e.g. on the basis of impact on product quality) to show that the proposed raw materials are therefore BAT.

Given the nature of the processes in this sector raw materials relate only to auxiliary chemicals used to facilitate the treatment process, e.g. flocculants coagulants etc. Table 2.19 highlights typical raw materials used in leachate treatment plant.

Table 2.19: Examples of raw material usage

Raw material	Application
Phosphoric Acid	Nutrient for biological treatment
Magnesium hydroxide, Kalic Lime, Sodium hydroxide	pH adjustment
Methanol, Acetic Acid	Carbon source for de-nitrification in Membrane Bioreactors
$FeClSO_4$	Coagulant
Polyaluminium chloride	Coagulant
Polyaluminium chloride hydroxide sulphate	Coagulant

Indicative BAT requirements for raw materials selection

1 The operator should maintain a list of raw materials and their properties as noted above.

2 The operator should have procedures for the regular review of new developments in raw materials and for the implementation of any suitable ones with an improved environmental profile.

3 The operator should have quality-assurance procedures for controlling the impurity content of raw materials.

4 The operator should complete any longer-term studies needed into the less polluting options and should make any material substitutions identified.

5 "Mercury-free" sodium hydroxide should be used.

2.4.2 Waste minimisation audit (minimising the use of raw materials)

The options for waste recovery and recycling are covered in **Section 2.6**. Waste avoidance/minimisation, and the use of clean technologies, is a theme which runs throughout **Section 2.1** and **Section 2.2**. This section deals with the systematic approach to look for other opportunities.

Waste minimisation can be defined simply as: *"a systematic approach to the reduction of waste at source, by understanding and changing processes and activities to prevent and reduce waste".*

A variety of techniques can be classified under the term waste minimisation, from basic housekeeping through statistical measurement, to application of clean technologies.

In the context of waste minimisation and this guidance, waste relates to the inefficient use of raw materials and other substances at an installation. A consequence of waste minimisation will be the reduction of gaseous, liquid and solid emissions.

Key operational features of waste minimisation will be:

- the ongoing identification and implementation of waste prevention opportunities
- the active participation and commitment of staff at all levels including, for example staff suggestion schemes
- monitoring of materials' usage and reporting against key performance measures.

For the primary inputs to activities which are themselves waste activities, e.g. incineration, the requirements of this section may have been met "upstream" of the installation. However, there may still be arisings that are relevant.

See the Waste minimisation support references for detailed information, guides and case studies on waste minimisation techniques.

Indicative BAT requirements for waste minimisation audits

Identify the raw and auxiliary materials, other substances and water you propose to use.

1. The operator should carry out a waste minimisation audit at least every 4 years. If an audit has not been carried out in the 2 years prior to submission of the application and the details made known at the time of the application, then the first audit shall take place within 2 years of the issue of the permit. The methodology used and an action plan for reducing the use of raw materials should be submitted to the regulator within 2 months of completion of the audit. The audit should be carried out as follows:
2. The operator should analyse the use of raw materials, assess the opportunities for reductions and provide an action plan for improvements using the following three essential steps
    - Process mapping
    - Materials mass balance
    - Action plan

3. The use and fate of raw materials and other materials, including by-products, solvents and other support materials, e.g. flocculating agents, should be mapped onto a process flow diagram (see the Waste minimisation support references). This should be achieved by using data from the raw materials inventory and other company data as appropriate. Data should be incorporated for each principal stage of the operation in order to construct a mass balance for the installation.
4. Using this information, opportunities for improved efficiency, changes in process and waste reduction should be generated and assessed. An action plan should then be prepared for implementing improvements to a timescale approved by the regulator.

2.4.3 Water use

Water use should be minimised within the BAT criteria for the prevention or reduction of emissions and be commensurate with the prudent use of water as a natural resource.

Reducing water use is usually a valid environmental (and economic) aim in itself, but any water passing through an industrial process is degraded by the addition of pollutants so there is generally an increase in pollutant load. The benefits to be gained from reducing water input include:

- reducing the size of (a new) treatment plant, thereby supporting the BAT cost-benefit justification of better treatment;
- cost savings where water is purchased from or disposed of to another party;
- associated benefits within the process such as reduced energy requirements for heating and pumping, and reduced dissolution of pollutants leading in turn to reduced sludge generation in the effluent treatment plant (and consequent disposal costs).

The use of a simple mass balance for water use should help to reveal where reductions can be made.

Advice on cost-effective measures for minimising water can be found in the Water efficiency references.

Indicative BAT requirements for water efficiency

1. Potable water shall not be used to dilute leachate in order to meet consented discharge limits.
2. The operator should carry out a regular review of water use (water efficiency audit) at least every 4 years. If an audit has not been carried out in the 2 years prior to submission of the application and the details made known at the time of the application, then the first audit should take place within 2 years of the issue of the permit.
   - Flow diagrams and water mass balances for the activities should be produced.
   - Water-efficiency objectives should be established, with constraints on reducing water use beyond a certain level being identified (which usually will be usually installation-specific).
   - Water pinch techniques should be used in the more complex situations such as chemical plant, to identify the opportunities for maximising reuse and minimising use of water (see the Water efficiency references:).

   Within 2 months of completion of the audit, the methodology used should be submitted to the regulator, together with proposals for a time-tabled plan for implementing water reduction improvements for approval by the regulator.
3. The following general principles should be applied in sequence to reduce emissions to water:
   - Water-efficient techniques should be used at source where possible
   - Water should be recycled within the process from which it issues, by treating it first if necessary. Where this is not practicable, it should be recycled to another part of the process that has a lower water-quality requirement.

- In particular, if uncontaminated roof and surface water cannot be used in the process, it should be kept separate from other discharge streams, at least until after the contaminated streams have been treated in an effluent treatment system and been subject to final monitoring.

4 Measures should be in place to minimise the risk of contamination of surface waters or groundwater by fugitive releases of liquids or solids (see Section 2.2.5).

5 The water quality requirements associated with each use should be established, and the scope for substituting water from recycled sources identified and input into the improvement plan.

6 Less contaminated water streams, such as cooling waters, should be kept separate from more contaminated streams where there is scope for reuse – though possibly after some form of treatment.

7 Water usage for cleaning and washing down should be minimised by:

- Vacuuming, scraping or mopping in preference to hosing down;
- Reusing wash water (or recycled water) where practicable;
- Using trigger controls on all hoses, hand lances and washing equipment.

8. Fresh water consumption should be directly measured and recorded regularly at every significant usage point - ideally on a daily basis.

2.5 Waste handling

The wastes produced by this sector are specific to the treatment techniques employed and are described in **Section 2.1.**

In general, the waste streams comprise:

- Sludges from biological treatment; with and without sludge thickening;
- Sludges from DAF, and coagulant dosing
- Sludges from pre-settlement with high inert contents
- Waste carbon from activated carbon usage
- Waste sands and other media used in filtration/rotating contactors
- Waste reactor contents in the event of over dosing (e.g. excessive alkalinity)
- Waste spent membranes
- Waste backwash waters
- Waste resins
- Waste spent chemical containers

The key pollutants likely to be present can be derived from knowledge of the process and composition of leachate treated. The presence of substances created by abnormal operation should be identified, since treatment abnormalities can carry through substances into some of the waste streams.

Indicative BAT requirements for waste handling
1. A system shall be in place and maintained that records the quantity, nature and origin of each waste stream and describes the measures for waste management, storage and handling, including where relevant, the destination, frequency of collection, mode of transport and treatment method of any waste that is disposed of or recovered. 2. Wherever practicable, waste should be segregated and the disposal route identified. This should be as close to the point of production as possible. 3. Records should be maintained of any waste sent off-site (Duty of Care). 4. All appropriate steps to prevent emissions (for example, liquids, dust, VOCs and odour) from storage or handling should be taken (see Section 2.2.4, Section 2.2.5 and Section 2.2.6). 5. Storage of sludge and liquid waste on site prior to disposal/recovery should meet the standards specified in Section 2.1.1. 6. Incompatible waste types should be kept separate.

2.6 Waste recovery or disposal

The Regulations require the regulator, in setting permit conditions, to take account of certain general principles, including that the installation in question should be operated in such a way that "waste production is avoided in accordance with Council Directive 75/442/EEC on waste; and where waste is produced it is recovered, or where this is technically or economically impossible it is disposed of, while avoiding or reducing the impact on the environment". The objectives of the National Waste Strategies should also be considered.

Waste avoidance (minimisation) at source is addressed in detail in Section 2.1 and related issues are addressed in the sections on abatement techniques (see Section 2.2). The specific requirement for a waste minimisation audit is noted in Section 2.4.2.

To meet these requirements, operators should provide the regulator with the information requested in point 2 below.

Indicative BAT requirements for waste recovery or disposal

Describe how each waste stream is proposed to be recovered or disposed. If you propose any disposal, explain why recovery is technically and economically impossible and describe the measures planned to avoid any impact on the environment.

1. Waste production should be avoided wherever possible.
2. Waste should be recovered, unless it is technically or economically impractical to do so.
3. Where waste must be disposed of, the operator should provide a detailed assessment identifying the best environmental options for waste disposal, unless the regulator agrees that this is unnecessary. For existing disposal activities, this assessment may be carried out as an improvement condition to a timescale to be approved by the regulator.

Contaminated containers

4. Most drums and IBCs are designed, manufactured and marked to enable reconditioning/refurbishment. As such 205 litre drums, 800 and 1000 litre IBCs should be cleaned and reconditioned to enable re-use where technically and economically possible.
5. Containers that cannot be re-used where there is no reconditioning market and which have been cleaned can be released into the secondary materials market.

Sludges

6. Where sludges are generated from the treatment of on site derived leachate, the return of the sludges to the landfill may be an acceptable option.
7. Where sludges are derived from imported leachate they may not be disposed of to the on-site landfill unless they have been treated to ensure that they do not constitute a liquid waste.
8. Prior to the deposit of the sludge on the on-site landfill an assessment must be made of the contribution of the sludge to the quality of the leachate within the landfill.

Concentrate

9. The return of concentrate from the reverse osmosis process to the on site landfill from which the leachate was originally extracted is only permissible if:
    - an assessment has been made of the impact on the leachate quality within the landfill that shows that the any potential increase in leachate concentration will not have an unacceptable impact on groundwater.
    - an assessment has been made of the impact on the leachate treatment techniques employed that shows that any potential increase in the levels of substances in the leachate will not adversely effect the continuation of leachate treatment.

Activated carbon

10. Waste carbon from activated carbon usage should be regenerated where technically and economically possible.

Ion exchange resin

11. Ion exchange resin should be regenerated where technically and economically possible.

Thermal destruction in landfill gas flares

12. The destruction of gases, particular ammonia, utilising on site landfill gas flares should only take place in enclosed flares that meet the appropriate emission limits taking account of the contribution of the gases generated from leachate treatment.

2.7 Energy

BAT for energy efficiency under the PPC Regulations will be satisfied provided the operator meets the following conditions:

Either

- The operator meets the basic energy requirements in Section 2.7.1 and Section 2.7.2 below and is a participant to a Climate Change Agreement (CCA) or a Direct Participant Agreement (DPA) within the Emissions Trading Scheme.

Or

- the operator meets the basic energy requirements in Section 2.7.1 and Section 2.7.2 below and the further sector-specific energy requirements in Section 2.7.3 below.

Note that even where a Climate Change Agreement or Direct Participant Agreement is in place, this does not preclude the consideration of energy efficiency (including those identified in Section 2.7.3) as part of an integrated assessment of BAT where they impact on other emissions, e.g. where:

- the choice of fuel impacts upon emissions other than carbon, e.g. sulphur in fuel
- the minimisation of waste by waste-to-energy does not maximise energy efficiency, e.g. by Combined Heat and Power (CHP)
- the most energy-intensive abatement leads to the greatest reduction in other emissions.

Further guidance is given in the guidance note *H2 Energy efficiency for IPPC*.

2.7.1 Basic energy requirements (1)

The BAT requirements of this section are basic low-cost energy standards that apply whether or not a CCA or DPA is in force for the installation.

Indicative BAT requirements for basic energy requirements (2.7.1)	
Provide a breakdown of the energy consumption and generation by source and the associated environmental emissions.	
1	The operator should provide annually the energy consumption information, shown in the table below, in terms of delivered energy and also, in the case of electricity, converted to primary energy consumption. For the public electricity supply, a conversion factor of 2.6 should be used. Where applicable, the use of factors derived from on-site heat and/or power generation, or from direct (non-grid) suppliers should be used. In the latter cases, the operator should provide details of such factors. Where energy is exported from the installation, the operator should also provide this information. In the application this information should be submitted in the inventory in the H1 software tool and should also supplement this with energy flow information (such as “Sankey” diagrams or energy balances) showing how the energy is used throughout the process.

2	The operator should provide the following Specific Energy Consumption (SEC) information. Define and calculate the SEC of the activity (or activities) based on primary energy consumption for the products or raw material inputs that most closely match the main purpose or production capacity of the installation. Provide a comparison of SEC against any relevant benchmarks available for the sector. (See BREF and Energy Efficiency Guidance)
3	The operator should provide associated environmental emissions. This is dealt with in the operator's response to the emissions inventory using the H1 software tool.

Table 2.20: Example breakdown of delivered and primary energy consumption.

Energy source	Energy consumption		
	Delivered, MWh	Primary, MWh	% of total
Electricity*			
Gas			
Oil			
Other (Operator to specify)			

* specify source

2.7.2 Basic energy requirements (2)

The BAT requirements of this section are basic low-cost energy standards that apply whether or not a CCA or DPA is in force for the installation.

Indicative BAT requirements for basic energy requirements (2.7.2)

Describe the proposed measures for improvement of energy efficiency.

1 **Operating, maintenance and housekeeping measures** should be in place in the following areas, where relevant: (Indicative checklists of appropriate measures are provided in Appendix 2 of the guidance note *H2 Energy efficiency for IPPC*).

- air conditioning, process refrigeration and cooling systems (leaks, seals, temperature control, evaporator/condenser maintenance);
- operation of motors and drives;
- compressed gas systems (leaks, procedures for use);
- steam distribution systems (leaks, traps, insulation);
- space heating and hot-water systems
- lubrication to avoid high-friction losses
- boiler operation and maintenance, e.g. optimising excess air
- other maintenance relevant to the activities within the installation.

2 **Basic low-cost physical techniques** should be in place to avoid gross inefficiencies. These should include insulation, containment methods, (such as seals and self-closing doors), and avoidance of unnecessary discharge of heated water or air (e.g. by fitting simple control systems such as timers and sensors).

3 **Energy-efficient building services** should be in place to deliver the requirements of the Building Services section of the guidance note *H2 Energy efficiency for IPPC*. For energy-intensive industries these issues may be of minor impact and should not distract effort from the major energy issues, but they should nonetheless find a place in the programme, particularly where they constitute more than 5 percent of the total energy consumption.

4 **Energy management techniques** should be in place, according to the requirements of Section 2.3 noting, in particular, the need for monitoring of energy flows and targeting of areas for reductions.

5 **An energy efficiency plan** should be provided that:

- identifies all techniques relevant to the installation, including those listed above and in Section 2.7.3, that are applicable to the installation;
- estimates the CO_2 savings that would be achieved by each measure over its lifetime;
- and, in the case where the activities are NOT covered by a CCA or DPA; provides information on the equivalent annual costs of implementation of the technique, the costs per tonne of CO_2 saved and the priority for implementation. A procedure is given in the Energy Efficiency Guidance Note.

6 An example format of the energy efficiency plan is shown in Table 2.21.

Table 2.21: Example format for energy efficiency plan

ALL APPLICANTS			ONLY APPLICANTS WITHOUT CCA		
Energy efficiency measure	CO_2 savings (tonnes)		Equivalent Annual Cost (EAC) £k	EAC/CO_2 saved £/tonne	Date for implementation
	Annual	lifetime			

The Energy Efficiency Guidance Note provides an appraisal methodology. If operators use other appraisal methodologies they should state the method in the application, and provide evidence that appropriate discount rates, asset life and expenditure (£/t) criteria have been employed.

The energy efficiency plan is required to ensure that the operator has considered all relevant techniques. However, where a CCA or DPA is in place the regulator will only enforce implementation of those measures in categories 1-3 above.

2.7.3 Further energy efficiency requirements

Where there is no CCA or DPA in place, the operator should demonstrate the degree to which the further energy-efficiency measures identified in the implementation plan, including those below, have been taken into consideration for this sector and justify where they have not.

Indicative BAT requirements for further energy requirements (2.7.3)
Climate Change Agreement or Trading Agreement.
1 The following techniques should be implemented where they are judged to be BAT based on a cost/benefit appraisal according to the methodology provided in Appendix 4 of the Guidance Note *H2 Energy efficiency for IPPC.*
Energy supply techniques
2 The following techniques should be considered: • use of Combined Heat and Power (CHP) • generation of energy from waste • use of less polluting fuels
3 The operator should provide justification that the proposed or current situation represents BAT, irrespective of whether or not a CCA or DPA is in place, where there are other BAT considerations involved, e.g.: • the choice of fuel impacts upon emissions other than carbon dioxide, e.g.. sulphur dioxide; • the potential for practical energy recovery from waste conflicts with energy efficiency requirements.
4 Where there is an on-site combustion plant other guidance is also relevant. For plants greater than 50MW, operators should consult the IPC guidance on power generation (reference IPC S2 1.01 Combustion Processes: Large boilers and furnaces 50MW(th) and over and supplement IPC S3 1.01 Combustion Processes). Operators of plant of 20-50MW should consult the Local Authority Air Pollution Control guidance. On IPPC installations this guidance will be generally applicable to plant under 20MW also. (All are available from the EA website).

2.8 Accidents

This section covers accidents and their consequences. It is not limited to major accidents but includes spills and abnormal operation.

Some installations will also be subject to the Control of Major Accident Hazards Regulations 1999 (COMAH) (see Appendix 2 for equivalent legislation in Scotland and Northern Ireland). IPPC and COMAH can sometimes overlap, and some systems and information may be usable for either regime.

The COMAH regime applies to major hazards, and for accident scenarios covered by COMAH, operators may refer in the application to any COMAH reports already held by the regulator. However, the accident provisions under IPPC also cover those which, are below the classification threshold for major accidents under COMAH, so operators need to consider smaller accidents and abnormal operation scenarios as well. Guidance prepared in support of the COMAH Regulations may also help IPPC operators in considering ways to reduce the risks and consequences of accidents - whether or not they are covered by the COMAH regime.

General management requirements are covered in Section 2.1. For accident management, there are three particular components:

- identification of the hazards posed by the installation/activity;
- assessment of the risks (hazard x probability) of accidents and their possible consequences;
- implementation of measures to reduce the risks of accidents, and contingency plans for any accidents that do occur.

Indicative requirements for accidents and abnormal operation (Sheet 1 of 3) Describe your documented system that you proposed (to be used) to identify, assess and minimise the environmental risks and hazards of accidents and their consequences.
A formal structured accident management plan should be in place which covers the following aspects: **A – Identification of the hazards** to the environment posed by the installation using a methodology akin to a Hazop study. Areas to consider should include, but should not be limited to, the following: • transfer of substances (e.g.. filling or emptying of vessels); • overfilling of vessels; • emissions from plant or equipment (e.g.. leakage from joints, over-pressurisation of vessels, blocked drains); • failure of containment (e.g.. physical failure or overfilling of bunds or drainage sumps); • failure to contain firewaters; • wrong connections made in drains or other systems; • incompatible substances allowed to come into contact; • unexpected reactions or runaway reactions; • release of an effluent before adequate checking of its composition • failure of main services (e.g.. power, steam, cooling water); • operator error • vandalism.

Indicative requirements for accidents and abnormal operation (Sheet 2 of 3) Describe your documented system that you proposed (to be used) to identify, assess and minimise the environmental risks and hazards of accidents and their consequences.
B – Assessment of the risks. The hazards having been identified, the process of assessing the risks should address six basic questions: • how likely is the particular event to occur (source frequency)? • what substances are released and how much of each (risk evaluation of the event)? • where do the released substances end up (emission prediction – what are the pathways and receptors)? • what are the consequences (consequence assessment – what are the effects on the receptors)? • what are the overall risks (determination of overall risk and its significance to the environment)? • what can prevent or reduce the risk (risk management – measures to prevent accidents and/ or reduce their environmental consequences)? The depth and type of assessment will depend on the characteristics of the installation and its location. The main factors to take into account are: • the scale and nature of the accident hazard presented by the installation and the activities • the risks to areas of population and the environment (receptors) • the nature of the installation and complexity of the activities and the relative difficulty in deciding and justifying the adequacy of the risk-control techniques.

Indicative requirements for accidents and abnormal operation (Sheet 3 of 3)
C – Identification of the techniques necessary to reduce the risks. The following techniques are relevant to most installations: • there should be an up-to-date inventory of substances, present or likely to be present, which could have environmental consequences if they escape. This should include apparently innocuous substances that can be environmentally damaging if they escape (for example, a tanker of milk spilled into a watercourse can destroy its ecosystem). The permit will require the regulator to be notified of any significant changes to the inventory. • procedures should be in place for checking and handling raw materials and wastes to ensure compatibility with other substances with which they may accidentally come into contact. • storage arrangements for raw materials, products and wastes should be designed and operated to minimise risks to the environment. • there should be automatic process controls backed-up by manual supervision, both to minimise the frequency of emergency situations and to maintain control during emergency situations. Instrumentation will include, where appropriate, microprocessor control, trips and process interlocks, coupled with independent level, temperature, flow and pressure metering and high or low alarms. • physical protection should be in place where appropriate (e.g.. barriers to prevent damage to equipment from the movement of vehicles). • there should be appropriate secondary containment (e.g. bunds, catchpits, building containment). • techniques and procedures should be in place to prevent overfilling of tanks – liquid or powder - (e.g. level measurement displayed both locally and at the central control point, independent high-level alarms, high-level cut-off, and batch metering). • where the installation is situated in a floodplain, consideration should be given to techniques which will minimise the risk of the flooding causing a pollution incident or making one worse. • security systems to prevent unauthorised access should be provided where appropriate. • there should be formal systems for the logging and recording of all incidents, near-misses, abnormal events, changes to procedures and significant findings of maintenance inspections. • there should be procedures for responding to and learning from incidents, near-misses, etc. • the roles and responsibilities of personnel involved in incident management should be formally specified. • clear guidance should be available on how each accident scenario might best be managed (e.g.. containment or dispersion, to extinguish fires or to let them burn). • procedures should be in place to avoid incidents occurring as a result of poor communications between staff at shift change or during maintenance or other engineering work. • safe shutdown procedures should be in place. • communication channels with emergency services and other relevant authorities should be established, and available for use in the event of an incident. Procedures should include the assessment of harm following an incident and the steps needed to redress this.

- appropriate control techniques should be in place to limit the consequences of an accident, such as isolation of drains, provision of oil spillage equipment, alerting of relevant authorities and evacuation procedures.
- personnel training requirements should be identified and training provided.
- the systems for the prevention of fugitive emissions are generally relevant (Section 2.2.4 and Section 2.2.5) and in addition, for drainage systems:
  - procedures should be in place to ensure that the composition of the contents of a bund sump, or sump connected to a drainage system, are checked before treatment or disposal;
  - drainage sumps should be equipped with a high-level alarm or with a sensor and automatic pump to storage (not to discharge);
  - there should be a system in place to ensure that sump levels are kept to a minimum at all times;
  - high-level alarms and similar back-up instruments should not be used as the primary method of level control.
- duplicate or standby plant should be provided where necessary, with maintenance and testing to the same standards as the main plant;
- spill contingency procedures should be in place to minimise accidental release of raw materials, products and waste materials and then to prevent their entry into water.
- process waters, potentially contaminated site drainage waters, emergency firewater, chemically-contaminated waters and spillages of chemicals should be contained and, where necessary, routed to the effluent system and treated before emission to controlled waters or sewer. Sufficient storage should be provided to ensure that this can be achieved. Any emergency firewater collection system should take account of the additional firewater flows and fire-fighting foams, and emergency storage lagoons may be needed to prevent contaminated firewater reaching controlled waters (see the Releases to water references).
- consideration should be given to the possibility of containment or abatement of accidental emissions from vents and safety relief valves/bursting discs. Where this may be inadvisable on safety grounds, attention should be focused on reducing the probability of the emission.

The following techniques are more specific to leachate treatment.

- Provision of alarm systems and failsafe cut outs on e.g.. aerators and pumps.
- Hardwired interlocks on key process valves, e.g. to prevent aeration operation when certain valves are open.
- The use of fail-safe ‘closed’ valves
- Consideration of stand-by power generation.
- Telemetry on process control systems, as sites are typically unmanned.

2.9 Noise

Within this section "noise" should be taken to refer to "noise and/or vibration" as appropriate, detectable beyond the site boundary.

Where noise issues are likely to be relevant, the operator will be required, in the application, to provide information on the following: (for more details see Noise references)

- the main sources of noise and vibration that will fall within the IPPC installation and also on infrequent sources of noise and vibration
- the nearest noise-sensitive sites
- conditions/limits imposed under other regimes
- the local noise environment
- any environmental noise measurement surveys, modelling or any other noise measurements
- any specific local issues and proposals for improvements.

The level of detail supplied should be in keeping with the risk of causing noise-related annoyance at sensitive receptors.

Where an installation poses no risk of noise-related environmental impact because the activities undertaken are inherently quiet, this should be justified and no further information relating to noise need normally be supplied. It should, however, be remembered that there can still be an underlying level of annoyance without complaints being made.

The PPC Regulations require installations to be operated in such a way that "all the appropriate preventative measures are taken against pollution, in particular through the application of BAT". The definition of pollution includes "emissions that may be harmful to human health or the quality of the environment, cause offence to human senses or impair or interfere with amenities and other legitimate uses of the environment". BAT is therefore likely to be similar, in practice, to the requirements of the statutory nuisance legislation, which requires the use of "best practicable means" to prevent or minimise noise nuisance. It is understood that raw material handling can generate noise where glass is being recycled or broken up. It is suggested that consideration be given to the use of sonic booths or sound proofing to control the generation of noise where such activities are being carried out.

In the case of noise, "offence to any human senses" can normally be judged by the likelihood of complaints, but in some cases it may be possible to reduce noise emissions still further at reasonable costs, and this may exceptionally therefore be BAT for noise emissions.

For advice on how noise and/or vibration related limits and conditions will be determined see H3 Part 1 Noise.

Indicative BAT requirements for noise and vibration
Describe the main sources of noise and vibration (including infrequent sources); the nearest noise-sensitive locations and relevant environmental surveys which have been undertaken; and the pro-posed techniques and measures for the control of noise.
1 The operator should employ basic good practice measures for the control of noise, including adequate maintenance of any parts of plant or equipment whose deterioration may give rise to increases in noise (for example, maintenance of bearings, air handling plant, the building fabric as well as specific noise attenuation measures associated with plant, equipment or machinery).
2 The operator should also employ such other noise control techniques to ensure that the noise from the installation does not give rise to reasonable cause for annoyance, in the view of the regulator and, in particular, should justify where either Rating Levels (LAeq,T) from the installation exceed the numerical value of the Background Sound Level (LA_{90},T).
3 Further justification will be required should the resulting field rating level (LAR,TR) exceed 50 dB by day and a facade rating level exceed 45 dB by night, with day being defined as 07:00 to 23:00 and night 23:00 to 07:00.
4 In some circumstances "creeping background" may be an issue. Where this has been identified in pre application discussions or in previous discussions with the local authority, the operator should employ such noise control techniques as are considered appropriate to minimise problems to an acceptable level within the BAT criteria.
5 Noise surveys, measurement, investigation (which can involve detailed assessment of sound power levels for individual items of plant) or modelling may be necessary for either new or existing installations depending upon the potential for noise problems. Operators may have a noise management plan as part of their management system.

2.10 Monitoring

This section describes monitoring and reporting requirements for emissions to all environmental media. Guidance is provided for selecting the appropriate monitoring methodologies, frequency of monitoring, compliance assessment criteria and environmental monitoring.

Monitoring infrastructure associated with landfill activities may be utilised in meeting the monitoring obligations identified.

2.10.1 Environmental monitoring (beyond installation)

Indicative BAT requirements for environmental monitoring (beyond installation)

Describe the proposed measures for monitoring emissions, including any environmental monitoring, and the frequency, measurement methodology and evaluation procedure proposed.

1 The operator should consider the need for environmental monitoring to assess the effects of emissions to controlled water, groundwater, air or land, or emissions of noise or odour.

2 Environmental monitoring may be required, for example, when:

- there are vulnerable receptors
- the emissions are a significant contributor to an Environmental Quality Standard (EQS) that may be at risk
- the operator is looking for departures from standards based on lack of effect on the environment;
- to validate modelling work.

3 The need should be considered for:

- groundwater, where it should be designed to characterise both quality and flow and take into account short- and long-term variations in both. Monitoring will need to take place both up-gradient and down-gradient of the site
- surface water, where consideration will be needed for sampling, analysis and reporting for upstream and downstream quality of the controlled water
- air, including odour
- land contamination,
- assessment of health impacts
- noise

4 Where environmental monitoring is needed, the following should be considered in drawing up proposals:

- determinands to be monitored, standard reference methods, sampling protocols
- monitoring strategy, selection of monitoring points, optimisation of monitoring approach
- determination of background levels contributed by other sources
- uncertainty for the employed methodologies and the resultant overall uncertainty of measurement

- quality assurance (QA) and quality control (QC) protocols, equipment calibration and maintenance, sample storage and chain of custody/audit trail
- reporting procedures, data storage, interpretation and review of results, reporting format for the provision of information for the Regulation.

2.10.2 Emissions monitoring

Indicative BAT requirements for emissions monitoring

Describe the proposed measures for monitoring emissions, including any environmental monitoring, and the frequency, measurement methodology and evaluation procedure proposed.

1. The following monitoring parameters and frequency are normally appropriate in this sector. Generally, monitoring should be undertaken during commissioning, start-up, normal operation and shutdown unless the regulator agrees that it would be inappropriate to do so.
2. Continuous monitoring (or at least sampling in the case of water) and recording are likely to be required under the following circumstances:
   - Where the potential environmental impact is significant or the concentration of substance varies widely.
   - Where a substance is abated continuous monitoring of the substance is normally required to show the performance of the abatement plant. In the case of leachate treatment plants continuous sampling or recording of some effluent parameters may be applicable e.g. flow rate. The frequency of sampling should reflect the practicalities of the measuring techniques, the potential impact, variability in concentration and type of discharge e.g. continuous or batch.
   - Where other control measures are required to achieve satisfactory levels of emission (e.g. material selection).
3. Where effective surrogates are available, they may be used to minimise monitoring costs.
4. Where monitoring shows that substances are not emitted in significant quantities, it may be possible to reduce monitoring frequency.

Monitoring and reporting of emissions to water and sewer

Discharges of more than 100m^3 per day to controlled waters shall be Subject to Direct Toxicity Assessment (DTA). This is achieved by testing of the effluent from the leachate treatment plant directly on living organisms. Where appropriate DTA shall be considered for discharges of less than 100m^3 per day.

5. Monitoring is required for environmentally significant (>10% of EQS/EAL) of direct emissions of ‘dangerous substances’ to controlled waters. Dangerous substances are List I and List II substances specified in the Dangerous Substances Directive 76/464/EEC. The significance of an emission should be assessed using the Environment Agency’s H1 guidance ‘Environmental Assessment and Appraisal of BAT’.

Indicative BAT requirements for emissions monitoring
6. Monitoring is required for environmentally significant (>10% of EQS/EAL) of direct emissions of 'dangerous substances' to controlled waters. Dangerous substances are List I and List II substances specified in the Dangerous Substances Directive 76/464/EEC. The significance of an emission should be assessed using the Environment Agency's H1 guidance 'Environmental Assessment and Appraisal of BAT'.
7. For lesser impacts of direct emissions and emissions to sewer of dangerous substances sampling and monitoring may be appropriate.
Monitoring and reporting of emissions to air
8 Where appropriate, periodic visual and olfactory assessment of releases should be undertaken to ensure that all final releases to air should be essentially colourless, free from persistent trailing mist or fume and free from droplets.
9 The operator should also have a fuller analysis carried out covering a broad spectrum of substances to establish that all relevant substances have been taken into account when setting the release limits. This should cover the substances listed in Schedule 5 of the Regulations unless it is agreed with the regulator that they are not applicable. The need to repeat such a test will depend upon the potential variability in the process and, for example, the potential for contamination of raw materials. Where there is such potential, tests may be appropriate.
10 Any substances found to be of concern, or any other individual substances to which the local environment may be susceptible and upon which the operations may impact, should also be monitored more regularly. This would particularly apply to the common pesticides and heavy metals. Using composite samples is the technique most likely to be appropriate where the concentration does not vary excessively.
Monitoring and reporting of waste emissions
11 For waste emissions, the following should be monitored and recorded: • the physical and chemical composition of the waste • its hazard characteristics • handling precautions and substances with which it cannot be mixed

2.10.3 Monitoring of process variables

Indicative BAT requirements for monitoring process variables Describe the proposed measures for monitoring emissions, including any environmental monitoring, and the frequency, measurement methodology and evaluation procedure proposed.
1. Some process variables may affect the environment and these should be identified and monitored as appropriate. Examples might be: ▪ Energy consumption; ▪ Temperature in biological processes; and ▪ pH in biological, physical and chemical processes.

2.10.4 Monitoring standards (Standard Reference Methods)

The Environment Agency has introduced its Monitoring Certification Scheme (MCERTS) to improve the quality of monitoring data and to ensure that the instrumentation and methodologies employed for monitoring are fit for purpose. Performance standards have been published for continuous emissions monitoring systems (CEMs), ambient air quality monitoring systems (CAMs), chemical testing of soils and manual stack emissions monitoring. Other MCERTS standards are under development to cover portable emissions monitoring equipment, water monitoring instrumentation, data acquisition and operators' own arrangements, such as installation, calibration and maintenance of monitoring equipment, position of sampling ports and provision of safe access for manual stack monitoring.

The following should be described in the application, indicating which monitoring provisions comply with MCERTS requirements or where other arrangements have been made:

- monitoring methods and procedures (selection of Standard Reference Methods)
- justification for continuous monitoring or spot sampling
- reference conditions and averaging periods
- measurement uncertainty of the proposed methods and the resultant overall uncertainty.
- criteria for the assessment of non-compliance with Permit limits and details of monitoring strategy aimed at demonstration of compliance
- reporting procedures and data storage of monitoring results, record keeping and reporting intervals for the provision of information to the regulator
- procedures for monitoring during start-up and shut-down and abnormal process conditions
- drift correction calibration intervals and methods
- the accreditation held by samplers and laboratories or details of the people used and the training/competencies.

Indicative BAT requirements for monitoring standards (Standard Reference Methods)
Describe the proposed measures for monitoring emissions, including any environmental monitoring, and the frequency, measurement methodology and evaluation procedure proposed. 1 As far as possible, operators should ensure their monitoring arrangements comply with the requirements of MCERTS where available, for example using certified instruments and equipment, and using a stack testing organisation accredited to MCERTS standards. Where the monitoring arrangements are not in accordance with MCERTS requirements, the operator should provide justification and describe the monitoring provisions in detail. See MCERTS approved equipment link via www.environment-agency.gov.uk/business/mcerts for future information on MCERTS and a listing of MCERTS equipment.

Sampling and analysis standards

2 The analytical methods given in Appendix 1 should be used. In the event of other substances needing to be monitored, standards should be used in the following order of priority:

- Comité Européen de Normalisation (CEN)
- British Standards Institution (BSI)
- International Standardisation Organisation (ISO)
- United States Environmental Protection Agency (US EPA)
- American Society for Testing and Materials (ASTM)
- Deutches Institut für Normung (DIN)
- Verein Deustcher Ingenieure (VDI)
- Association Française de Normalisation (AFNOR)

3 Further guidance on standards for monitoring gaseous releases relevant to IPC/IPPC is given in the Monitoring Guidance. A series of updated Guidance Notes covering this subject is being prepared. This guidance specifies manual methods of sampling and analysis that will also be suitable for calibration of continuous emission monitoring instruments. Further guidance relevant to water and waste is available from the publications of the Standing Committee of Analysts.

4 If in doubt the operator should consult the regulator.

2.11 Closure

The PPC Regulations require an applicant to submit a site report, describing the condition of the site, as part of the application. Guidance is given in Environment Agency Guidance H7 on the protection of Land.

Indicative BAT requirements for closure

Describe the proposed measures, upon definitive cessation of activities, to avoid any pollution risk and return the site of operation to a satisfactory state (including, where appropriate, measures relating to the design and construction of the installation).

1 **Operations during the IPPC Permit**

Operations during the life of the IPPC Permit should not lead to any deterioration of the site if the requirements of the other sections of this and the specific-sector notes are adhered to. Should any instances arise which have, or might have, impacted on the state of the site, the operator should record them along with any further investigation or ameliorating work carried out. This will ensure that there is a coherent record of the state of the site throughout the period of the IPPC permit. This is as important for the protection of the operator as it is for the protection of the environment. Any changes to this record should be submitted to the regulator.

2 **Steps to be taken at the design-and-build stage of the activities**

Care should be taken at the design stage to minimise risks during decommissioning. For existing installations, where potential problems are identified, a programme of improvements should be put in place to a timescale agreed with the regulator. Designs should ensure that:

- underground tanks and pipework are avoided where possible (unless protected by secondary containment or a suitable monitoring programme)
- there is provision for the draining and clean-out of vessels and pipework prior to dismantling
- lagoons and landfills are designed with a view to their eventual clean-up or surrender
- insulation is provided that is readily dismantled without dust or hazard
- materials used are recyclable (having regard for operational or other environmental objectives)

3 **The site-closure plan**

A site closure plan should be maintained to demonstrate that, in its current state, the installation can be decommissioned to avoid any pollution risk and return the site of operation to a satisfactory state. The plan should be kept updated as material changes occur. Common sense should be used in the level of detail, since the circumstances at closure will affect the final plans. However, even at an early stage, the closure plan should include:

- either the removal or the flushing out of pipelines and vessels where appropriate and their complete emptying of any potentially harmful contents

- plans of all underground pipes and vessels
- the method and resource necessary for the clearing of lagoons.
- the method of ensuring that any on-site landfills can meet the equivalent of surrender conditions
- the removal of asbestos or other potentially harmful materials unless agreed that it is reasonable to leave such liabilities to future owners
- methods of dismantling buildings and other structures, which gives guidance on the protection of surface and groundwater at construction and demolition-sites
- testing of the soil to ascertain the degree of any pollution caused by the activities and the need for any remediation to return the site to a satisfactory state as defined by the initial site report.

4 For existing activities, the operator should complete any detailed studies, and submit the site-closure plan as an improvement condition to a timescale to be agreed with the regulator but in any case within the timescale given in Section 1.1 (Note that radioactive sources are not covered by this legislation, but decommissioning plans should be co-ordinated with responsibilities under the Radioactive Substances Act 1993.)

2.12 Installation issues

In some cases it is possible that actions that benefit the environmental performance of the overall installation will increase the emissions from one permit holder's activities. For example, taking treated effluent as a raw water supply will probably slightly increase emissions from that activity, but could dramatically cut the total emissions from the whole installation.

Where you are not the only operator of the installation, describe the proposed techniques and measures (including those to be taken jointly by yourself and other operators) for ensuring the satisfactory operation of the whole installation.

This section will be particularly relevant where a third party (other than the landfill operator) is the operator of the leachate treatment plant, which forms a directly associated activity to a PPC regulated landfill. In this instance the management of leachate on the landfill site, which will be outside of the direct control of the treatment plant operator, becomes of critical importance. All permit holders must ensure that adequate communication channels are in place to keep the treatment plant operators informed of any changes that may impact on their ability to adequately treat the leachate.

Indicative BAT requirements for installation issues

Where you are not the only operator of the installation, describe the proposed techniques and measures (including those to be taken jointly by yourself and other operators) for ensuring the satisfactory operation of the whole installation.

1 The operator should consider possibilities for minimising environmental impact to the environment as a whole, by operating together with other permit holders. Possibilities include:

- Communication procedures between the various permit holders; in particular those needed to ensure that the risk of environmental incidents is minimised.
- Benefiting from the economies of scale to justify the installation of a CHP plant.
- The waste from one activity being a possible feedstock for another.
- The treated effluent from one activity being of adequate quality to be the raw water feed for another activity.
- The combining of effluent to justify a combined or upgraded effluent-treatment plant.
- The avoidance of accidents from one activity that may have a detrimental knock-on effect on the neighbouring activity.
- Land contamination from one activity affecting another – or the possibility that one operator owns the land on which the other is situated.

3. Emission benchmarks

3.1 Emissions inventory

The Regulations require the applicant to describe the nature, quantities and sources of foreseeable emissions into each medium. This will be done by completing the inventory of emission and consumption in the H1 software tool. The information required is as follows.

Provide a table of significant emissions of substances (except noise, vibration, odour and heat which are covered in their respective sections) that will result from the proposals and should include, preferably in order of significance:

- substance (where the substance is a mixture, for example, VOCs or COD, separate identification of the main constituents or inclusion of an improvement proposal to identify them)
- source,
- media to which it is released
- any relevant EQS or other obligations
- benchmark
- proposed emissions normal/max expressed, as appropriate for:
  - mass/unit time
  - concentration
  - annual mass emissions
- statistical basis (average, percentile etc.)
- notes covering the operators confidence in his ability to meet the benchmark values
- if intermittent, the appropriate frequencies
- plant loads at which the data is applicable
- whether measured or calculated (the method of calculation should be provided)

The response should clearly state whether the emissions are current emission rates or those planned following improvements, and should cover emissions under both normal and abnormal conditions for:

- point-source emissions to surface water, groundwater and sewer
- waste emissions
- point-source emissions to air
- significant fugitive emissions to all media, identifying the proportion of each substance released that is due to fugitives rather than point-source releases
- abnormal emissions from emergency relief vents, flares and the like
- indirect and direct emission of carbon dioxide associated with energy consumed or generated.

Emissions of carbon dioxide associated with energy use should be broken down by energy type and, in the case of electricity, by source, for example, public supply, direct supply or on-site generation. Where energy is generated on-site, or from a direct (non-public) supplier, the operator should specify and use the appropriate factor. Standard factors for carbon dioxide emissions are provided in the guidance note *H2 Energy efficiency for IPPC*.

Where VOCs are released, the main chemical constituents of the emissions should be identified.

For waste, emissions relate to any wastes removed from the installation, or disposed of at the installation under the conditions of the permit, for example, landfill. Each waste should have its composition determined and the amounts expressed in terms of cubic metres or tonnes per month.

Indicative BAT requirements for the emissions inventory
Describe the nature, quantities and sources of foreseeable emissions into each medium (which will result from the techniques proposed in Section 2).
1 The operator should compare the emissions with the benchmark values given in the remainder of this section.
2 Where the benchmarks are not met, the operator should revisit the responses made in Section 2 as appropriate and make proposals for improvements or justify not doing so as part of the BAT assessment.

3.2 Emissions benchmarks

Guidance is given below on release concentrations or mass release rates achievable for key substances using the best combination of techniques. These BAT-based benchmarks are not mandatory release limits and reference should be made to Section 1 and the Guide for Applicants regarding their use.

3.2.1 Emissions to air associated with the use of BAT

The emissions quoted below are daily averages based upon continuous monitoring during the period of operation. See Section 3.2.6 for the standard conditions that should be applied. Care should always be taken to convert benchmark and proposed releases to the same reference conditions for comparison. To convert measured values to reference conditions, see the Monitoring Guidance for more information. The benchmarks given do not take sampling, analytical errors, or uncertainties into account. These will be considered when setting an Emission Limit Value (ELV) for a permit.

Limits in permits may be set for mean or median values over long or short periods. The periods and limits selected should reflect:

- the manner in which the emission may impact upon the environment
- likely variations which will arise during operation within BAT
- possible failure modes and their consequences
- the capabilities of the monitoring and testing system employed.

Where emissions are expressed in terms of concentrations and where continuous monitors are employed, it is recommended that limits are defined such that:

- not more than one calendar monthly average during any rolling twelve month period shall exceed the benchmark value by more than 10%
- not more than one half hour period during any rolling 24 hour period shall exceed the benchmark value by more than 50% (for the purpose of this limit half hourly periods commence on the hour and the half hour)

Where spot tests are employed:

- the half hour limit above shall be applied over the period of the test
- the mean of three consecutive tests taken during a calendar year shall not exceed the benchmark value by more than 10%.

Table 3.1: Emissions to air

Released substance	Bench mark value (mg/Nm^3) The reference conditions applicable are: temperature 273 K (0^{o}C), pressure 101.3 k Pa (1 atmosphere), no correction for water vapour or oxygen.
Hydrogen Sulphide	5
VOC total Class A	20
VOC total Class B (expressed as carbon)	75
Releases should be colourless, free from persistent mist or fume and free from droplets. The basis for the benchmark is parity with other UK industrial sector benchmarks.	

3.2.2 Emissions to water associated with the use of BAT

Where automatic sampling systems are employed, limits may be defined such that:

- not more than 5% of samples shall exceed the benchmark value

Where spot samples are taken:

- no spot sample shall exceed the benchmark value by more than 50%

Table 3.2 Emissions to Water

Released substance	Benchmark value (mg/l) for different types of treatment process		
	SBR	MBR	RO
BOD_5	40	5	15
Ammoniacal-N	4	2	10
Nitrate-N	1500	150	1

The following table shows the basis for the values in the table above.

SBR	Taken from Table 2.13 'Typical performance data of tank based SBR leachate treatment schemes' and taking account of the comments made during the consultation process.
MBR	Taken from Table 2.14 'Typical performance data from MBR leachate treatment schemes'. The level of Nitrate-N assumes a denitrification process.
RO	Taken from performance data of 2 stages RO plant provided by Clarke Energy during the consultation period.

BAT includes the technical components, process control, and management of the installation given in Section 2 of this guidance, and the benchmark levels for emissions identified here. Departures from these benchmark levels can be justified at the installation level by taking into account the technical characteristics of the installation concerned, its geographical location and the local environmental conditions.

An example of such a departure could be for ammoniacal-N. Achieving low levels of ammoniacal-N requires energy and long residence times in SBR and MBR processes. If the effluent from the leachate treatment plant is discharged to a sewage works with no likelihood of sewer by-pass and the sewage works has the necessary nitrification capacity then it may be acceptable to consider higher emission limits. The IPPC Directive sets out at Article 2(6) how indirect releases to water (i.e. releases to sewer) are to be addressed when setting emission limit values from PPC installations. That provision is repeated within Regulation 12(5) of the PPC Regulations, which states: "The effect of a waste water treatment plant may be taken into account when determining the emission limit values applying in relation to indirect releases into water from a Part A installation or Part A mobile plant provided that an equivalent level of protection of the environment as a whole is guaranteed and taking such treatment into account does not lead to higher levels of pollution."

3.2.3 Standards and obligations

In addition to meeting the requirements of BAT, there are other national and international standards and obligations that must either be safeguarded through the IPPC permit or, at least, taken into account in setting permit conditions. This is particularly the case for any EC-based EQSs.

EC-based EQ standards

IPPC: A Practical Guide explains how these should be taken into account and contains an annex listing the relevant standards. (See Appendix 2 for equivalent legislation in Scotland and Northern Ireland). They can be summarised as follows:

Air quality

- Statutory Instrument 1989 No 317, Clean Air, The Air Quality Standards Regulations 1989 gives limit values in air for nitrogen dioxide (any emission from the process should not result in a breach of this standard beyond the site boundary), sulphur dioxide and suspended particulates.
- Environmental Protection, The Air Quality Regulations 1997.
- Statutory Instrument 2000 No.928, Air Quality (England) Regulations 2000 gives air quality objectives to be achieved by:
  - 2005 for nitrogen dioxide
  - 2004 for SO2 and PM10
  - 2003 for CO, 1,3-butadiene and benzene
  - in two stages for lead by 2004 and 2008 respectively

Water quality

- Directive 76/464/EEC on Pollution Caused by Dangerous Substances Discharged to Water contains two lists of substances. List I relates to the most dangerous and standards are set out in various daughter Directives. List II substances must also be controlled. Annual mean concentration limits for receiving waters for List I substances can be found in SI 1989/2286 and SI 1992/337 the Surface Water (Dangerous Substances Classification)

Regulations. Values for List II substances are contained in SI 1997/2560 and SI 1998/389. Daughter Directives cover EQS values for mercury, cadmium, hexachlorocyclohexane, DDT, carbon tetrachloride, pentachlorophenol, aldrin, dieldrin, endrin, isodrin, hexachlorobenzene, hexachlorobutadiene, chloroform,1,2-dichloroethane, trichloroethane, perchloroethane and trichlorobenzene.

- Other waters with specific uses have water quality concentration limits for certain substances.

These are covered by the following Regulations:

- SI 1991/1597 Bathing Waters (Classification) Regulations
- SI 1992/1331 and Direction 1997 Surface Waters (Fishlife) (Classification) Regulations
- SI 1997/1332 Surface Waters (Shellfish) (Classification) Regulations
- SI 1996/3001 The Surface Waters (Abstraction and Drinking Water) (Classification) Regulations

Future likely changes include:

- Some air quality and water quality standards may be replaced by new ones in the near future
- The SED on the limitation of emissions of VOCs due to the use of organic solvents in certain activities and installations

Other standards and obligations

Those most frequently applicable to most sectors are:

- Hazardous Waste Incineration Directive
- Waste Incineration Directive.
- Large Combustion Plant Directive.
- Reducing Emissions of VOCs and Levels of Ground Level Ozone: a UK Strategy (published by the Department of the Environment in October 1993. It sets out how the Government expects to meet its obligations under the UNECE VOCs Protocol to reduce its emissions by 30% (based on 1988 levels) by 1999, including the reductions projected for the major industrial sectors).
- Water Quality Objectives – assigned water quality objectives to inland rivers and water courses (ref. Surface (Rivers Ecosystem) Classification).
- The UNECE convention on long-range transboundary air pollution (negotiations are now underway which could lead to a requirement further to reduce emissions of NOx and VOCs. A requirement to further reduce SO2 emissions from all sources has been agreed. The second Sulphur protocol (Oslo, 1994) obliges the UK to reduce SO2 emissions by 80% (based on 1980 levels) by 2010).
- The Montreal Protocol.
- The Habitats Directive (see Section 4.3).
- Sulphur Content of Certain Liquid Fuels Directive 1999/32/EC (from 1 January 2003, the sulphur content of heavy fuel oil must not exceed 1% except when it is burnt in plants fitted with SO2 abatement equipment. Sulphur levels in gas oil must not exceed 0.2% from 1 July 2000, and 0.1% from the start of 2008.)

3.2.4 Units for benchmarks and setting limits in permits

Releases can be expressed in terms of:

- **“concentration”** (for example mg/l or mg/m3), which is a useful day-to-day measure of the effectiveness of any abatement plant and is usually measurable and enforceable The total flow must be measured/controlled as well
- **“specific mass release”** (for example, kg/ product or input or other appropriate parameter), which is a measure of the overall environmental performance of the plant (including the abatement plant) compared with similar plants elsewhere
- **“absolute mass release”** (for example, kg/hr, t/yr), which relates directly to environmental impact

When endeavouring to reduce the environmental impact of an installation, its performance against each of these levels should be considered, as appropriate to the circumstances, in assessing where improvements can best be made.

When setting limits in permits, the most appropriate measure will depend on the purpose of the limit. It may also be appropriate to use surrogate parameters, which reflect optimum environmental performance of plant as the routine measurement, supported by less frequent check-analyses on the final concentration. Examples of surrogate measures would be the continuous measurement of conductivity (after ion-exchange treatment) or total carbon (before a guard-column in activated carbon treatment) to indicate when regeneration or replacement is required.

The emission level figures given in this chapter are based on average figures, not on maximum, short-term peak values, which could be expected to be higher. The emission levels given are based on a typical averaging period of not less than 30 minutes and not greater than 24 hours.

3.2.5 Statistical basis for benchmarks and limits in permits

Conditions in permits can be set with percentile, mean or median values over annual, monthly or daily periods, which reflect probable variation in performance. In addition, absolute maxima can be set.

Where there are known failure modes, which will occur even when applying BAT, limits in permits may be specifically disapplied, but with commensurate requirements to notify the regulator and to take specific remedial action.

For water: UK benchmarks or limits are most frequently 95 percentile concentrations or absolute concentrations, (with flow limited on a daily average or maximum basis).

For air: benchmarks or limits are most frequently expressed as daily averages or, typically 95 percent of hourly averages.

3.2.6 Reference conditions for releases to air

The reference conditions of substances in releases to air from point-sources are:

- temperature 273 K (0^{o}C),
- pressure 101.3 kPa (1 atmosphere), no correction for water vapour or oxygen.

The reference conditions for combustion or incineration processes are as given in the appropriate Guidance Note.

These reference conditions relate to the benchmark release levels given in this Note and care should always be taken to convert benchmark and proposed releases to the same reference conditions for comparison. The permit may employ different reference conditions if they are more suitable for the process in question.

To convert measured values to reference conditions, see the Monitoring Guidance for more information.

4. Impact

4.1 Impact assessment

The operator should assess that the emissions resulting from the proposals for the activities/installation will provide a high level of protection for the environment as a whole, in particular having regard to EQS etc, revisiting the techniques in Section 2 as necessary. The use of IPPC Environmental Assessments for BAT, and the IPPC Environmental Assessments for BAT software tool, and the other tools on the application CD, will lead the applicant through the process.

The depth to which the impact assessment should go should be discussed with the regulator. For some low risk sites the requirements may be reduced.

Indicative BAT requirements for the impact assessment

Provide an assessment of the potential significant environmental effects (including transboundary effects) of the foreseeable emissions.

1 Provide a description, including maps as appropriate, of the receiving environment to identify the receptors of pollution. The extent of the area may cover the local, national and international (for example, transboundary effects) environment as appropriate.

2 Identify important receptors, which may include: areas of human population including noise or odour-sensitive areas, flora and fauna (that is, Habitat Directive sites, special areas of conservation, Sites of Special Scientific Interest (SSSI or in Northern Ireland ASSI) or other sensitive areas), soil, water, that is groundwater (water below the surface of the ground in the saturation zone and in direct contact with the ground and subsoil) and watercourses (for example, ditches, streams, brooks, rivers), air, including the upper atmosphere, landscape, material assets and the cultural heritage.

3 Identify the pathways by which the receptors will be exposed (where not self-evident).

4 Carry out an assessment of the potential impact of the total emissions from the activities on these receptors. IPPC Environmental Assessments for BAT provides a systematic method for doing this and will also identify where modelling needs to be carried out, to air or water, to improve the understanding of the dispersion of the emissions. The assessment will include comparison (see *IPPC: A Practical Guide*) with:

- community EQS levels
- other statutory obligations
- non-statutory obligations
- environmental action levels (EALs) and the other environmental and regulatory parameters defined in IPPC Environmental Assessments for BAT

5 In particular it will be necessary to demonstrate that an appropriate assessment of vent and chimney heights has been made to ensure that there is adequate dispersion of the minimised emission(s) to avoid exceeding local ground-level pollution thresholds and limit national and transboundary pollution impacts, based on the most sensitive receptor, be it human health, soil or terrestrial ecosystems.

6 Where appropriate, the operator should also recognise the chimney or vent as an emergency emission point and understand the likely behaviour. Process upsets or equipment failure giving rise to abnormally high emission levels over short periods should be assessed. Even if the applicant can demonstrate a very low probability of occurrence, the height of the chimney or vent should nevertheless be set to avoid any significant risk to health. The impact of fugitive emissions can also be assessed in many cases.

7 Consider whether the responses to Sections 2 and 3 and this assessment adequately demonstrate that the necessary measures have been taken against pollution, in particular by the application of BAT, and that no significant pollution will be caused. Where there is uncertainty about this, the measures in Section 2 should be revisited as appropriate to make further improvements.

8 Where the same pollutants are being emitted by more than one permitted activity on the installation, the operator should assess the impact both with and without the neighbouring emissions.

4.2 Waste Management Licensing Regulations

Some requirements of the Waste Framework Directive (WFD) are implemented in England and Wales through Schedule 4 of the Waste Management Licensing Regulation 1994 (WMLR) (for equivalent legislation in N Ireland see Appendix 2) or the Waste Management Licensing Regulations (Northern Island) 2003. Article 4 of the WFD is concerned with the 'relevant objectives' and is implemented via paragraph 4 of Schedule 4 of the WMLR. These 'relevant objectives' are over arching provisions that apply to all installations that undertake the disposal or recovery of waste.

The application of BAT is likely to already address the risks to water, air, soil, plants or animals, odour nuisance and some aspects of effects on countryside. It is also necessary to ensure that any places of special concern that could be affected, such as SSSIs, are identified and commented upon although, again, these may have been addressed in the assessment of BAT, in which case a cross-reference may suffice.

The PPC permit also implements the requirements imposed by Article 9 of the WFD. These provisions will apply to all installations that dispose of waste by means of operations specified in Annex IIA of the WFD. This definition of disposal covers a broad range of activities such as landfill, waste treatment and storage.

Many installations will undertake on-site treatment operations of waste generated as a result of production activities e.g. effluent treatment. In future, greater emphasis will be placed on the treatment of waste to meet permit conditions that mirror the obligations of Regulation 11(3) set out in Section 2.6, or Regulation 10 of the Landfill (England and Wales) Regulations 2002 (for equivalent legislation in Northern Ireland see Appendix 2) or the Landfill Regulations (Northern Ireland) 2003.

Permits that authorise these Annex IIA disposal activities are required to address Article 9 requirements whether the disposal is a 'listed activity' or a directly associated activity'. The mechanisms and structure of a PPC application are likely to address most of these requirements. It will however, be necessary for the operator briefly to consider each of these points individually and ensure they are addressed by their proposals.

Indicative BAT requirements for the Waste Management Licensing Regulations Explain how the information provided in other parts of the application also demonstrates that the requirements of the relevant objectives of the Waste Management Licensing Regulations 1994 have been addressed, or provide additional information in this respect.	
1	In relation to activities involving the disposal or recovery of waste, the regulators are required to exercise their functions for the purpose of achieving the relevant objectives as set out in Schedule 4 of the Waste Management Licensing Regulations 1994. (For the equivalent Regulations in Northern Ireland, see Appendix 2.)
2	The relevant objectives, contained in paragraph 4, Schedule 4 of the Waste Management Licensing Regulations 1994 (SI 1994/1056 as amended) are as follows: Ensuring the waste is recovered or disposed of without endangering human health and without using process or methods which could harm the environment and in particular without:

- risk to water, air, soil, plants or animals or
- causing nuisance through noise or odours or
- adversely affecting the countryside or places of special interest

Implementing, as far as material, any plan made under the plan-making provisions.

Operators should identify any development plans made by the local planning authority, including any waste local plan, and comment on the extent to which the proposals accord with the contents of any such plan.

3. Where a regulator grants or modifies a permit and the activities authorised by the permit include the disposal of waste, t is required to exercise its function as set out in paragraph 6 of the Schedule 4 of the Waste Management Licensing Regulations 1994, “Matters to be covered by permit”. (For equivalent Regulations in Northern Ireland, see Appendix 2.). In particular, the regulator must ensure that the permit covers:

   a the types and quantities of waste,
   b the technical requirements,
   c the security precautions to be taken,
   d the disposal site, and
   e the treatment method.

4. Where other Directives may apply (for example, the Waste Incineration Directive or Waste Oils Directive), many of the requirements referred to in the paragraph above will have been specified in detail as a result of the requirements of such Directives.

4.3 The Habitats Regulations

Indicative BAT requirements for the Habitats Regulations

Provide an assessment of whether the installation is likely to have a significant effect on a European site in the UK and if it is, provide an assessment of the implications of the installation for that site, for the purposes of the Conservation (Natural Habitats etc) Regulations 1994 (SI 1994/2716). Your response should cover all relevant issues pertinent to your installation, including those below. In doing so you should justify your proposals against any indicative requirements stated.

1 An application for a PPC permit will be regarded as a new plan or project for the purposes of the Habitats Regulations (for the equivalent Regulations in Northern Ireland see Appendix 2). Therefore, operators should provide an initial assessment of whether the installation is likely to have a significant effect on any European site in the UK (either alone or in combination with other relevant plans or projects) and, if so, an initial assessment of the implications of the installation for any such site. The application of BAT is likely to have gone some way towards addressing the potential impact of the installation on European sites and putting into place techniques to avoid any significant effects. The operator should provide a description of how the BAT assessment has specifically taken these matters into account, bearing in mind the conservation objectives of any such site.

2 European sites are defined in Regulation 10 of the Habitats Regulations to include Special Areas of Conservation (SACs); sites of community importance (sites that have been selected as candidate SACs by member states and adopted by the European Commission, but which are not yet formally classified); and Special Protection Areas (SPAs). It is also Government policy (set out in PPG 9 on nature conservation) that potential SPAs and candidate SACs should be considered to be European sites for the purposes of Regulation 10.

3 Information on the location of European sites and their conservation objectives is available from:

- English Nature (01733 455000), www.english-nature.org.uk
- Countryside Council for Wales (01248 385620), www.ccw.gov.uk
- Scottish Natural Heritage (0131 447 4784), www.snh.org.uk
- Joint Nature Conservation Committee (01733 866852), www.jncc.gov.uk
- Environment and Heritage Service, Northern Ireland (02890254754) www.ehsni.gov.uk.

4 The regulator will need to consider the operator's initial assessment. If it concludes that the installation is likely to have a significant effect on a European site, then the regulator will need to carry out an "appropriate assessment" of the implications of the installation in view of that site's conservation objectives. The Regulations impose a duty on the regulator to carry out these assessments, so it cannot rely on the operator's initial assessments. Therefore the regulator must be provided with any relevant information upon which the operator's assessment is based.

5 Note that in many cases the impact of the Habitats Regulations will have been considered at the planning application stage, in which case the regulator should be advised of the details.

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Referenced Guidance

For a full list of available Technical Guidance see Appendix A of the Guide for Applicants or visit the Environment Agency Website http://www.environment-agency.gov.uk**.** Many of the references below are being made free of charge for viewing or downloading on the Website. The same information can also be accessed via the NIEHS Website www.ehsni.gov.uk. Most titles will also be available in hard copy from the Stationary Office (TSO). Some existing titles are not yet available on the Website but can be obtained from TSO.

Assessment methodologies

E1 BPEO Assessment Methodology for IPC

IPPC Environmental Assessment for BAT H1. **EA website.**

Waste minimisation support references

Waste minimisation information accessible via: wwww.environment-agency.gov.uk/sibjects/waste/131528

Waste Minimisation-an environmental good practice guide for industry. Available free to companies who intend to undertake a waste reduction programme (tel: 0345 337700)

Profiting from Pollution Prevention – 3Es methodology (emissions, efficiency, economics). Video and A4 guide aimed at process industries. Available from Environment Agency, North East Region (tel. 0113 244 0191, ask for Regional PIR).

Waste Minimisation Interactive Tools (WMIT). Produced in association with Envirowise and the BOC Foundation (a software tool designed for small and medium businesses). Available free from The Environmental Helpline (tel: 0800 585794).

ENVIROWISE. A joint DTI/DEFRA programme, with over 200 separate case studies, good practice guides, leaflets, flyers, software tools and videos covering 12 industry sectors, packaging, solvents and the generic areas of waste minimisation and cleaner technology. ENVIROWISE is accessible via a FREE and confidential helpline (tel: 0800 585794) or via the web site www.envirowise.gov.uk

Increased Profit Through Improved Materials Additions: Management/Technical Guide, ENVIROWISE, GG194/195.

Waste Management Information Bureau. The UK's national referral centre for help on the full range of waste management issues. Short enquires are free (tel: 01235 463162)

Waste Minimisation – Institution of Chemical Engineers Training Package E07. Basic course which contains guide, video, slides, OHPs etc. (tel 01788 578214).

BIO-WISE – profiting through industrial biotechnology. A DTI programme providing free advice and information about how biotechnology can be used within manufacturing industry. Case studies, guides website and Helpline 0800 432100. dti.gov.uk/biowise.

HSE Guidance References

HSG51, Storage of flammable liquids in containers, ISBN 0-7176-1471-9

CS21, The Storage and Handling of Organic Peroxides , ISBN 0-7176-2403-X

Storage and Handling of Corrosive Liquids, ITN/IPC4/02, Environment Agency

The Storage and Handling of Drums and Intermediate Bulk Containers PPG 26, Environment Agency.

Water Efficiency References

Simple measures restrict water cost, ENVIROWISE, GC22.

Effluent costs eliminated by water treatment, ENVIROWISE, GC24.

Saving money through waste minimisation: Reducing water use, ENVIROWISE, GG26

ENVIROWISE Helpline 0800 595794

Optimum use of water for industry and agriculture dependent on direct abstraction: Best practice manual. R&D technical report W157, Environment Agency (1998), WRc Dissemination Centre, Swindon (tel: 01793 865012)

Cost-effective Water Saving Devices and Practices ENVIROWISE GG067

Water and Cost Savings from Improved Process Control ENVIROWISE GC110

Tracking Water Use to Cut Costs ENVIROWISE GG152

Releases to Water References

BREF on Waste Water and Waste Gas Treatment

A4 Effluent Treatment Techniques, TGN A4, Environment Agency, ISBN 0-11-310127-9, **EA Website.**

Pollution Prevention Guidance Note – Above ground oil storage tanks, PPG2, Environment Agency, **EA Website.**

Construction of bunds for oil storage tanks, Mason, P. A, Amies, H. J, Sangarapillai, G. Rose, Construction Industry Research and Information Association (CIRIA), Report 163, 1997, CIRIA, 6 Storey's Gate, Westminster, London, SW1P 3AU.

Policy and Practice for the Protection of Groundwater (PPPG) **EA Website**

Choosing Cost-effective Pollution Control ENVIROWISE GG109

Cost-effective Separation Technologies for Minimising Wastes and Effluents ENVIROWISE GG037

Cost-effective Membrane Technologies for Minimising Wastes and Effluents ENVIROWISE GG044

Waste Management References

Investigation of the criteria for and guidance on the landspreading of industrial wastes – final report to Defra, the Environment Agency and MAFF, May 1998.

Energy References

Energy Efficiency Guidance, Horizontal Guidance Note IPPC H2, **EA Website.**

Monitoring References

MCERTS approved equipment link via www.mcerts.net

Technical Guidance Note M18 – Monitoring of discharges to water and sewer, Version 1, 2004. **EA Website**

Direct Toxicity Assessment for Effluent Control, Technical Guidance (2000), UKWIR 00/TX/02/07

Odour References

Internal Guidance for the Regulation of Odour at Waste Management Facilities, **EA Website**.

Integrated Pollution Prevention and Control (IPPC) IPPC Horizontal Guidance Note for Odour – H4: Parts 1 and 2.

Noise References

Integrated Pollution Prevention and Control (IPPC) IPPC Horizontal Guidance Note for Noise – H3: Parts 1 and 2.

Closure references

Working at Construction and Demolition sites (PPG 6) **EA Website**

Integrated Pollution Prevention and Control (IPPC) Draft IPPC H8 Horizontal Guidance Note for Surrender Site Report

Integrated Pollution Prevention and Control (IPPC) IPPC H7 Horizontal Guidance on the Protection of Land under the PPC Regime.

Directives

Hazardous waste incineration Directive (1994/67/EC)

Habitats Directive (92/43/EC)

Abbreviations

BAT	Best Available Techniques – see IPPC A Practical Guide or the Regulations for further definition.
BAT Criteria	The criteria to be taken into account when assessing BAT, given in Schedule 2 of the PPC Regulations.
BOD	Biochemical Oxygen Demand
BPEO	Best Practical Environmental Option
BREF	BAT Reference Document
CEM	Continuos Emission Monitoring
CHP	Combined heat and power plant
COD	Chemical Oxygen Demand
ELV	Emission Limit Value
EMS	Environmental Management System
EQS	Environmental Quality Standard
ETP	Effluent Treatment Plant
ITEQ	International Toxicity Equivalents
MCERTS	Monitoring Certification Scheme
NIEHS	Northern Ireland Environment and Heritage Service
SAC	Special Areas of Conservation
SECp	Specific Energy consumption
SED	Solvent Emissions Directive
SEPA	Scottish Environment Protection Agency
SPA	Special Protection Area
TSS	Suspended solids
TOC	Total Organic Carbon
VOC	Volatile Organic Compounds
WML	Waste Management Licence

Appendix 1: Common monitoring and sampling methods

The Environment Agency has produced technical guidance notes on a variety of monitoring techniques these are summarised below.

Table 4.1 Monitoring technical guidance notes

M1	Sampling requirements for stack emissions monitoring
M2	Monitoring of stack emissions to air
M8	Ambient monitoring strategy
M9	Ambient monitoring methods
M13	Monitoring hydrogen sulphide and total reduced sulphur in atmospheric releases and ambient air
M16	Monitoring volatile organic compounds (VOCs) to air from industrial installations
M17	Monitoring ambient particulates in air around waste facilities
M18	Monitoring discharges to water and sewer
M20	Quality assurance of continuos emissions monitoring systems

Appendix 2: Equivalent legislation in Scotland, Northern Ireland and Wales

England	Wales	Scotland	Northern Ireland
The Pollution Prevention and Control Regulations (England and Wales) 2000, (SI 2000 No.273 as amended)		The Pollution Prevention and Control (Scotland) Regulations 2000 (SI 2000 No. 323 as amended)	The Pollution Prevention and Control Regulations (Northern Ireland) 2003 (SR 2003 No.323)
Waste Management Licensing Regulations 1994 (SI 1994 1056 as amended)			The Waste Management Regulations (Northern Ireland) 2006 (SR 2003 No. 493)
Control of Major Accident Hazards Regulations (COMAH) 1999 (SI 1999 No.743)			Control of Major Accident Hazards Regulations (Northern Ireland) 2000 (SR 2000 No. 93)
The Hazardous Waste (England and Wales) Regulations 2005 (SI 2005 No. 894)	The Hazardous Waste (Wales) Regulations 2005 (WSI 2005 No. 1806 (W.138))	The Special Waste Regulations 1996 (SI 1996 No 972 as amended)	The Hazardous Waste Regulations (Northern Ireland) 2005 (SR 2005 No. 300)
The List of Wastes (England) Regulations 2005 (SI 2005 No. 895)	The List of Wastes (Wales) Regulations 2005 Welsh Statutory Instrument 2005 No. 1820 (W.148)	The Special Waste Amendment (Scotland) Regulations 2004 (SI 2004 No. 112 as amended)	The List of Wastes Regulations (Northern Ireland) 2005 (SR 2005 No. 301)