

1. Summary/Introduction

1.1 This chapter considers pressures arising from the presence of “sanitary” parameters, ammonia and biological oxygen demand (BOD). The main focus is on ammonia as, while not universally the case, measures to reduce ammonia levels will also in general provide lower BOD.

1.2 The information currently available is incomplete and mostly provided by the Water Industry working group. The absence of information from other sectors cannot be assumed as meaning that they have no contribution to make. One of the main outcomes of this chapter may well be agreement on the need for further monitoring and/or modelling work to apportion the contribution of the various sectors; and then to develop mechanisms for identifying which of the available measures (or combination of measures) to address ammonia and BOD pressures are the most practical and cost effective in any particular circumstance.

2. Relevant WFD Objectives

2.1 The two relevant default WFD objectives are: prevention of deterioration and achievement of good status. Additional objectives may be relevant in the case of waters designated as ‘protected areas’.

2.2 The relevant water quality standards for ammonia and BOD in rivers are expected to be based on those currently proposed by UKTAG (UK Environmental Standards and Conditions (Phase1), Final Report, August 2006). These are as set out in the following tables.

Table. 2.1 Standards for ammonia

Standards for ammonia			Existing standards	
Total Ammonia (mg/l)			Total Ammonia (mg/l)	
(90-percentile)			(90-percentile)	
Type	High	Good	High	Good
Upland and low alkalinity	0.2	0.3	Existing classification schemes (note 1)	
Lowland and high alkalinity	0.3	0.6	0.25	0.6

1. The existing values are the thresholds used for the River Quality Objectives, RE1 and RE2, for England and Wales, and for Class A and B of the General Quality Assessment.

Table 2.2 Standards for oxygen conditions (BOD)

Standards for oxygen conditions (BOD)			Existing standards (note 1)	
Biochemical Oxygen Demand (mg/l)			Biochemical Oxygen Demand (mg/l)	
(90-percentile)			(90-percentile)	
Type	High	Good	High	Good
Upland and low alkalinity	3	4		
Lowland and high alkalinity (note 2)	4	5	2.5	4

Note

1. The existing values are the thresholds for the River Quality Objectives, RE1 and RE2 for England and Wales, and for the best two classes of the schemes used in all countries.
2. Where a lowland, high alkalinity water body is a salmonid river then the standards for the upland, low alkalinity type will apply.

Table 2.3 Standards for oxygen in rivers (DO)

Standards for oxygen in rivers			Existing standards		
Dissolved Oxygen (per cent saturation)			Dissolved Oxygen (per cent saturation)		
(10-percentile)			(10-percentile)	(5-percentile)	
Type	High	Good	High	Good	
Upland and low alkalinity	80	75		Freshwater Fish Directive (note 2)	
Lowland and high alkalinity	70	60	80	70	65 - 75 Salmonid 45 55 Cyprinid

Note:

1. The existing values are those for River Quality Objectives, RE1 and RE2 for England and Wales and for the best two classes of the schemes used in all countries.
2. The values from the Freshwater Fish Directive as 6 mg/l would typically represent a 10-percentile of percentage saturation of approximately 65 to 75%. The value of 4 mg/l would represent a 10-percentile of percentage saturation between 45 to 55%.

2.3 Ammonia is directly toxic to fish and aquatic animals in rivers, particularly in its unionised form. Its degradation in the aquatic environment also contributes to oxygen depletion. BOD is the measure of the oxygen uptake of an effluent. The higher the BOD the greater the potential of the effluent to cause a drop in dissolved oxygen in the receiving water potentially killing fish and other aquatic life.

2.4 UKTAG suggest that the Dissolved Oxygen (DO) standard is used for assessing and reporting compliance of rivers, and that the BOD standards, developed on the basis of oxygen conditions associated with macro invertebrate communities, are used for deciding action to meet the DO standard in the river. This is because the levels of BOD can be misleading in clean rivers, and because the link between BOD and DO is a complex and uncertain issue if dealt with on a site by site basis. The ammonia standards have been developed on the basis of ammonia conditions associated with macroinvertebrate communities at high and good status. Further work will be done during the first cycle of river basin management plans to confirm that the proposed values also protect communities of freshwater fish.

2.5 Standards for DO in lakes have also been derived by UKTAG, these standards are based on the protection of fish. Oxygen consumption in lakes depends on the natural productivity of the lake and the shape of its basin. UKTAG propose two morphological types: mixed, and stratified during summer. They also propose to divide lakes into those that support natural populations of salmonid fish, and those with natural populations of cyprinids.

2.6 It is proposed by UKTAG that DO is measured on a single occasion each year of a 3-5 year period, and that this is done in July or August, as this is when oxygen levels are likely to be lowest. The proposed standard is the mean of the whole water column in fully mixed lakes and the water column below the thermocline in stratified lakes.

Table 2.4 Standards for dissolved oxygen in lakes

Status	Proposed boundary in UK lakes	
	Mean in July-August (mg/l)	
	Salmonid	Cyprinid
High	9	8
Good	7	6
Moderate	4	4
Poor	1	1

2.7 Further work, during the first river basin management planning cycle, is proposed to develop standards for transitional and coastal waters (estuaries and inshore sea).

2.8 UKTAG has not proposed standards for ammonia in lakes. Where needed for discharge control purposes, it is expected that the ammonia standards for rivers would apply.

2.9 For protected areas, where standards are relevant, the UKTAG standards are expected to almost invariably apply, where more stringent than those under the legislation creating the protected area.

3. Pressures, trends and associated uncertainty

Pressures

3.1 Typical sources of ammonia and BOD are sewage effluents, food and related industry effluents and diffuse agricultural and urban run off. Effluent treatment systems that limit BOD and ammonia discharges usually involve aerobic biological treatment. Ammonia is more difficult to remove than BOD and reducing ammonia levels is usually the limiting factor in the treatment of sewage and related effluents.

3.2 The first river basin characterisation exercise for England and Wales RBC1 assessed

- 23% of river length (11852km of 51183km) as 'at risk'; and
- 81% of transitional and coastal waters (2195km² of 2964 km²) and 8% of coastal waters (1162km² of 14458km²) as 'probably at risk'

of failure to meet good status. because of point source sanitary discharges

Trends

3.3 The Urban Waste Water Treatment Directive (UWWTD) sets treatment levels and BOD emission limits applicable to all continuous sewage discharges above a size threshold. This and other EU and national measures already in force have resulted in improvements in water quality. The general load of BOD being discharged to controlled water has decreased markedly over the last 17 years (particularly to coastal discharges), as the major improvement programmes to deliver secondary treatment under UWWTD Directive, and tertiary treatment in UWWTD Sensitive areas, have been delivered. However, in many cases, additional measures will be required to meet expected WFD standards, even taking into account measures delivered already or planned for the current investment cycle (AMP4).

Uncertainties

3.4 RBC1 identified point sources as the most likely cause of failure to meet WFD objectives but, in view of the many uncertainties regarding ammonia and

organic enrichment, further work during the early part of RBMP1 to inform RBMP2 will be required to clarify sanitary pressures particularly in relation to transitional and coastal waters.

4. Apportionment and associated uncertainty

Apportionment

4.1 The main sectors contributing to this pressure are:

- Water industry (through sewage discharges)
- Agriculture (principally the dairy, beef, pig and poultry sectors and horticulture); (both direct and in-direct pathways of ammonia arising from manure and slurry in livestock farming and application of nitrogen fertilisers. Ammonia emissions to air can be absorbed into rainfall and enter surface waters directly and via drains and sewers).
- Other industry.

4.2 The Environment Agency's Strategic Assessment indicated that approximately 85% of ammonia in rivers is attributed to Sewage Treatment Works (STWs). UKTAG standards report (Table 4.1) indicates that in England 14.6% of rivers fail existing ammonia standards and it is predicted that 17.3% will fail proposed new standards. (1.4% and 2.7% respectively in Wales). In light of the information available it is reasonable to infer STW effluent, combined sewer overflows, storm tanks and misconnections are the dominant source of failures.

Table 4.1 Implications of proposed UKTAG standards for BOD and Ammonia

Location	BOD		Ammonia	
	Per cent of river length reported as less than good			
	Existing	Proposed	Existing	Proposed
England	25.6	18.7	14.6	17.3
Wales	3.7	3.7	1.4	2.7
Scotland	8.2	7.6	7	10.7
Northern Ireland	19.0	16.3	4.4	16.3

4.3 Ongoing EA SIMCAT modelling at national and regional level should provide more detail on apportionment. The indication at present is that half

of the failures could be put right solely by improvements to discharges from sewage treatment works and it is expected that further investigation at a regional level will indicate that the majority of the remaining failures can be attributed to sewerage infrastructure

4.4 Sources of organic enrichment (BOD), include discharges of sewage effluent (both continuous and intermittent), other industrial discharges (e.g. paper mill effluent). Diffuse urban and agricultural run off can also be relevant.

Uncertainties

4.5 It has not been possible to identify information which gives a comprehensive assessment of apportionment of ammonia and BOD pressures across all water bodies or particular groups of bodies (e.g. rivers, lakes). There is some preliminary data from the Ribble pilot study which indicates that, in that particular case, 95% of ammonia comes from water industry discharges and 5% from urban run off. Overall – evidence from consents and flow suggest that a high proportion of ammonia in rivers comes from water industry, with industry discharges and agricultural sources playing a smaller part.

4.6 More information is required on the contribution from individual sectors so that local solutions can be determined or the local or national impacts assessed. For example: minor sewage treatment works are generally located in more rural areas where other sectors such as agriculture could be making the greater contribution; the extent to which effluent produced in a catchment is discharged to estuarial, coastal or inland waters may affect the impact of point source discharges.

5. Groups of measures to meet WFD objectives

5.1 The Water Industry group refers to the Environment Agency's request to assess costs for 1, 3 and 5 mg/l ammonia consent limits. Although these are 95 percentiles not maxima, performance data shows that, where tight ammonia limits apply, mean effluent levels substantially less than the limit values are achievable.

5.2 Within the water industry, technology is available to achieve very low ammonia concentrations in final effluents from sewage treatment works. Currently a high proportion of STWs are operating to ammonia consents of between 5 and 10 mg/l. 1 mg/l ammonia is on the boundary of what is technically achievable with current technology on a regular basis owing to the natural variation in temperature and the effectiveness of biological sewage treatment processes.

5.3 Therefore, for future improvements in sanitary conditions, the following options were explored in the water industry group report;

- 5mg/l ammonia with 15mg/l BOD;

- 3mg/l ammonia with 10mg/l BOD
- 1mg/l ammonia with 5mg/l BOD.

The choice of which set of limits might apply will depend on the current quality of the receiving water and dilution available for natural degradation and attenuation.

5.4 In general, the water companies agreed that processes are available to achieve tighter consents but that these may not be cost/effective in terms of energy and maintenance. Process breakpoints are dependent on individual site circumstances. Although activated sludge should be able to achieve < 5 mg/l ammonia there are environmental dis-benefits (increased CO₂ emissions from energy use.). Similarly BOD standards <10 mg/l will normally require tertiary treatment to be provided, which also has associated environmental dis-benefits in terms of power consumption.

5.5 The non-agricultural sector did not identify measures which would specifically target ammonia or BOD but some measures that deal generally with preventing water pollution by runoff, (e.g. dealing with misconnections of domestic sewage into surface water drains, and implementing SUDs where appropriate) would contribute to the reduction of the ammonia and BOD load.

5.6 To reduce ammonia emissions from agricultural sources measures can be aimed at reducing gaseous emissions to tackle ammonia independently or employing husbandry or attenuation techniques that reduce the entry into surface waters of diffuse pollutants in general.

5.7 Scenarios

The four options that have been suggested are:

1. Hard enforcement: change consents at STWs which are at risk of failing to meet the new WFD standards as proposed by UKTAG.
2. Only change consents when assets are needing upgrade or when there are multiple reasons for doing so - e.g. at same time as N and P removal
3. Try innovative measures - performance or system management - rather than capital expenditure - e.g. flow balancing
4. Further research into diffuse sources - to determine apportionment and measures to control.

6. Costs of groups of measures

Agriculture

6.1 Investigation of specific measures to reduce gaseous emissions of ammonia found that store covers for manure were found to be have the lowest marginal cost in reducing ammonia emissions to air (Cost-effective means of reducing ammonia emissions from UK agriculture using the NARSES model, Webb *et. al*), though these measures would be unlikely to cause a substantial emission reduction used in isolation.

6.2 Immediate incorporation of dairy sludge to arable by disc (rather than spraying) has the highest reduction in emissions at the lowest marginal cost. Emission change of $3.080 \text{ t} \times 10^3$ for a marginal cost of $\text{£}0.49 \text{ kg}^{-1}$ (apart from replacing Urea with ammonium nitrate – which would reduce gaseous emissions of ammonia but would increase nitrate loading). Storing all broiler type manure would also have a considerable reduction in emissions $3.789 \text{ t} \times 10^3$ for a marginal cost of $\text{£}0.64 \text{ kg}^{-1}$

6.3 Such measures are in addition to those that would be employed to prevent Phosphorus reaching watercourses.

6.4 One measure costed to reduce ammonia, storing all pig farmyard manure which would reduce emissions by $3.281 \text{ t} \times 10^3$ at a marginal cost of $\text{£}1.73 \text{ kg}^{-1}$, would also be likely to reduce phosphates and so can be considered as a cross-cutting measure. Other measures specific to reducing nutrients will have no impact on ammonia levels (e.g. by reducing P in fertilisers).

6.5 Alternative measures used to reduce other pressures - techniques such as using buffer zones, reducing use of ammonium nitrate fertiliser and reducing stocking density should also have a beneficial impact on reducing ammonia emissions, though these have not been quantified. With an anticipated reduction in agricultural livestock stocking density of 25% by 2015, the ammonia component that derives from agricultural sources should be considerably reduced.

Diffuse sources

6.6 While it is presumed that the majority of ammonia in rivers is largely due to sewage discharges at a national scale, contribution from other sectors may be more significant at local levels. E.g. agriculture potentially could contribute a greater proportion in rural areas than STWs.

6.7 Situation specific investigations would be required to ensure cost-beneficial investment is made. Water companies are strongly recommending a programme of investigations in AMP5 (2010-2015) which would help determine the scale of diffuse input of ammonia to aquatic systems at a more regional level, ensuring the polluter pays principle.

Non-agriculture

6.8 Not considered in reports available.

Water Industry

6.9 Under scenario 1, changing consents at STWs which are at risk of failing to meet the new WFD standards, the costs depend on the level of consent imposed. It is estimated that for all “at risk” STWs to upgrade to meet 5mg/l the cost would be £296.4m/year; to meet 3mg/l would cost £508.4m/y and to meet 1 mg/l would be £824.7m/year (see Table 6.1).

Table 6.1 Financial costs of achieving consents of 5, 3 and 1mg/l at STWs which are currently at risk of meeting proposed UKTAG standards for ammonia and the % reduction in load this equates to.

	Size of STW (note 1)	Total financial costs per party per annum (£m/year)	Reduction of total load from STW at risk (%)
5 mg/l	<250	7.8	
	STW Band D	109.8	
	Total	296.4	65.2
3 mg/l	<250	8.8	
	STW Band D	155.6	
	Total	508.4	73.52
1 mg/l	<250	13.4	
	STW Band D	227.3	
	Total	824.7	87.17

Note. 1 STW Band D: 100,000 people equivalent and over

6.10 A targeted approach where there are current failures is considered a sensible approach though the water industry has concerns over the level of consent proposed. It considers that a 1 mg/l ammonia limit is on the boundary of what is technically achievable on a regular basis owing to the natural variation in temperature and the effectiveness of biological sewage treatment processes. Achieving this effluent standard on a consistent basis, even with well-designed plant, would be difficult. And once ammonia standards of 1mg/l or less are required substantial process upgrading is required (rebuild rather than add-on, as is reflected in costs which are approximately 2.5 times greater than to achieve 5mg/l).

6.11 Scenario 2 which suggests only changing consents when assets are needing upgraded or when there are multiple reasons for doing so, in theory should reduce costs, but there is no cost information available to quantify. The pCEA exercise asked companies for separate information for P, N and ammonia, not for overlaps and so companies would need to cost this overall package of measures on a site specific basis as it depends on what is there already.

6.12 For the 5mg/l ammonia consent level there may be opportunities to combine maintenance/refurbishment work with quality improvements. For the tighter consents of 3mg/l and 1mg/l there would be fewer opportunities as specialised tertiary treatment would be required.

6.13 Improved primary and secondary treatment for ammonia/BOD would assist with P reduction, so there would be a technology over-lap (but the

effect is not quantifiable at this stage). There is potential incompatibility with N reduction technologies

6.14 Under scenario 3 innovative measures could be employed to try and reduce ammonia levels without the need for rebuilding or retrofitting. This is in line with the acknowledgement by water companies that the WFD will drive significant development of modelling techniques and tools, in addition to an increased understanding of the environment. However, this option may require substantial time and resources in developing new techniques and in testing their effectiveness.

6.15 While innovation may deliver cheaper, less energy intensive solutions there is an associated lower level of certainty in delivery, if the decision is to proceed with this scenario.

6.16 Water companies recommend that further development of modelling tools and techniques, and research into sustainable technological developments for subsequent investment should be supported in AMP5.

6.17 For smaller sewage treatment works, there is a stronger case for trialling technologies and phasing in work to reduce the overall cost.

7. Measures not considered

Measures ruled out as obviously not cost effective

7.1 It was determined by the water industry group that more detailed analysis would need to be carried out to provide technical and economic comparisons between conventional treatment, new technologies and abandonment options. However, most companies were of the view that an ammonia consent levels below 1mg/l would not be cost effective or necessarily result in improved effluent quality. The processes used for the removal of ammonia are biological and based on forced aeration to achieve this standard. On the basis of current technology, a further reduction in the consent level would not result in an improved effluent quality with respect to ammonia, rather, it would result in increased risk of failure to the water company.

7.2 Other measure not favoured by water companies include:

- replacing existing biological filter STWs with Activated Sludge Plants, as it was considered likely that this option would greatly increase the costs (OPEX, CAPEX and GHG emissions)
- various technologies involving harvesting of algae for ammonia removal and carbon sorption due to lack of land available or impracticality/cost at many of the sites concerned
- the design standard of 1mg/l ammonia with 5mg/l BOD (rather than 10 mg/l BOD). Although technically feasible this was dismissed as financially/environmentally inappropriate due to an operating

expenditure increase of over 100% and a power and subsequent carbon dioxide increase of approximately 200%. Note that this standard of treatment is only likely to be required at some of the works that contribute or are likely to contribute to failure of UKTAG standards.

7.3 The agriculture working group primarily dealt with the policies to tackle phosphorus pollution, because of the complex nature and lack of data on other pressures. (It is likely that the most significant ammonia sources from agriculture are from farmstead surface water drainage and access roadways, not from fields).

7.4 The non-agriculture sector report did not focus on ammonia/BOD and neither group has identified any specific measures to be ruled out (or in!) in relation to these pressures.

8. Measures to reduce uncertainty

8.1 The most obvious requirement and first step in resolving the various uncertainties identified in this chapter is an information gathering and analysis exercise. This should include increased effort in monitoring of environmental activities, (i.e. sources, pathways and receptors) and discharges and modelling scenarios and options. Much of this work using currently available data is being carried out by the Environment Agency in its SIMCAT modelling. The costs of such an exercise have not been identified but are likely to be significantly lower than the potential costs of unnecessary expenditure on measures which go beyond what might be required to contribute to meeting WFD objectives.

8.2 There is a clear need for much improved monitoring, and subsequent modelling of urban runoff, and mapping and monitoring of surface water sewer systems. Similarly there is a clear need for significantly increased monitoring and modelling of agricultural land use and runoff.

9. Conclusions

9.1 Although there are gaps in the evidence available it is considered that the majority of ammonia levels in water can be attributed to sewage discharges (either from domestic or industrial origin) and problems with sewerage infrastructure. Site investigations have routinely found that point release of ammonia from STW, especially in storm conditions or other times when they are not operating at optimal efficiency, have resulted in fish kills.

9.2 Although agriculture is responsible for 80% of gaseous ammonia emissions into the environment there is little evidence to point to much of this entering the aquatic environment. The ammonia in rainfall is dilute and readily degraded by soil microbiology and chemistry. The direct input of ammonia from rainfall entering surface waters directly and via land drains and sewers is minimal.

9.3 While most evidence points to STWs being the principal source of ammonia on a national scale, this is not likely to be uniform across the UK. In rural catchments with smaller STWs, agricultural sources of ammonia may prove to be more significant and so more detailed modelling at regional level should be employed to aid decision on ameliorative action.

9.4 The impact ammonia has on the ecology of a water body while well understood, also varies as a function of the population the STW deals with and also on the flow dynamics, temperature and alkalinity of the receiving water body. Therefore a one size fits all approach to ammonia consenting is not advisable for planning measures.