

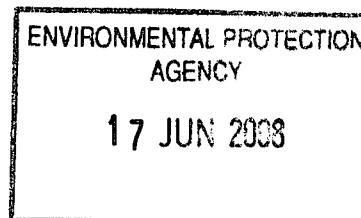


Eastern Regional Fisheries Board
Bord Iascaigh Réigiúnach an Oirthir



Fisheries Ireland
Our Natural Heritage

Office of Climate, Licensing & Resource Use
Environmental Protection Agency
PO Box 3000
Johnstown Castle Estate
County Wexford



10 June 2008

Dear Sir

Section 4 Discharge License by Ballon Meats Ltd at Raheen, Ballon, Co. Carlow

Dear Sir,

With reference to the IPPC License Application by Ballon Meats Ltd. the Eastern Regional Fisheries Board note that the applicant proposes discharging treated effluent to the extreme headwaters of the Douglas River. Please note that the catchment area of the watercourse at the proposed discharge point is very small at less than 0.5km² and is subject to minimal flows during prolonged dry spells. The Douglas River is an important salmonid system with very good populations of trout & salmon. Excellent salmon spawning was recorded in the Douglas River in 2005 & 2006 and the Eastern Board has carried out extensive habitat works in the Douglas to promote the system as a salmon spawning / nursery River. The Douglas system is also known to hold populations of lamprey. Please note also that significant volumes of treated sewage from Carlow County Councils, Ballon WWTP enters this watercourse a short distance downstream of the proposed discharge point.

A recent inspection of the Ballon Meats site by Fisheries Board staff indicated seriously polluted conditions in the adjoining watercourse to which Ballon Meats currently discharges. The polluted conditions related to discharges from a surface water drain which we suspect is connected to the constructed wetland system at Ballon Meats. The Board have serious concerns that much of the waste water being discharged to the ICW system may be by-passing the ponds or is discharged to ground / surface waters with limited / if any treatment.

The EPA Report "An Evaluation of the Implications of the Location of Farm Integrated Constructed Wetlands (ICWs) for Groundwater and Associated Receptors" states that "pollution of groundwater by ammonia from farm ICWs is making a significant contribution to the water quality problems in the Annestown Stream" and that "even in situations where containment of pollutants is being attempted (by achieving a permeability of 1×10^{-8} m/s), up to 33% of the ICW water is being discharged to groundwater".

We note that the applicant states that a geotechnical assessment was undertaken prior to the construction of the wetland system at Ballon Meats, that the sub-soil conditions generally

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comprised of topsoil over dark brown firm to stiff clay, becoming stiffer with depth and that the contractor was instructed to **puddle** the material to provide a low permeability liner to the ponds. The Board requests that the applicant submits a copy of this geotechnical assessment.

Given that up to 33% of ICW water was being discharged to groundwater in situations where containment of pollutants is being attempted by achieving a permeability of 1×10^{-8} m/s in the Anne Valley area, we believe that the issue of discharge of effluent to ground water at this site has not been adequately addressed.

Planning permission was sought for the waste water treatment system including wetlands at Ballon Meats in 2002 in the planning application reference PL02/259 and this Board highlighted our concerns regarding the threat to waters from this development. Carlow County Council imposed a number of planning conditions relevant to environmental protection at the site which included

- The applicant shall put in an impervious liner in the constructed wetland to ensure that there is no risk whatsoever of seepage from the wetland into groundwater.
- Uncontaminated surface water runoff should not be allowed to enter the constructed wetland and should be directed to a surface water drain.
- The applicant shall ensure that the primary & secondary treatment system is capable of treating the trade effluent to the following standards before discharge to the constructed wetland; BOD 25mg/l, COD 125mg/l, Suspended solids 125mg/l, Total N 15mg/l, Total Ammonia 10mg/l, Total Phosphorus 2mg/l and Oils, Fats & Greases 10mg/l

We believe that the Waste Water Treatment system at Ballon Meats is in breach of the above planning conditions.

The Board have concerns relating to the ability of ICW systems to treat high strength wastes and note the nature of the discharge to this ICW system. We believe that the inability of the ICW systems to treat high strength wastes is demonstrated by the fact that the applicant needs to divert all surface water run-off from roofs, front & back yards and hard standing lairage yard areas to the ICW system to provide additional dilution to the effluent. In the paper "The relationship between plant vigour and ammonium concentrations in surface waters of constructed wetlands used to treat meat industry wastewaters in Ireland" by A. Harrington (study carried out at Ballon Meats and copy of paper enclosed) found that growth of *Carex riparia* was severely inhibited at ammonium concentrations in excess of 400mg/l while as concentrations decreased below 200mg/l plant vigour significantly increased (the Max. daily average for ammonia in the IPPC License application is 458mg/l). The EPA Report "An Evaluation of the Implications of the Location of Farm Integrated Constructed Wetlands (ICWs) for Groundwater and Associated Receptors" states that "As the available data and information are inadequate to enable definitive conclusions to be drawn, independent research on the role of ICWs and other constructed wetlands in treating polluted water, particularly polluted water with a **high nutrient loading** is recommended".

With regard to the proposed willow scheme we note that the applicant intends to spread waste here using a low pressure pipe network, which laid on the soil surface will evenly distribute the liquid over the entire willow plantation. Given that almost 7.5 acres are to be planted the Board requests that the applicant details how this spreading can be done in an "even" manner over the entire plantation. Given that Board staff visits to the site indicated "dirty" water throughout the entire pond network we have concerns relating to blockages in any pipe distribution network on this site. The Board request that the applicant supplies details of where such irrigation systems

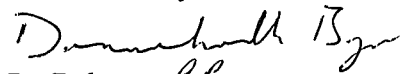
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have been successfully employed in the past how the potential issue of blockages will be addressed.

In summary up, the concerns of the Eastern Regional Fisheries Board relate to the limited flows in the proposed receiving watercourse (catchment area approx. 0.25Km²), existing poor water quality in the adjoining watercourse which we believe relates to leaks from the ICW network, failure to address the issue of losses to groundwater from ICW systems, the breach of planning conditions relating to the WWTP system at this site, doubts relating to the ability of ICW systems to treat wastes with high nutrient loadings and lack of details relating to the irrigation network for the proposed willow plantation. The Board request that all such issues are addressed as part of this application.

The Board notes that no flow details for the receiving watercourse were supplied and we request that such details be included, also given the lack of long-term physico-chemical data for this watercourse a Biological assessment of water quality would provide an indication of long term water quality status.

Yours faithfully



Pat Doherty P.D.
Chief Executive Officer

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**An Evaluation of the Implications of the Location of
Farm Integrated Constructed Wetlands (ICWs) for
Groundwater and Associated Receptors**

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Donal Daly
Hydrometric and Groundwater Section
Office of Environmental Assessment
Environmental Protection Agency

February 2007

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Summary, Conclusions and Recommendations

Context

- This report considers the role of groundwater as a pathway for pollutants arising from farm ICWs (i.e. a wastewater with a relatively high nutrient loading) to associated receptors – groundwater bodies, wells and springs used for drinking water, surface water ecosystems and groundwater dependent terrestrial ecosystems. It does not deal with the direct input of ICW water to streams.
- The data and information available were insufficient to enable definitive conclusions to be drawn, and they will not be available in the near future. However, as ICWs are currently being installed and as DAF/DEHLG Guidance is being prepared in relation to ICWs, conclusions are drawn based on an evaluation of the evidence available.
- The draft DAF/DEHLG Guidance on ICWs is taken to provide the minimum site suitability, assessment and design requirements for ICWs, and the general conclusions given below assume compliance with this guidance. Most of the data and information relate to ICWs in the Anne Valley, County Waterford, where some were not designed and constructed to the requirements of the DAF/DEHLG guidance.

Potential of ICWs to Pollute Groundwater and Associated Receptors

- ICWs receive large volumes of dirty water, particularly in wet weather, with relatively high nutrient loadings.
- The current ICW design allows discharge of a proportion (up to ~33%) of the ICW water to groundwater. As leakage to groundwater occurs beneath all of the ICW ponds, the concentrations in groundwater of some pollutants will be higher than in the ICW water discharged directly to surface water.
- Attenuation of phosphate is shown to occur in the subsoil beneath ICWs and consequently groundwater does not appear to be providing a pathway for phosphate to surface water. However, the long-term ability of the minimum subsoil depth (1.5 m) to retain phosphate is an issue that needs further consideration. On balance, phosphate in groundwater arising from ICWs is not considered to be a significant issue.
- Low numbers of faecal bacteria were found in the groundwater in the vicinity of the ICW ponds in the Anne Valley. In general, microbial pathogens in ICW water should not pose a major threat to groundwater. Nevertheless, it is recommended that drinking water wells should not be permitted immediately down-gradient of ICWs.
- High ammonia concentrations were found in the groundwater beneath ICWs in the Anne Valley. In view of the volume of ICW water that leaks to groundwater, the reducing conditions present in the ICW ponds and the high concentrations in the groundwater beneath ICWs, **ammonia is the main pollutant that arises from farm ICWs**. Ammonia concentrations comparable to those found beneath the ICWs in the Anne Valley are seldom found in uncontaminated groundwater in Irish aquifers.
- The impact of groundwater containing high ammonia, arising from ICWs, depends firstly, on whether there are sensitive receptors down-gradient and secondly, on whether sufficient attenuation of the ammonia occurs prior to the groundwater entering the receptors. This is a hydrogeological setting and specific site issue.
- In general, the lower the permeability and the greater the subsoil thickness beneath the ICW ponds, the lesser the risk to receptors from ammonia. In addition, where oxidation of the ammonia occurs in the underlying aquifer, the threat will be minimised if this occurs before the groundwater reaches the receptor. However, where the minimum subsoil liner requirements of the DAF/DEHLG Guidance (1.5 m subsoil with the upper 0.5 m having a maximum permeability of 1×10^{-8} m/s) are met, the ammonia in the groundwater poses a threat to receptors. If the ponds were lined with an artificial liner or a subsoil liner with a maximum permeability of 1×10^{-9} m/s, this issue would not be significant.
- On balance, while ammonia in groundwater poses a major threat, it is probable that in a high proportion of settings, either the ammonia will be converted in the groundwater to nitrate or

there will be no sensitive receptor nearby; consequently, a site appraisal may often conclude that this will not be a significant issue.

Impact of ICWs on the Annestown Stream

- While the surface water quality improved initially after ICWs were installed in the Anne Valley, the surface water quality is now unsatisfactory: the ammonia concentrations are high and are rising; if the WFD status classification was undertaken based on 2006 data, the Annestown stream would be classed as less than "good" status, thereby requiring actions to return the stream to 'good' status.
- It is concluded that pollution of groundwater by ammonia from the farm ICWs is making a significant contribution to the water quality problems in the Annestown stream.

Authorisation of ICWs

- An exemption from the requirements of the new Groundwater Directive (2006/118/EC) is allowed where the input of pollutants is "considered by the competent authorities to be of a quantity and concentration so small as to obviate any present or future danger of deterioration in the quality of the receiving groundwater".
- It is concluded that, based on the hazard posed by farm ICWs, the potential and measured impact on groundwater, the variability of hydrogeological settings in Ireland, and the sensitivity of certain ecosystems, **licensing of discharges to groundwater should be required**, both in circumstances where the main discharge route is to surface water and where the only discharge route is to groundwater. This recommendation is additional to the requirement for licensing of discharges to surface water given in the DAF/DEHLG Guidance (January 2006 draft).
- In most circumstances, licensing of discharges to groundwater is not likely to pose a significant additional site investigation requirement; however, it ensures that the higher risk scenarios are noted, and appropriate conclusions on site suitability are drawn.

Discharge of All ICW Water to Groundwater

- In certain hydrogeological settings, this is a potential, though challenging, option.
- In view of the high hydraulic loading, a comprehensive site investigation is needed to enable confident prediction that all the ICW water will enter groundwater without any significant environmental or health impact.
- If it is planned to use this option, it is recommended that the DAF/DEHLG Guidance on ICWs should include information on the approach to calculating the maximum daily volume of ICW water needing disposal and on the comprehensive site investigation and calculations needed to ensure safe disposal of the ICW water.
- Licensing of the discharge to groundwater is recommended.

Adequacy of Subsoil Liner with a Maximum Permeability of 1×10^{-8} m/s

- It is recommended that the subsoil liner requirements in the draft DAF/DEHLG Guidance should be applied to all the ICW ponds, with the possible exception of the final pond when discharge to groundwater is planned. More stringent liner requirements, in particular a lower permeability, may be necessary for ICWs in the vicinity of sensitive receptors.

Further Investigation and Research on ICWs

- While ICWs increase the wetland component of the landscape and are a viable means of treating polluted water, they have the capacity, in certain circumstances, to cause serious environmental and health risks. As the available data and information are inadequate to enable definitive conclusions to be drawn, independent research on the role of ICWs and other constructed wetlands in treating polluted water, particularly polluted water with a high nutrient loading, is recommended.

DAF/DEHLG Guidance on Farm ICWs

- It is recommended that the draft DAF/DEHLG Guidance on farm ICWs should be developed to take account of the relevant issues highlighted in this report, e.g. high ammonia concentrations in groundwater beneath ICWs and the sensitivity of certain associated receptors.

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An Evaluation of the Implications of the Location of Farm Integrated Constructed Wetlands (ICWs) for Groundwater and Associated Receptors

1 Introduction

This evaluation has been undertaken at the request of Mr. Pat Duggan, Department of Environment, Heritage and Local Government (DEHLG). Four issues are examined:

1. The likely role of groundwater as a pathway for pollutants from ICWs to the Annestown stream;
2. The requirement for 'prior investigation and authorisation' for ICWs.
3. The adequacy of a maximum permeability 1×10^{-8} m/s for the subsoil liner beneath the ICW ponds.
4. Disposing of **all** the ICW water by discharge to groundwater.

In undertaking this evaluation, the papers and reports listed in Section 8 were considered. In addition, discussions were held with the following:

- ◆ Jer Keohane (GES Limited) on groundwater aspects.
- ◆ Paul Johnston (TCD) on groundwater aspects.
- ◆ Rory Harrington (DEHLG) on ICWs in the Anne Valley.
- ◆ John Lucey (EPA) on biological water quality of the Annestown Stream.
- ◆ Michael Neill (EPA) on chemical water quality of the Annestown Stream.
- ◆ Martin McGarrigle (EPA) on chemical quality of streams.
- ◆ Margaret Keegan (EPA) on regulatory aspects.
- ◆ Pat Byrne (EPA) on licensing aspects.
- ◆ Matthew Craig (EPA) on ERA groundwater monitoring data.

In considering this report, the following points should be noted:

- ◆ The objective was not to produce a comprehensive evaluation of ICWs. Therefore, it does not attempt to provide a balanced appraisal of the environmental benefits and shortcomings of ICWs.
- ◆ The report focuses on the groundwater aspects only. However, this means not only considering the potential impact on groundwater, aquifers and wells/springs, but also associated surface water bodies (i.e. in hydraulic continuity with the groundwater body and receiving a significant input from groundwater) and groundwater dependent terrestrial ecosystems (GWDTEs).
- ◆ The draft (January 2006) DAF/DEHLG Guidance "Integrated Constructed Wetlands for Treatment of Farmyard Wastewater" is taken as the starting point for adequate siting and design of ICWs.
- ◆ The data and information available were not adequate to enable definitive conclusions on the likely impact of ICWs on groundwater or on the Annestown stream. While concerns and uncertainties are raised, nevertheless conclusions are drawn using risk assessment and weight of evidence approaches, judgement based on experience and expertise in the groundwater area, and on the basic principles of groundwater flow and pollutant attenuation.
- ◆ The report only deals with the use of ICWs for disposal of dirty water from farmyards, i.e. a usage with relatively high nutrient loading input.

2 Relevant Background Factors

2.1 Risk-based Approach

In evaluating the potential impact on water of pollutants entering ICWs, this report takes a risk-based approach, which takes account of the hazard or environmental pressure, the underground pathway for pollutants and four potential receptors – groundwater, wells, groundwater dependent ecosystems (GWDTEs) and surface water. The impact of direct discharge of pollutants from ICWs on surface water is not considered.

2.2 Pollutant Movement and Attenuation Beneath Potentially Polluting Developments

The transport and attenuation of pollutants depends on the properties of the underlying geological materials. Subsoils are the single most important factor in minimising detrimental impacts; however, they vary in thickness and in their hydrogeological properties (from permeable sand/gravel to low permeability clayey deposits). Therefore, while they can mitigate impacts, their influence as a pathway for pollutants and as an attenuating medium is highly variable, from virtually completely preventing the vertical movement of pollutants in thick clayey deposits to allowing easy access of pollutants into groundwater with some attenuation in sand/gravel areas. As the bedrock in Ireland is fissured, it provides little attenuation of pollutants (there are some exceptions, such as impure limestones, where denitification can occur). In addition, bedrock can provide an easy pathway for pollutants to receptors such as wells and rivers, even in poorly productive aquifers. In our main aquifers – the karstified limestones – which display conduit flow, the groundwater is particularly susceptible to pollution, and pollutants can be transported rapidly to surface water receptors. Consequently, the hydrogeological settings present in Ireland play a crucial role in influencing the potential impact of polluting activities and therefore of their location, investigation and design. As it is seldom possible to produce regional maps with sufficient detail to encompass the variability in hydrogeological settings, specific site-based investigations, appropriate to the risk posed, are needed for all developments with the capacity to impact both on groundwater and on surface water in hydraulic continuity with the groundwater.

In the author's experience in the last 27 years, there has been a tendency to overestimate the ability of the underground in Ireland to attenuate pollutants. This overestimation is usually based on research and experience from countries, particularly Britain, which have different hydrogeological settings to those found in Ireland. However, research and monitoring undertaken in Ireland has shown that groundwater in many areas is vulnerable due to the presence of permeable or thin subsoil, and that in bedrock, contaminant attenuation is minimal and groundwater velocities are relatively fast. Consequently, depending on the hydrogeology of an area groundwater can be readily contaminated and wells can be affected, and groundwater can act as a transporting medium for pollutants to rivers and lakes.

2.3 Implications of the Water Framework Directive (WFD) and Groundwater Directive 2006/118/EC (GWDD)¹

2.3.1 Introduction

Under the WFD/GWDD, there are three key objectives for groundwater quality:

1. Achieving good chemical status for groundwater bodies and preventing the deterioration of such status (Article 3 of WFD and Articles 3 and 4 of GWDD);
2. Preventing or limiting the input of pollutants into groundwater (Article 17 of WFD and Article 6 of GWDD); and
3. Reversing any significant and sustained upward trend in pollutant concentrations (Article 5 of GWDD).

Essentially these objectives will be achieved by the implementation of a "programme of measures" by each Member State.

While Member States are not required to 'bring into force the laws, regulations and administrative provisions necessary to comply' with the GWDD until January 2009, the implications of this Directive is taken as the relevant driving force for considering the need for 'prior investigation and authorisation' for ICWs.

2.3.2 Limiting the Input of Pollutants into Groundwater

The limit objective is the main factor relevant to ICWs. This requires that the input of non-hazardous substances to groundwater must not cause pollution, significant and sustained upward trends and any

¹ The text in this Section is based on draft text from the WFD/GWDD UK-Ireland Groundwater Task Team guidance papers.

deterioration in groundwater status. Of these, pollution is in practice the most stringent requirement as it is assessed locally. For pollution to occur, there must be some actual or likely harmful effect to a receptor, such as drinking water protected areas, aquatic ecosystems, groundwater dependent terrestrial ecosystems (GWDTes) and other legitimate uses of the environment. The approach in assessing a potential impact will be to take the quality standard for the receptor (e.g., EQSs for surface water and GWDTes, drinking water standards for wells), calculate a compliance concentration at an appropriate compliance point (no advice is given on the location of the compliance point; the boundary of the site is suggested), which is set to ensure the quality standard required at the receptor is met, and then calculate a limit value at the source. This limit concentration must not only protect the receptor, but must also be set to avoid an increased pollutant loading that would cause a deterioration in status of the groundwater body. Consequently, if ICWs are considered to have the potential to have a significant impact on groundwater, the permitting process is likely to require back calculations from the standards that determine an unacceptable input to groundwater, taking account of the pollutant loading and the hydrogeological processes that may result in attenuation along the groundwater flow path. An appropriate hydrogeological investigation will be required to enable this assessment.

2.3.3 Implementation of Measures

The key to achieving the objectives of the WFD and GWDD is the implementation of a 'programme of measures' by Member States. Article 11 of the WFD specifically refers to point source discharges and states that for point source discharges liable to cause pollution, basic measures shall consist of "*a requirement for prior regulation, such as a prohibition on the entry of pollutants into water, or for prior authorisation, or registration based on general binding rules, laying down emission controls for pollutants concerned,*". Article 6 of the GWDD, which is linked to Article 11 of the WFD, is titled "*Measures to prevent or limit inputs of pollutants into groundwater*". It states that for pollutants considered by Member States to present an existing or potential risk of pollution, the programme of measures should include "*all measures necessary to limit inputs into groundwater so as to ensure that all such inputs do not cause deterioration or significant or sustained upward trends in the concentration of pollutants in groundwater*".

Article 6 of the GWDD allows exemptions from the Directive in certain circumstances, in particular, where the input of pollutants is "*considered by the competent authorities to be of a quantity and concentration so small as to obviate any present or future danger of deterioration in the quality of the receiving groundwater*".

The issue of whether farm ICWs should be exempt from the requirements of the GWDD is considered in Section 5.2

3 Assessment of Relevant Pollutants – Generation, Transport, Attenuation and Potential Impacts

3.1 Introduction

The data and information available from the Anne Valley studies are used in this assessment, although they relate to ICWs that were not installed, in some circumstances at least, to the standards in the proposed DAF/DEHLG guidance (January, 2006). However, as these studies have not provided adequate data to enable definitive conclusions to be drawn, a 'typical' dairy farm scenario is taken to give concrete figures on which an assessment of the likely magnitude of the risks posed by ICWs can be made. Therefore throughout the report, reference is made not only to the data available from the Anne Valley and a small number of other ICWs, but also to calculations made for this hypothetical 'typical' dairy farm.

3.2 Volume of ICW Water Discharged to Groundwater

3.2.1 Volume generated

The total hydraulic loading consists of the following components: rainfall on the farmyard; rainfall less evapotranspiration on ponds; and wash water. For a typical dairy farm (approx. 50 ha), with a farmyard area of 5,000 m², a pond area of 10,000 m², average annual rainfall of 1,000 mm, and

2,000 m³ wash water, the total quantity of ICW water generated will be approximately 11,000 m³. (It is assumed that evapotranspiration accounts for 6,000 m³ of the rainfall). While the average daily discharge volume is therefore approximately 30 m³, there is considerable temporal variation due to variations in rainfall. Consequently, the volume of ICW water is relatively large; if compared to a single house, it would be equivalent an average of approx. 42 houses in volume terms, and may be more in wet periods.

The volume of water being discharged to groundwater depends on the planned final disposal route – to surface water or groundwater. The initial proposal was for the former, but now both options are being proposed.

3.2.2 Surface water route

The proposed design of ICWs (DAF/DEHLG, January 2006 draft) requires that the ponds should be underlain by at least 1.5 m subsoil, with the upper 0.5 m having a maximum permeability of 1×10^{-8} m/s. This design assumes that discharge to surface water is allowed. Provided this is achieved, the maximum leakage through the base of the ICW would be 14 m³/d where the total pond area is 1 ha. Using average daily values, this represents approximately 47% of the total ICW water from a typical farm. In practice, where the maximum permeability value is achieved, the input to groundwater is likely to be somewhat less, as firstly, the permeability may be lower; secondly, sealing by the organic matter may reduce the permeability beneath some of the ponds; and thirdly, in wet weather, the flow into surface water is likely to be greater than average. In estimating the discharge to groundwater in the absence of detailed information, it is suggested that a discharge of 1.0 l/m² pond area/day (or 10 m³/d for 1 ha of pond area) could be taken as likely, assuming that the minimum condition of the DAF/DEHLG Guidance (maximum subsoil permeability of 1×10^{-8} m/s) is met. Therefore, even in situations where 'containment' of the pollutants is being attempted (by achieving a permeability of 1×10^{-8} m/s), up to 33% of the ICW water is being discharged to groundwater.

3.2.3 Groundwater route

If it were proposed to discharge all the ICW water to groundwater, then the average discharge rate would be 30 m³/d. However, in wet weather, particularly after a long wet period, the daily discharge rate will need to be much higher in order to achieve disposal of all the water without overflowing of the ponds. No evidence was available to enable the likely maximum daily discharge rate in these circumstances to be estimated (This information is needed so the hydrogeological or geotechnical requirements for the final infiltration pond can be specified properly).

3.3 Relevant Pollutants

The principal pollutants posing a threat to groundwater and to surface water receiving a significant input of groundwater are as follows:

- ◆ Ammonia and nitrate;
- ◆ Phosphate;
- ◆ Microbial pathogens.

Each of these is now considered in turn with respect to the hazard they pose (i.e. their volume and concentration); pathway factors, such as attenuation and movement to receptors; and likely impact on receptors.

3.4 Ammonia and Nitrate

3.4.1 Hazard Characterisation

In the Anne Valley, the characteristics of the dirty water generated on 12 farms are as follows (DAF/DEHLG, January 2006 draft; and Keohane *et al.*, 2005):

- ◆ Mean ammonia as N = 80 mg/l N; range of 0.1-1900).
- ◆ Mean nitrate as N = <1 mg/l; range of <1-10. The data presented by Scholz (2006), which may reflect more up to date data, give a mean nitrate concentration of 1.1 mg/l as N.

This represents a nitrogen loading of approx. 400 kg N for a typical ICW taking 5000 m³/yr dirty water.

The characteristics of the water discharging to surface water from the ICWs in the Anne Valley were as follows (Carroll *et al.*, 2005 and Keohane *et al.*, 2005):

- ♦ Mean ammonia as N = 0.7 mg/l; range of 0.1-17. (The mean figure of 0.5 mg/l given in the DAF/DEHLG, January 2006 draft seems to be an error.)
- ♦ Mean nitrate as N = <1; range of <1-17. The mean nitrate concentration calculated from the data presented in Scholz was 1.8 mg/l as N.

According to Harrington (2005), 60 kg of nitrogen or 38% of the total nitrogen loading was 'discharged to the ground' from ICW 11 in the Anne Valley over the year of the study. A subsequent re-evaluation suggests that 30 kg may be lost as leakage through the side wall/bank of the final pond, which parallels the river (Harrington, pers. comm.).

Based on the concentrations given above, the influent dirty water clearly poses a major potential threat to groundwater and surface water. Therefore, it is essential that the ICWs are an effective treatment facility. The data indicate a substantial reduction in the ammonia concentrations, even though most of these wetlands would not have been constructed to the new proposed DAF/DEHLG standards. However, the maximum ammonia and nitrate concentrations are relatively high.

3.4.2 Pathway Factors

The two factors of relevance in this assessment are:

- ♦ Attenuation of pollutants before a relevant receptor is reached; and
- ♦ Transport of pollutants to receptors.

Attenuation of Ammonia

The attenuation of pollutants beneath the ponds depends on the underlying geological deposits. The presence of subsoil rather than bedrock is critical. A minimum of 1.5 m of subsoil is being proposed (DAF/DEHLG, January 2006 draft), although the greater the thickness the lower the risk to groundwater.

In general, ammonia has low mobility in subsoil and attenuation is usually taken to occur close to the source of pollutants. The presence of high ammonia concentrations in groundwater usually indicates proximity to a source of organic pollution and reducing conditions in the groundwater. In the author's experience, it can also indicate proximity to peaty areas and sometimes it is relatively high in newly drilled wells. While a lot of research has been undertaken on nitrate in groundwater in Ireland, the author is not aware of any specific research on ammonia.

The readily available information on ammonia in groundwater in Ireland and in the Anne Valley is summarised below:

- Since 1993, the EPA have monitored 560 groundwater sites and taken 6,493 samples nationally. Two sites (0.36%) had concentrations greater than 20 mg/l ammonia as N and five (0.9%) had concentrations greater than 4 mg/l. However all five showed evidence of pollution – faecal bacteria in three, high chloride in four and high potassium in three (Matthew Craig, pers. comm.). In 2005, 1,254 water samples were taken by the EPA in the South-east Region (Michael Neill, pers. comm.); no samples had greater than 4 mg/l ammonia as N and 12 (0.96%) had concentrations greater than 0.3 mg/l.
- Relatively high concentrations of ammonia have been noted in the vicinity of old dumps and sources of pollution with a high organic loading. In addition, in the author's experience, high concentrations (relative to the drinking water standard) are sometimes found in the vicinity of peatlands. For instance, in 1989 and 1990, a number of boreholes were drilled by the GSI at Clara Bog in County Offaly. A sample taken immediately after drilling a well in the middle of Clara Bog had an ammonia concentration (as N) of 3.5 mg/l. When sampled in mid 1990, the concentration was <0.02 mg/l. The high ammonia was probably due to the effects of drilling (this is a common occurrence.). Eight wells in the immediate vicinity of the bog, usually in the cutover bog area, were sampled in mid 1990. A summary of the ammonia concentrations found is as follows: median = 0.15; mean = 0.38; range <0.02-1.7 mg/l as N.
- The mean and range ammonia concentrations in piezometers set at 3 m depth below the depth of the ICWs in the Anne Valley were 4 mg/l as N (DAF/DEHLG, January 2006 draft) and 0.3-17 mg/l (Keohane, *et al.*, 2005), respectively. In the area surrounding one of the ICWs – ICW 3 – ammonium concentrations in the monitoring points averaged 18.67 ± 15.07 mg/l (Carroll, *et*

al., 2005). The authors suggest that the reason for these high concentrations is waterlogged conditions in the flood plain of the Annestown stream. This may be the cause; however it is difficult to resolve this as no research has been undertaken on ammonia levels in groundwater. While no definitive conclusions can be drawn, on balance it is considered that natural concentrations with a mean of 18 mg/l and a maximum of 33 mg/l are unlikely.

- The mean ammonia concentration in groundwater of 4 mg/l is higher than the average concentrations in the water discharging to surface water (0.7 mg/l) from the ICWs in the area, understandably as this water has undergone all possible treatment in the ICW, whereas leakage of ICW water to groundwater will be occurring beneath all the ponds, including the first. An additional factor that may increase the impact on groundwater is that there may be conversion of nitrate from the surrounding area to ammonia as the groundwater moves through the reducing conditions beneath the ponds.
- At ICW 11, where 70% of the ICW water percolates to groundwater, the mean concentration of ammonia in four wells down-gradient of the ponds was 1.9 mg/l as N, with the range of means of 0.3-3.8 (Scholz, 2006). The mean ammonia concentration in the up-gradient farm well was 0.01. In contrast, nitrate concentration at 3 m depth beneath the ICWs was given as 0.2 mg/l as N. Harrington *et al.*, (2005) estimated a nitrogen loss to the ground of 60 kg or 38% of the total entering the ICW at ICW 11. The discharge to groundwater was estimated as 10,840 m³, giving a concentration of 5.5 mg/l N, assuming no attenuation. If the correct loading figure is 30 kg, the resulting concentration would be 2.7 mg/l N.
- High ammonia concentrations (mean = 7.1 mg/l as N; range of 2.24-13.31) were found in four samples taken in lysimeters set at 0.7 m beneath the bottom of an ICW pond taking slaughterhouse waste (data provided by Rory Harrington to Pat Duggan, 5/12/2006).
- For a typical farmyard, with a nitrogen loading of 400 kg and 11,000 m³ ICW water, assuming all the ICW discharge is to groundwater, only a 10% nitrogen loss to the ground (40 kg) is needed to give a concentration of 4 mg/l N in the groundwater. This calculation and the values found in the monitoring wells highlight that the potential is high for nitrogen loss to groundwater, as ammonia.

Attenuation of Nitrate

In contrast to ammonia, nitrate is mobile underground and attenuation is not significant where oxidising conditions are present. Where reducing conditions are present, denitrification can occur.

The mean nitrate concentration at 3 m beneath the ICWs was 0.2 mg/l as N (DAF/DEHLG, January 2006 draft). Similarly, at ICW 11, the concentrations in the wells down-gradient of the ponds were less than 0.03 mg/l as N, whereas in the up-gradient farm well, the nitrate concentration was 12.9 mg/l as N.

Nitrate concentrations are high – on average slightly above the drinking water limit of 11.3 mg/l as N – in the farm wells located near, but up-gradient of the ICWs. While these wells are not necessarily representative of the nitrate in the groundwater as they are located close to farmyards, it is probable that they indicate high nitrates in this aquifer. This is supported by the relatively high nitrate concentrations in the Annestown stream, where the trend is upwards. One issue not considered in this report is whether some of the ammonia arising from the ICWs is converting to nitrate in the stream water.

Transport of pollutants

Once the pollutants enter bedrock, groundwater will transport both ammonia and nitrate until they reach a receptor – generally a nearby well or surface water. Flow rates in the bedrock are relatively fast (1-5 metres per day in most aquifers, but metres per hour in some karstified aquifers). Ammonia will generally be oxidised to nitrate, however the rate of oxidation is difficult to predict and it is not possible to quantify the distance required before ammonia concentrations are significantly reduced; probably a short distance in pure limestone aquifers and sand/gravel aquifers but greater distances in confined/semi-confined aquifers, impure limestones and certain poorly productive rocks.

3.4.3 Impact on Receptors

Use of Standards

The potential impact depends largely on the health or environmental quality standards (taken here to be standards, trigger action values (TAV) and thresholds) set for the different receptors. These values reflect the sensitivity of the receptors to specific pollutants.

The ammonia standards are as follows:

Receptor	Standard/TAV/threshold	Source
Drinking water	Standard (as a peak value): 0.3 mg/l (as ammonium; equivalent to 0.23 mg/l as N) Interim guideline value: 0.15 mg/l N	Drinking water standard EPA (2003)
Rivers & lakes	EQS High/Good Boundary <0.035 mg/l N (as an annual median) EQS Good/Moderate Boundary <0.060 mg/l N	SE RBD Programmes of Measures and Standards Project, Feb 2007 draft*

The nitrate standards are as follows:

Receptor	Standard/TAV/threshold	Source
Drinking water	Standard (as a peak value): 11.3 mg/l as N Interim guideline value: 5.6 mg/l as N	Drinking water standard EPA (2003)
Groundwater body	Standard (as a mean value): 11.3 mg/l as N Threshold: 8.45mg/l as N	GWDD Predicted from UK-Irl WFD/GWDD guidance*

Assessment of Impact on Groundwater

- ICWs are a significant potential point source of nitrogen pollution to groundwater. The reason for this is mainly because of the form of the nitrogen rather than the total nitrogen loading.
- The ammonia concentrations are high relative to the drinking water standard (the appropriate comparison is with the peak values, not the mean). Consequently, the high ammonia concentrations pose a threat to nearby wells, particularly domestic supply wells directly down-gradient and in close proximity to the ICWs (the distance depends on the degree of oxidation of the ammonia in the groundwater). The problem may be exacerbated in areas where the surrounding groundwater has high nitrates, due to conversion of this nitrate to ammonia beneath the ponds. In practice, the likelihood of wells being located immediately down-gradient and in close proximity is low; however a appraisal of this is always needed prior to decisions on the location of ICWs.
- Of greater significance is the potential of the high groundwater ammonia concentrations on nearby surface water and terrestrial ecosystems. The mean ammonia concentrations found in the Anne Valley is more than 100 times the EQS for high status surface water bodies under the WFD. In circumstances where oxidation of the ammonia does not occur prior to discharge to sensitive and/or small streams, there may be a significant local impact on these receptors. In determining this impact, account might need to be taken not only of the nitrogen arising from the ICW, but also of the nitrogen in the groundwater flowing beneath and in the immediate vicinity of an ICW.
- The presence of high ammonia in the groundwater beneath ICWs has not been highlighted as a significant environmental issue. Inferences that ICWs have less impact on groundwater than other farming practices, such as landspreading, are not correct for all hydrogeological settings. Even if the total nitrogen present down-gradient of ICWs in the Anne Valley is less than up-gradient (although the evidence is not conclusive on this, as there were no deep down-gradient wells comparable to the up-gradient farm wells), as the nitrogen in the down-gradient pollution plume is in the ammoniacal form, it poses a greater environmental and health threat than the oxidised nitrogen (nitrate).

* Until these reports are finalised, the figures should be regarded as confidential.

- At a distance down-gradient of the ICW, the ammonia is likely to convert to nitrate in oxygenated groundwater. In highly transmissive aquifers (e.g., pure limestone aquifers) with well oxygenated groundwater, this may occur beneath or close to the ICW ponds. Evidence for this at a large ICW at Kilmeaden was provided by Harrington (pers. comm.) and at a site in Limerick by Keohane (pers. comm.). In intensive agricultural areas, the resulting nitrate plume will have similar (or even slightly lower in the most intensive areas) concentrations to the surrounding groundwater. In areas with low nitrate concentration, a localised plume of higher nitrate is likely to be present. Apart from small abstraction wells and highly sensitive GWDTEs immediately down-gradient of an ICW, this is unlikely to pose a significant threat to receptors.
- Much of the evaluation in this report is based on considering mean values of parameters. The significance of high maximum ammonia concentrations is unclear, and has not been dealt with adequately in the available papers. If the ammonia concentrations in the ICW ponds are relatively high in late summer and early autumn when stream flows are low and the streams are dependent on baseflow, high ammonia concentrations in the groundwater flowing beneath and in the vicinity of ICWs may have a greater impact on sensitive surface water receptors than at other times of the year. It was not possible to evaluate this further in writing this report.
- If **all** the ICW water is discharged to groundwater, the nitrogen loading will be increased, thereby posing an increased threat to nearby sensitive receptors.
- In conclusion, the nitrogen entering groundwater from ICWs will pose a significant threat to receptors in the following circumstances:
 - ◆ To sensitive and/or small streams, GWDTEs and nearby small abstraction wells when the groundwater is in the ammoniacal form;
 - ◆ To nearby small abstraction wells when the nitrogen is in the nitrate form.

3.5 Phosphate

3.5.1 Hazard Characterisation

In the Anne Valley, the characteristics of the dirty water generated on 12 farms were as follows (DAF/DEHLG, January 2006 draft; and Keohane *et al.*, 2005):

- ◆ Mean MRP as P = 25 mg/l; range of 0.01-900 mg/l.
- ◆ The characteristics of the discharge water from the ICWs in the Anne Valley were as follows (DAF/DEHLG, January 2006 draft; and Keohane *et al.*, 2005):
- ◆ Mean MRP as P = 0.5 mg/l; range of 0.01-7 mg/l.

The data indicate a substantial reduction in the MRP concentrations, even though most of these wetlands would not have been constructed to the new proposed DAF/DEHLG standards. However, the maximum phosphate concentrations are relatively high.

3.5.2 Pathway Factors

The two factors of relevance in this assessment are:

1. Attenuation of pollutants before a relevant receptor is reached; and
2. Transport of pollutants to receptors.

Attenuation of Phosphate

In general, phosphate has low mobility in subsoil and attenuation readily occurs. The presence of high phosphate concentrations in groundwater usually indicates a shallow depth of subsoil and/or preferential flow paths through the subsoil. There is increasing evidence of the presence of relatively high phosphate concentrations (concentrations sufficiently high to pose a threat to sensitive surface ecosystems) in 'extremely' vulnerable, karstified aquifers.

The mean phosphate concentration in piezometers set at 3 m below the depth of the ICWs in the Anne Valley was <0.01 mg/l (DAF/DEHLG, January 2006 draft), with a range of <0.01-0.07). Also, at ICW 11, where 70% of the ICW water percolates to groundwater, the mean concentration of

phosphate in four wells down-gradient of the ponds was <0.03 mg/l as P mg/l. The concentrations in the groundwater at Kilmeaden were low (Harrington, pers. comm.).

The phosphate concentrations in lysimeters set at 0.7 m beneath the bottom of an ICW pond taking slaughterhouse waste (data provided by Rory Harrington to Pat Duggan, 5/12/2006) and the ponds at Kilmeaden, were low, although occasional high 'spikes' were present at Kilmeaden.

These results confirm the low mobility of phosphate in subsoil and therefore of the crucial role of the subsoil beneath the ponds in attenuating phosphate. It is therefore essential that bypassing of the subsoil should not occur.

There are two issues of concern that require further explanation and/or research:

1. According to Harrington *et al.* (2005), 39.5 kg of phosphorus was 'discharged to ground' over a one year period beneath the ponds at ICW 11. It was concluded that the phosphorus 'is expected to be quickly bound to the receiving soils in the area'. While this is a reasonable conclusion as a short-term reaction in the subsoil, the long-term ability of 1.5 m of subsoil (the minimum thickness required by the draft Guidance) to retain this capacity may be questionable in certain circumstances.
2. A typical farm (50 ha) will generate approximately 5000 m³/yr dirty water and therefore contributes ~125 kg P to the ICW. Consequently, the typical P requirements of the farm (9-10 kg P/ha/yr) will enter the ICW in 4-5 years. Yet Scholz recommends removal of the sediment every 10-15 years, based on analysis of P build up in the sediments. The draft Guidance (DEHLG/DAF, January 2006) recommends removal of sediments approximately every 10 years. This discrepancy needs explanation as loss of P to groundwater may be causing the difference in the two, although it does not seem a likely explanation.

Transport of pollutants

Once the pollutants enter bedrock, groundwater will transport phosphate until it reaches a receptor – generally a nearby well, a surface water body or a GWDE.

3.5.3 Impact on Receptors

Use of Standards

The potential impact depends largely on the environmental or health quality standards (taken here to be standards, trigger action values (TAV) and thresholds) set for the different receptors.

The phosphate standards are as follows:

Receptor	Standard/TAV/threshold	Source
Drinking water	Standard: 5.0 mg/l as MRP Interim guideline value: 0.03 mg/l	Drinking water standard EPA (2003)
Rivers & lakes	TAV High status sites: <16 µg P/l TAV Good sites: <30 µg P/l EQS High <34 µg P/l EQS Good <50 µg P/l	SE RBD Programmes of Measures and Standards Project, Feb 2007 draft*

Assessment of Impact on Groundwater

- The mean concentrations found beneath the ICWs in the Anne Valley are slightly lower than the proposed EQS for rivers and lakes. While it is higher than the TAV for rivers and lakes, it is likely that any risk assessment undertaken as part of an authorisation process for ICWs would conclude that, provided the minimum requirement of 1.5 m subsoil with 0.5 m having a maximum permeability of 1×10^{-8} m/s beneath the ICW ponds is complied with, it is unlikely that groundwater will provide a significant pathway for phosphate.
- Where it is planned to discharge all the ICW water to groundwater at the final pond, the subsoil permeability will need to be greater than 1×10^{-8} m/s. Where the subsoil is relatively thin (while

* Until these reports are finalised, the figures should be regarded as confidential.

still >1.5 m), over saturation of the subsoil and subsequent release of phosphate into underlying groundwater may arise.

- In conclusion, it is unlikely that phosphate leaching into groundwater from ICWs will pose a significant threat to the environment, except perhaps in the scenario given in the last bullet point.

3.6 Microbial Pathogens

3.6.1 Hazard Characterisation

In the Anne Valley, the mean values for *E. Coli* in the dirty water generated from 12 farms was 216,000 cfu per 100 mls, with a range of 1,000-513,000.

The average concentrations in the discharge water from the final pond was 386 cfu per 100 mls, with a range of <100-9,000 and a standard deviation of 1,320 (Carroll *et al.*, 2005; Keohane *et al.*, 2005).

The data indicate a substantial reduction as the dirty water moves through the ponds. However, in considering the potential impact on groundwater, the high pathogen numbers in the first and earlier ponds must be taken into account.

3.6.2 Pathway Factors

The two factors of relevance in this assessment are:

1. Attenuation of pollutants before a relevant receptor is reached; and
2. Transport of pollutants to receptors.

Attenuation of pollutants

In general, microbial pathogens are removed mainly by both die-off and filtration in subsoil. Typically 1.0 m of moderate or low permeability subsoil will remove a high proportion of faecal bacteria, and it is usually assumed that 2-3 m will remove all pathogens, provided no preferential flowpaths are present.

The mean number of *E. Coli* in boreholes at 3 m depth beneath the ICWs in the Anne Valley was 25 cfu/100ml (DAF/DEHLG, January 2006 draft), with a range of 1-50 (Keohane *et al.*, 2005).

In three lysimeters set at 0.7 m beneath the bottom of an ICW pond taking slaughterhouse waste (data provided by Rory Harrington to Pat Duggan, 5/12/2006), zero, 30 and 60 total coliforms, respectively, was recorded. These results confirm the ability of subsoil to remove bacteria.

Transport of pollutants

Once the bacteria enter bedrock, groundwater will transport them until they reach a relevant receptor – in this case a nearby well. Whether they reach a receptor will depend on the time of travel to the well; if it takes less than 100 days, they may be present in the drinking water.

3.6.3 Impact on Receptors

Use of Standards

The potential impact depends largely on the environmental or health quality standards set for the different receptors.

The limit for *E. Coli* in drinking water is zero.

Assessment of Impact on Groundwater

- The number of faecal bacteria in the piezometers in the vicinity of the ICWs in the Anne Valley, while relatively low considering their proximity to the ICWs, is higher than expected. These results may reflect the driving 'head' of the ICW water (approx. 0.3 m above the bottom of the ICW) or some inflow of surface water down the outside of the piezometers. On the other hand, the lysimeter results confirm the ability of subsoil to remove bacteria.
- Provided that the minimum requirement of 1.5 m subsoil with a maximum permeability of 1×10^{-8} m/s beneath the ICW ponds and a minimum separation distance to nearby wells are complied with, it is unlikely that groundwater will provide a significant pathway for microbial pathogens to

wells down-gradient of ICWs. However, the site characterisation process should nevertheless take account of both existing and potential future wells in the area.

4 Impact of ICWs on the Annestown Stream

4.1 Existing Water Quality

4.1.1 Presence of Fish

According to Harrington *et al.*, (2005), sea trout have returned to the stream after many decades of absence.

4.1.2 Q Values

In summary, the EPA Q values have improved from Q value 2 in 1998 to 3-4 in 2004. More recent (2006) 'Q' value ratings, undertaken by UCD, show decline since 2004. In the vicinity of Dunhill the rating has dropped from Q4 to Q3-4. Also, the Q value for the tributary in the vicinity of the Dunphy Farm has dropped to Q2 (serious pollution), although this may be due in part to leakage from an ICW through an old land drain (information provided by Rory Harrington to Pat Duggan, 5/12/2006).

4.1.3 MRP

Phosphate concentrations have been satisfactory since 2001, with median MRP concentrations varying between 0.02 and 0.03. These concentrations are lower than the proposed EQS for good status sites (see Section 3.5.3).

4.1.4 Nitrate

There has been an upward trend in nitrate concentrations since 2002. Median concentrations are relatively high; in 2006, at the four monitoring points moving from the upper to the lower part of the catchment, the values were 7.0, 7.0, 7.6 and 5.6 mg/l as N.

4.1.5 Ammonia

Ammonia concentrations have increased at all four river monitoring points since 2001 (information provided by Rory Harrington to Pat Duggan, 5/12/2006). Of particular significance is that the median concentration at the lowest monitoring point was 0.066 mg/l ammonia as N. In addition, the data show a rising trend. Stream and ICW effluent samples were taken on 13/2/2007 upstream and downstream of five ICWs and the Dunhill village ICW (Harrington, pers. comm.). The concentrations increased below four of the farm ICWs and there was a substantial increase below the village ICW. However, without detailed measurements of the stream flow and the outflows from the ICW, it is not possible to separate the role of ammonia in the groundwater from ammonia in the ICW effluent.

4.2 Assessment of Water Quality

The water quality improved initially after the installation of the ICWs. However, there has been a decline in recent years. The rising trend and the high concentrations of ammonia are significant. The median ammonia concentration at the lowest monitoring point in 2006 is higher than the proposed EQS for good status sites (see Section 3.4.3). Consequently, if the methodology for deciding on the status of the Annestown stream was applied to the 2006 data, **this stream would be rated as less than 'good', the minimum requirement of the WFD.** In addition, a Q value of 3-4 would also give a status rating of less than 'good'. If there is no improvement by 2008, this status would have to be reported to the EU and the implication of this is that actions to address the source of the elevated ammonium will be required in the River Basin Management Plan. Consequently, the situation with the Annestown stream is unsatisfactory.

In summary, ammonia rather than phosphate is causing the water quality concerns, and consequently, this is the issue that requires examination.

4.3 Possible Causes of Unsatisfactory Stream Water Quality

4.3.1 Introduction

The ICWs have added to the wetland component of the Anne Valley, thereby adding aesthetic and other values to the area. In addition, it can readily be argued with justification that the water quality of the river would be worse without the initiation of ICWs in the area. However, it can also be argued that 'proper' management of dirty water (i.e. minimisation, collection and landspreading) would have improved the surface water quality, although it is likely that firstly, achieving this would be difficult in practice and secondly, it might have raised the nitrate levels in groundwater (based on the research at Moorepark). The recent decline in the stream water quality now requires a re-evaluation of the use of ICWs to dispose of dirty water from farmyards. In assessing this issue, definitive conclusions cannot be drawn as the available information and data are not adequate.

The possible causes of the decline are as follows:

- ◆ Dirty water from farmyards not connected to ICWs;
- ◆ Increased loading to the Dunhill village ICW;
- ◆ On-site wastewater treatment systems for single houses;
- ◆ Landspreading of organic manures and slurries; and
- Farm ICWs.

4.3.2 Dirty Water from Farmyards Not Connected to ICWs

Approximately 80% of the farms in the Anne Valley use ICWs to dispose of their dirty water (Harrington, pers. comm.). As there is no information on the remaining farms, it is not possible to assess whether the dirty water from these farms is disposed of in an adequate manner.

4.3.3 Dunhill ICW

In recent years the ammonia concentrations were higher downstream of the Dunhill village ICW compared to those upstream, suggesting that this ICW is contributing to the reduction in water quality. The data for 13/2/2007 confirm this. A possible explanation is that this ICW is too small for the nutrient loading (Harrington, pers. comm.). However, this does not fully explain the situation with the stream; firstly, the upstream monitoring shows an upward trend and secondly, concentrations increase between the Dunhill Castle and Monument (lowest) monitoring stations.

4.3.4 On-site Wastewater Treatment Systems

Without further analysis of the role of on-site wastewater treatment systems, it is not possible to give a definitive view. However, while there may be some problem systems, they are unlikely to be a significant contributor as the overall nitrogen loading will be relatively low and most of the nitrogen will be converted to nitrate underground.

4.3.5 Landspreading of Organic Manures and Slurries

There are two possible pathways for ammoniacal nitrogen from landspreading to enter the stream; over ground via surface runoff or underground via groundwater. The over ground route seems unlikely; firstly because a corresponding increase in phosphate concentrations would occur (McGarrigle, pers. comm.), which is not the situation; and secondly as the drainage density is low. The underground route is less clear. Aerobic conditions are likely to be present over virtually all of the available landspreading areas. The evidence for this is as follows: the nitrate concentrations in the farm wells are generally high, the area is underlain by a relatively permeable, regionally important aquifer; drainage density is relatively low; and the results from the Kilmeaden site indicate oxygenated conditions in the aquifer. Consequently, nitrogen in the aquifer arising from landspreading is likely to be present as nitrate rather than ammonia.

4.3.6 Farm ICWs

The ICWs are undoubtedly contributing ammonia to the stream both directly through the outlet pipes from the final pond and indirectly via groundwater beneath and through the sides of all of the ponds. Based on the available data, the direct discharges to the stream have ammonia concentrations with mean concentrations over 10 times greater than the EQS. However, examining the role of direct discharge is not an objective of this report.

4.4 Role of Groundwater Arising from ICWs

It was not possible for this author to conclude definitively on the contribution of pollution of groundwater arising from the ICWs to the poor stream water quality, as the data available were inadequate. Consequently, to enable a conclusion to be drawn, a **weight of evidence** approach was adopted. The evidence is summarised as follows:

- ◆ The ammonia concentrations in the Annestown stream are high and the median ammonia concentrations are rising.
- ◆ If the situation does not improve in the next year, the Annestown stream would have a WFD status classification of less than "good", based on the high ammonia concentrations and the Q values (Section 4.2).
- ◆ A substantial proportion of the outflows from the ICWs is likely to be underground (Section 3.2).
- ◆ The average ammonia concentrations measured in the groundwater beneath the ICWs is high – on average 17 times the drinking water limit, more than 60 times higher than the proposed EQS for "good" status rivers and more than 100 times higher than the proposed EQS for "high" status rivers (Section 3.4).
- ◆ The mean ammonia concentration in the groundwater (4 mg/l as N) is almost six times higher than the mean concentration in the surface ICW water (0.7 mg/l) entering the stream from the ICWs. Consequently, unless the groundwater input to the stream is less than 1/6th of the surface input, the ammonia in the groundwater will have a greater impact than the surface input. It is likely that substantially more than 1/6th is provided by groundwater in the Anne Valley, where for instance, 70% of the ICW water is lost to groundwater at one ICW (ICW 11) and where achieving the minimum requirement of the DAF/DEHLG Guidance (probably not achieved in at least some of the ICWs in the Anne Valley) results in ~30% loss to groundwater.
- ◆ As the ICWs are located alongside the Annestown stream, the underground flowpath length to the stream is short (<10 m in most circumstances). Consequently, it is likely that the ammonia does not have a sufficient opportunity to convert to nitrate, which would pose less of a threat to the stream water quality.
- ◆ 'Back of the envelope' calculations (e.g. estimations of the input of ICW water entering the stream via groundwater, proportion of the stream length with ICW ponds alongside) indicate that the proportion of the stream flow that arises from groundwater flowing beneath and close to the ICWs in the Anne Valley could contribute sufficient ammonia to be impacting on the stream water quality.

It is concluded that pollution of groundwater by the farm ICWs in the Anne Valley is making a significant contribution to the water quality problems in the Annestown stream.

In order to prove definitively whether the above conclusion is correct, **a detailed investigation by an independent group is needed**. This would involve the installation of piezometers into the bedrock, permeability testing, comprehensive stream flow measurements, measurements of inflows and outflows from the ICWs, chemical and bacteriological analyses of groundwater and surface water, and evaluations of the river biota.

It is recommended that no further farm ICWs should be constructed in the Anne Valley until it is shown definitively that the existing farm ICWs are having no detrimental effect on the stream, or either they are located where it can be ensured that the ammonia will be oxidised prior to reaching the stream or the ICWs are lined such that there is minimal leakage to groundwater.

5 Prior Investigation and Authorisation for ICWs

5.1 Introduction

This report only deals with 'reasonably sized' farm ICWs. The level of investigation and the need for authorisation should depend on the degree of risk posed, which in turn depends to a large degree on the scale of a development, but also on the hydrogeology and the presence of nearby sensitive receptors. The scale or size cut-off is not dealt with in this report.

5.2 Do Discharges to Groundwater from Farm ICWs need to be Licensed?

The new Groundwater Directive allows Member States to exempt measures where the input of pollutants is "considered by the competent authorities to be of a quantity and concentration so small as to obviate any present or future danger of deterioration in the quality of the receiving groundwater" (see Section 2.3.3). Is the input of pollutants from an ICW so small as to allow this exemption? In summary, the situation for a typical farm ICW is as follows:

- ♦ The total volume of ICW water is equivalent to over 40 houses on average, but greater in wet weather (see Section 3.2.1). This represents a substantial hydraulic loading.
- ♦ The overall loading of nutrients and pathogens to ICWs is high (see Sections 3.4, 3.5 and 3.6)
- ♦ As containment of the farmyard dirty water by artificial liners is not part of the ICW design, a proportion of the ICW water will leak from the ponds, even when the design requirements of the DAF/DEHLG Guidance (January 2006) are met.
- ♦ The ammonia concentrations measured in groundwater beneath the ICWs in the Anne Valley are high (see Section 3.4). High ammonia concentrations in groundwater can pose a significant threat to both groundwater and associated surface water and terrestrial ecosystems.
- ♦ Microbial pathogens entering ICWs pose a threat to groundwater and therefore to nearby wells (see Section 3.6).
- ♦ The ICWs in the Anne Valley may be contributing to the increasing deterioration of surface quality in the Annewtown stream (see Section 4.4).

Therefore, the risk posed by farm ICWs by discharge to groundwater is significant and it is concluded that they should not be exempt from the measures and actions required by both the WFD and GWDD.

In view of the degree of hazard posed by ICWs, the sensitivity of certain receptors to high ammonia concentrations and microbial pathogens, the variety of hydrogeological settings and pathways for pollutants in Ireland, and both the potential and measured impact on groundwater, **licensing of discharges to groundwater** of 'typical' farm ICWs water is recommended, even where the main proposed discharge route is to surface water. This proposed requirement is additional to the requirement for licensing of discharges to surface water given in the DAF/DEHLG Guidance (January 2006 draft). In addition, the approach to considering the limit objective of the GWDD, as outlined in Section 2.3, is recommended.

5.3 Adequacy of Subsoil Liner with a Maximum Permeability of 1×10^{-8} m/s

The minimum groundwater protection requirement given in the DAF/DEHLG Guidance is that all ICWs should be underlain by at least 1.5 m of moderate or low permeability subsoil, with the upper 0.5 m enhanced where necessary to achieve a permeability of 1×10^{-8} m/s. The leakage from the ponds will be approx. 1.0 l/s/m^2 (or $10 \text{ m}^3/\text{d}$ where the pond area is 1 ha (see Section 3.2.2)). This is equivalent to the discharge from approx. 14 houses. The impact on nearby receptors can be assessed using this quantity and a mean ammonia concentration of 4.0 mg/l as N. In addition, consideration should be given to the significance of low numbers of microbial pathogens in the groundwater flowing from beneath the ponds.

The approach outlined in Section 2.3.2 should be used in assessing the likely impacts of an ICW on groundwater and surface water receptors. It is likely that in the majority of physical settings (based on hydrogeology, particularly permeability and degree of oxygenation, and absence of nearby sensitive receptors such as wells and ecosystems) an ICW will not pose a significant threat. However, in certain scenarios, e.g. a small sensitive stream or a small stream with water quality problems or an underlying aquifer where reducing conditions are likely, either ICWs should not be allowed or the liner requirements must be more stringent. These factors need to be taken into account in the site investigation and highlight the need for proper authorisation procedures. The density of ICWs in these scenarios should also be taken into account.

It is recommended that the minimum requirements of the DAF/DEHLG Guidance regarding the permeability and thicknesses of the liner should be applied to all the ICW ponds, with the possible exception of the final pond (this is dealt with in Section 6), as the pollutant loading is relatively high in these ponds.

5.4 Site Characterisation Requirements

Without a site characterisation process, similar to that outlined in DAF/DEHLG Guidance (January 2006 draft), licensing of discharges to groundwater from ICWs and evaluation of the subsoil permeability requirements would not be feasible. Consequently, the site assessment outlined in the DAF/DEHLG Guidance is recommended. The main issue that has arisen in this report – high ammonia concentrations in groundwater – will not have additional onerous site investigation requirements for the majority of proposed farm ICWs. As part of the risk assessment process, in particular the desk study, consideration will need to be given to the presence of nearby susceptible and sensitive receptors (e.g. down-gradient wells, small streams, high status surface water bodies and GWDETs with limited dilution potential), existing surface water and groundwater quality, and the potential for nitrification of ammonia in the underlying aquifer. Where the desk study indicates a risk to a receptor, the site investigation will need to provide sufficient information to enable prediction of potential impact and a defensible decision on the suitability of the site and/or the design requirements needed to mitigate any impacts. In addition the density of ICWs should be considered, as too many farm ICWs (or other ICWs taking a high nutrient loading) in a catchment may cause high ammonia concentrations in groundwater and water quality problems in associated surface water.

6 Discharge of All ICW Water to Groundwater

6.1 Introduction

Where no suitable stream is present for discharge of the ICW water (either because there is none present nearby or the sensitivity of the stream is high or the assimilative capacity is inadequate), discharge to groundwater from the final ICW pond has been proposed (discharge through forestry has also been mentioned). This creates the interesting scenario where the earlier ponds must provide substantial containment, while the liner beneath the last pond must be sufficiently permeable to enable percolation of all the remaining ICW water. Combining both adequate containment and leakage on the same site, without use of artificial liners, is a challenging requirement. For a dairy typical farm (see Section 3.2.1) where the liner in the earlier ponds achieves a permeability of 1×10^{-8} m/s (see Section 3.2), an average of 20 m³/d must discharge to groundwater from the final pond (the average quantity will be greater if the permeability beneath the earlier ponds is less than 1×10^{-8} m/s). However, in wet weather, a far higher daily percolation rate would be needed.

Three main issues arise in considering this option:

1. The loading of nutrients reaching groundwater and the potential impacts on surface water receptors;
2. The concentration of pollutants in the underlying groundwater and the potential impact on groundwater and surface water receptors;
3. The capacity of the underlying geological materials to accept the hydraulic loading.

6.2 Site Characterisation Requirements

6.2.1 Loading and Concentration of Pollutants

The overall pollutant loading will be greater than an ICW constructed to the requirements of the DAF/DEHLG guidance where discharge to surface water is planned. Information on the water quality of the ICW water entering the final pond (rather than leaving it) is needed to enable a proper assessment to be undertaken. It is likely that, in many situations, particularly where there are no nearby sensitive receptors and/or it is concluded that high ammonia concentrations in groundwater either will not occur or will not pose a threat to a receptor, this issue will not prevent the use of ICWs with discharge to groundwater alone.

6.2.2 Hydraulic Loading Issue

This is likely to be the main issue in deciding on site suitability. A comprehensive site investigation would be needed to enable a confident prediction that the effluent will get away underground without overflowing of the ponds. As a starting point, the maximum daily hydraulic loading would need to be calculated. The site investigation would need to involve: drilling; permeability testing both of the underlying subsoil and bedrock; determination of water levels, particular in winter, and both vertical

and horizontal hydraulic gradients. The required minimum vertical permeability of the subsoil will depend on the size of the final pond, the maximum loading rate and the vertical hydraulic gradient; it is likely that a permeability of at least 1×10^{-7} m/s will be required. One concern that would need to be addressed is whether the required permeability of the final pond could, in certain circumstances, be reduced over time due to siltation or other processes, keeping in mind that some proponents of ICWs have emphasised their self sealing nature. In certain hydrogeological settings, where the subsoil is fluvio-glacial sand/gravel, the subsoil permeability may be too high (a permeability $> 1 \times 10^{-5}$ m/s would be typical) and sufficient attenuation of the ICW water in the subsoil may not occur. Even where the subsoil is shown to have a sufficient permeability to enable percolation of the ICW water vertically into the underlying bedrock aquifer, in many circumstances the permeability of this aquifer may not be sufficient to enable the water to flow away without backing up in the aquifer. This situation will apply in poor aquifers in particular, which underlie approximately 30% of the country, and may also apply to some areas of locally important aquifers that are generally unproductive except for local zones, which underlie 40% of the country. Consequently, it is critical that both the vertical pathway beneath the ICW ponds and the horizontal pathway away down-gradient from the ponds to the eventual surface water discharge point are adequately characterised.

6.2.3 Requirement for Guidance, Investigation, Monitoring and Licensing

Discharge of all the ICW water to groundwater is feasible in certain hydrogeological settings. In view of the points raised in Sections 6.2.1 and 6.2.2 above, if this means of disposal continues to be considered, the DAF/DEHLG Guidance would need to deal with the issues raised. In particular, the approach to estimating the maximum daily hydraulic loading and the site investigation requirements would need to be outlined. Unlike with the ICWs where the final discharge route is to surface water, installation of monitoring points in the subsoil and bedrock and monitoring of groundwater down-gradient of the ICW ponds are recommended. Licensing of the discharge to groundwater is recommended. As part of the licensing process, both the pollution issues and the hydraulic issues should be dealt with comprehensively. In particular, the horizontal pathway for the ICW water would need to be characterised and the ability of this pathway to accept all the ICW water in wet periods, together with the recharge up-gradient and down-gradient of the ICWs, should be clearly indicated.

7 Summary, Conclusions and Recommendations

7.1 Potential of ICWs to Pollute Groundwater and Associated Receptors

- ICWs receive large volumes of dirty water with relatively high nutrient loadings, particularly in wet weather.
- The current ICW design allows discharge of a proportion (up to ~33%) of the ICW water to groundwater. As leakage to groundwater occurs beneath all of the ICW ponds, the concentrations in groundwater of some pollutants will be higher than in the ICW water discharged directly to surface water.
- Attenuation of phosphate is shown to occur in the subsoil beneath ICWs and consequently groundwater does not appear to be providing a pathway for phosphate to surface water. However, the long-term ability of the minimum subsoil depth (1.5 m) to retain phosphate is an issue that needs further consideration. On balance, phosphate in groundwater arising from ICWs is not considered to be a significant issue.
- Low numbers of faecal bacteria were found in the groundwater in the vicinity of the ICW ponds in the Anne Valley. In general, microbial pathogens in ICW water should not pose a major threat to groundwater. Nevertheless, it is recommended that drinking water wells should not be permitted immediately down-gradient of ICWs.
- High ammonia concentrations were found in the groundwater beneath ICWs in the Anne Valley. In view of the volume of ICW water that leaks to groundwater, the reducing conditions present in the ICW ponds and the high concentrations in the groundwater beneath ICWs, **ammonia is the main pollutant that arises from farm ICWs**. Ammonia concentrations comparable to those

found beneath the ICWs in the Anne Valley are seldom found in uncontaminated groundwater in Irish aquifers.

- The impact of groundwater containing high ammonia, arising from ICWs, depends firstly, on whether there are sensitive receptors down-gradient and secondly, on whether sufficient attenuation of the ammonia occurs prior to the groundwater entering the receptors. This is a hydrogeological setting and specific site issue.
- In general, the lower the permeability and the greater the subsoil thickness beneath the ICW ponds, the lesser the risk to receptors from ammonia. In addition, where oxidation of the ammonia occurs in the underlying aquifer, the threat will be minimised if this occurs before the groundwater reaches the receptor. However, where the minimum subsoil liner requirements of the DAF/DEHLG Guidance (1.5 m subsoil with the upper 0.5 m having a maximum permeability of 1×10^{-8} m/s), the ammonia in the groundwater poses a threat to receptors. If the ponds were lined with an artificial liner or a subsoil liner with a maximum permeability of 1×10^{-9} m/s, this issue would not be significant.
- On balance, while ammonia in groundwater poses a major threat, it is probable that in a high proportion of settings, either the ammonia will be converted in the groundwater to nitrate or there will be no sensitive receptor nearby; consequently, a site appraisal may often conclude that this will not be a significant issue.

7.2 Impact of ICWs on the Annestown Stream

- While the surface water quality improved initially after ICWs were installed in the Anne Valley, the surface water quality is now unsatisfactory: the ammonia concentrations are high and are rising; if the WFD status classification was undertaken based on 2006 data, the Annestown stream would be classed as less than "good" status, thereby requiring actions to return the stream to 'good' status.
- It is concluded that pollution of groundwater by ammonia from the farm ICWs is making a significant contribution to the water quality problems in the Annestown stream.

7.3 Authorisation of ICWs

- An exemption from the requirements of the new Groundwater Directive (2006/118/EC) is allowed where the input of pollutants is "considered by the competent authorities to be of a quantity and concentration so small as to obviate any present or future danger of deterioration in the quality of the receiving groundwater".
- It is concluded that, based on the hazard posed by farm ICWs, the potential and measured impact on groundwater, the variability of hydrogeological settings in Ireland, and the sensitivity of certain ecosystems, **licensing of discharges to groundwater should be required**, both in circumstances where the main discharge route is to surface water and where the only discharge route is to groundwater. This recommendation is additional to the requirement for licensing of discharges to surface water given in the DAF/DEHLG Guidance (January 2006 draft).
- In most circumstances, licensing of discharges to groundwater is not likely to pose a significant additional site investigation requirement; however, it ensures that the higher risk scenarios are noted, and appropriate conclusions on site suitability are drawn.

7.4 Discharge of All ICW Water to Groundwater

- In certain hydrogeological settings, this is a potential, though challenging, option.
- In view of the high hydraulic loading, a comprehensive site investigation is needed to enable confident prediction that all the ICW water will enter groundwater without any significant environmental or health impact.
- If it is planned to use this option, it is recommended that the DAF/DEHLG Guidance on ICWs should include information on the approach to calculating the maximum daily volume of ICW

water needing disposal and on the comprehensive site investigation and calculations needed to ensure safe disposal of the ICW water.

- Licensing of the discharge to groundwater is recommended.

7.5 Adequacy of Subsoil Liner with a Maximum Permeability of 1×10^{-8} m/s

- It is recommended that the subsoil liner requirements in the draft DAF/DEHLG Guidance should be applied to all the ICW ponds, with the possible exception of the final pond when discharge to groundwater is planned. More stringent liner requirements, in particular a lower permeability, may be necessary for ICWs in the vicinity of sensitive receptors.

7.6 Further Investigation and Research on ICWs

- While ICWs increase the wetland component of the landscape and are a viable means of treating polluted water, they have the capacity, in certain circumstances, to cause serious environmental and health risks. As the available data and information are inadequate to enable definitive conclusions to be drawn, independent research on the role of ICWs and other constructed wetlands in treating polluted water, particularly polluted water with a high nutrient loading, is recommended.

7.7 DAF/DEHLG Guidance on Farm ICWs

- It is recommended that the DAF/DEHLG Guidance on farm ICWs should be developed to take account of the relevant issues highlighted in this report, e.g. high ammonia concentrations in groundwater beneath ICWs and the sensitivity of certain associated receptors.

8 References

Carroll P; Harrington R; Keohane J; Ryder C (2005). Water treatment performance and environmental impact of integrated constructed wetlands in the Anne Valley watershed, Ireland. In: Nutrient Management in Agricultural Watersheds: A Wetlands Solution (Dunne E J; Reddy K R; Carton O T eds), pp 207-217, Wageningen Academic Publishers, Wageningen.

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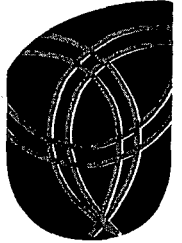
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C A R L O W
COUNTY COUNCIL

COMHAIRLE CHONTAE CHEATHARLOCHA



REF.NO: 02/259

04/07/2002

TO: Mr Alan McGurdy
Eastern Regional Fisheries Board
15a Main Street
Blackrock
Co Dublin

Re: *Planning and Development Act 2000*
Ballon Meats Ltd.

A Chara

I refer to letter of correspondence received from you in connection with an application by Ballon Meats Ltd. for PERMISSION for a wastewater treatment system comprising a mechanical treatment plant approximately 0.8 hectares of constructed wetlands and associated civil works at Ballon Meats Ltd. Raheen Ballon, Carlow and am to advise that Carlow County Council by Order dated 4/3/02 having taken your submission into consideration decided to grant PERMISSION. I am attaching for your information a copy of the Council's decision.

Please note that you have the right of appeal to An Bord Pleanala against the Council's decision on this application. Your appeal should be address to An Bord Pleanala, 64 Marlborough Street, Dublin 1 and should include, your name and address, details of the nature and site of the proposed development, the name of the Planning Authority, the planning register number and the applicants name and address. The appeal must be received by An Bord Pleanala within **four weeks** beginning on the date of the Council's decision.

The **full** grounds of appeal and supporting material and arguments must be submitted from the start. The correct **appeal fee** must also be enclosed. If an appeal does not meet **all** the legal requirements, it will be **invalid** and **cannot** be considered by the Board.

APPEAL FEES

- (A) €380 (in the case of an appeal by the applicant for permission against a decision of a planning authority on a planning application relating to commercial development).
- (B) €150 (in the case of an appeal against a decision of a planning authority, other than an appeal mentioned at (a) above)
- (C) €75 for an oral hearing.

Mise, le meas

Helena Tonkin
COUNTY SECRETARY

COUNTY OFFICES, ATHY ROAD, CARLOW.

TEL: 0503 70300 FAX: 0503 41503

E-MAIL: secretar@carlowcoco.ie

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CARLOW COUNTY COUNCIL
PLANNING AND DEVELOPMENT ACT 2000
NOTIFICATION OF DECISION TO GRANT

TO: Ballon Meats Ltd.
I.E. Consulting Engineers
Green Road
Carlow

Planning Register Number: 02/259

Valid Application Received: 13/05/2002

Further Information Received Date:

In pursuance of the powers conferred upon them by the above-mentioned Acts, Carlow County Council has by Order dated 4/7/02 decided to GRANT PERMISSION for development of land, namely:-

a wastewater treatment system comprising a mechanical treatment plant approximately 0.8 hectares of constructed wetlands and associated civil works AT Ballon Meats Ltd. Raheen Ballon, Carlow IN ACCORDANCE WITH THE PLANS SUBMITTED WITH THE APPLICATION, hereto for the reasons set out in the First Schedule hereto but subject to the 7 conditions set out in the Second Schedule hereto.

Subject to the 7 conditions set out in the attached schedule.

Signed on behalf of CARLOW COUNTY COUNCIL

Helen Tomkins
for COUNTY SECRETARY

Date: 4/7/02

An appeal against a decision of a Planning Authority maybe made to An Bord Pleanala. THE APPLICANT FOR PERMISSION OR ANY OTHER PERSON may appeal within four weeks beginning on the date of the making of the decision by the Planning Authority. Appeals should be addressed to An Bord Pleanala, 64 Marlborough Street, Dublin 1, and be accompanied by a fee of :-

- (A) €380 (in the case of an appeal by the applicant for permission against a decision of a planning authority on a planning application relating to commercial development).
- (B) €150 (in the case of an appeal against a decision of a planning authority, other than an appeal mentioned at (a) above)
- (C) €75 for an oral hearing.

Appeals submitted without the appropriate fee will be invalid. An appeal by the applicant for permission should be accompanied by this form. In the case of an appeal by any other person, the name of the applicant, particulars of the proposed development or of the structure proposed to be retained and the date of the decision should be stated.

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FIRST SCHEDULE

Having regard to the proposed development and reports received from environmental section, it is considered that the proposed development will not prejudice the amenities of the area. I recommend a grant of permission in accordance with Schedule 2.

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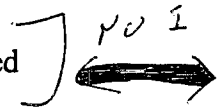
SECOND SCHEDULE

PL02/259 Planning Permission sought for a waste water treatment system comprising a mechanical treatment plant approximately 0.8 hectares of constructed wetlands and associated civil works at Ballon Meats Ltd., Raheen, Ballon, Co. Carlow.

1. The development shall be carried out in accordance with plans and particulars submitted to the Planning Authority, except where altered or amended by conditions in this permission.

Reason: To enable the Planning Authority to check the proposed development when completed, by reference to approved particulars.

2. Uncontaminated surface runoff should not be allowed to enter the constructed wetland and should be directed to a storm water drain. BREACH



Reason: To oversee environmental protection.

3. The applicant shall submit details of the method(s) to be used for the disposal of all wastes arising from activities carried out on site and request written approval within one month of the date of grant of planning permission.

Reason: To oversee environmental protection.

4. The applicant shall put in an impervious liner in the constructed wetland to ensure that there is no risk whatsoever of seepage from the wetland into the groundwater. BREACH

Reason: To oversee environmental protection.

5. The applicant shall apply for a licence to discharge trade effluent to waters under Section 4 of the Local Government (Water Pollution) Acts, 1977 – 1990 before commencing the installation of the waste water treatment system.

Reason: To oversee environmental protection.

6. The applicant shall ensure that the primary and secondary treatment system is capable of treating the trade effluent to the following standards before discharge to the constructed wetlands.

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SECOND SCHEDULE

PL02/259 Planning Permission sought for a waste water treatment system comprising a mechanical treatment plant approximately 0.8 hectares of constructed wetlands and associated civil works at Ballon Meats Ltd., Raheen, Ballon, Co. Carlow.

Parameter	Limit Value	Sampling Method
PH	6-9	24 hour composite sample
B.O.D. ₅ (mg/l)	25	24 hour composite sample
C.O.D (mg/l)	125	24 hour composite sample
Suspended Solids (mg/l)	35	24 hour composite sample
Total Nitrogen (mg/l as N)	15	24 hour composite sample
Total Ammonia	10	24 hour composite sample
Total Phosphorous (mg/l as P)	2	24 hour composite sample
Oils, Fats and Grease (mg/l)	10	24 hour composite sample

Reason: To oversee environmental protection.

7. The applicant shall employ a licensed rendering plant for the disposal of blood offal screenings and all high-risk wastes.

Reason: To oversee environmental protection.

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The relationship between plant vigour and ammonium concentrations in surface waters of constructed wetlands used to treat meat industry wastewaters in Ireland

A. Harrington

13 Ardfield View, Grange, Douglas, Cork, Ireland

Abstract

Constructed wetlands have the ability to treat various wastewaters with varying nutrient concentrations. Studies have been carried out to assess the impact of influent concentrations of ammonium on the growth of helophyte species in constructed wetlands used to treat wastewaters. Plants used in constructed wetlands have shown to have a threshold level of between 100 mg l^{-1} and 200 mg l^{-1} ammonium. The objectives of this study were to investigate the relationship between ammonium concentrations in wetland surface waters and plant vigour of a helophyte species *Carex riparia* (Curtis). This study was carried out on an integrated constructed wetland (ICW) treating waste water from a meat processing facility in Co. Carlow. The wetland comprised of three different segments. For the purposes of sampling each segment was divided into sections. At each sampling station the characteristics of plant growth were recorded and water samples were taken, which were later analysed for ammonium. Results suggest that as ammonium concentrations decreased with distance from wetland inlet down through the wetland system, plant vigour increased. Ammonium concentrations in upper wetland segments were $388 \pm 131 \text{ mg l}^{-1}$ (mean \pm standard deviation), whereas in the lower section, average concentrations were $171 \pm 41 \text{ mg l}^{-1}$. Plant growth seemed to be limited in upper wetland segments.

Keywords: Constructed wetlands, helophyte species, ammonium concentration, *Carex riparia* (Curtis).

Introduction

Constructed wetlands are designed to treat various types of wastewaters through a combination of physical, chemical and biological processes. Free surface flow constructed wetland treatment systems are designed to allow water flow above the wetland substrate. They are typically densely planted with helophyte species, which are plant species that are specifically adapted to survive and grow under a wide range of environmental conditions that can range from flooded to dry conditions. The ability of helophyte species to assimilate nutrients, to create favourable conditions for bio-films that enhance microbial decomposition of organic matter and increase residence time for through-flowing water are the main reasons they are often used in constructed wetlands to help improve water quality.

Plants can extract and use various forms of nitrogen (N) from soil porewater, most importantly are the inorganic ions ammonium (NH_4^+) and nitrate (NO_3^-). Although plants require ammonium for growth, studies have shown that there is a threshold level of ammonium, which plants can

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Constructed wetlands and water quality

tolerate (McCaskey *et al.*, 1994). McCaskey *et al.* (1994) indicated that high ammonium concentrations (in excess of 100 mg l^{-1}) can be toxic to plants such as wetland vegetation. A study carried out by Clarke and Baldwin (2002) to assess the impacts of ammonium concentration on helophytic species in constructed wetlands that were treating animal waste, found that ammonium levels in excess of 200 mg l^{-1} inhibited the growth of *Juncus effusus* (L), *Sagittaria latifolia* (Willd) and *Typha latifolia* (L). The growth of *Schoenoplectus tabernaemontani* was limited by ammonium concentrations in excess of 100 mg l^{-1} . Ammonium can be a substantial component in polluted wastewaters, such as meat processing industry wastewaters. Therefore, ammonium concentrations are often a fundamental limiting factor in the design of constructed wetlands to treat these waters.

Vegetation such as *Typha* and *Juncus* sp., are often the most obvious biological component of a constructed wetland ecosystem. The design, construction and maintenance of constructed wetlands is often focused towards the establishment of dense vegetation stands in order to optimise nutrient assimilation and provide suitable conditions for microbial decomposition processes (Peterson, 1998). However, in heavily nutrient loaded constructed wetland systems such those previously mentioned, the concentration of ammonium may limit vegetation establishment and consequently reduce nutrient assimilation by the wetland.

Under aerobic wetland conditions ammonium is transformed to nitrite and then to nitrate (nitrification), which is then denitrified to N_2 under anaerobic conditions. Helophytic vegetation has the ability to transfer oxygen from plant shoots to roots, which facilitates an oxidised micro-environment around plant roots and rootlets, which is known as a plant's "rhizosphere." This oxidised micro-environment stimulates decomposition processes and the growth of nitrifying bacteria.

The overall objective of this study was to determine the relationship between the concentration of ammonium in wetland surface waters and plant vigour, as defined by growth and re-growth of *Carex riparia* Curtis (greater pond sedge), which is a commonly used plant within constructed wetland systems used to treat meat industry wastewaters in Ireland.

Materials and methods

Site description

The site for the study was an 8000 m^2 integrated constructed wetland (ICW) treatment system built in 2002 to treat meat industry wastewater from Ballon Meats Ltd, Co. Carlow (Figure 1). It comprised of four ponds/segments all of which cover a similar area of about 2000 m^2 . Wetland segments one to three were used in this study. A number of sample sites were used within each segment of the wetland to measure plant vigour and take samples of overlying water, which would be later analysed for ammonium concentrations.

The effluent from the meat factory was initially treated through dissolved air floatation (DAF) unit. The effluent from the DAF unit was then allowed to discharge to the first wetland. The wetland was designed to treat 150 m^3 of effluent a day, through the four wetlands. The influent ammonia concentrations were often in excess of 400 mg l^{-1} . In situ soils were used for wetland construction.

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Wetland segments one to three were planted with *Carex riparia* (Curtis), *Typha latifolia* (L) and *Glyceria maxima* (Hartm.). The plants were planted approximately one meter apart in order to achieve a dense vegetation cover throughout most of the wetland. *Carex riparia* was the dominant plant species used, comprising about 80% of the individual plants planted.

Species description

Carex riparia Curtis (Common Pond Sedge) is a perennial evergreen that grows to 1.5 m to 2 m. This species is usually glabrous, with three angled stems and rather harsh grass-like leaves (Figure 2). In Ireland, it flowers from May to June and seeds typically ripen between July and August. Naturally, it is found in ditches, marshes and river-banks, mainly near coastal areas, occasionally in the east of Ireland, but rare elsewhere. Plants can be easily cultivated in damp to wet soil in full sun or shade.



Figure 1. Wetland segment one of constructed wetland system used to treat meat industry wastewaters at Ballon Meats, Co. Carlow.



Figure 2. Habit of *Carex riparia* in flower May to June.

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Constructed wetlands and water quality

Sampling

A systematic sampling system was carried out to investigate the relationship between ammonium concentration and plant vigour. Sampling was carried out during June 2002. There were sixteen sampling stations within the first three wetland segments. The first two segments were divided into three sections; upper, middle, and lower. The third wetland segment was divided into upper and lower sections only.

At each sample station the overlying water was sampled and collected samples were analysed for ammonium. Parameters such as concentration of ammonia in the overlying water; height of the individual plant; diameter of the plant; number of new shoots on the plant; colour of plant; and the density of plants in the row were recorded.

Results

Results are shown in Table 1. Concentrations of ammonium were highest in wetland segment one in comparison to the other two wetland segments. Surface water concentrations of ammonium also decreased between upper, middle and lower sections of each wetland segment.

Plant height, plant diameter and the number of new shoots on plants were lower in wetland segment one, in comparison to the second and third wetland segments. These results may suggest that plants were stressed in wetland segment one and with distance from the inlet, plant stress, as assessed by measuring plant height, plant diameter and number of new shoots, decreased with increasing distance from influent (Figure 3). There was a significant relationship between the concentration of ammonium in wetland surface waters and the number of new shoots on wetland plants ($p < 0.05$).

Table 1. Surface water ammonium concentrations and plant vigour parameters of the integrated constructed wetland that was used to treat meat industry wastewaters. Values represent means \pm one standard deviation.

Wetland segment	Sections	Ammonia (mg l ⁻¹)		Plant height cm		Plant diameter (cm)		New shoots on plant		Plant colour
1	Upper	630	156	47.5	3.5	1.75	0.4	1	1.4	light/grey
1	Middle	480	71	47.5	3.5	14	5.6	6	2.8	yellow/green
1	Lower	380	57	47.5	25	7.5	6.4	0	0	brown/green
2	Upper	305	21	76.5	9	18	1.4	1	1.4	dark/green
2	Middle	275	7	66.5	9	17	1.4	1.5	2.1	yellow/green
2	Lower	260	-	77.5	3.5	18	8.5	5.5	3.5	green/brown
3	Upper	212	18	51	47	12.5	4.9	2	0	green
3	Lower	130	14	110	7	30	5.6	8.5	0.7	dark green
Inlet		440								
Outlet		82								

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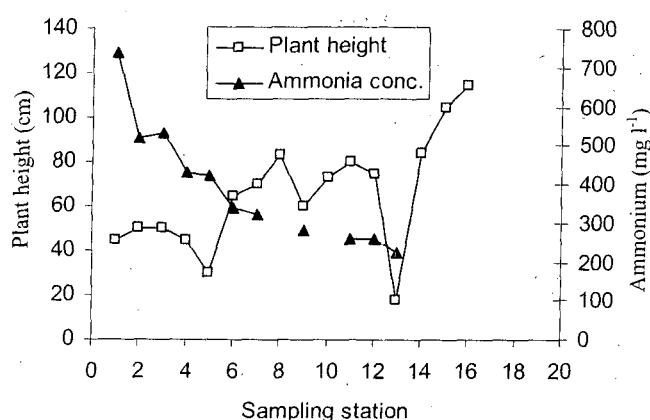


Figure 3. Plant height and ammonium concentration at each sampling station in the different wetland segments down through the constructed wetland system.

In general, the threshold concentration for ammonium in this constructed wetland system was about 200 mg l⁻¹. Thus, these findings are somewhat similar to others reported even though there different wetlands and different helophyte species were investigated.

Conclusions

The study carried out indicated that while *Carex riparia* was found growing in effluent with a concentration in excess of 400 mg l⁻¹, its growth was severely inhibited. As ammonium concentrations decreased below 200 mg l⁻¹ plant vigour significantly increased, as there was an improvement in the physiological structure of the plant as indicated by increased plant height, plant diameter and the number of new shoots.

When designing constructed wetlands for the treatment of concentrated effluents, such as meat industry wastewaters, it is important to reduce the concentration of influent ammonium to the wetland, as these concentrations seem to limit plant growth. An effective and simple way of reducing the concentration of ammonium discharging to a wetland would be to dilute the incoming effluent with on site storm water, generated from rainfall on site impervious surfaces.

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