Obj. No. 4

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15th February 2007

Office of Licensing and Guidance,
EPA headquarters,
P.O. Box 3000,
Johnstown Castle Estate,
County Wexford.

Ref: Reg No. P0738-01.

Objection to IPPC Licence Proposed Determination, Shell E&P Ireland Limited, Bellanaboy Bridge Gas Terminal.

My name is William Walker, I am chairman of a lobster v-notching (lobster restocking) group in north mayo.
We are a group of approx 45 inshore fishing boat owners located from achill-head to belderrig in north mayo.
We fish mostly for lobster and brown crab.

Our objection relates to the monitoring programme included in the Proposed Determination, Schedule C6 Receiving Water Monitoring, which is proposed for the area adjacent to the outfall pipe from the refinery at bellinaboy Reg No. P0738-01.

It seems from reading the IPPC licence application that Shell E&P (or persons paid by them) will monitor the effects on the marine environment.
We find this totally unacceptable, we would expect an independent body to undertake this task.
Self-policing of a discharge into the sea off our coast seems ludicrous when you think of the possible consequences of bioaccumulation or contamination of the marine environment.
We request/demand that this monitoring is undertaking by an independent body/group such as the E.P.A / Duchas / An Taisce or some other body with no vested interested in this project.
We have several reports (including the MLVC report) highlighting the fact that some of the substances discharged through this outfall pipe have the ability to bio-accumulate and/or bio-magnify in marine organisms .
To have Shell E&P in control of this task does not instil confidence in the local fishing community, on the contrary it will cause them to suspect that Shell E&P would attempt to hide/cover-up any findings that might be a cause for concern.
We have a report by an aquatic eco-toxicologist "Professor Peter Matthiessen" (attached). *He indicates that although his overall environmental risk assessment of the*

proposed produced water discharge does not reveal major problems, there remains a need for comprehensive environmental monitoring of the possible effects of the discharge.
In the report he also highlights the unknown risks of a fire at the refinery and the potential discharge to sea of "PAHs from partially-burned hydrocarbons and fire-fighting foams containing zinc and perfluorooctane sulphonate (PFOS)"

He states
"There is no doubt that two of the likely contaminants of firewater (i.e. zinc and PAHs) show acute and chronic toxicity to aquatic life, and are able to bio accumulate in some organisms. Furthermore, recent discoveries (Ankley et al., 2005; Sanderson et al., 2004; Boudreau et al., 2003a&b) have shown that the common foam ingredient PFOS is persistent, bio accumulative and toxic to fish and crustaceans".
In light of this and other scientific data (attached) you must agree, that to have Shell E&P in charge of monitoring the effects of this discharge is indeed inappropriate!

He has also assessed the proposed monitoring regime submitted by Shell E&P, (his conclusions attached)
While he says "I think it is OK as far as it goes", he goes on to state "but my main criticism is that it is unclear whether any attempt will be made to monitor for biological effects (as opposed to chemical contamination).
He lists a number of measures that he feels should be added to the monitoring regime.

(1) "I would suggest that chemical analysis of edible crab or lobster should also be included, specifically to reassure fishermen that their livelihood is not coming under threat. Crab and/or lobster are useful precisely because they are relatively sedentary scavengers and are likely to be exposed to contaminants from a wide range of sources, so I don't quite follow the reasoning of the document in this regard (see Table 1)." Professor Matthiessen has subsequently suggested that monitoring of crab or lobster should also include assessment for possible tainting.
(2) As the programme will be going to the trouble of taking benthic grab samples of sediments from around the outfall (a sound proposal), I believe the programme should go the extra mile and analyse the samples for benthic invertebrate community diversity as well as for chemical contamination. This is a useful catch-all biological measure of impact. If one cannot see a change in community structure, one can be fairly confident that invertebrates generally are not being damaged.
(3) While I concur with the choice of mussels as a target of the inter-tidal programme, again I suggest that they should go the extra mile and monitor them for biological effects as well as chemical contamination. I would be happy to advise on appropriate techniques, and would seriously consider broad-spectrum measures of chemical impact such as lysosomal stability and/or scope for growth. These are sensitive measures of effect which respond to many different contaminants. Metallothionein induction is also worth considering as a response to metal exposure.
(4) Continuing with the mussel theme, it would be worth considering the deployment of caged mussels in the zone of discharge, probably attached to buoys, as well as around the bay. This technique has been frequently used in other areas, and would be a useful backup to benthic community measurements.
(5) I support targeting a benthic fish such as dab, although it should be remembered that they migrate annually to deeper water to breed, and may therefore experience limited non-local exposure. As with mussels, it would be a pity to go to all the trouble of trawling for fish without measuring biological effects as well as chemical contamination. Again, I can advise on possible effects measures, but one very good one in the present context would be induction of an enzyme system known as cytochrome P450 1A1. This is specifically induced by hydrocarbons, and would provide a sensitive measure of overall hydrocarbon exposure.

Professor Peter Matthiessen is a qualified expert in the field of aquatic eco-toxicology (CV attached).
We as fishermen have faith and trust in his opinions, his observations sound logical and reasonable to us.
In conclusion, as well as our request/demand that the monitoring is undertaken by an independent body/group.
We also request that the concerns/measures outlined by Professor Matthiessen are covered in the monitoring regime.

List of attachments:

(1) **Cheque for €126 made payable to Environmental Protection Agency.**
(2) **The report by Professor Peter Matthiessen on Predicted effects on local fisheries of the proposed produced water discharge from the Corrib gas field, Republic of Ireland.**
(3) **Professor Peter Matthiessens Curriculum Vitae**
(4) **Hard copy of email from Professor Matthiessen on proposed monitoring regime.**

(2)

Predicted effects on local fisheries of the proposed produced water discharge from the Corrib gas field, Republic of Ireland

Professor Peter Matthiessen, Independent Environmental Consultant
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January 2007

Contents

1. Summary

1.1 This report assesses the likely impact of the Corrib gas field produced water discharge from the proposed Bellanaboy gas terminal on local marine fisheries.

1.2 The nature of the produced water is similar to most other gas production waters in terms of volume and content. It contains a number of substances with the potential to harm aquatic life.

1.3 The proposed treatment of the produced water before discharge is predicted by this report to produce an effluent that will cause no significant impacts on local fisheries.

1.4 In the event of an accidental discharge of untreated production water, any impacts are expected to be relatively minor and restricted to within 1 km of the diffuser.

1.5 A large fire at the Bellanaboy terminal would generate significant amounts of firewater contaminated with substances that could potentially cause fishery damage. However, insufficient information is available to predict the risks of an untreated spill with any reliability.

1.6 The report makes several recommendations for the provision of additional information that would be desirable to give reassurance about the produced water and possible firewater discharges.

2. Introduction

This report was commissioned by Mr William Walker on 19 December 2006. Mr Walker is a fisherman in the area of Broadhaven Bay in northwest Ireland, and represents a committee of other fishermen known as the 'Lobster V Notching Group'. They had requested an evaluation of the available information on the proposed produced water discharge near Broadhaven Bay derived from the new Corrib gas field, and an assessment of its likely effects on local fisheries. The report is required to include not only an assessment of the proposed discharge, but an evaluation of the consequences, a) of a catastrophic failure of discharge treatment processes and controls at the Bellanaboy Bridge gas terminal, and b) the likely effects of an unrestricted release of firewater in the event of an emergency at the terminal.

The prime sources of information on the proposed produced water discharge are the IPPC Licensing Application (reg. no. 738) submitted to the Irish Environmental Protection Agency (EPA) in 2004 by the developers of the Bellanaboy terminal (Shell), and the Shell E&P Gas Terminal Planning Application (no. P03/3343) to Mayo County Council, updated on 30 April 2004. These and other documents have been accessed via the Irish EPA's website at http://www.epa.ie/terminalfour/ippc/ippc-view.jsp?regno=P0738-01 and the Mayo County Council website at http://services.mayococo.ie/mcc4/Planning/Gas_TerminalIndex.asp.
The information provided therein will be compared with the characteristics and effects of waters produced from other gas fields, and the impacts predicted in the planning application will be compared with internationally available information on the toxicity of the produced water's components. The objective of this report is therefore to assess whether the predicted characteristics and effects of the produced water (the latter claimed in the IPPC application and offshore environmental impact statement [EIS] to be negligible) are credible in the light of international experience with other gas field discharges.

3. Background on the environmental effects on marine ecosystems of hydrocarbon exploration and production

3.1 Oil spills

It is a commonly held belief that offshore oil and gas exploration is harmful to the environment, and there is no doubt that certain aspects of this activity do indeed cause damage to marine ecosystems. From the general public's point of view, the most eye-catching aspect concerns occasional catastrophic spills of crude oil from tankers, which can cause greater or lesser degrees of mortality in seabirds and mammals, and mortality and tainting of fish, crustaceans and molluscs (e.g. the *Exxon Valdez* incident in Alaska ; the *Braer* incident in the Shetlands; the *Amoco Cadiz* in Brittany; and the *Sea Empress* in Wales – GESAMP, 1993; Baker et al., 1991; Patin, 1999). More frequent but smaller spills and crude oil discharges from tankers, platforms and refineries also cause some environmental damage, especially oiling of seabirds. It is a lesser-known fact that crude oil spills, whether small or large, cause little permanent environmental damage (mainly because oil is rapidly biodegraded), but the immediate impacts are very unpleasant and should be avoided if at all possible.

3.2 Well drilling

However, other less visible aspects of oil exploration and production (or 'expro') may also cause environmental damage. The two principal sources of marine pollution from offshore expro are the overboard disposal of drilling cuttings and fluids during the exploration phase, and the discharge of so-called produced water during the production phase. Produced water is essentially the water which emerges from the hydrocarbon-bearing formation, which includes natural hydrocarbons and other substances originating in the formation, as well as various chemicals needed to assist production, and its volume tends to increase over the lifetime of a field. Produced water from gas fields also includes water condensed from the gas.

Although not of direct relevance to the objectives of this report, it is worth briefly considering the environmental effects of drilling cuttings and fluids. Drilling fluids are complex mixtures of substances designed to maintain hydrostatic pressure and integrity of the well, lubricate the drill bit and carry the rock cuttings to the surface. The fluid is largely separated from the cuttings before the latter are disposed of, generally over the side of the drilling rig. The cuttings accumulate in a large pile which smothers benthic organisms living on and in the seabed, and residual drilling fluid in and around the pile can cause localised toxic effects on the benthos.

Many environmental surveys have shown that diesel oil-based drilling fluids (which have been phased out in the area of north-west Europe, including Ireland, under the jurisdiction of the Oslo and Paris Commission – OSPAR) caused major impoverishment of benthic invertebrate communities living around drilling rigs. For example, in the North Sea, serious and persistent damage was caused to these communities at up to 1 km from rigs, while more subtle effects could be detected out to 5 km in some cases (GESAMP, 1993), and drilling fluid residues were present in sediments out to ≤12 km. On the other hand, more modern water-based drilling fluids (such as those used in the Corrib field) cause less impact, and full recovery of the benthos from these substances can occur within 2-14 months of the cessation of drilling (Daan and Mulder, 1994). Overall, the total area of seabed in the UK sector of the North Sea which has been seriously damaged by drilling discharges amounts to about 106 km^2 (or 0.04% of the UK continental shelf), while the area that is more mildly affected in UK waters is about 400 km^2 (Davies et al., 1989). This compares, for example, with bottom trawling for demersal fish which temporarily damages huge areas of seabed (e.g. 2.5 times the area of the Irish Sea bed was swept by bottom trawls in 1978 - Brander, 1980).

3.3 Produced water

As stated above, water from the hydrocarbon-bearing formation, containing oil in solution and suspension, plus various other natural substances (e.g. metals and alkylphenols) and production chemicals, is discharged during oil and gas production. The discharge is generally into the sea, but sometimes the water is re-injected into the formation. Far more produced water emanates from oil installations than from gas wells. While the discharge from an oil-producing installation generally lies in the range 2400-40,000 m^3/day, gas wells typically generate produced water at the rate of 1.6-30 m^3/day (with a maximum of 125 m^3/day) (E&P Forum, 1994). The Oslo and Paris Commission (OSPAR, 2006) lists Ireland as having only 2 gas production water discharges, compared with 100 in the Dutch sector of the North Sea, and 145 in the UK sector. The total Irish produced water discharge in 2004 was a mere 3007 m^3/year (=8.2 m^3/day), compared with 252 million m^3/year discharged by the UK. In general, the volume of produced water increases throughout the lifetime of a field, although it should be noted that the reverse applies to the proposed Bellanaboy discharge.

OSPAR recommends that all offshore produced water discharges should achieve a performance standard of 30 mg/l dispersed oil (although not all do at present, with concentrations ranging up to 220 mg/l), and refineries are expected to work to a more stringent 5 mg/l standard. These recommendations have the aim of progressively reducing the oil content until 2020, when the remaining oil in produced waters should not be causing any harm to the environment (OSPAR Recommendation 2001/1). Produced waters are therefore usually subject to some treatment to remove oil, but they generally still contain a variety of contaminants when discharged.

Gas production waters are often more contaminated than those emanating from oilfields, although the total volume discharged is small. A summary of these contaminants in North Sea produced waters as discharged (i.e. after any treatment) is shown in Table 1. It is clear that discharged concentrations vary considerably.

Table 1. Key contaminants found in North Sea gas production waters (as discharged).

Contaminant	Concentration (mg/l)	Reference
mercury	<0.0002-0.033	Jacobs and Marquenie (1991) Jacobs et al. (1992) Bijstra (1992)
cadmium	<0.002-0.49	"
lead	<0.001-18	"
zinc	0.02-150	"
copper	0.007-<0.5	"
chromium	0.004-0.22	"
silver	<0.3	"
arsenic	<0.001-0.1	"
carboxylic acids	81-97	Cofino et al. (1993)
phenols	1.1-14	"
volatile aromatic hydrocarbons	0.3-440	"
polycyclic aromatic hydrocarbons (PAH)	<0.001-0.3 (depending on the congener)	E&P Forum (1994)
chemical oxygen demand (COD)	96-15800	O'Day and Tomson (1987) E&P Forum (1994)
biochemical oxygen demand (BOD_5)	28-6700	"

Produced waters of this type can show acute toxicity (e.g. lethality and immobilisation) to a large range of marine fish and invertebrates (reviewed in: Middleditch, 1984; Neff et al., 1987; Somerville et al., 1987; E&P Forum, 1994; Patin, 1999). For example, North Sea gas production waters cause rapid toxic effects (4 day EC/LC 50) in the concentration range 0.9-36 g/l (algae), 1.8-32 g/l (amphipod crustaceans) and 7.5-423 g/l (fish) (Jacobs, 1987; Jacobs and Marquenie, 1991). These data reflect the fact that gas production water is generally more contaminated than oil production water, and show that unicellular micro-algae are the most sensitive group (although the differences overall in acute toxicity between taxa are not large).

Chronic toxicity data (e.g. effects on growth and reproduction) are not available for gas production water, but equivalent data for oil production water obtained with the planktonic crustacean *Acartia tonsa* show that chronic toxicity only occurs at concentrations within a factor of ten below the acutely toxic level (Girling, 1987; Girling and Streatfield, 1988). Some components of gas production water (e.g. some metals and polycyclic aromatic hydrocarbons - PAH) can undoubtedly cause chronic toxicity, but as with acute toxicity, such effects can only occur if safe levels are exceeded. The degree of dilution, biodegradation, volatilisation and precipitation experienced by produced water discharges is therefore a crucial factor driving the occurrence of actual impacts on the marine environment.

Providing a produced water discharge is not on or near the seabed, or in an estuary or shallow coastal water, dilution in the sea is extremely rapid. Under North Sea conditions (where water depths, tidal flow and mixing energy are broadly similar to those found on the west coast of Ireland in the area of the proposed Corrib gasfield discharge), field measurements and computerised modelling show that medium/large discharges (much larger than gas discharges) experience near-instantaneous dilution factors of 600-1000 within 50-100 metres of the installation (e.g. Baumgartner et al., 1992; Law and Hudson, 1986; Somerville et al., 1987). Further dilution in the far field takes place more slowly, but can reach factors of 10,000 to 50,000 within one day, and in the northern North Sea factors of up to 1 million are theoretically expected within 1 km of the discharge point. This dilution and dispersion is augmented by the rapid volatilisation, biodegradation and/or precipitation of most produced water components, such as volatile aromatic hydrocarbons, carboxylic acids, and metals, respectively.

Given that gas production water is discharged in relatively small amounts, it experiences even greater dilution than most oilfield discharges, and it is predicted on the basis of the toxicity data described above (and on semi-field mesocosm data – Gamble et al., 1987) that such discharges to open sea waters, even if untreated, should only cause acute toxicity within about 100 metres of the installation. This is indeed borne out by observations, and no adverse effects in the far field of produced water discharges have been reported. Some studies have shown biochemical reactions to hydrocarbon exposure (e.g. cytochrome P450 detoxification-enzyme induction) in fish larvae across significant areas of the central North Sea oil and gas production area (e.g. Stagg and McIntosh, 1996), but these changes are probably adaptive and do not indicate wide-scale damage to fish populations.

Recent studies using modern chemical and biological techniques near the large Statfjord produced water discharge in the North Sea (Hylland et al., 2006a & b; ICES,

2002) demonstrated some biological changes in fish and mussel tissues very close to the installation, but with only trivial implications for population-level impacts. Other recent studies have also shown that produced water can exert some oestrogenic effects (possibly due to its load of alkylphenols), but again this can only be detected very close to discharges (Thomas et al., 2004).

Some petroleum hydrocarbons (e.g. PAHs and alkylphenols) etc. derived from produced water are nevertheless able to bioaccumulate in certain marine organisms, and this could be an important issue (in terms of saleability) for fisheries if accumulated concentrations grew high enough. For example, mussels *Mytilus edulis* held beside installations in the large Brent field in the North Sea accumulated hydrocarbons to levels 60-100 times above background, but tissue concentrations were only 6-10 times background at 6 km, and were no higher than background within 10 km (Somerville, 1987). Other species such as crustaceans and fish have more efficient detoxification and excretory systems, and so accumulate far less hydrocarbon or metal. Metals in produced water discharges rapidly form insoluble compounds in seawater which precipitate and settle into sediments adjacent to the installation. Due to their insolubility, they are essentially not available for bioaccumulation except by detritivorous invertebrates living in the sediment.

Bioaccumulated hydrocarbons can cause tainting in fish and shellfish which would affect their marketability. Such effects have been reported in demersal fish at up to 5 km from oil and gas platforms, although this has generally been attributed to oil-based drilling fluids (now phased out) rather than produced water (Patin, 1999). Thresholds in water for various gas produced water components that can cause tainting in fish range from 0.25 mg/l for ethylbenzene to 1-10 mg/l for phenol (Swan et al., 1994), and these concentrations are only rarely encountered at sea, very near some offshore installations.

Finally, the data in Table 1 show that produced waters can have quite high oxygen demands, meaning that they have the potential to cause dissolved oxygen concentrations in the receiving water to decrease (or 'sag'), either by chemical processes or through microbial biodegradation. However, both field measurements and modelling have shown that oxygen sags near offshore installations do not occur beyond about 10 metres of even large produced water discharges (E&P Forum, 1994). Modelling shows that a dilution factor of only 200 is sufficient to ensure that natural aeration compensates for the oxygen consumption caused by biodegradation of organic acids in produced water (Somerville, 1987).

Overall, the OSPAR Quality Status Report (OSPAR, 2000) concluded that although slight hydrocarbon contamination of fish has been found in the vicinity of platforms in the OSPAR area, the impact on fish stocks was considered to be small, although long-term impacts of produced water discharges could not be ruled out. In fact, despite many years of offshore hydrocarbon expro in northwest Europe, impacts of offshore oil and gas operations (and particularly of produced water discharges) on fisheries of any description have never been clearly established.

Despite this generally optimistic picture, it is nevertheless now necessary to assess the likely specific impact on valuable local fisheries of the proposed produced water discharge from the Bellanaboy Bridge gas treatment plant.

4. Key facts and predictions about the proposed produced water discharge near Broadhaven Bay

4.1 Discharge location

This has been moved further offshore than originally proposed by Shell, largely in recognition of the fact that Broadhaven Bay itself is a candidate Special Area of Conservation (cSAC 472). It is now proposed to lie just outside Broadhaven Bay in 64 m of water (stated as 68.5 m in the IPPC application) at kilometre point (KP) 71.0 (lat/long 54°19'35.7"N 09°59'12.3"W). The modelling predictions for the discharge assume 60 m depth (KMC, 2002), but this is not expected to make any significant difference to model predictions (if anything, it may cause predicted concentrations to be slightly lower than in the KMC report).

According to the Offshore EIA (section 2), the discharge pipe will be fitted with a diffuser to assist in rapid mixing. The precise position of this diffuser is not stated, but the EIA implies that it will be located at the seabed rather than above it. At the discharge location, the flood tidal stream tends to set to the north-east, while the ebb tends to run south-west, and peak current speeds at flood and ebb are approximately 0.5 m/sec.

This depth and peak current speed are broadly similar to those found at many produced water discharge locations in the North Sea (see below).

4.2 Discharge volume

The total produced water flow-rate in Year 1 is predicted in the Bellanaboy EIS to be 3.2 m^3/hr (76.8 m^3/day), rising to 3.3 m^3/hr in Year 2, and thereafter steadily decreasing to 0.2 m^3/hr in Year 21. To this is added surface water runoff from paved process areas at a rate of 2.1 m^3/hr. It is noteworthy that almost all the produced water will consist of water condensed from the gas rather than formation water. This explains why the discharge volume will not increase with time.

The predicted maximum flow-rate (79.2 m^3/day) places the Bellanaboy discharge in the upper range of gas production water volumes compared with the North Sea (E&P Forum, 1994), but below the reported maximum of 125 m^3/day. It is, of course, much smaller than produced water volumes from oil fields. Modelling of a representative oil production water discharge in the North Sea (Baumgartner et al., 1992) used figures of 6340 m^3/day for flow volume, water depth of 80 m, discharge pipe depth of 30.5 m, and current speed of 0.3 m/sec, and predicted that under well-mixed conditions the dilution factor at 80 m from the discharge would be more than 500. Under stratified conditions, the predicted dilution at 80 m is only about 300. The Bellanaboy discharge is much smaller than the volume used in this model, and the current speed is greater, implying even greater predicted initial dilution (probably a factor of >1000 within 1 km). However, it should be noted that the Bellanaboy discharge is apparently located at the seabed, which will curtail dispersion and dilution to some extent.

4.3 Contaminants in raw produced water

The predicted 'worst case' concentrations of contaminants in the Bellanaboy produced water (before treatment) are shown in Table 2, and are largely based on those listed as the 'Design Basis' in Table 10.9 of the EIS. It should be noted that these concentrations may be somewhat different from those which are actually pumped ashore, so it will be important to monitor the produced water for all these variables once it starts flowing.

Table 2. Predicted composition of the Ballanaboy produced water, prior to treatment. The majority of these data are taken from Table 10.9 of the EIS submitted to Mayo County Council, and are identical with those submitted to the Irish EPA in the IPPC application. In cases where the values in the IPPC application exceed those in the Mayo CC data, the larger of the two has been used.

Contaminant	Predicted concentration in untreated discharge (mg/l except where stated otherwise)	Dilution factor required to reach background concentrations in Broadhaven Bay (data from 2000/2001)
Inorganic substances		
Sodium	23,050	-
Potassium	3,196	-
Calcium	2,059	5
Magnesium	737	0.6
Barium	3.25*	428
Strontium	46.1	7
Iron (dissolved)	185	-
Iron (total)	215	21,500
Chloride	41,200	-
Sulphate	4,093	-
Bicarbonate	195	-
Boron	8.1*	400
Aluminium	1.3	-
Silicon	4.6	-
Phosphorus	1.0	-
Hydrogen sulphide	0	-
Ammonia (total)	5	-
Lithium	2.3	-
Heavy metals		
Chromium (total)	1.24*	1240
Manganese	5.13*	37
Nickel	15.7	3140
Copper	0.44	40
Zinc	25	5000
Arsenic	0.5	83
Selenium	0.1	2
Silver	0.1	>100
Cadmium	0.05	>1250

Contaminant	Predicted concentration in untreated discharge (mg/l except where stated otherwise)	Dilution factor required to reach background concentrations in Broadhaven Bay (data from 2000/2001)
Mercury	1.0	24,390
Lead	1.51*	1748
Organic substances		
Oil/fat/grease (free)	15	-
Total dissolved organic carbon	200	-
Methanol	150	-
Phenol	10	-
BTEX (benzene, toluene, ethylbenzene and xylene)	25	-
Polycyclic aromatic hydrocarbons (PAH)	1.0	-
Organic acids	30	-
Other		
pH at 20°C	7.4 units	-
Specific gravity at 60°F	1.05 units	-
Total dissolved solids	81,900*	-
Suspended solids	320	-
Chemical oxygen demand (COD)	500	-

*Data from IPPC application

Comparison of the predicted contaminant concentrations in untreated Bellanaboy produced water (Table 2) with those typical of North Sea discharges (Table 1), shows that the Bellanaboy water is broadly comparable with the North Sea range. The exceptions are the organic acids which will be somewhat less concentrated than those observed in North Sea discharges, and mercury, chromium, arsenic and PAHs which will be more concentrated. It should be noted that the data in Table 1 refer to water as discharged (i.e. after any treatment), whereas those in Table 2 are pre-treatment values.

Table 2 also shows calculated dilution factors required to reduce the predicted contaminant concentrations in the raw production water to the background values observed in Ballanaboy Bay. These are of course not relevant for the treated discharge, but are of interest in the event of an uncontrolled release of untreated production water (see Section 6 for a discussion of this scenario).

5. **Predicted environmental concentrations of expected contaminants derived from Corrib produced water**

5.1 Treated production water

Shell E&P Ireland has stated in the EIS that, using fairly advanced treatment technology, they are intending to achieve the Irish environmental quality standards (EQS) for contaminants in the produced water in the discharge, rather than in the receiving water. This objective is ostensibly conservative because EQS values are designed to be protective of the environment i.e. they are usually required to be met at the edge of a small sacrificial mixing zone around the discharge, not in the discharge itself. Concentrations beyond the mixing zone are intended to be harmless. It is worth stating that EQSs are intended in themselves to be reasonably conservative because they incorporate a range of so-called 'assessment' or 'safety' factors, and are based on toxicity data for the test organism found to be the most sensitive to the substance in question. Table 3 compares the Irish EQS values cited by the EIS with those used in some other jurisdictions.

Table 3. Predicted maximum contaminant concentrations in the Ballanaboy discharge (equal to Irish EQS values as presented in the EIS), compared with EQSs from some other jurisdictions.

Substance	**Irish EQS (mg/l unless otherwise stated) – Irish Environmental Protection Agency**	**English and Welsh marine EQS (mg/l as an annual average, unless otherwise stated) – Environment Agency**	**OSPAR ecotoxicological assessment criteria (mg/l dissolved) – Oslo and Paris Commission**	**United States chronic marine criteria values (mg/l dissolved) – US Environmental Protection Agency**
Barium	0.5 (95%-ile)	-	-	-
Iron (total)	1.0	1.0 (dissolved)	-	-
Boron	2.0	7.0	-	-
Aluminium	0.2 (95%-ile)	-	-	-
Chromium (total)	0.1	0.005 (dissolved)	0.001-0.01	0.05 (chromium VI)
Manganese	0.3	-	-	-
Nickel	0.1 (annual average)	0.015	0.0001-0.001	0.008
Copper	0.05	0.005	0.000005-0.00005	0.003
Zinc	0.1	0.01	0.0005-0.005	0.081
Arsenic	0.05	0.025	0.001-0.01	0.036
Selenium	0.02	-	-	0.071
Silver	0.01	0.0005	-	-
Cadmium	0.005	0.0025	0.00001-0.0001	0.009
Mercury	0.0001	0.0003	0.000005-0.00005	0.00094
Lead	0.005	0.01	0.0005-0.005	0.0081
Ammonia (total)	0.3	0.021 (un-ionised)	-	0.19-31 depending on temperature and

Substance	**Irish EQS (mg/l unless otherwise stated) – Irish Environmental Protection Agency**	**English and Welsh marine EQS (mg/l as an annual average, unless otherwise stated) – Environment Agency**	**OSPAR ecotoxicological assessment criteria (mg/l dissolved) – Oslo and Paris Commission**	**United States chronic marine criteria values (mg/l dissolved) – US Environmental Protection Agency**
				pH
Polycyclic aromatic hydrocarbons (PAH)	0.0002	0.00003-0.000002 depending on congener	0.000001-0.05 depending on congener	-
Phenol	0.0005	0.03	-	-
Benzene, toluene, ethylbenzene and xylene (BTEX)	0.01	Xylene 0.03 Toluene 0.04 Benzene 0.03 Ethylbenzene 0.02	-	-
Oil, fat and grease	0.3	-	-	-
pH	6-9 units	6.0-8.5 units (95%-ile)	-	6.5-8.5 units
Chemical oxygen demand (COD)	No Irish EQS (target conc. will be 400)	-	-	-
Total organic carbon (TOC)	No Irish EQS (target conc. will be 100)	-	-	-

It will be apparent from Table 3 that EQS values vary considerably between jurisdictions. This is because there is no international consensus on how such values should be calculated, and some jurisdictions apply much larger (and therefore more precautionary) assessment factors than others. In the opinion of the author, the OSPAR ecotoxicological assessment criteria are probably over-precautionary, while those published by the England and Wales Environment Agency (EA) and the US Environmental Protection Agency (USEPA) are more likely to be in the right range. The Irish EPA values cited in the EIS tend, with exceptions, to be less precautionary than those of the EA and USEPA, so it cannot be assumed that compliance with them indicates acceptable environmental risk.

Bearing in mind previous experience with, and modelling of, produced water discharges (see above), it is reasonable to expect that under well-mixed conditions in the open sea they will be massively diluted. A dilution factor of at least 1000 is therefore to be expected within <1 km of the Ballanaboy discharge. Inspection of Table 3 shows that applying a dilution of 1000 to the contaminants in the proposed discharge gives concentrations that are all below the EQSs used by other jurisdictions, even the very precautionary Ecotoxicological Assessment Criteria published by

OSPAR. This simple calculation is in agreement with the more sophisticated modelling work in the Shell EIS (derived for water of 60 m depth), which predicts that concentrations of the various toxic elements will only increase within 0.5 km of the discharge by a maximum of 1.2% (in the case of chromium). Given that Broadhaven Bay is an almost pristine environment with respect to contaminants, such a small increase can be considered negligible.

5.2 Untreated production water

Turning now to consideration of an accidental, uncontrolled discharge of untreated production water, it can be seen in Table 2 that some elements (iron, chromium, nickel, zinc, cadmium, mercury and lead) would be expected to require dilution of more than 1000 to reach background concentrations. However, a dilution of just 1000 (which is expected to occur within 1 km of the discharge), produces the concentrations shown in Table 4.

Table 4. Predicted environmental concentrations of key contaminants resulting from an uncontrolled discharge of untreated production water, assuming a dilution factor of 1000.

Contaminant	Predicted environmental concentrations assuming x1000 dilution (mg/l)
Iron (dissolved)	0.18
Aluminium	0.001
Ammonia (total)	0.005
Chromium (total)	0.001
Manganese	0.005
Nickel	0.016
Copper	0.0004
Zinc	0.025
Arsenic	0.0005
Selenium	0.0001
Silver	0.0001
Cadmium	0.00005
Mercury	0.0001
Lead	0.0015
Oil/fat/grease (free)	0.015
Total dissolved organic carbon	0.2
Methanol	0.15
Phenol	0.01
BTEX (benzene, toluene, ethylbenzene and xylene)	0.025
Polycyclic aromatic hydrocarbons (PAH)	0.0001
Organic acids	0.03
Suspended solids	0.32
Chemical oxygen demand (COD)	0.5

Table 4 shows that a continuous discharge of untreated production water, subject to a dilution of 1000 and no other mitigation processes, would produce contaminant concentrations that are almost all equal to or lower than the Irish EQS values. The exception is phenol, which would be diluted to 0.01 mg/l (in comparison with the Irish EQS of 0.0005 mg/l). Comparison of the predicted concentrations with the EQS values published by the English and Welsh Environment Agency (EA) and the US Environmental Protection Agency (USEPA) shows that they all meet the standards except zinc which would slightly exceed the EA standard, and nickel which would slightly exceed the USEPA standard. On the other hand, several heavy metal concentrations would fail the very stringent OSPAR criteria.

So far, the only mitigation factor to be considered is dilution, but several other processes operate to reduce contaminant concentrations still further. The first of these is biodegradation by micro-organisms which would act quickly to degrade organic substances like phenol to carbon dioxide and water. The second is adsorption to suspended and dissolved organic matter, which would tend to rapidly reduce bioavailability of most of the metals, plus non-polar organics such as PAH. Those substances adsorbed to suspended particulates would then tend to be lost from the water column through sedimentation, although some would be consumed by suspended sediment feeders such as certain bivalve molluscs. Metals would also be lost to the sediment due to chemical reactions in the water column producing insoluble substances such as carbonates. In sediments, the metals would also react in the anaerobic layers to become insoluble sulphides with negligible bioavailability. A third process (volatilisation) will act to reduce the concentrations of volatile organics such as BTEX.

It is therefore expected that dilution by a factor of 1000 within 1 km will be augmented by the various mitigation processes, producing an even greater reduction in contaminant levels.

6. Predicted impacts on the marine ecosystem and local fisheries

The local fisheries in the vicinity of the proposed produced water discharge (although largely further inshore) consist mainly of potting for brown crab (*Cancer pagurus*) and lobster (*Homarus gammarus*), but there is also some bottom trawling for various whitefish. These fisheries could potentially be damaged by produced water, through a variety of processes including toxic effects on reproduction or sensitive early life stages (causing impaired recruitment), bioaccumulation of contaminants in adults to levels unacceptable for human consumption, or induction of tainting which would impair marketability. It is also possible that even if none of these processes occurred, the public might nevertheless mistakenly perceive that the fishery products were somehow harmful, but this is a problem of presentation and public relations which will not be taken further here.

The issue of possible impacts on the fisheries will be handled in two sections, covering treated and untreated production water, respectively.

6.1 Treated production water

According to the EIS, the produced water is going to be treated using fairly advanced technology including distillation to remove volatile organics such as methanol and BTEX, ultra- and nano-filtration to remove particulates, granular activated carbon to remove organics, and ion-exchange treatment to remove metals and other inorganics. This is expected to reduce the contaminants in the discharge down to at least the level of the Irish EPA EQS values, and it is expected that these concentrations will be reduced by a factor of at least 1000 within 1 km of the discharge, due to dilution, volatilisation, degradation, chemical reaction and adsorption.

According to the calculations presented above, none of the known contaminants from the treated discharge will exceed safe levels outside the immediate mixing zone around the discharge. Even the very stringent OSPAR criteria will be met, and this will ensure that toxic effects, bioaccumulation and tainting should be avoided. This particularly applies to bottom-trawled whitefish whose early-life stages mainly occur elsewhere, and whose adult stages are highly mobile and are able to avoid contaminated areas. Fish also have highly efficient metabolisms which are able to degrade and excrete most of the substances in produced water.

The local crustacean fisheries, because they are based on relatively immobile organisms (crab and lobster), have a slightly higher potential for impact. However, this would only apply within a few hundred metres of the discharge, and probably not even there. As a precaution, once the produced water begins discharging, it would be sensible to take crab and lobster samples from the immediate vicinity of the discharge for chemical analysis of a few key contaminants, plus organoleptic tests for tainting, but it is not expected that these will show significant effects beyond the immediate mixing zone.

It is worth pointing out that the organisms on which whitefish, crab and lobster feed are also not expected to suffer adverse effects of the treated production water, and none of the contaminants are of the type which could biomagnify up food chains and damage charismatic organisms such as seabirds and marine mammals. It should also be noted that predicted environmental concentrations of substances which cause tainting in fish and shellfish (particularly ethylbenzene and phenol) will be well below the thresholds for this effect. Finally, it should be noted that the oxygen demand of the effluent after discharge will be negligible, and no decreases in dissolved oxygen are therefore expected.

6.2 Untreated production water

The best-designed treatment facilities may nevertheless fail from time to time. It is to be hoped that such a failure would be detected rapidly as a result of the routine discharge monitoring that is proposed, but it is conceivable that a treatment failure might go undetected for several days. Would this cause impacts on local fisheries?

The short answer is that this would be unlikely. The calculations in section 5.2 above assume continuous discharge of untreated water for at least several weeks, and even under these circumstances, dilution would reduce the concentrations of most contaminants below long-term EQS values. The various other mitigation processes (degradation, adsorption, reaction and volatilisation) would almost certainly reduce all contaminants to safe levels within 1 km of the diffuser, and tainting of fish and shellfish would also not be expected except in the immediate vicinity of the diffuser. Furthermore, a decline in dissolved oxygen due to the oxygen demand of the effluent would at most only occur very close to the diffuser.

However, in the event of such an unplanned discharge, it would be important to monitor local fisheries and the organisms on which they depend, both for key contaminants, and for possible toxic and tainting effects. It is also recommended that Shell E&P Ireland be requested to give an undertaking that any untreated discharge would be stopped immediately on discovery, and that Shell would cover the costs of a survey of the fishery as described above.

7. Predicted effects of untreated firewater

The recent Buncefield incident in the UK made it clear that oil and gas fires can burn out of control for several days (http://www.buncefieldinvestigation.gov.uk/index.htm) and produce very large volumes of firewater contaminated with such materials as PAHs from partially-burned hydrocarbons and fire-fighting foams containing zinc and perfluorooctane sulphonate (PFOS). The Buncefield incident required the use of >250,000 litres of foam concentrate, and substantial amounts of this and other contaminants leaked from the site due to inadequate bunding, some reaching surface and ground waters.

It is impossible to predict reliably the likely impact on fisheries of a large fire at the Bellanaboy terminal because too many key factors are unknown. However, it appears from the Shell EIS that the planned fire retention pond would only hold 6 hours-worth of firewater (assuming a rate of firewater generation of 1200 m^3/hr), and it is unknown whether a continuing incident would lead to the site bunding being overtopped or breached, or to untreated firewater being discharged via the produced water outlet.

There is no doubt that two of the likely contaminants of firewater (i.e. zinc and PAHs) show acute and chronic toxicity to aquatic life, and are able to bioaccumulate in some organisms. Furthermore, recent discoveries (Ankley et al., 2005; Sanderson et al., 2004; Boudreau et al., 2003a&b) have shown that the common foam ingredient PFOS is persistent, bioaccumulative and toxic to fish and crustaceans. The UK Drinking Water Inspectorate have set an advisory safe limit for PFOS in drinking water of 0.003 mg/l, and there are moves to phase out its use in the European Union as soon as possible. The safe concentration for aquatic life is probably below 0.01 mg/l (based on a 21-day 50% effect concentration for reduced fish fecundity of 0.23 mg/l – Ankley et al., 2005), but no EQS has yet been derived.

Assuming a worst-case release of >250,000 litres of foam concentrate containing 3% PFOS (note that this is based on Buncefield, and might be an over-estimate for a gas blaze), this would represent >7500 litres of pure PFOS that would require $>7.5\times10^{11}$ litres of water to dilute it to a level that was putatively safe for the aquatic environment. However, the persistence and ability to bioaccumulate of PFOS suggest that it should not be used at all at Bellanaboy if effective alternatives become available.

It is therefore recommended that Shell should be requested to conduct an impact assessment of the uncontrolled release of large amounts of firewater, and should also provide reassurance that the containment facilities on the Bellanaboy site are sufficient to prevent firewater being discharged untreated into the river or sea. It would also seem sensible to replace PFOS-containing fire-fighting foams on the site with environmentally safer alternatives as soon as practicable.

8. Conclusions and Recommendations

8.1 In broad terms, the volume and components of the produced water from the Corrib gas field are of a similar nature to other gas production waters. However, it is vital that Shell E&P Ireland should monitor the produced water as promised, and report the results at regular intervals.

8.2 Despite a large amount of environmental monitoring of produced water discharges, they have only been shown to have effects within a few hundred metres of the discharge, and no fisheries are known to have been significantly damaged by such discharges into well-mixed open sea waters like those which will receive the Bellanaboy discharge.

8.3 Shell E&P Ireland have proposed that the Bellanaboy produced water will receive a high level of treatment, and the present report predicts that the treated discharge will not cause any significant damage to whitefish, crab or lobster fisheries in the vicinity of Broadhaven Bay. Damage to other marine organisms is also not expected.

8.4 It is, however, recommended that fish and crustaceans from the fishery should be surveyed for possible contamination, tainting and effects once the produced water begins to flow, and that Shell E&P Ireland should cover the costs of this exercise.

8.5 If the produced water were to be accidentally discharged in an untreated condition, dilution and other natural mitigation processes are likely to restrict any impacts to the immediate vicinity of the discharge i.e. to less than 1 km from the outlet. The EIS seems to imply that the diffuser head will be located on the seabed, but if additional dilution is required, it is recommended that the head should be moved up into the water column.

8.6 In the event of a discharge of untreated water, Shell E&P should undertake to close off the discharge as soon as the treatment failure is discovered, and should cover the costs of a survey of local fisheries for contamination, tainting and impact.

8.7 It is impossible to predict the environmental impact of firewater emanating from an incident at the Bellanaboy terminal. However, several components of firewater (zinc, PAHs, and PFOS) are persistent, bioaccumulative, toxic or all of these. Recent experience at Buncefield shows that bunding can fail, leading to the release of large volumes of firewater.

8.8 Shell E&P should therefore conduct a proper environmental impact assessment of a firewater release, and should provide reassurance that the Bellanaboy facilities are constructed in such a way that firewater from a large incident cannot escape from the site without treatment. The replacement of

PFOS-containing fire-fighting foams with environmentally safer alternatives should be considered when practicable.

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(3)

Professor Peter Matthiessen   Curriculum Vitae

Summary

- Self-employed consultant in aquatic ecotoxicology
- Associate of Watts and Crane Associates
- >35 years of experience in conducting research on effects of aquatic pollution
- Major research interest: endocrine disruption and its ecosystem impacts
- 120 research publications
- Experience in the environmental risk assessment of pesticides and other chemicals
- Experience in design and operation of environmental monitoring for chemical effects
- Strong advisory role in bodies such as PSD, Defra, EA, HSE and OECD
- Experience managing teams of 20-50 environmental scientists

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General

Date of birth: 11 March 1949
Place of birth: Harrow, Middlesex, England
Nationality: British
Marital status: Married, 2 children

Education

1967-1970 Bristol University
BSc (Hons) in Zoology, upper second class

1970-1973 London University, Queen Elizabeth College
PhD in Zoology. Thesis title: Zinc uptake and its effects on the oxygen consumption and gill ultrastructure of the stickleback *Gasterosteus aculeatus* L.

Awards

2002-2007 Visiting Professor, Department of Biological Sciences, University of Lancaster
2006-2009 Fellow of the Centre for Ecology and Hydrology

Employers

1973-1985, employed by the Tropical Development and Research Institute (formerly the Centre for Overseas Pest Research; latterly the Natural Resources Institute), UK Overseas Development Administration (now Department for International Development).

1985-1997, Ministry of Agriculture, Fisheries and Food, Fisheries Laboratory, Burnham-on-Crouch, UK.

1997-2001, MAFF (now Defra) Centre for Environment, Fisheries and Aquaculture Science, Burnham-on-Crouch, UK.

2001-2006, Centre for Ecology and Hydrology, Lancaster, (Natural Environment Research Council).

2006-, Self-employed

Experience

Research experience since 1970 has been concerned with the effects of pollutants on aquatic wildlife. Initially, this involved studies of the effects of heavy metals on the physiology of fish, but since 1973, attention has been focussed on pesticides, industrial chemicals, and complex wastes. Between 1973 and 1977, laboratory toxicology studies were made of the impact of molluscicides, larvicides and insecticides on tropical aquatic organisms, and progress was made towards the development of more target-specific compounds.

Between 1977 and 1985, my work was largely field-based in Africa, where I conducted studies of the environmental impact of tsetse fly control operations in Botswana and Zimbabwe. In particular, the impact of the widespread use of DDT and endosulfan on both fish and terrestrial organisms such as birds and bats was monitored in remote and inaccessible areas. Consultancy work for the Asian Development Bank was carried out in Indonesia. This involved an assessment of the impact of current crop pest control practices on humans and wildlife, and advice on the possible adverse environmental effects of the Indonesian National Crop Protection Project.

Between 1985 and 1997 I was employed by the UK Ministry of Agriculture Fisheries and Food (MAFF – now Defra) as an ecotoxicologist at Burnham-on-Crouch Fisheries Laboratory as Head of the Biological Effects Group. In 1997, our organisation changed its name to the Centre for Environment, Fisheries and Aquaculture Science (CEFAS), an Agency of MAFF (Defra), and I became Principal Ecotoxicologist and leader of the Pollution Effects Team. Latterly, I was Science Area Head of the Environmental Quality group, with management responsibility for about 55 scientists. Research involved field and laboratory studies of the impact of wastes, industrial chemicals and pesticides on aquatic fauna and flora. I have also been responsible for monitoring UK marine environmental quality, and my group was one of the first in the world to discover the oestrogenic or feminising effects of certain polluting substances on fish. I have also led the field in investigations of the androgenic (masculinising) impacts on molluscs of tributyltin-based antifouling paints. I have acted as an environmental consultant for a large number of commercial and governmental organisations.

I became Director of the CEH Windermere laboratory in February 2001 and was responsible for the management of the laboratory, for planning and managing the relocation of the laboratory to modern premises on the Lancaster University campus, and for developing the capability for conducting aquatic ecotoxicology within CEH. In 2004, coincident with the relocation to Lancaster, CEH was reorganised nationally and all Site Director posts eliminated. In April 2004, I became Head of the Environmental Chemistry and Pollution Section at Lancaster, and I took Voluntary Redundancy from CEH in October 2006.

I am a member of the UK Advisory Committee on Pesticides and its Environmental Panel, deputy chairman of the UK Biocides Consultative Committee, and a member of the UK Expert Panel on Environmental Quality Standards for Annex VIII of the Water Framework Directive (formerly the Environmental Quality Standards Steering Group). I have, in addition, been responsible for advice to the UK Department of Trade and Industry on the environmental effects of chemicals used in the offshore oil and gas industry, and am a past member of the Freshwater Sciences Peer Review Committee of the Natural Environment Research Council (NERC). I have also been an adviser to a number of international organisations including the Oslo and Paris Commission, the Organisation for Economic Cooperation and Development (within which I co-chair the Validation Management Group for Ecotoxicity Tests), the International Council for the Exploration of the Sea (within which I have been Chairman of the Marine Environmental Quality Committee, chairman of the Working Group on the Biological Effects of Contaminants, and a member of the ICES Publications Committee and the Advisory Committee on the Marine Environment), and the European and Mediterranean Plant Protection Organisation. I am a past member of the Editorial Board of the international journal *Environmental Pollution,* a present member of the Editorial Boards of *Environment International* and *Environmental Toxicology and Chemistry*, and a Founder member and past Council Member of the Society of Environmental Toxicology and Chemistry - Europe (SETAC-Europe).

I am an Associate of Watts and Crane Associates (**http://www.wfcenvironment.co.uk/**), and have considerable experience in the provision of environmental consultancy advice to public and private bodies. Recent contracts have included:-

- advice to a company manufacturing road-salt additives on the aquatic environmental risks posed by their products;
- advice to a company and their legal representatives on the likely environmental impacts of an accidental spill of their cleaning product into a stream;
- participation in the scientific audit of a UK government scientific agency;
- provision of advice to a UK government agency on the development of environmental quality standards

Languages

Mother tongue: English

Other languages: French, German, Danish (all basic)

Interests

Mountaineering, walking, yachting. I am interested in education, and for eight years was Vice-Chairman of Governors at St Peter's High School, Burnham on Crouch.

Training record

- Introduction to Budgeting, 3 days, 2005

- Directing Safely in a Research Environment, 1 day, 2002
- Molecular biology – basic terms and techniques, 1 day, 2001
- Stress management, 1 day, 2001
- Budgeting course, 3 days, 1999
- Internet training course, 1 day, 1996
- MAFF Marketing Seminar, 2 days, 1995
- Equal Opportunities Workshop, 1995
- Workshop for experienced Grade 7's, 3 day STB course, 1994
- Expert Systems, 1 day CSC course, 1993.
- Access database software course, 2 day MAFF course, 1993.
- Civil Service & The Media, 1 day CSC course, 1993.
- Team leadership, 4 day MAFF STB course, 1992.
- Senior Management training, 4 day CSC course, 1991.
- Excel spreadsheet software course, 2 day MAFF course, 1991.

Prior to this, attended a variety of courses on such topics as presentation skills, interviewing skills and use of statistics.

Publications

See attached list - currently 120 scientific publications and major reports (published, in press or submitted).

Professor Peter Matthiessen **Publications and Major Reports**

1. **Matthiessen, P.** & Brafield, A. E. (1973). The effects of dissolved zinc on the gills of the stickleback *Gasterosteus aculeatus* L. *Journal of Fish Biology* **5**, 607-613.

2. Brafield, A. E. & **Matthiessen, P.** (1976). Oxygen consumption by sticklebacks (*Gasterosteus aculeatus* L.) exposed to zinc. *Journal of Fish Biology* **9**, 359-370.

3. **Matthiessen, P.** & Brafield, A. E. (1977). Uptake and loss of dissolved zinc by the stickleback *Gasterosteus aculeatus* L. *Journal of Fish Biology* **10**, 399-410.

4. **Matthiessen, P.** (1974). The effects of slow-release bis(tri-n-butyl-tin)oxide on the tropical food fish, *Tilapia mossambica* Peters. Proceedings of the First Controlled Release Pesticide Symposium, Akron, Ohio. 16-18 Sept. 1974, pp 25.1-25.17. University of Akron, Ohio.

5. **Matthiessen, P.** (1977). Uptake, metabolism and excretion of the molluscicide N-tritylmorpholine by the tropical food fish *Sarotherodon mossambicus* (Peters) (Pisces: Cichlidae). *Journal of Fish Biology* **11**, 497-509.

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(4)

william walker

From: "Peter Matthiessen" <peter@matthiessen.freeserve.co.uk>
To: "'william walker'" <walkerfamily@esatclear.ie>
Sent: 12 February 2007 11:21
Subject: RE: monitoring proposals for corrib

William,

I have now given the monitoring plan a quick look. I think it is OK as far as it goes, but my main criticism is that it is unclear whether any attempt will be made to monitor for biological effects (as opposed to chemical contamination). The proposals to measure contaminants are fine, but of necessity can only cover a very small proportion of the likely range of contaminants that one might expect. Carefully chosen biological effects measures will allow the monitoring programme to account for the effects of substances that will not be analysed chemically, and will also account for possible mixture effects. My main proposals and comments are as follows:-

1) The choice of mussels and dab as the main biological targets looks OK, but I would suggest that chemical analysis of edible crab or lobster should also be included, specifically to reassure fishermen that their livelihood is not coming under threat. Crab and/or lobster are useful precisely because they are relatively sedentary scavengers and are likely to be exposed to contaminants from a wide range of sources, so I don't quite follow the reasoning of the document in this regard (see Table 1).
2) As the programme will be going to the trouble of taking benthic grab samples of sediments from around the outfall (a sound proposal), I believe the programme should go the extra mile and analyse the samples for benthic invertebrate community diversity as well as for chemical contamination. This is a useful catch-all biological measure of impact. If one cannot see a change in community structure, one can be fairly confident that invertebrates generally are not being damaged.
3) While I concur with the choice of mussels as a target of the inter-tidal programme, again I suggest that they should go the extra mile and monitor them for biological effects as well as chemical contamination. I would be happy to advise on appropriate techniques, and would seriously consider broad-spectrum measures of chemical impact such as lysosomal stability and/or scope for growth. These are sensitive measures of effect which respond to many different contaminants. Metallothionein induction is also worth considering as a response to metal exposure.
4) Continuing with the mussel theme, it would be worth considering the deployment of caged mussels in the zone of discharge, probably attached to buoys, as well as around the bay. This technique has been frequently used in other areas, and would be a useful backup to benthic community measurements.
5) I support targeting a benthic fish such as dab, although it should be remembered that they migrate annually to deeper water to breed, and may therefore experience limited non-local exposure. As with mussels, it would be a pity to go to all the trouble of trawling for fish without measuring biological effects as well as chemical contamination. Again, I can advise on possible effects measures, but one very good one in the present context would be induction of an enzyme system known as cytochrome P450 1A1. This is specifically induced by hydrocarbons, and would provide a sensitive measure of overall hydrocarbon exposure.

In summary, I don't think the proposed programme is too far off beam, but I would certainly include certain biological effects measures to supplement the chemical ones.

Best wishes,
Peter

-----Original Message-----
From: william walker [mailto:walkerfamily@esatclear.ie]
Sent: 09 February 2007 14:29
To: Peter Matthiessen
Subject: monitoring proposals for corrib

Hello again.
I have attached A .pdf file outlining the monitoring measures proposed for the outfall/discharge location.
Do you have any comment to make on it?
Is it sufficient?