ATTACHMENT D.2.1: IMPACT ASSESSMENT REPORT, JULY 2023

1. Introduction

This Report provides a summary of the Impact Assessments prepared to determine the impact of the operational discharges from the Midleton and Carrigtwohill agglomeration on the receiving waterbodies, Lough Mahon (Harper's Island), North Channel Great Island, Owennacurra Estuary, Tibbotstown (Tibbotstown_010), Dungourney_020, and Owennacurra_40, and also addresses the criteria as outlined in **Section D.2**. of the EPA guidance document.

The Water Quality Modelling, Environmental Impact Assessment Report, Natura Impact Statement, and Water Framework Directive Assessment provide scientific evidence to support the proposed Emission Limit Values (ELVs) outlined in **Table D.2.1 – D.2.3** below for the amalgamated Midleton and Carrigtwohill agglomeration.

In 2021 the strategic water quality model assessment was commenced. The aim of the study is to establish a strategic water quality model which is suitable to support the assessment of all Uisce Éireann discharges in Cork Harbour. The model study was carried out in accordance Uisce Éireann's (UÉ) revised Technical Standard for Marine Modelling.

The Technical Standard sets out a defined process for all modelling studies carried out on behalf of UÉ, including:

- Phase 1 Model Scoping;
- Phase 2 Marine Surveys;
- Phase 3 Model Build, Calibration and Validation;
- Phase 4 Scenario Analysis and Reporting.

A report has been prepared for each phase of the marine modelling study. A copy of the report produced for Phase 4 Midleton WWDA Licence Review (this Marine Modelling Survey) is appended to **Attachment D.2.3.** The outputs of which are discussed under **Section 3** below.

For reference, the proposed ELVs for the Carrigtwohill Waste Water Treatment Plant (WwTP) (SW009), Midleton WwTP combined discharge point (SW001), and the Midleton WwTP effluent monitoring point (SW100) are presented in **Table D.2.1 – D.2.3** below.

Table D.2.1 - Proposed ELVs for the primary discharge at Carrigtwohill (SW009)

Parameter	Emission Limit Value Note 1
Biological Oxygen Demand	25 mg/l
Chemical Oxygen Demand	125 mg/l
Suspended Solids	35 mg/l
Total Phosphorus (as P)	1 mg/l
Ortho-P (as P)	0.5 mg/l
DIN	25 mg/l
pH	6 - 9

Note 1: Proposed based on the annual mean *i.e.,* the annual mean of the samples shall not exceed the ELV.

The European Communities Environmental Objective (Surface Waters) Regulations 2009 (as amended) set a DIN (Dissolved Inorganic Nitrogen) standard depending on the salinity of the coastal water body and do not set an EQS for Ammonia (NH_3) or Total Oxidised

Nitrogen (TON) in Coastal or Transitional waters. It is therefore proposed that although the receiving waters are Transitional, if the Agency deem ELVs for Nitrogen are required, that DIN is the stipulated ELV instead of TON and NH_3.

Table D.2.2 - Proposed ELVs for the Midleton Combined Discharge Point (SW001)

Parameter	Emission Limit Value Note 1
Biological Oxygen Demand	25 mg/l
Chemical Oxygen Demand	125 mg/l
Suspended Solids	35 mg/l
Total Nitrogen (as N)	15 mg/l
Ortho-P (as P)	2 mg/l
Faecal Coliforms	Geometric mean of < 250 fc/100mls of sample and 95%ile ≤1000fc/100mls.
pH	6 - 9

Note 1: Proposed based on annual mean *i.e.,* the annual mean of the samples shall not exceed the ELV.

Under this licence review a change to the pH ELV for the Midleton discharge point (*e.g.*, pH range change) is proposed. This is to ensure consistency with pH ELVs ranges with wastewater discharge authorisations on a national basis.

Table D.2.3 - Proposed UWWTD ELVs for Midleton WwTP (SW100)

Parameter	Emission Limit Value at WwTP
Biological Oxygen Demand	25 mg/l
Chemical Oxygen Demand	125 mg/l
Suspended Solids	35 mg/l
Total Nitrogen (as N)	15 mg/l

As the proposed secondary discharge is a combined outfall and discharges treated effluent from Midleton WwTP and Industries associated with industrial licences P0442-02 and P1103-01, the ELVs in **Table D.2.3** will continue to apply directly at the Midleton WwTP (SW100) as per Condition 4.16 of the original licence to comply with the Urban Waste Water Treatment Directive (UWWTD) requirements. There are no proposed changes to the UWWTD ELVs that apply directly at the WwTP.

Condition 2

UÉ is proposing the Agency consider the inclusion of the following conditions to be included as part of the Interpretation section of the revised licence.

- In accordance with the UWWTD 91/271/EEC (as amended) on Urban Waste Water Treatment and S.I. No. 254 of 2001, S.I. No. 440 of 2004 and S.I. No. 48 of 2010: For parameters Total Phosphorus (TP) and Total Nitrogen (TN), the annual mean of the samples shall not exceed the ELV.
- A 12°C temperature condition for the annual mean TN ELV of 15mg/l is also proposed because of the critical dependency of temperature on nitrification. See attached a Design Note prepared by Professor Tom Casey (2015).

2. Water Environment

The operational discharges from the Midleton and Carrigtwohill agglomeration discharge to six different receiving waterbodies, and there are 21 operational discharges associated with the Midleton and Carrigtwohill agglomeration. The list of operational discharges associated with the licence review are listed in **Table D.2.4**.

Table D.2.4 – Waterbodies Hydrologically Linked to operational discharges.

Receiving Waterbody	Type of Waterbody	Operational Discharges	WFD Status 2016 – 2021	WFD Risk (3rd cycle)	Trophic Status 2018 - 2020 (where applicable)
Lough Mahon – Harper's Island (IE_SW_060_0300)	Transitional	*SW009 (Primary) SW005 SW008	Moderate	At Risk	Intermediate
North Channel Great Island (IE_SW_060_0300)	Transitional	**SW001 (Secondary)	Moderate	At Risk	Intermediate
Tibbotstown_010 (IE_SW_19T250870)	River	*SW003 *SW004 SW006 SW007	Good	Review	Not applicable
Owennacurra Estuary (IE_SW_060_0400)	Transitional	**SW010 **SW011 **SW012 SW013 SW020 SW022	Moderate	At Risk	Potentially Eutrophic
Owennacurra_040 (IE_SW_19O030500)	River	**SW014	Moderate	At Risk	Not applicable
Dungourney_020 (IE_SW_19D070700)	River	SW015 SW016 SW017 SW018 SW019 SW021	Poor	At Risk	Not applicable

**Discharges currently licensed under D0044-01- SW009 =SW001, SW003 & SW004*

***Discharges currently licensed under D0056-01 - SW001 = SW01MIDL, SW010 = SW03MIDL; SW011 = SW04MIDL; SW012 = SW05MIDL & SW014 = SW07MIDL*

Note – Where there is a difference in licensed coordinates versus those proposed, this is due to updated and more accurate data.

Each of these waterbodies are part of the Lee, Cork Harbour, and Youghal Bay Catchment area (Hydrometric Area 19). This catchment area includes the area drained by the River Lee and all streams entering tidal water in Cork Harbour and Youghal Bay and between Knockaverry and Templebreedy Battery, Co. Cork, draining a total area of 2,153km².

The draft 3rd cycle Catchment Report (2021) for this hydrometric area, determined that for river waterbodies the main significant issues include morphological issues, nutrient pollution, organic pollution, hydrological issues, and sediment. For transitional waterbodies the significant issues include nutrient and organic pollution. Excess nutrients followed by morphological issues are the most prevalent issue for all waterbodies within the Lee, Cork Harbour, and Youghal Bay Catchment. Midleton (D0056) and Carrigtwohill (D0044) agglomerations are mentioned in the Catchment Report as significant pressures to their receiving waterbodies. The Owennacurra Estuary and Lough Mahon (Harper's Island) are identified as the receiving waterbodies which are in receipt of significant pressures from Midleton and Carrigtwohill, respectively.

The EPA undertake biological monitoring of river waterbodies at various locations. Q value data is only available for the Dungourney_020 River. Upstream of the SW016, SW018 and SW021 operational overflows at RS19D070600 (*ca*. 2.8km upstream), the 2005 monitoring reported a Q value of 4 (Good, unpolluted). Downstream of SW016, SW018, and SW021 (*ca*. 0.05km downstream), the 2020 monitoring reported a Q value of 3 (Poor, Moderately Polluted).

Recent ambient monitoring data for the receiving waters of the primary discharge, Lough Mahon (Harper's Island) (2020-2022) is shown in the table below.

Table D.2.5 - Ambient Monitoring – Downstream of the Primary Discharge Location at TW05003153LE6001 (Data Source: Uisce Éireann EDEN MDS Compliance Data Mar 2020 – Oct 2022)

Parameter	pH (pH Unit)	BOD (mg/l)	Ortho-phosphate (mg/l)	Total Ammonia (mg/l)	Total Oxidised Nitrogen (as N)(mg/l)	DO (%sat)	Temp (°C)
Number of Samples	12	12	12	12	10	12	12
Max result	8.1	5	7.07	0.40	5.48	102	18.8
Min result	7.6	0.71	0.01	0.05	0.04	74.9	9.1
Average result	**7.94**	**1.87**	**0.74**	**0.12**	**1.33**	**94.51**	**13.7**
95%ile		**3.6**				**102.6**	
*95%ile EQS as per S.I. No. 288/2022 Good Status **		*≤4.0*	*≤ 0.060 (median)*			**95%ile** >70% <130%	
*95%ile EQS as per S.I. No. 288/2022 High Status **		*≤3.0*	*≤ 0.030 (median)*			**95%ile** >80% <120%	
*Overall compliance with relevant **95%ile EQS Good Status** **		**Yes**	**No**			**Yes**	
*Overall compliance with relevant **95%ile EQS High Status** **		**No**	**No**			**Yes**	

*EQS under S.I. No. 288 of 2022

Note: Where the concentration in the result is less than the limit of detection (LOD), a value of LOD/sqrt(2) was applied.
Note: This table is showing the monitoring results for the current downstream ambient monitoring location TW05003153LE6001.

Recent ambient monitoring data for the secondary discharge waters, North Channel Great Island (2020-2022) is shown in the table below.

Table D.2.6 - Ambient Monitoring – Upstream of the Secondary Discharge Location at TW05003153LE6005 (Data Source: Uisce Éireann EDEN MDS Compliance Data Feb 2020 – Aug 2022)

Parameter	pH (pH Unit)	BOD (mg/l)	Ortho-phosphate (mg/l)	Total Ammonia (mg/l)	DO (%sat)	Temp (°C)
Number of Samples	20	2	20	20	20	20
Max result	0.082	2.6	0.036	0.082	134	19.5
Min result	7.9	1.8	0.00003	0.01	83	8.6
Average result	**8.1**	**2.2**	**0.01**	**0.05**	**107.6**	**15**
95%ile result		2.56			130.2	
*95%ile EQS as per S.I. No.288/2022 Good Status **		≤4.0	*≤ 0.060 (median)*		>70% **95%ile** <130%	
*95%ile EQS as per S.I. No.288/2022 High Status **		≤3.0	*≤ 0.030 (median)*		>80% **95%ile** <120%	
*Overall compliance with relevant **95%ile EQS Good Status** **		**Yes**	**Yes *(median)***		**No**	
*Overall compliance with relevant **95%ile EQS High Status** **		**Yes**	**Yes *(median)***		**No**	

*EQS under S.I. No. 288 of 2022. Mean Practical Salinity Unit (PSU) reading of 31.7 from measured Trac data Feb 2020 – Aug 2022
Note: Where the concentration in the result is less than the limit of detection (LOD), a value of LOD/sqrt(2) was applied

Table D.2.7 - Ambient Monitoring – Downstream of the Secondary Discharge Location at TW05003153LE6006 (Data Source: Uisce Éireann Compliance Data Feb 2020 – Aug 2022 at TW05003153LE6006)

Parameter	pH (pH Unit)	BOD (mg/l)	Ortho-phosphate (mg/l)	Total Ammonia (mg/l)	Total Oxidised Nitrogen (as N)(mg/l)	DO (%sat)	Temp (°C)
Number of Samples	21	20	19	21	21	21	21
Max result	8.3	3.3	0.057	0.094	0.027	120	19.5
Min result	7.9	0.7	0.00003	0.02	0.01	74.9	9.1
Average result	**8.1**	**1.26**	**0.02**	**0.05**	**0.13**	**104.9**	**14.6**
95%ile		**3.2**				**120**	
*95%ile EQS as per S.I. No. 288/2022 Good Status **		≤4.0	*≤ 0.060 (median)*			>70% **95%ile** <130%	
*95%ile EQS as per S.I. No. 288/2022 High Status **		≤3.0	*≤ 0.030 (median)*			>80% **95%ile** <120%	
*Overall compliance with relevant **95%ile EQS Good Status** **		**Yes**	**Yes *(median)***			**Yes**	
*Overall compliance with relevant **95%ile EQS High Status** **		**No**	**Yes *(median)***			**Yes**	

*****EQS under S.I. No. 288 of 2022

Note: Where the concentration in the result is less than the limit of detection (LOD), a value of LOD/sqrt(2) was applied

Based on UÉ Compliance Data from 2020 - 2022 at Station TW05003153LE6001, which is *ca.* 4.3km d/s of the proposed primary discharge location, the 95%ile concentration for BOD and Dissolved Oxygen (Sat%) were within the required EQSs for Good Status (95%ile). Dissolved Oxygen is meeting the required High Status EQS. The Compliance Data also shows that MRP is not within the required Mean EQS for Good Status.

Based on UÉ Compliance Data collected from TW05003153LE6005 *ca.* 0.9km u/s of the proposed secondary discharge, the 95%ile concentration for BOD was meeting the High Status EQSs (95%ile), the results were not within the required 95%ile Good EQS for Dissolved Oxygen (Sat%). MRP is within the required Mean EQS for High Status at this location.

The UÉ Compliance Data collected from at TW05003153LE6006 *ca.* 1km d/s show that the 95%ile concentration for BOD was within the required EQSs for Good Status (95%ile). Dissolved Oxygen (Sat%) is meeting the High Status EQS. The Compliance Data also shows that MRP is also within the required Mean EQS for High Status at this location.

Based on the UÉ Compliance Data for Feb 2020 – Aug 2022 available both upstream and downstream of the secondary discharge ambient monitoring location it is observed that the secondary discharge does not appear to be having an observable negative impact on the Water Framework Directive Status of the North Channel Great Island transitional waterbody.

There are no Fresh Water Pearl Mussel (FWPM) designated waterbodies in the vicinity of the operational discharges. There are also no designated Salmonid River Waterbodies upstream or downstream of the receiving waters.

The Tibbotstown_010 and the Owennacurra_040 Rivers are designated Drinking Water Abstraction Rivers. The Tibbotstown_010 discharges to the Lough Mahon (Harper's Island) and the Owennacurra_040 discharges to the Owennacurra Estuary. The drinking water abstraction points from the Tibbotstown and the Owennacurra Rivers are upstream of the operational discharges from the Midleton and Carrigtwohill WwTPs and do not pose a risk to drinking water supplies.

The Owennacurra Estuary / North Channel and Lee Estuary / Lough Mahon are designated as '*sensitive'* in accordance with the Urban Waste Water Treatment Directive (UWWTD) 91/271/EEC (as amended) on Urban Waste Water Treatment and S.I. No. 254 of 2001, S.I. No. 440 of 2004 and S.I. No. 48 of 2010. The primary discharge enters directly into the Lee Estuary / Lough Mahon Nutrient Sensitive Area. The secondary discharge enters directly into the Owennacurra Estuary / North Channel Nutrient Sensitive Area. For the Owennacurra Estuary / North Channel, N is the limiting nutrient and for the Lee Estuary / Lough Mahon, P is the limiting nutrient. Based on these designations, along with the fact that the p.e of the agglomeration is greater than 10,000, the existing TN ELV at Midleton WwTP of 15mg/l and the existing TP ELV of 1mg/l at Carrigtwohill WwTP are proposed to be maintained but as annual averages as detailed in **Section 1**.

The Primary Discharge from the Carrigtwohill WwTP (SW009) discharges directly to the Great Island Channel SAC and the Cork Harbour SPA. The Secondary Discharge (SW001) from Midleton WwTP discharges into the immediate zone of influence of the Great Island Channel Special Area of Conservation (SAC) and the Cork Harbour Special Protection Area (SPA).

The Great Island Channel SAC (Site Code: 001058) is protected for habitats and/or species listed in Annex I/II of the E.U. Habitats Directive, they include:

- [1140] Tidal Mudflats and Sandflats, and [1330] Atlantic Salt Meadows.

The Cork Harbour SPA (Site Code: 004030) is designated under the E.U. Birds Directive of special conservation interest.

The proposed primary discharge from Carrigtwohill WwTP discharges directly into the Great Island Channel pNHA. The pNHAs within the surrounding environment which have a hydrological connection to the primary discharge include:

- The Douglas River Estuary pNHA (Site Code: 001046) *ca.* 5.5km downstream;
- Monkstown Creek pNHA (Site Code: 001979) *ca.* 8km downstream;
- Lough Beg pNHA (Site Code: 001066) *ca.* 12km downstream;

- Cuskinny Marsh pNHA (Site Code: 001987) *ca.* 13km downstream;
- Whitegate Bay pNHA (Site Code: 001084) *ca.* 14km downstream.

The proposed secondary discharge from the Midleton WwTP discharges directly into the immediate zone of influence of Great Island Channel pNHA. The pNHAs within the surrounding environment which have a hydrological connection to the secondary discharge include:

- Rostellan Lough, Aghada Shore and Poulnabibe Inlet pNHA (Site Code: 001076) *ca.* 2.3km downstream;
- Cuskinny Marsh pNHA *ca.* 6.2km downstream;
- Whitegate Bay pNHA *ca.* 5.7km downstream;
- Lough Beg pNHA *ca.* 9.9km downstream;
- Monkstown Creek pNHA *ca.* 12km downstream;
- Owenboy River pNHA (Site Code: 001990) *ca.* 13km downstream.

Carrigtwohill WwTP primary discharge discharges *ca*. 2 km from the boundary of the Great Island North Channel designated shellfish waters, and *ca*. 8 km from the boundary of the Rostellan designated shellfish waters. The Midleton WwTP secondary discharge discharges *ca*. 1.5 km from the boundary of the Great Island North Channel designated shellfish waters, and *ca*. 3 km from the boundary of the Rostellan designated shellfish waters. Bacteria concentrations in Cork Harbour are generally low and predicted impacts from Uisce Éireann assets do not significantly impact water quality in the Designated Shellfish Waters.

Water Quality Modelling carried out in 2023 (see **Section 3** below), based on the latest available data, predicts that the effluent discharge standards proposed for the primary and secondary discharges are appropriate in terms of ensuring that the Carrigtwohill and Midleton WwTP do not impinge on the achievement of Good WFD Status of Lough Mahon (Harper's Island) or the North Channel Great Island by 2027 in accordance the European Communities Environmental Objectives (Surface Water) Regulations, 2009 (as amended), and thereby will ultimately ensure that there is no environmental risk posed to the receiving water environment.

Based on the information contained in this WWDA application, including the Water Quality Modelling, WFD Screening Assessment Report, the combined AA Screening and NIS, and EIAR and the measures/recommendations contained therein, it can be concluded that the operational discharges from the amalgamated agglomeration will not cause a deterioration in the overall water quality of the receiving 6 no. waterbodies, namely, Lough Mahon (Harper's Island), North Channel Great Island, Owennacurra Estuary, Owennacurra_040, Dungourney_020, the Tibbotstown_010, and will not compromise the achievement of the objectives and EQSs established for the relevant Designated sites (*e.g*., European sites, Shellfish Waters), within the operational discharges zone of influence.

3. Water Quality Modelling

The aim of the marine model is to demonstrate that the proposed Emission Limit Values for the amalgamated Midleton and Carrigtwohill agglomerations are compatible with the achievement of the WFD objectives and will not cause any untoward impact on designated sites.

A baseline case was modelled for the period 2019-2021, to inform a validation exercise, comparing modelled output to monitoring data for the baseline period. This model has been used to evaluate two scenarios.

- The proposed Future Scenario: Summer & Winter conditions: future average flow (DWF *1.25), ELV (BOD) and assumed winter/summer nutrient concentrations.

- A Future '*Notionally Clean'* River Scenario[1] that retains the future discharge from the outfall but removes all other asset discharges and inputs a calculated natural contributing concentration for all river discharges under summer and winter conditions to allow comparison of modelled water quality.

The simulations considered the following:

- Deterministic assessments of the mixing zone of Uisce Éireann discharges in terms of key WFD parameters of biochemical oxygen demand (BOD), dissolved inorganic nitrogen (DIN) and orthophosphate (as molybdate reactive phosphorus (MRP)) against Environmental Quality Standard (EQS), and to determine compatibility with the achievement of Conservation Objectives of the Protected Areas.
- Trophic assessments of the impact of DIN and MRP over the wider Cork Harbour Waterbody, particularly Nutrient Sensitive Waters, against relevant WFD standards in each WFD Waterbody within Cork Harbour.
- Microbiological impacts on Bathing Waters (BW) and Designated Shellfish Waters (SFW) in Cork Harbour.

A summary of the modelled discharges from Carrigtwohill and Midleton under the scenarios considered are presented in **Tables D.2.8 and D.2.9** below.

Table D.2.8 - Flow and Effluent Quality for Midleton discharges simulated in each scenario

Scenario	Flow (m^3/s)	BOD (mg/l)	Ammonia (mg/l)	TON (mg/l)	DIN (mg/l)	MRP (mg/l)
Future Condition WINTER	0.109	25.0	1.1	8.76	9.90	2.0
Future Condition SUMMER	0.084	25.0	1.3	5.60	6.9	2.0
Notionally Clean Future Condition WINTER	0.109	25.0	1.1	8.76	9.90	2.0
Notionally Clean Future Condition SUMMER	0.084	25.0	1.3	5.60	6.9	2.0

[1] A baseline scenario simulating baseline DIN and MRP dynamics was also prepared and is presented in the report

Table D.2.9 - Flow and Effluent Quality for Carrigtwohill discharge simulated in each scenario

Scenario	Flow (m^3/s)	BOD (mg/l)	Ammonia (mg/l)	TON (mg/l)	DIN (mg/l)	MRP (mg/l)
Future Condition WINTER	0.106	25.0	5.0	20.0	25.0	0.6
Future Condition SUMMER	0.077	25.0	5.0	20.0	25.0	0.6
Notionally Clean Future Condition WINTER	0.106	25.0	5.0	20.0	25.0	0.6
Notionally Clean Future Condition SUMMER	0.077	25.0	5.0	20.0	25.0	0.6

As discussed in **Section 1**, it is proposed that the ELVs for TP and TN are annual mean ELVs, in accordance with the UWWTD 91/271/EEC (as amended) on Urban Waste Water Treatment and S.I. No. 254 of 2001, S.I. No. 440 of 2004 and S.I. No. 48 of 2010: For parameters Total Phosphorus and Total Nitrogen the annual mean of the samples shall not exceed the emission limit value.

Furthermore, as referred to in Section 1, UÉ are proposing the Agency to include for a 12°C temperature condition for the annual mean TN ELV of 15mg/l because of the critical dependency of temperature on nitrification. See attached a Design Note prepared by Professor Tom Casey (2015).

This is in accordance with Footnote 3 of Part 2 of the Second Schedule of S.I. No. 440 of 2004 which states:

"These values for concentration[TN] are annual means as referred to in paragraph 4 (c) of the Fifth Schedule. However, the requirements for nitrogen may be checked using daily averages when it is proven, in accordance with paragraph 1 of that Schedule, that the same level of protection is obtained. In this case, the daily average must not exceed 20 mg/l of total nitrogen for all the samples when the temperature of the effluent in the biological reactor is superior or equal to 12°C. The conditions concerning temperature can be replaced by a limitation on the time of operation to take account of regional climatic conditions."

The predictions of the Future Scenario indicate that the water quality impacts from Midleton WwTP are minimal (no significant mixing zone simulated to occur for any of the parameters considered) and will not cause a deterioration in the overall WFD body Status. This is primarily due to the high assimilative capacity in the receiving waters.

The predictions of the Future Scenario indicate that the water quality impacts from Carrigtwohill WwTP are minimal with respect to BOD (no significant mixing zone simulated to occur) [**Modelling Report Figure 3-9, 3-5**]. Elevated concentrations for DIN (**Modelling Report Figure 3-21, 3-25**) and MRP (**Modelling Report Figure 3-37, 3-41)** were simulated as occurring around the Carrigtwohill WwTP discharge in the Future Scenario, however at a waterbody scale the modelling results show no impacts on overall WFD Status.

A baseline scenario, simulating the impact of concentrations and volumes discharged currently, is also presented in the modelling report for context (**Modelling Report Appendix A**). These plots show that, while there are elevated concentrations simulated around the Carrigtwohill discharge point, DIN and MRP concentrations vary minimally between the Baseline and Future scenarios despite the increased load.

A Future '*Notionally Clean'* River scenario provides further insight into the potential impacts of the Future Scenario on the Trophic Status in Lough Mahon and the mixing zone around Harper's Island. The key conclusions from review of model outputs simulating this scenario are:

- DIN: Outside of the mixing zone with a maximum longitudinal extent of approx. 800m in winter and 1,200m in summer, Good or High indicative quality for DIN is achieved around the Carrigtwohill discharge (**Modelling Report Figure 3-29, 3-33)**.
- MRP: Outside of a mixing zone with a maximum longitudinal extent of approx. 600m which is present in summer scenario only, Good or High indicative quality is achieved around the Carrigtwohill discharge. There is no mixing zone under this scenario for winter. **(Modelling Report Figure 3-49, 3-45)**.

The predictions of the '*Notionally Clean'* River scenario indicate that the inputting rivers are significant contributors to nutrient water quality impacts; overall concentrations of DIN and MRP decrease significantly, and the indicative quality across Cork Harbour significantly improves, as compared to the Future Scenario. This confirms that both Midleton and Carrigtwohill WwTP discharges represent a small percentage of the overall contribution to the receiving waters. The modelling results show that the discharges from the amalgamated agglomeration will not impact the WFD Status of Lough Mahon (Harper's Island) or North Channel Great Island and do not impede the WFD objectives set out for the receiving waterbodies being met by 2027.

Bacteria concentrations in Cork Harbour are generally low and predicted impacts from Uisce Éireann assets and Industrial discharges do not significantly impact water quality in the Designated Shellfish Waters (SFWs) and Bathing Waters (BW).

Refer to **Attachment D.2.3** for a copy of Water Quality Modelling Report (July 2023).

4. Appropriate Assessment

A combined Appropriate Assessment (AA) Screening and Natura Impact Statement (NIS) Report was prepared in June 2023 to accompany this WWDL review application. The Report will enable the EPA, as the Competent Authority, to conduct an AA Screening Determination and Stage 2 AA in respect of the Midleton and Carrigtwohill agglomeration operational discharges, for the purposes of the European Union (Waste Water Discharge) Regulations 2007 to 2020.

The AA Screening of the operational discharges assessed whether the discharge activity, alone or in combination with other plans and projects, is likely to have significant effects on a European Site(s) in view of best scientific knowledge and the conservation objectives of the site(s). Based on the information set out in the AA Screening, and the documentation referenced therein, it was concluded that the likelihood of significant effects to the Great Island Channel SAC and the Cork Harbour SPA cannot be excluded, and a Stage Two AA was therefore provided.

The NIS was prepared following the EPA (2009) '*Note on Appropriate Assessments for the purposes of the Waste Water Discharge (Authorisation) Regulations, 2007 (S.I. No. 684 of 2007)*'. The Department of the Environment, Heritage and Local Government guidance

'*Appropriate Assessment of Plans and Projects in Ireland. Guidance for Planning Authorities'* (DoEHLG, 2009) was also taken into account.

The NIS has concluded, upon the implementation of proposed measures/recommendations, that the operational discharges from the Midleton and Carrigtwohill agglomeration will not prevent the achievement of the conservation objectives of the qualifying interests of the Great Island Channel SAC and the Cork Harbour SPA or any other European Site, in view of these site's conservation objectives and that the Conservation Status of the Annex I habitats, or Annex I bird species, will not be compromised by the agglomeration discharges either directly, indirectly or cumulatively.

It is therefore concluded that the Midleton and Carrigtwohill agglomeration operational discharges, alone or in-combination with other plans and / or projects will not give rise to adverse effects on the integrity of Great Island Channel SAC, Cork Harbour SPA, or any other European Site.

This combined AA Screening and NIS will enable the EPA, as the Competent Authority, to formally conduct an AA Screening and AA in respect of the Midleton and Carrigtwohill agglomeration operational discharges, for the purposes of the European Union (Waste Water Discharge) Regulations 2007 to 2020.

Please refer to **Attachment D.2.2** for a copy the AA Screening and NIS Report (June 2023) prepared to inform this WWDL review process.

5. Environmental Impact Assessment

This WWDA application review for Midleton (D0056-01) is for a WwTP with a capacity of greater than 10,000 p.e. as defined in Article 2, point (6), of the Urban Waste Water Treatment Directive (*i.e,* 48,750 p.e. which is a combination of the design p.e's for Carrigtwohill and Midleton WwTP, and Industrial Emission (IE) discharges downstream of Midleton WwTP.). Therefore, a mandatory EIA, and the preparation of an Environmental Impact Assessment Report (EIAR) is required to inform the WWDA process.

The EIAR includes an assessment of the operational discharges from the agglomeration to the receiving waterbodies.

The approach adopted in this impact assessment, and the overall preparation of the EIAR, was based on the recommendations in the Guidelines on information to be contained in Environmental Impact Assessment Reports (EPA, 2022) and is in line with the EIA Directive 2014/52/EU, and indeed takes account of all current ad relevant guidance documents published at the time of preparing the EIAR. Due regard has also been taken of the scoping responses received from the EIA Scoping Process.

The EIAR has concluded that the Midleton and Carrigtwohill agglomeration operational discharges would not be likely to have significant effects on the environment once the measures as proposed therein are implemented in full.

This EIAR will enable the EPA, as the Competent Authority to conduct an EIA in respect of the Midleton and Carrigtwohill agglomeration operational discharges, for the purposes of the European Union (Waste Water Discharge) Regulations 2007 to 2020.

Please refer to **Attachment B.5** for a copy the Environmental impact Assessment Report (July 2023) prepared to inform this WWDL review process.

6. Priority Substance Assessment Report

An assessment of the potential for impacts on receiving waters from priority substances in the *primary discharge* from Carrigtwohill WwTP has been carried out. The assessment considers the primary discharge relevant to Environmental Quality Standards (EQS) for priority substances in surface waters, as set out in the European Communities Environmental Objectives (Surface Waters) Regulations 2009, as amended. Based on the estimated data from the UÉ UWW PRTR Electronic Toolset, all parameters apart from one (*i.e.,* Benzo[a]pyrene) were identified as being lower than the required EQS, after dilution. Carrigtwohill is included on the UÉ Dangerous Substance Programme for 2023, where sampling and analysis is scheduled. Benzo[a]pyrene is included on this sampling plan.

An assessment of the potential for impacts on receiving waters from priority substances in the *secondary discharge* from Midleton WwTP has also been carried in line with the methodology as detailed above. This desktop assessment concluded that after dilution none of the substances listed in the Specific Pollutants, Priority and Priority Hazardous Substances as outlined in the Surface Water Regulations, are likely to be present in the effluent discharge to North Channel Great Island, at concentrations above the specified standards as per European Communities Environmental Objectives (Surface Waters) Regulations 2009, as amended.

Refer to **Attachment D.2.4** for a copy of the Priority Substance Assessment Report (May 2023).

7. Shellfish Waters

Carrigtwohill WwTP primary discharge discharges *ca*. 2 km from the boundary of the Great Island North Channel designated shellfish waters, and *ca*. 8 km from the boundary of the Rostellan designated shellfish waters.

The Midleton WwTP primary discharge discharges *ca*. 1.5 km from the boundary of the Great Island North Channel designated shellfish waters, and *ca*. 3 km from the boundary of the Rostellan designated shellfish waters.

The Water Quality Modelling prepared concludes that bacteria concentrations in Cork Harbour are generally low and predicted impacts from Uisce Éireann assets and Industrial discharges do not significantly impact water quality in the Designated Shellfish Waters.

Please refer to **Attachment D.2.3**, Water Quality Modelling Report (July, 2023), for further details.

8. Bathing Waters

There are no designated bathing waters located downstream in the vicinity of the discharges.

9. Combined Approach

The Waste Water Discharge Authorisation under the European Union (Waste Water Discharge) Regulations 2007 to 2020, specify that a '*combined approach'* in relation to licensing of waste water works must be taken, whereby the emission limits for the discharge are established on the basis of the stricter of either or both, the limits and controls required under the Urban Waste Water Treatment Regulations, 2001, as amended, and the limits determined under statute or Directive for the purpose of achieving the environmental objectives established for surface waters, groundwater or protected areas for the water body into which the discharge is made.

The design p.e. of both Carrigtwohill and Midleton WwTP is greater than 15,000 p.e (Carrigtwohill 30,000, Midleton 15,000) and is therefore in line with Article 4 of the directive, "*Member States shall ensure that urban waste water entering a collecting system shall before discharge be subject to secondary treatment or an equivalent treatment for all discharges from agglomerations of more than 15,000 p.e*". The existing Carrigtwohill WwTP provides tertiary treatment, with N & P removal. The existing Midleton WwTP provides tertiary treatment *via* disinfection of the final effluent, with N removal.

As described in **Section 2,** the receiving waters of the primary discharge and secondary discharge are designated "*Nutrient Sensitive Areas*" under Article 5 of the Urban Treatment Regulations 2001 (as amended). The primary discharge (SW009) discharges into the Owennacurra Estuary / North Channel which is designed as nutrient sensitive for Nitrogen. The secondary discharge (SW001) discharges into Lough Mahon (Harper's Island) and is designated as nutrient sensitive for Phosphorus. In accordance with Article 5 of the directive "*Member States shall ensure that urban waste water entering collecting systems shall before discharge into sensitive areas be subject to more stringent treatment than that described in Article 4, by 31 December 1998 at the latest for all discharges from agglomerations of more than 10000p.e*". Both Carrigtwohill and Midleton WwTP provide treatment and meets the requirements of Article 5 of the Directive.

Table D.2.1 – D.2.3 presents the proposed ELVs and the annual mean ELVs for TP of 1 mg/l at Carrigtwohill and TN ELV of 15mg/l at Midleton which are in line with the combined approach as defined above.

In summary, the proposed ELVs give effect to the principle of the Combined Approach as defined in European Union (Waste Water Discharge) Regulations, 2007 to 2020 in that they accommodate the Urban Waste Water Regulations and the relevant status / designations of the receiving waterbodies, Lough Mahon (Harper's Island) and North Channel Great Island. Based on the modelling undertaken, the proposed primary and secondary discharge is likely to be compatible with the achievement of WFD objectives for Lough Mahon (Harper's Island) and North Channel Great Island, on the basis of the contributing impact from WwTP's and Industrial discharges. In summary, based on the modelling, the proposed discharges do not preclude the achievement of '*Good'* water quality in the receiving waterbodies.

10. Compliance with Relevant National or EU Legislation

The proposed effluent standards for the primary and secondary discharges, and the operation of the agglomeration overflows as set out in this review (which includes the Midleton Waste Water Network Project to upgrade non-compliant overflows by Q4 2029), will ensure that the operational discharges from the agglomeration do not impede (i) the achievement of Lough Mahon (Harper's Island), North Channel Great Island, Owennacurra Estuary, Owennacurra_040 and the Dungourney_020 waterbodies attaining Good Status by 2027 (ii) maintaining the Good WFD Status of the Tibbotstown_010 waterbody and (iii) ensuring that there is no environmental risk posed to the receiving water environment and its associated designations as a result of the discharges from the agglomeration.

As detailed in **Attachment B.6**, the discharge activities within the amalgamated agglomeration will operate in compliance with EU and National Regulations.

For further details refer also to **Attachment B.5** for a copy of the Environmental Impact Assessment Report (July 2023) and Water Framework Directive Screening Assessment (July 2023)**, Attachment D.2.2** for a copy of the AA Screening and NIS (July 2023),

Attachment D.2.3 for the Water Quality Modelling Report (July 2023), and **Attachment D.2.4**. for the Priority Substance Assessment Report (May 2023).

11. Data Sources

The following data sources were used to complete this application.

- Online data available on held by the NPWS, the EPA, NIEA and Uisce Éireann:
    - www.npws.ie
    - epawebapp.epa.ie
    - gis.epa.ie/EPAMaps
    - catchments.ie
- GIS data for European site boundaries obtained in digital format online from European Environmental Agency
- Uisce Éireann / Cork County Council Monitoring & Sampling Data

12. Cumulative and In Combination Effects

The combined AA Screening and NIS Report (June 2023), and the EIAR (June 2023) address cumulative and in-combination effects.

Refer to **Attachment B.5** for a copy of the EIAR. Refer to **Attachment D.2.2** for a copy of the AA Screening and NIS Report.

13. Mixing zone or transitional areas of exceedance

Modelling undertaken in July 2023 estimates the dilution within the immediate proximity of the discharge points of the receiving waters from the primary and secondary discharges to be *ca.* 2.9 summer and 5.6 winter dilutions at SW009 Carrigtwohill, and *ca.* 46 summer and 46.6 winter dilutions at SW001 Midleton.

When referring to the impacts from the primary (SW001) and secondary (SW009) discharges, the Water Quality Modelling Report (2023) employs the term '*mixing zone*' when referring to a plume discharging into an area where an EQS is applicable and defines the zone within which the relevant EQS may is exceeded.

Under the Future Scenario, results from the modelling of BOD (**Modelling Report Figure 3-4, 3-8**) show at the Midleton discharge there is no discernible mixing zone as the EQS value is met immediately at the surface with concentrations (~1 mg/l) around the discharge.

At the Carrigtwohill discharge, by virtue of its location, the same level of dilution is not achieved. There is a clearly defined BOD mixing zone of *ca.* 200m in length and *ca.* 100m in width in the immediate vicinity of the Carrigtwohill WwTP outfall. Under the Future Notionally Clean River Scenario, the DIN mixing zones are of *ca.* 26ha and 23ha in summer and winter respectively, are predicted around the Carrigtwohill outfall (with Good Status achieved within the rest of the waterbody) **[Modelling Report Figure 3-29 & 3-33].**

Under the Future Notionally Clean River Scenario for MRP, Good status is attained throughout the channel under winter conditions, while a mixing zone of *ca.* 14ha is predicted around the Carrigtwohill outfall in summer (with Good Status achieved within the rest of the waterbody) **[Modelling Report Figure 3-45 & 3-49].**

14. Dilutions and retention times for lakes

Not applicable. No discharges to lakes.

15. The impact of the discharges on any environmental media other than those into which the emissions are to be made

Not applicable. No other relevant media into which the emissions are to be made.

16. Groundwater Details

Not applicable. No discharge to ground waters.

17. High Status Waterbodies

Not applicable. No High Status waterbodies within the region of the Midleton and Carrigtwohill WwTP and/or the operational discharges.

18. Fresh Water Pearl Mussels

There are no Designated Freshwater Pearl Mussel (FWPM) Waterbodies downstream of the primary discharge from the Carrigtwohill WwTP or the secondary discharge from the Midleton WwTP.

19. Impacts on Transboundary / Territory of other States

The operational discharges to which this application relates will not result in transboundary impacts or impacts on the territory of other states.

20. For waste water treatment plants with coastal discharges, provide evidence that the end of the discharge pipe is below the mean spring tide low water line

Not applicable. Discharge is not to a coastal waterbody.

Design Note

Urban Wastewater Treatment

Selection of a Process Design Temperature for N-Removal

Tom Casey, 2015

Design Note
Urban Wastewater Treatment
Selection of a process design temperature for N-removal

INTRODUCTION

The selection of a process design temperature is of particular significance for urban wastewater treatment installations that discharge treated effluents to sensitive waters and hence have to meet specified low effluent limit values (ELV) for nitrogen (N) and/or phosphorus (P). N-removal is carried out by a temperature-dependent biological process. Hence, the rate of removal reduces considerably as the wastewater temperature falls over the winter period. Under Irish climatic conditions urban wastewater temperature may typically vary from a low of 6°C in winter to a high of 20+ °C in summer. This note presents a review of the factors that influence selection of a process design temperature to meet a specified ELV for N that is invariably specified as an annual mean value with attached conditionality in relation to the magnitude and frequency of exceedence. This design note examines the impact of such conditionality on process design, including environmental and economic considerations.

NITROGEN EFFLUENT LIMIT VALUE SPECIFICATION

The Environmental Protection Agency (EPA) is the responsible body for the issue of Licences that specify ELVs for Irish urban wastewater treatment plants (WWTP). ELVs must be compliant with the Urban Wastewater Treatment Regulations (UWTR), 2001(SI 254) that give effect in Ireland to the EU Water Framework Directive provisions relating to urban wastewater treatment. The UWTR document specifies the following nitrogen limits for discharges from urban wastewater treatments plants to sensitive water bodies, stating that the values for concentration ***or*** for the percentage reduction shall apply.

Works size (PE)	Effluent TKN (mg/l)	Min % reduction
10,000 – 100,000 PE	15	70-80
>100,000 PE	10	70-80

Where the effluent standard is specified in % TKN removal terms, it has to be converted to an effluent concentration value to define a treatment process design target value. The relation of % TKN reduction to effluent TKN concentration value is a function of the influent TKN concentration and the average daily wastewater discharge. The TKN component of urban wastewater is generally within the range 9-12 g/PE.d, while the average urban wastewater volume is typically within the range 150-250 l/PE.d. The relative magnitudes of the alternative ELV specifications for TKN are illustrated graphically in Fig 1.

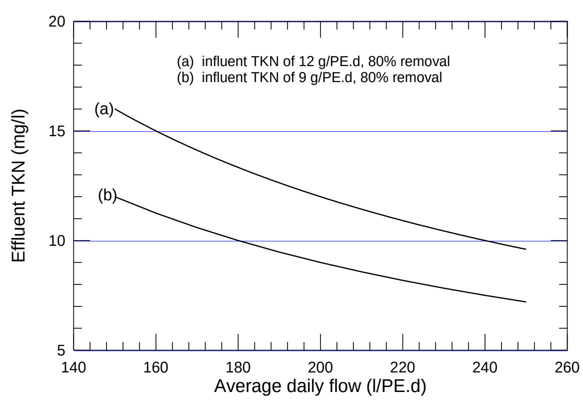

Fig 1 **Relation of % TKN removal to effluent TKN concentration**

The foregoing effluent TKN limit values relate to annual averages, based on 24h composite sampling. It is specified that samples be taken at regular intervals throughout the year, the specified required minimum sample number depending on the size of the treatment plant.

It is noteworthy in the context of this process design note that the UWTR makes allowance for the negative impact of low influent wastewater temperature on nitrogen removal, stating that, subject to specified monitoring conditions, the daily average must not exceed 20 mg/l of total nitrogen when the temperature of the effluent in the biological reactor is superior or equal to 12 °C.

NITROGEN REMOVAL KINETICS

The enhanced biochemical removal of nitrogen from wastewaters is carried out in two distinct process stages. The first stage is the process of *nitrification*, or the conversion of ammonia to nitrate, and the second stage is *denitrification*, or the reduction of nitrate to gaseous nitrogen end-products.

Nitrification

Microbial nitrification is a two-step process, the first step being the conversion of ammonia to nitrite, which is accomplished by *Nitrosomonas* bacteria, while the second step involves the conversion of nitrite to nitrate by *Nitrobacter* bacteria. The overall chemical oxidation reaction is:

$$NH_4^+ + 2O_2 \rightarrow NO_3^- + 2H^+ + H_2O \qquad (1)$$

The nitrifying bacteria are chemoautotrophs; their growth energy is derived from the oxidation of inorganic nitrogen and their sole carbon source is carbon dioxide.

The growth rate of nitrifiers is estimated to be some 10-20 times slower than the growth rate of heterotrophs which are responsible for carbonaceous BOD removal. Of the two species responsible for nitrification, *Nitrobacter* has a higher growth rate than *Nitrosomonas* in the prevailing Irish wastewater temperature range, i.e. ≤ 20 °C. The growth of the latter, which is responsible for the conversion of ammonia to nitrite, is thus normally rate-limiting for the nitrification process. It also follows from this that nitrite is not usually found in high concentrations in nitrifying processes operating under steady state conditions.

The net growth rate of the nitrifying microbial biomass X_N (mg l^{-1}) in a completely mixed reactor can be expressed as follows:

$$\frac{dX_N}{dt} = \mu X_N - k_d X_N \text{ mg l}^{-1}\text{ d}^{-1} \qquad (2)$$

Where μ is the specific growth rate coefficient (d^{-1}) and k_d is the decay coefficient (d^{-1}). According to the Monod growth model, the dependence of the specific growth rate coefficient on substrate concentration is expressed as follows:

$$\mu_N = \hat{\mu}_N \frac{N}{K_N + N} \qquad (3)$$

where
- μ_N = specific growth rate of *Nitrosomonas* (d^{-1})
- $\hat{\mu}_N$ = maximum specific growth rate of *Nitrosomonas* (d^{-1})
- K_N = half-saturation coefficient for *Nitrosomonas* (mg l^{-1} NH_4^+-N)
- N = NH_4^+-N concentration (mg l^{-1})

For design purposes, the value of K_N may be taken to be of the order of 0.5 mg $NH4^+$-N l^{-1}, while the value of the maximum specific growth rate constant is dependent on temperature and may be represented by the following empirical Arrhenius-type expression (USEPA, 1993):

$$\hat{\mu}_N = 0.47\theta^{(T-15)} \qquad (4)$$

where θ is generally taken to have a value of about 1.12.

Because of the relatively low value of K_N, the nitrification process proceeds, under typical wastewater treatment conditions, at the maximum growth rate for the *Nitrosomonas* bacteria, i.e. it is a zero-order process, independent of the ammonia concentration. If, however, the ammonia nitrogen concentration drops close to the half saturation constant level of 0.5 mg l^{-1}, then the process becomes rate-limited by the reduced concentration according to equation (2).

The microbial decay rate is similarly temperature-dependent with a decay rate constant k_d, which is empirically quantified as follows:

$$k_d = 0.033\ F_d^{(T-15)} \qquad (5)$$

where F_d is found to have a value of about 1.04.

The accumulation of nitrifying bacteria in a biological reactor is a function of the difference between the growth and decay rates and the microbial solids residence time in the reactor or so-called sludge age (SA). Using the foregoing parametric values and correlations, the calculated steady state NH_4^+-N in a completely mixed activated sludge aeration basin, is plotted in Fig 2 as a function of SA for a set of process temperatures in the range 5-20 ^oC. The model plots illustrate two key features of the nitrification process, namely (a) for a given process temperature the nitrification process fails below a particular minimum SA value, as reflected by a rapid rise in the NH_4^+-N concentration, and (b) the minimum SA for a stable nitrification process is very sensitive to process temperature, to which it bears an inverse relation.

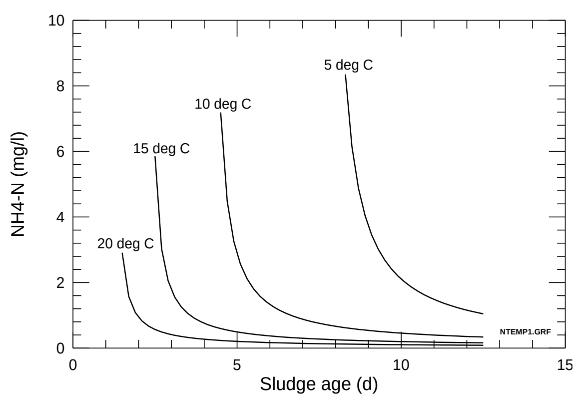

Fig 2 Influence of process temperature and SA on nitrification

While the primary focus of this design note is on process temperature, it is important to note that nitrification is also influenced by other environmental factors, including the dissolved oxygen (DO) concentration and process pH (nitrification exerts a substantial alkalinity demand). There is also the risk that the growth of nitrifying bacteria may be adversely affected by inhibitory constituents in the wastewater being treated.

Denitrification

The microbial reduction of nitrate to gaseous nitrogen is brought about by a variety of oxygen-utilising facultative heterotrophic bacteria which, in the absence of oxygen, are capable of using nitrate in place of oxygen as a terminal electron acceptor. Research has shown that anoxic respiration of this kind may also take place at low DO concentration. The DO concentration at which denitrification stops has been reported to be 0.2 mg l^{-1} in pure cultures (Focht and Chang, 1975) and in activated sludge systems to be in the range 0.3-1.5 mg l^{-1} (Burdick at al., 1982). If oxygen is present, it is preferentially used over nitrate.

The rate of growth of the heterotrophic denitrifying organisms can be quantified by Monod-type kinetics as outlined above for the autotrophic nitrifying organisms, the key rate-controlling substrate being biodegradable carbon, conventionally quantified as BOD or COD. The denitrification process may be regarded as an effectively zero order process in respect of nitrate concentration, the rate of nitrate reduction being independent of concentration when the nitrate concentration is above about 0.5 mg N l^{-1}.

However, as not all activated sludge bacteria are facultative, the rate of BOD removal in an anoxic environment is likely to be lower than in an aerobic environment, under similar environmental conditions. It has been observed (Barnard, 1975) that the rate of denitrification is influenced by substrate composition, proceeding rapidly in the presence of easily assimilated carbon sources such as volatile fatty acids and more slowly when respiration relates to the assimilation of particulate and more complex organic compounds.

Denitrification reduces the aeration requirements of the associated aerobic process, 1 g of NO_3-N having the respiratory equivalence of 2.86 g O_2.

As with all biological processes, denitrification is significantly influenced by temperature. The magnitude of this influence can be expressed by an Arrhenius-type function of the form:

$$\mu_D = \mu_{D(20)}\theta^{(T-20)} \qquad (7)$$

where μ_D is the specific growth rate for the denitrifying microbial biomass (d^{-1}), $\mu_{D(20)}$ is its value at 20 ^oC; the value of θ lies within the range 1.02-1.08 (USEPA, 1993). At a θ value of 1.05, the mean of the range, the growth rate at 10 ^oC is calculated to be 61% of its rate at 20 ^oC.

As well as being influenced by temperature, process denitrification capacity is a function of (a) the availability of biodegradable carbon, and (b) the anoxic sludge age. The availability of biodegradable carbon is a key determinant of denitrification capacity. Empirical evidence from municipal wastewater treatment practice (Schlegel, 1987) indicates denitrification capacity may not be expected to exceed 0.15 kg NO_3^--N per kg influent BOD_5. The required anoxic sludge age is discussed in the following section.

In general, the denitrification process is much less sensitive to inhibitory substances than is the nitrification process. Experimental findings indicate that denitrification rates may be depressed below pH 6 and above pH 8.

Combined nitrification and denitrification processes

The nitrogen content of urban wastewaters is invariably in ammoniacal and organically-bound forms. Hence, its removal requires a combination of nitrification and denitrification processes. It is clear from the foregoing discussion that nitrification and denitrification processes have conflicting environmental requirements. Nitrification requires a highly aerobic environment with a sufficiently long microbial residence time or sludge age to allow the development of a sufficiently high concentration of the slow-growing nitrifying bacteria, Nitrosomonas and Nitrobacter. These conditions result in a very low biodegradable carbon substrate level in nitrifying reactors. Denitrification, on the other hand, requires an anoxic environment and the availability of an ample biodegradable carbon substrate concentration. These conflicting process environments require the compartmentalisation of activated sludge reactors designed for enhanced nitrogen removal. Such compartmentalisation can be achieved by either (a) providing physically separated aerobic and anoxic cells with appropriate inter-cell recycle transfer (Barnard, 1973) or (b) spatial separation of anoxic and aerobic zones achieved by a combination of localised oxygen input and reactor geometry, as exemplified by reactors of the carrousel type.

The sludge age (SA) for such reactors is the total sludge mass in the reactor (anoxic + aerobic) divided by the sludge wasting rate. The effective sludge age for nitrification is $SA\frac{V_A}{V_R}$, where V_A is the volume of the aerobic zone and V_R is the overall reactor volume, while the effective sludge age for denitrification is $SA\left(1-\frac{V_A}{V_R}\right)$.

As outlined above, both nitrification and denitrification rates decrease with falling temperature. Of the two, nitrification is the more critical process as without nitrification enhanced nitrogen removal is not possible. Hence, the logical design approach is to select an aerobic design SA to meet the selected minimum design temperature for nitrification while optimising the complementary denitrification process for this temperature. The selected design temperature must ensure that the specified nitrogen ELV regime can be achieved over the influent wastewater temperature range. The latter is reviewed in the following section.

WASTEWATER TEMPERATURE

The degree to which the temperature of urban wastewater differs from that of the water supply from which it is derived is influenced by number of factors, including storage time within buildings, hot water use, residence time in the sewerage system, surface water ingress to the sewerage system, the contact air temperature.

Recorded wastewater temperature data at five Irish WwTWs are plotted in Figs 3 to 7, inclusive. Two of these are very large works, namely the Ringsend WwTW (Fig 3) serving Dublin City and its environs and Carrigrennan WwTW (Fig 4), serving Cork city and its environs. The other three, namely Sligo WwTW (Fig 5), Portlaoise WwTW (Fig 6) and Castlebar WwTW (Fig 7) are medium size installations.

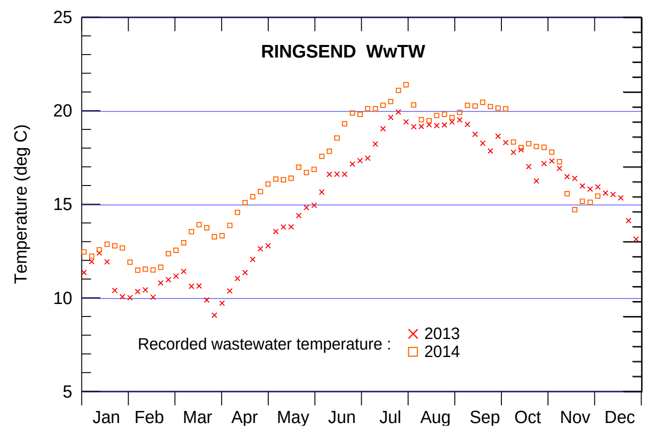

Fig 3 **Annual wastewater temperature variation**

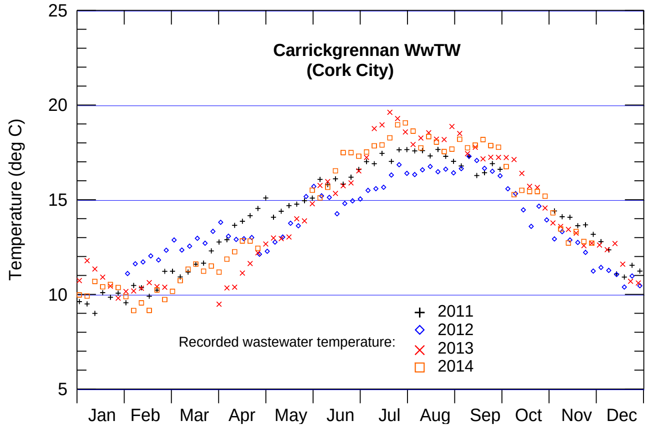

Fig 4 **Annual wastewater temperature variation**

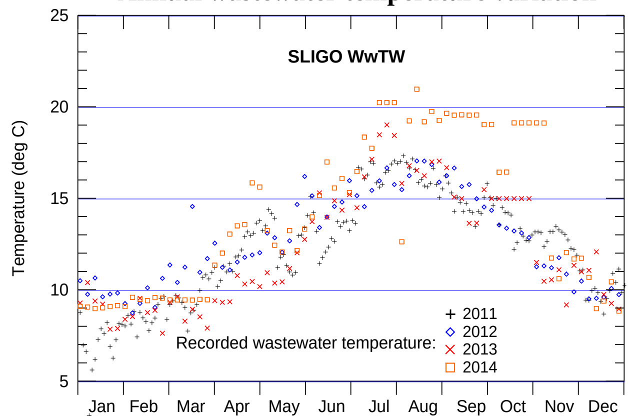

Fig 5 **Annual wastewater temperature variation**

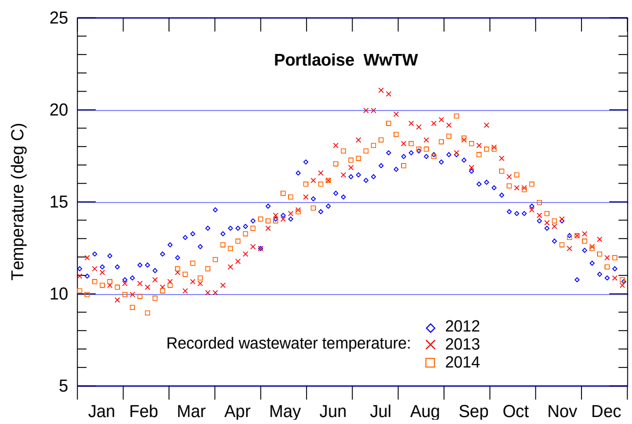

Fig 6 **Annual wastewater temperature variation**

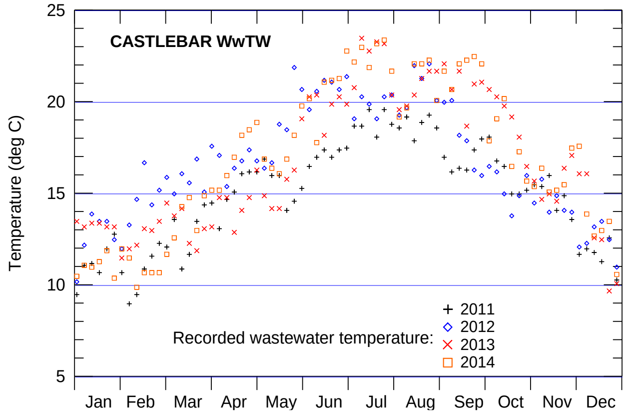

Fig 7 **Annual wastewater temperature variation**

The foregoing recorded wastewater temperature data indicate a normal annual temperature span ranging from a low of about 6 °C in winter time to a high of about 20 °C in summertime with the in-between temperature profiles reflecting Irish climatic conditions.

The magnitude and duration of low wastewater temperature is of special interest in relation to process design for enhanced nitrogen removal. As might be expected, the data indicate that duration of low wastewater temperature typically prevails from December to March, inclusive. The Ringsend, Carrigrennan, Portlaoise and Castlebar data show the prevailing low temperature in wintertime to be marginally below 10 °C, while the Sligo data indicate a prevailing low wintertime temperature in the range 6-10 °C. As will be clear from the previous discussion on nitrogen removal process kinetics such a temperature difference has a significant influence on process design.

PROCESS DESIGN

The primary goal of the process designer is reliable delivery of an effluent quality that satisfies the quality criteria set out in the WwTW discharge licence, using the most efficient available technology. In relation to meeting the ELV for nitrogen, where the discharge is to sensitive water body, biological process design requires the adoption of a lower limit process design temperature at which the required nitrogen ELV can be achieved. Where the licence simply specifies ELV compliance based on the average annual concentration, as required by SI 254, the process design can take advantage of the annual wastewater temperature profile rather than base process design on winter conditions. However, where the licence attaches exceedence conditionality to the annual average ELV for N, without reference to the prevailing wastewater temperature, the designer is obliged to reduce the process design temperature, resulting in increased capital and operating costs.

In this regard it is noted that in specifying the nitrogen ELV for discharge to sensitive waters as an annual average value rather than an individual limit value, the EU Urban Wastewater Directive is taking into account both the influence of wastewater temperature on process performance and the target environmental benefit to the receiving water. The latter dividend is at its lowest in winter time when receiving water temperatures are low. The typical annual variation in Irish river/lake water is illustrated in Fig 8, which shows recorded temperature data for six Irish rivers and also the average monthly air temperature at Mullingar weather station for the period 1971-2000. The latter provides a useful guide to the annual temperature variation in Irish rivers/lakes, which, as the plotted show, roughly fits within the upper quartile of the average monthly air temperature. The data indicate Irish receiving water temperature to be predominantly in the range 5-10 °C in wintertime.

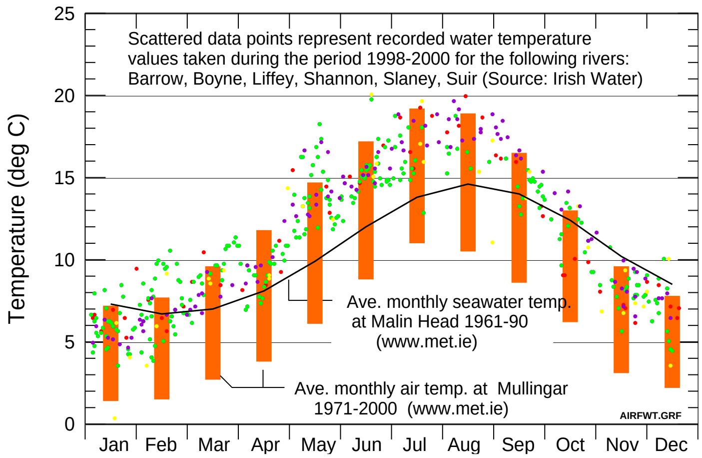

Fig 8 **Recorded annual temperature variation**

It is also of interest to note that the role of wastewater temperature is explicitly taken into account in the statutory implementation of the Urban Wastewater Directive in some other EU member countries. For example, the German Waste Water Ordinance – AbwV (2004), in reference to treated effluent nitrogen limit requirements, states (Appendix 1) the following:

> '*The requirements apply to ammonium nitrogen and total nitrogen, at a waste water temperature of 12°C and above in the effluent from the biological reactor of the waste water treatment plant. The 12°C threshold may be replaced by the following time limit: from 1 May to 31 October. The water discharge license may stipulate a higher concentration for total nitrogen, of up to 25 mg/l, provided the reduction of the total nitrogen load is at least 70 percent. The reduction shall refer to the ratio between the nitrogen load in the influent and that in the effluent, over a representative period of time not exceeding 24 hours. The load in the influent shall be based on the sum of organic and inorganic nitrogen.*'

A clear benefit of the German approach is that it provides definitive guidance on process design temperature for nitrogen removal, which has lead to the development of national process design guidelines (ATV-DVWK, 2001) that have been also been widely used outside Germany.

On the basis of the Irish wastewater annual temperature profile data presented in Figs 3-7, inclusive, the adoption of a design temperature of 12 ºC, would not compromise the achievement of the specified annual average target limit values for nitrogen for discharges to sensitive waters. It would of course mean that a TN value lower than the ELV would have to be achieved outside the winter period to negative any exceedences incurred during the winter period.

SUMMARY

SI 254 (2001) gives statutory effect in Ireland to the Provisions of the EU Urban Waste Water Directive, prescribing a minimum mandatory ELV for total nitrogen for effluents discharged to sensitive waters, set at 15 mg/l for WwTWs in the 10000-100000 PE range and at 10 mg/l for WwTWs of capacity greater than 100000 PE. The ELV relates to the annual average value, based on a specified number of 24h composite samples, the number increasing with plant size.

Wastewater nitrogen removal is achieved by a biological process that incorporates nitrification and denitrification steps. Process kinetics is strongly influenced by temperature, requiring an increasing reactor volume to process a given nitrogen load as the wastewater temperature reduces. As shown in the body of this note, urban wastewater temperature in Ireland typically varies from a low of about 6 ºC in wintertime to a high of about 20 ºC in summertime. Hence, by judicious selection of an intermediate process design temperature the requirement to meet the specified annual average ELV can be economically achieved.

The attachment of conditionality to the annual average ELV for nitrogen, without differentiation in respect of wastewater temperature, has the effect of forcing a lowering of the process design temperature below that required to meet the annual average value, thereby leading to increased capital and operating costs, with minimal environmental dividend. However, where such additional requirements are specified to apply only above a set threshold temperature, their objective is targeted on improved process performance during the critical warmer part of the annual temperature cycle when receiving waters are also likely to be above the selected threshold value, as illustrated by the data presented in the body of this note. This approach is exemplified by the requirements of the German Waste Water Ordinance, which, as noted above, sets a compliance temperature threshold at or above 12 ^{o}C or alternatively a time limit extending from 1 May to 31 October.

The adoption of the threshold temperature model in urban waste water licence ELV nitrogen specification relating to effluent discharges to sensitive waters would be beneficial to process design. It would provide clarity as to the process design temperature and would yield environmental and economic dividends by putting an emphasis on the requirement for enhanced process performance when the wastewater temperature exceeded the set threshold value. On the basis of the Irish wastewater annual temperature profile data presented in Figs 3-7, inclusive, the adoption of a design temperature of 12 ^{o}C, would not compromise the achievement of the specified annual average target limit values for nitrogen for discharges to sensitive waters. It would of course mean that a TN value lower than the ELV would have to be achieved outside the winter period to negative any exceedences incurred during the winter period.

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