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Justification of derogation from achieving the BAT-AELs for liquid effluents from cokemaking at British Steel, Scunthorpe

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Effluents from cokemaking operations at Appleby coke plant at British Steel's Scunthorpe Works are treated at a dedicated Biological Effluent Treatment Plant (BETP) before discharge to the River Trent. The site's environmental permit includes limits on the effluent quality from the BETP, but although research to improve the treatment performance has been undertaken, it has not been possible to consistently achieve the limits for every species. A recent review of operations at the site has led to a decision to close the existing coke plant by the end of 2026 and an increase in some of the discharge limits for is requested until this date.

Because the discharge limits are already at the top of the range of BAT-associated emission levels (BAT-AELs), increasing the limits would require a formal derogation under Article 15(4) of the Industrial Emissions Directive (IED). The first requirement of a derogation is that any claim of disproportionate costs should relate to the geographical location of the installation, local environmental conditions or technical characteristics of the installation. Coke oven effluent treatment at Scunthorpe is affected by a number of circumstances arising from the historical development of cokemaking at the site that do not apply at the typical plants in Europe upon which the BAT Conclusions are based, and so there are technical characteristics that make it more technically difficult and costly to comply at Scunthorpe.

A cost-benefit analysis has been undertaken that shows that the costs of achieving all the BAT-AELs at the biological effluent treatment plant for British Steel's coke oven effluent would be disproportionately high compared to the environmental benefits. This would therefore meet the requirements for a derogation under Article 15(4) of the Industrial Emissions Directive.

The report also discusses the impacts on the River Trent of current discharges and the potential impacts if BAT were to be achieved. PAH levels in the river would be expected to exceed the Environmental Quality Standards even when the plant is operating within the BAT-AELs. PAH levels are only one of the reasons for the Trent not currently achieving good status, so even if PAH discharges from the BETP were eliminated entirely, the overall status of the water body would not change.

Justification of derogation from achieving the BAT-AELs for liquid effluents from cokemaking at British Steel, Scunthorpe

1. Introduction

Effluents from cokemaking operations at Appleby coke plant at British Steel's Scunthorpe Works are treated at a dedicated Biological Effluent Treatment Plant (BETP) before discharge to the River Trent. The site's environmental permit[1] includes limits on the effluent quality from the BETP which came into force on 8th March 2016, but although research to improve the treatment performance has been undertaken, it has not been possible to consistently achieve the limits for every species. A recent review of operations at the site has led to a decision to close the existing coke plant by the end of 2026 and as a result an increase in the limits for nitrogeneous species, cyanide and PAHs is requested until this date.

Because the discharge limits are already at the top of the range of BAT-associated emission levels (BAT-AELs) from the Iron and Steel BAT Conclusions[2], increasing the limits would require a formal derogation under Article 15(4) of the Industrial Emissions Directive (IED). This report describes a cost-benefit analysis study to investigate whether such a derogation would be justified using the criteria in the IED and UK guidance. The report also discusses the impacts on the River Trent of current discharges and the potential impacts if BAT were to be achieved.

2. Emissions

Table 1 shows the range of concentrations measured in the BETP effluent during 2020, along with the relevant discharge limits. Although the treated effluent was compliant with limits in place prior to 2016 and is, in most cases, compliant with the revised limits, the levels of some species currently discharged do not always achieve the limits that have applied since March 2016.

In the case of nitrogenous species – the sum of ammonia (NH_4^+ as N), nitrate (NO_3^- as N) and nitrite (NO_2^- as N) – recent improvements in treatment within the BETP mean that since August 2020 ammonia concentrations have generally been below 10 mg/l and the majority of the discharge is of nitrate, which is less toxic than ammonia, though it does still have detrimental impacts in the aquatic environment. Both nitrification and denitrification stages are required in order to achieve the BAT-AEL as described in the EU BAT Reference document for Iron and Steel[3], but in the case of coke oven effluent treatment at Scunthorpe, although the nitrification of ammonia to nitrate is effective, denitrification is limited by the composition of the incoming effluent as described in Section 3.

Parameter	Measured values (mg/l) Minimum	Average	Maximum	Limit (mg/l)	Proportion > Limit
Biological Oxygen Demand for 5 days (BOD_5)	1.7	6.3	15	20	0%
Chemical Oxygen Demand (COD)	53	85	140	220	0%
Suspended solids	6	30	55	150	0%
Nitrogeneous species [a]	62	120	162	50	100%
Heavy metals [b]	0	0.09	0.27	1	0%
Total Hydrocarbons	<2	<2	4	5	0%
Cyanide (CN^-), easily released	0.013	0.04	0.099	0.1	0%
PAHs [c]	0.0028	0.05153	0.1338	0.05	50%
Mono phenols	<0.1	<0.1	<0.1	0.5	0%
Sulphides, easily released	0.06	0.09	0.11	0.1	15%
Thiocyanide (as CNS)	<0.5	0.7	3.2	4	0%

a Sum of ammonia (NH_4^+ as N), nitrate (NO_3^- as N) and nitrite (NO_2^- as N)
b Sum of As, Cd, Cr, Cu, Hg, Pb and Zn
c Sum of fluoranthene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a]pyrene, indeno[1,2,3-cd]pyrene and benzo[g,h,i]perylene

Table 1: BETP effluent quality, calendar year 2020

3. Technical characteristics impacting on applicability of BAT

Coke oven effluent treatment at Scunthorpe is affected by a number of circumstances arising from the historical development of cokemaking at the site that do not apply at the typical plants in Europe upon which the BAT Conclusions are based.

- The BETP at Scunthorpe was originally designed to treat effluents from three operational cokemaking plants (two at the current Scunthorpe integrated steelworks and one at Normanby Park steelworks, which has since closed), as well as effluents from a chemical plant and a tar distiller. It is now treating strong effluent from only one operational coke plant (Appleby) along with weaker drainage waters from Appleby and from the locations of non-operational coke plants on the Scunthorpe site. Thus the existing BETP configuration is not optimal for the effluent composition and volume now requiring treatment, which impacts on the efficiency of the plant.
- As a consequence of the BETP being originally shared between two different steelmaking sites, the treatment plant is several kilometres from Appleby coke plant

itself, which means that the temperature of the waste waters entering the BETP is significantly lower than would normally be expected, and this adversely affects the biological treatment processes.

- Primary cooling of the coke oven gas at Appleby coke ovens is effected by spraying water directly into the gas stream, rather than the more commonly used indirect cooling. In the case of indirect cooling, the water is circulated in a closed cycle and will not influence the waste water quantity; in the case of direct gas cooling, the cooling water is treated as a washing liquor alongside other effluent streams (see BREF[3], page 221).
- Typical European coke plants (see Table 5.9 of the BREF) have specific effluent flowrates ranging from 0.31 to 0.69 m³ per tonne coke. At Scunthorpe, the volume of effluent treated is currently around 1 m³ per minute for an annual coke production rate of around 400,000 tonnes, equivalent to 1.3 m³ per tonne coke, which is well outside the typical range from the BREF. The higher specific volume at Scunthorpe arises from the use of direct primary cooling and the inclusion of relatively high drainage water flows and means that the process waters make up less than 50% of the total flow.
- As a result of the higher specific volume flows and low proportion of process waters, the effluent received at the Scunthorpe treatment plant is more dilute than would be expected at a typical BETP and some of the effluent characteristics, such as the ratio of soluble chemical oxygen demand to total nitrogen, are such as to make incorporating nitrification and denitrification stages more technically difficult at Scunthorpe than at the reference plants quoted in the BREF. Table 2 compares the typical influent compositions from Table 5.9 of the BREF with measured compositions at Scunthorpe during 2020.

Species	Typical range from BREF (mg/l)	Range at Scunthorpe (mg/l)
COD	200 – 6,500	96 – 120 *
Ammonia	50 – 200	39 – 76
Thiocyanate	150 – 380	56 – 138

* Soluble COD, based on only three measurements

Table 2: BETP influent composition at reference plants and Scunthorpe

3.1. Research programme

In 2013 a research programme utilising a pilot-scale biological treatment facility was initiated to investigate measures that could be applied at the Scunthorpe BETP to achieve the BAT-AEL for nitrogenous species. The research programme was necessary because, in contrast to purely physical or chemical abatement techniques, which can be precisely characterised, there is still a lack of in-depth understanding of the fundamentals of the different biological processes that occur during coke oven effluent treatment and how they may interact. The effluent characteristics and sludge (biomass) characteristics at each BETP are unique and “best practice” evolves in an empirical manner such that experience from one plant is not always directly transferrable to a different plant. A research programme was thus required to determine the optimal treatment parameters for the Scunthorpe situation whilst ensuring that improving treatment for some pollutants would not have an unintended detrimental impact on the treatment of other species.

The closure of Dawes Lane coke ovens in March 2016 resulted in changes to the volume and composition of the effluent to be treated. Some activities at Dawes Lane that generated effluents continued after closure, and furthermore one of the batteries at Appleby coke ovens was undergoing extensive maintenance at the same time; this meant that the effluent volume and composition did not stabilise at the new "normal" levels until after August 2016. Some elements of the research that had already been completed have had to be subsequently reviewed in the light of the closure of Dawes Lane and consequent changes in effluent characteristics.

Although some improvements in treatment have been possible through the research programme, it has been found that denitrification, which would be necessary to reduce the nitrate levels to below the BAT-AEL, cannot be effectively implemented at the Scunthorpe BETP, principally as a result of the ratio of soluble chemical oxygen demand to total nitrogen in the incoming waste water stream, which is outside the range at the reference plants quoted in the BREF. The research findings are described in more detail in Appendix 1.

4. River quality and impacts of BETP discharges

4.1. Receiving waters

The Environment Agency's Catchment Data Explorer[4], indicates that the River Trent from Laughton Drain (at Owston Ferry, 16 km upstream from the BETP discharge) to the confluence with the River Ouse is classed as part of the upper Humber estuary (see Figure 1), so this is the relevant water body for this assessment. The Humber Estuary is designated as a Special Area of Conservation under the EU Habitats Directive and a Special Protection Area under the EU Birds Directive – the SAC extends to Keadby Bridge, 2½ km upstream from the BETP but the SPA only extends a short distance up the River Trent to Alkborough.

No measurements of the river flow at the BETP discharge location are available, but a conservative estimate can be made using measurements taken at a non-tidal gauging station at North Muskham near Newark, over 50 km upstream from Scunthorpe. Between Newark and Scunthorpe a number of other rivers feed into the Trent, the most significant of which are the Torne, the Idle and Foss Dyke (all of which are artificial discharges, rather than naturally flowing watercourses). Only data for the Trent, the Idle and its tributary the Ryton are available from the National River Flow Archive[5], maintained by the Centre for Ecology and Hydrology and these are shown in Table 3.

		River flow data (m^3/s)	
River	**Gauging Station**	**Mean**	**Q_{95}**
Trent	28022 – North Muskham	89.25	28.8
Idle	28015 – Mattersey	2.32	0.84
Ryton	28016 – Serlby Park	1.75	0.45

Table 3: River flows

The additional flow from the Idle/Ryton is thus relatively small compared to the Trent's flow at North Muskham; a conservative assumption would be that the additional flow from other rivers between Newark and Scunthorpe is insignificant and hence the mean flow of the Trent at Scunthorpe would be 93 m^3/s, or 335,000 m^3/hour and the Q_{95} flow (i.e. the flow that is exceeded for 95% of the time) 30 m^3/s or 108,000 m^3/hour.

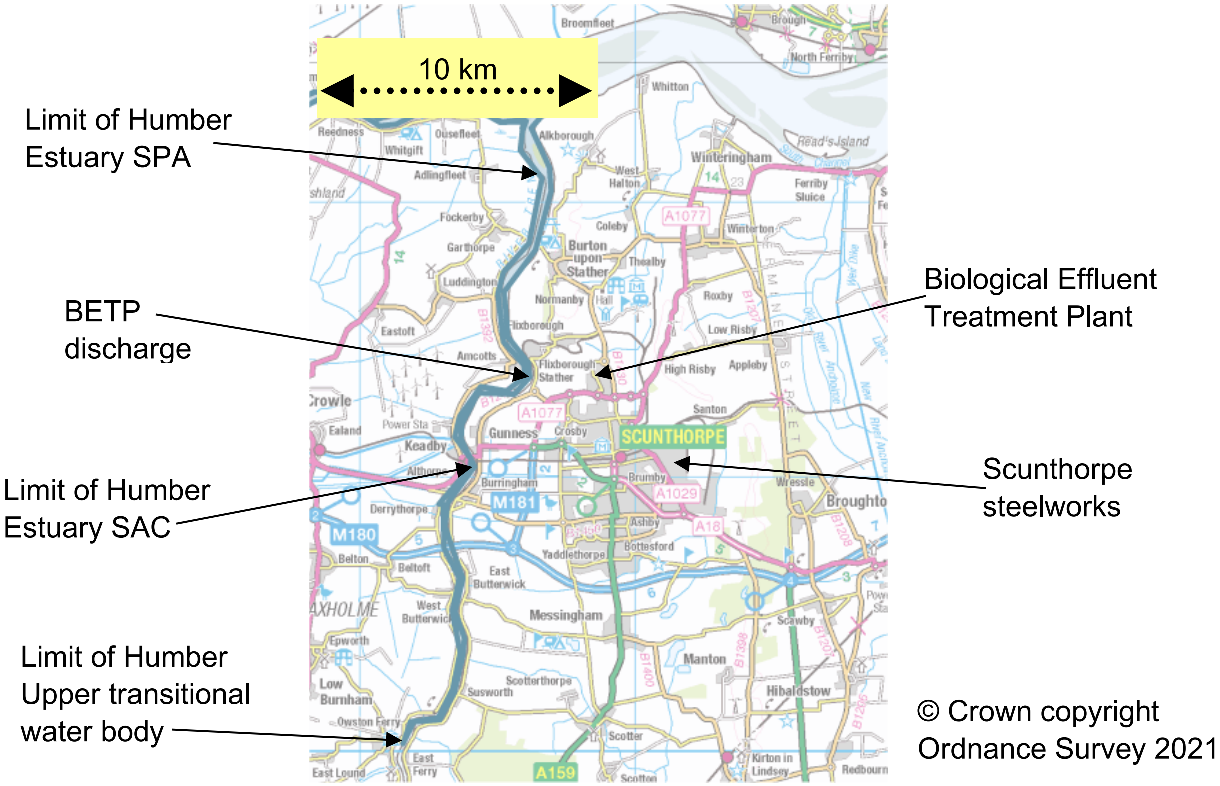

Figure 1: River Trent and upper Humber estuary

4.2. Current status of water body

The most recent (2019) assessment[4] of the Humber Upper water body shows that the overall water body status within the meaning of the Water Framework Directive is moderate, as was also the case for all previous assessments. The overall classification is made up of a number of separate elements, including concentrations of specific substances, and in 2019 the following species were noted as failing:

- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Benzo(g-h-i)perylene
- Mercury and Its Compounds
- Cypermethrin
- Tributyltin Compounds
- Polybrominated diphenyl ethers (PBDE)

The first four of these have been detected in the discharge from the coke oven effluent treatment plant. Other reasons why this water body does not currently meet good status are shown in Table 4.

Reason Type	SWMI	Activity	Category	More	Classification Element
RNAG	Point source	Sewage discharge (continuous)	Water Industry	Details	Dissolved oxygen
RNAG	Physical modification	Other (not in list, must add details in comments)	Local and Central Government	Details	Mitigation Measures Assessment
RNAG	Physical modification	Other (not in list, must add details in comments)	Local and Central Government	Details	Mitigation Measures Assessment
RNAG	Natural	Natural conditions - other	No sector responsible	Details	Angiosperms
RNAG	Physical modification	Flood protection - structures	Sector under investigation	Details	Angiosperms
RNAG	Flow	Surface water abstraction	Other	Details	Dissolved oxygen
RNAG	Diffuse source	Poor nutrient management	Agriculture and rural land management	Details	Dissolved oxygen

Table 4: Reasons for not achieving good status – Humber Upper

4.3. Natura 2000 sites

The citation for the Humber Estuary Special Protection Area[6] lists 29 protected bird species as being present for some or all of the year. In the "Threats, pressures and activities with impacts on the site" section of the citation, the most important categories for negative impact are listed as:

- I01 – invasive non-native species
- M02 – changes in biotic conditions
- M01 – changes in abiotic conditions
- K01 – abiotic (slow) natural processes
- G01– outdoor sports and leisure activities

None of those categories would be associated with discharges from the Scunthorpe BETP and pollution to surface water (code H01) is not listed as an important threat. On this basis, it is judged that the existing discharges from the BETP do not have a significant negative impact on the SPA.

The citation for the Humber Estuary Special Area of Conservation[7] lists twelve different protected habitat types, four protected fish species and two protected mammal species as being present within the SAC. In the "Threats, pressures and activities with impacts on the site" section, the most important categories for negative impact are listed as:

- J02 – human-induced changes in hydraulic conditions
- M01 – changes in abiotic conditions
- H02 – pollution to groundwater (point sources and diffuse sources)
- E02 – industrial or commercial areas
- K01– Abiotic (slow) natural processes

Although groundwater pollution is included amongst the greatest threats, pollution to surface waters (H01), which might be associated with discharges from the Scunthorpe BETP, is not listed. On this basis, it is judged that the existing discharges from the BETP do not have a significant negative impact on the SAC.

4.4. Impacts – sampling in the River Trent

In January 2014 the Environment Agency undertook an ad-hoc sampling exercise specifically to assess the impact of discharges from the BETP. Samples were taken from a boat upstream and downstream of the discharge point on the ebb tide, whilst treated effluent was being discharged (two samples at each location). No measurements of total phenol or sulphides were undertaken and PAHs were only measured at the upstream location (and were below the limit of detection); Table 5 shows the results for all other species with a relevant BAT-AEL.

		Concentrations in River Trent		BAT-AEL for BETP discharge
Species	Units	Upstream	Downstream	
BOD	mg/l	<1.00-1.56	1.41-1.50	20
COD	mg/l	24-26	15-19	220
Thiocyanate	mg/l	<0.2	<0.2	4
Free cyanide	mg/l	<0.005	<0.005	0.1
Ammonia (as N)	mg/l	0.10-0.11	0.11	50

Table 5: Results from Environment Agency sampling exercise

Although this is only a single survey, it does not show any evidence of a significant impact from the discharge of treated coke oven effluent from the existing BETP (despite ammonia levels being in excess of the BAT-AEL at that time). Furthermore, this assessment was undertaken prior to the closure of Dawes Lane coke ovens and since that time both the volume of effluent discharged and the ammonia concentrations have fallen, which will have further reduced the already negligible impact.

4.5. Impacts – H1 assessment

The impact of current emissions from the BETP on the quality of the receiving waters has been assessed using the methodology in the Environment Agency's guidance[8] on "Surface water pollution risk assessment for your environmental permit". This sets out a series of steps to assess the risk of contributing to a breach of any applicable Environmental Quality Standards (EQSs). For estuaries and coastal waters (which includes transitional waters such as the tidal River Trent at the BETP discharge point), EQSs are listed in two spreadsheets[9,10]. The EQSs that relate to pollutants measured in the BETP effluent are shown in Table 6. The Maximum Allowable Concentration EQSs are used to evaluate short-term environmental impacts, based on maximum discharge levels, and the Annual Average EQSs for long-term impacts using average concentrations.

The first step of the assessment is to check whether the pollutant levels in the discharge exceed the EQS limits. In the case of the Scunthorpe BETP, this is the case for several species so further assessment is required.

The next step, in the upper parts of an estuary where the water is mainly fresh, is to check whether the discharge is directly to the low water channel (i.e. check that the effluent does not flow across the estuary bed at any stage of the tide). Although the BETP at Scunthorpe is a continuous operation, the discharge is discontinuous. Treated effluent collects in a holding tank and is only discharged to the river for a period that starts an hour after each high tide, typically for a period of around two hours. Under these conditions, the effluent is discharged directly to the river – see Figure 2 – and the discharge is into largely fresh water.

		Environmental Quality Standards (µg/l)	
	Substance	**Annual Average**	**Maximum Allowable Concentration**
Priority Hazardous Substances and Priority Substances	Anthracene	0.1	0.1
	Benzo(a)pyrene	See figure for total PAHs	0.027
	Benzo(b)fluoranthene	See figure for total PAHs	0.017
	Benzo(k)fluoranthene	See figure for total PAHs	0.017
	Benzo(g,h,i)perylene	See figure for total PAHs	0.00082
	Cadmium	0.2	-
	Fluoranthene	0.0063	0.12
	Indeno(1,2,3-cd)pyrene	See figure for total PAHs	-
	Lead	1.3	14
	Mercury	-	0.07
	Naphthalene	2	130
	Total PAHs *	0.00017	-
Others	Ammonia - un-ionised	21	-
	Arsenic	25	-
	Copper	3.76	-
	Phenol	7.7	46
	pH	-	6 - 8.5 (95th percentile)
	Zinc	6.8	-

* Total PAHs is the sum of Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(g,h,i)perylene and Indeno(1,2,3-cd)pyrene

Table 6: Relevant Environmental Quality Standards

Figure 2: Discharge to the River Trent

The EA guidance then directs the assessment to proceed as if the discharge were to fresh water, but using the EQSs relevant to estuaries and coastal waters.

For intermittent discharges that start and stop regularly, as is the case for the BETP discharge, the EA guidance states that the average flow rate to be used in the assessment should be calculated by multiplying the average flow rate <u>during discharge</u> by the proportion of the year that the discharge takes place. The discharge rate from the holding tank is not measured, but can be estimated by considering the inflow to the effluent treatment plant, which is typically between 800 and 1,200 l/minute. Taking a figure of 1,000 l/minute, this means that the daily discharge from the BETP is typically 1,440 m^3 and assuming that this is discharged over two two-hour periods each day, the average flow during discharge would be 360 m^3/hour. The proportion of the time when the discharge occurs is 4 hours per day, or 16.7% of the time, and so the average flow rate for the purposes of the H1 impact assessment is 360 x 0.167 = 60 m^3/hour or 0.017 m^3/s.

The tidal nature of the River Trent at Scunthorpe and the fact that effluent is only discharged on the ebb tide, when the fluvial flow is augmented by the receding tidal flow, complicates any assessment of the relevant flow parameters and dilution. But overall, using the river flows from Table 3, the dilution factor in the Trent would be 93/0.017 = 5,600 if the river flow is at the mean level and 1,800 for low river flows (Q_{95}) – both these dilution factors may be conservative as they do not account for the augmented flow in the Trent on the ebb tide. It should be noted that the EQS for total PAHs (0.00017 µg/l) is so low that a dilution factor of around 300,000 would be required to avoid breaching the EQS downstream of the BETP discharge if the PAH levels were at the BAT-AEL of 50 µg/l[1].

The Environment Agency's H1 tool (version 2.7.8, dated January 2017) has been used to assess the potential impact of discharges from the Scunthorpe BETP, using the average and maximum concentrations measured during 2020 as shown in Table 7.

		Measured concentrations (µg/l)	
	Substance	**Average**	**Maximum**
Priority Hazardous Substances and Priority Substances	Anthracene	0.42	1.6
	Benzo(a)pyrene	13	44
	Benzo(b)fluoranthene	13	43
	Benzo(k)fluoranthene	5.5	16
	Benzo(g,h,i)perylene	8.2	22
	Cadmium	3.2	18
	Fluoranthene	4.6	17
	Indeno(1,2,3-cd)pyrene	7.5	15
	Lead	5.9	24
	Mercury	0.15	1.1
	Naphthalene	0.85	5.4
	Total PAHs *	47	126
Others	Ammonia - total	65,663	123,500
	Arsenic	35	137
	Copper	10	64
	Phenol	<100	<100
	Zinc	30	146

* Total PAHs is the sum of Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(k)fluoranthene, Benzo(g,h,i)perylene and Indeno(1,2,3-cd)pyrene

Table 7: Measured concentrations, Calendar Year 2020

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[1] The EQS for total PAHs refers to the sum of five species (Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(g,h,i)perylene, Benzo(k)fluoranthene and Indeno(1,2,3- cd)pyrene), whereas the BAT-AEL refers to the sum of six species (the five above plus Fluoranthene). Fluoranthene generally accounts for less than 10% of the total PAHs reported against the BAT-AEL, and so a conservative assumption has been made that all BAT-AEL PAHs contribute to the EQS.

Table 8 shows the Process Contributions in the receiving waters calculated by the H1 tool, compared to the relevant EQSs. Also in Table 8 are the predicted Environmental Concentrations, calculated assuming that the background (upstream) concentrations of all species are at 10% of the EQS level.

		Annual Avg EQS						MAC* EQS			
Substance	Bkgrnd Conc. µg/l	PC µg/l	PEC µg/l	(PEC - BC)/ EQS	PEC -BC >10% AA EQS	% PEC of EQS %	PEC >100% AA EQS	PC µg/l	PEC µg/l	% PEC of MAC %	PEC >100% MAC
	e.g. 200				Test 3		Test 4a				Test 4b
Anthracene (River Trent)	0.01	0.000234	0	-10.0%	Pass	0	Pass	0.00638	0.0164	16.4	Pass
Benzo (b) fluoranthene (River Trent)	0.000017	0.00724	0.00725	######:	Fail	4,264	Fail	0.172	0.172	1,008	Fail
Benzo (ghi) perylene (River Trent)	0.000017	0.00457	0.00458	######:	Fail	2,694	Fail	0.0877	0.0877	10,691	Fail
Benzo (k) fluoranthene (River Trent)	0.000017	0.00306	0.00308	######:	Fail	1,810	Fail	0.0638	0.0638	375	Fail
Cadmium and its compounds (≥ 200 mg/l CaCO3) (River T	0.02	0.00179	0.0218	0.7%	Pass	8.72	Pass	0.0718	0.0918	6.12	Pass
Fluoranthene (River Trent)	0.00063	0.00256	0.00319	40.6%	Fail	50.7	Pass	0.0678	0.0684	57.0	Pass
Indeno (1,2,3-cd) pyrene (River Trent)	0.000017	0.00418	0.00419	######:	Fail	2,465	Fail	0.0598	0	-	Pass
Mercury and its compounds (River Trent)	0.007	0.00008345	0		Pass	-	Pass	0.00439	0.0114	16.3	Pass
PAH: sum as per EQS (River Trent)	0.000017	0.0262	0.0262	#######	Fail	15,392	Fail	0.502	0	-	Pass
Polyaromatic hydrocarbons (PAH): Benzo (a)pyr	0.000017	0.00724	0.00725	14.5%	Fail	14.5	Pass	0.176	0.176	175	Fail

Table 8: Process Contributions and Predicted Environmental Concentrations in the River Trent

For most of the PAHs, the Process Contribution alone exceeds the EQS; this is inevitable given the extremely low EQS for PAHs – a dilution of around 300,000 would be required if the PAH discharges were at the BAT-AEL. It should be noted that the figures in Table 8 are based on measured discharge concentrations – the potential impact of emissions under different future scenarios are discussed in Section 5.5.

The guidance on surface water pollution risk assessment[8] also includes a further test for some Priority Hazardous Substances by comparing the annual mass emissions to specified significant loads. The only species for which this is exceeded is benzo(a)pyrene – the significant load is 5 kg/annum and the estimated mass emission in 2020 was 6.8 kg.

5. Scenarios

The following sections describe three future scenarios that will be considered in the cost-benefit analysis. Operating costs are also considered, but only the difference between business as usual and potential future operating costs is relevant for this assessment.

5.1. Business as usual

This is the base case, which assumes ongoing operation of the BETP at current discharge levels. Operating costs for other scenarios are defined relative to the operating costs of business as usual (BAU).

5.1.1. Costs

The costs for the baseline scenario are the operating costs of the existing BETP, which will include labour costs, energy and other materials used at the BETP and energy used in pumping effluent from the steelworks site to the BETP and from there to the holding tank and the River Trent. For the purposes of this assessment, the baseline costs are taken to be £200,000 per annum, and it is assumed that the plant might need to operate for up to a year after closure of Appleby coke ovens to treat effluents produced during decommissioning.

5.2. BAT scenario

The research programme described in Section 3.1 and Appendix 1 has concluded that the technical characteristics of the waste waters to be treated at the BETP mean that it is not possible to fully achieve all the BAT-AELs for coke oven effluent treatment in the BAT Conclusions document[2]. The only potential scenario considered here to prevent further breaches of the BAT-AELs is to transport the untreated coke oven effluent by road tanker to an alternative third-party effluent treatment plant where it can be combined with other waste waters (particularly those with high dissolved COD levels) to bring about more effective treatment than can be achieved in the stand-alone BETP at Scunthorpe.

A number of specialist wastewater treatment companies have previously been contacted to quote for off-site treatment and some possible operators had been identified. However, all the third parties had some constraints on the volume of effluent that they could treat, and the most promising site could handle no more than 200 m^3 per day (14% of the total effluent). Although this option has been considered further, it is by no means clear that it is a technically feasible solution given the constraints.

The number of tankers required to transfer all the coke oven effluent to a third party would necessitate modification of the existing tanker filling point at Appleby, and so there would be some delay before this option could be pursued. In addition, contracts would have to be agreed with suitable external plants, so for the purposes of this assessment it is assumed that this route would commence in November 2021. It is assumed that this operation would continue until the closure of Appleby coke ovens by the end of 2026, and for a short period afterwards to treat any effluents from the decommissioning of the coke oven plant. During 2027, it is assumed that the number of tankers requiring treatment would halve.

5.2.1. Costs

The mean flowrate of effluent currently treated at the Scunthorpe BETP is around 1,000 litres per minute. A road tanker will typically hold 25 tonnes of liquor, so on average a tanker would be filled every 25 minutes, equivalent to 58 tankers a day or 21,024 per year. Quotes received in 2017 for the transport and treatment of coke oven effluent by third-parties ranged from £510 to £820 per tanker.

For the purposes of this assessment, it is assumed that a large contract over several years would attract a significant discount and a cost of £300 per tanker at current prices, covering both transport and treatment, has been used in the cost-benefit analysis.

The cost of modifying the existing tanker filling point at Appleby to accommodate the number of tankers required to transfer all the coke oven effluent to a specialist wastewater treatment plant has been assumed to be negligible.

The total annual cost of the BAT option is therefore estimated as £6.3M.

5.2.2. Emissions to air

In the case of transferring coke oven effluent from Scunthorpe to a third-party treatment plant, there would also be some emissions to air arising from road transport, depending on the location or locations of the alternative facilities. For the purposes of this assessment it is assumed that a plant in Hull can treat the whole of the effluent. The distance from

Scunthorpe to Hull is about 26.5 miles each way, so the total distance travelled by tankers over the course of a year would be 1.1M miles or 1.8M kilometres.

For Heavy Goods Vehicles, road transport emission factors from the UK National Atmospheric Emissions Inventory[11], based on the 2019 vehicle fleet, give different factors for urban, rural and motorway driving – for the purposes of this assessment it is assumed that the journey is 25% urban, 25% rural and 50% motorway. Table 9 shows the emission factors and estimated mass of pollutants emitted to air associated with the transport of effluent to a third-party treatment plant.

Also in Table 9 are CO_2 emissions estimated from factors for articulated HGVs (3.5 to 33 tonnes) taken from greenhouse gas reporting guidance from BEIS[12]. It is assumed that half the journey will be undertaken fully loaded and the return journey empty.

	Emission factors (g/km)										
	NO_x	PM_{10}	$PM_{2.5}$	CO	VOC	NH_3	SO_2	Benzene	N_2O		CO_2
Urban	1.117	0.015	0.015	0.199	0.061	0.004	0.001	0.001	0.011	Empty	633
Rural	0.987	0.011	0.011	0.098	0.025	0.004	0.001	0.001	0.004	100% load	949
Motorway	1.320	0.011	0.011	0.120	0.020	0.005	0.001	4E-04	4E-03		
Weighted average *	1.186	0.012	0.012	0.134	0.031	0.005	0.001	6.4E-04	5.6E-03	Average	791
Annual mass (tonnes)	2.1	0.021	0.021	0.24	0.056	0.0084	0.0018	0.0011	0.010		1418

* Assuming 25% urban driving, 25% rural and 50% motorway

Table 9: HGV emission factors

5.3. Preferred option

The preferred option is to continue to operate the existing BETP at Scunthorpe, but with increases in the discharge limits for some species to reflect the difficulties in consistently achieving all the BAT-AELs. Operation would continue until the closure of Appleby coke ovens by the end of 2026, and for up to a year afterwards to treat any effluents from the decommissioning of the coke oven plant.

The new discharge limits requested are:

- Nitrogenous species 200 mg/l (limit applicable before 2016)
- Cyanide 0.3 mg/l (limit applicable before 2016)
- PAHs 0.15 mg/l

A derogation would be required to allow the setting of discharge limits that exceeds the top of the ranges of BAT-associated emission levels from the Iron and Steel BAT Conclusions.

5.3.1. Costs

The costs for the preferred option are the same as for the baseline scenario, i.e. £200,000 per annum.

5.4. Reduction in discharges to the aquatic environment

In the case of the Business as Usual scenario and the preferred option it is assumed that the discharge of all species would be continuously at the relevant limits (BAT-AEL for most species, new limits as defined in section 5.3 for nitrogenous species, PAHs and cyanide).

It is assumed that a third-party effluent treatment plant (BAT scenario) would achieve all the BAT-AELs for coke oven effluent treatment. For most species the emissions would therefore by the same as for the other scenarios, but there would be a decrease in the mass of nitrogenous species, PAHs and cyanide discharged to the environment. The mass emissions attributable to the different scenarios are shown in Table 10.

	Concentration (mg/l)		Annual mass load (kg)	
Species	BAT-AEL	Requested limit	BAT-AEL	Requested limit
Ammonia	50	200	26,280	105,120
PAH	0.05	0.15	26	79
Cyanide	0.1	0.3	53	158

Table 10: Mass discharged to the aquatic environment

It should also be noted that, depending on the location of the third-party sites, the residual discharges may be released into other water bodies than the Trent. If these water bodies are smaller than the Trent, with less dilution, then it is possible that the impact on the other water bodies may be worse than in the Trent, even if the mass discharged is lower. In particular, for the case of PAHs, no river in the UK would have sufficient dilution to avoid exceeding the EQS even for discharges at the BAT-AEL.

5.5. Potential impact on receiving waters

The H1 assessment described in Section 4.5 is based on measured discharge concentrations, but under the scenarios above, where emissions are assumed to be continuously at the limit, the potential impact would be different. The annual average Process Contribution, after dilution in the River Trent (using the Q_{95} flow of 30 m^3/s), for total PAHs would be 0.028 µg/l for the BAT scenario and 0.084 µg/l for the preferred option. Since the relevant EQS is 0.00017 µg/l, this would be exceeded even in the case of discharges that meet the BAT-AEL.

6. Cost-benefit assessment

In order to demonstrate whether the BAT scenario is excessively costly compared to the preferred option of continuing to operate the BETP with increased emission limits until the closure of Appleby coke ovens, the Net Present Value (NPV) of each option must be determined. The NPV is calculated relative to the preferred option, taking into account any additional capital expenditure required, any change in operating costs and any reduction in pollutant emissions. In order to compare the costs and benefits (reduced pollution) on a like-for-like basis, the pollutant emissions have to be monetised. For air emissions this is achieved by the use of damage costs, which represent the marginal external cost attributable to each additional tonne of pollutant emitted.

In the case of discharges to water, there are no recognised “damage costs” that can be used to monetise impacts in the same way and section 3.6.3.3 in a previous Environment Agency guidance document on Cost-Benefit Analysis[13] refers instead to the National Water Environmental Benefits Survey (NWEBS). The original survey[14] was commissioned to assess the value placed by households on improvements to the water environment, based on “willingness to pay”. Different methods of eliciting this information resulted in different valuations, giving rise to a range of values in the final analysis. The survey took into account six different indicators of aquatic environmental quality:

- Fish
- Other animals such as invertebrates
- Plant communities
- Clarity of water and presence or absence of pollution
- The condition of the river channel and flow of water
- The safety of the water for recreational contact

The original survey quoted values separately for England and for Wales and an overall value for the two countries combined. A 2013 update[15] included more detailed analysis of the impact of population density and the existence of local alternatives to derive different values for individual catchments. The methodology only values a change in the status (e.g. from moderate to good quality) of one or more of the ecosystem components, so any reduction in the levels of a pollutant that does not bring about such a step change would effectively have no value. It should be noted that the NWEBS values apply to changes in the six components listed above – not to changes in the status under the Water Framework Directive, though it is acknowledged that there will be some correlation between the two measures.

As discussed in section 4.2, some of the reasons for the Upper Humber not attaining good status are not linked to discharges from British Steel's coke oven effluent treatment plant. This means that, using the NWEBS framework, there will be no step change improvement in ecosystem quality arising from further reductions in discharges from the BETP and the value of such reductions would therefore effectively be zero. However, for sensitivity analysis, the value of an improvement in the water body status has also been assessed and this is discussed in Section 6.1.3.

6.1. Environment Agency CBA tool

The Environment Agency has developed a cost-benefit analysis tool to undertake assessments using a standard methodology when applying for a derogation from the requirements of the IED. The latest finalised version of this tool is version 6.17, dated September 2017 but it is noted[16] that this version uses damage costs from 2013. A newer BETA version of the tool is also available (version 6.21, dated July 2020), which incorporates DEFRA's latest (2020) damage costs and so this version has been used for the assessment reported here.

It should be noted that the CBA tool does not include any quantitative consideration of impacts on the aquatic environment.

6.1.1. Inputs

The inputs to the CBA tool were based on the cost data from sections 5.1.1, 5.2.1 and 5.3.1 of this report and data on emissions to air from section 5.2.2.

In order to carry out sensitivity analysis, the CBA tool also requires an estimate of the uncertainty around the additional operating costs (the cost of transporting and treating the effluent at a third-party facility), which has been assumed to be ± 25%. One additional input to the CBA tool is the weighted average cost of capital, but in this assessment there is no capital expenditure, so this is not relevant in this case.

6.1.2. *Results*

The central estimate of the Net Present Value of the BAT scenario is –£31M compared to that of the preferred option – this is principally due to the cost of treating the effluent at a third-party facility. On this basis, the achievement of BAT would lead to disproportionately high costs compared to the environmental benefits, which would meet the requirements for a derogation under Article 15(4) of the Industrial Emissions Directive.

6.1.3. *Sensitivity analysis*

The central estimate of the NPV is derived from the operating costs entered into the CBA tool along with DEFRA's central estimate of the damage costs of the relevant pollutants. The tool also undertakes sensitivity analysis for different values of these parameters using ranges of damage costs and the operating cost uncertainty described in section 6.1.1. The sensitivity analysis included in the CBA tool confirms that there are no circumstances where the NPV of the BAT option is positive.

As previously noted, the CBA tool does not include any quantitative consideration of impacts on the aquatic environment. Although it is not expected that any reduction in pollutant discharges from the BETP would lead to a step change in the ecosystem quality, to check the sensitivity of the final conclusions, the potential benefit of a change in the status of the Upper Humber water body from moderate to good has been assessed and included in the cost-benefit analysis.

The area of the Upper Humber water body is 12.332 km²[4] and the 2013 NWEBS update includes the following values for transitional waters in the Humber River Basin District:

	Annual value per km² (2012 prices)	
Change in Status	**Central Value**	**Range**
Bad to Poor	£6,990	£5,730 to £8,249
Poor to Moderate	£8,081	£6,624 to £9,538
Moderate to Good	£9,417	£7,719 to £11,115

The Environment Agency's Water Appraisal Guidance[17] gives examples of the use of NWEBS values in monetising the benefits of measures that affect the water environment; the assessment hinges on the extent to which the proposed measures may bring about a step change in any of the six ecosystem quality indicators (the figures in the table above apply if all six indicators increase simultaneously). If a conservative assessment is made that all six components could be increased from moderate to good status, the benefit of improving the river quality would therefore be £9,417 x 12.3 = £116,130 per annum at 2012 prices, or around £140,000 at current prices.

Thus the additional benefit of raising the quality of the Upper Humber water body from moderate to good is still less than 2½% of the cost of transporting and treating the effluent to a third party facility. Including this figure would not change the overall assessment that the achievement of BAT would lead to disproportionately high costs compared to the environmental benefits.

7. Justification for a derogation

Guidance published by the Environment Agency in 2013[18] describes the application of the IED in the UK and paragraphs 4.37 to 4.46 outline the requirements relating to derogations from meeting BAT-AELs. Paragraph 4.39 states that any claim of disproportionate costs should relate to the geographical location of the installation, local environmental conditions or technical characteristics of the installation. Amongst the technical characteristics that may be relevant (paragraph 4.41) are:

- The configuration of the plant on a given site, making it more technically difficult and costly to comply
- The intended remaining operational lifetime of the installation as a whole or of the part of it giving rise to the emission of the pollutant(s), where the operator is prepared to commit to a timetable for closure

Both of these characteristics can be applied to the situation at the Scunthorpe BETP, giving grounds for a derogation. In order to prevent further breaches of the BAT-AELs for nitrogenous species, PAHs and cyanide, the only option considered feasible would be to transport the effluent to a third-party treatment plant. Use of the Environment Agency's CBA tool confirms that the benefits (reduced pollution) of achieving the BAT-AELs in this way would be outweighed by the additional operating costs incurred.

This situation therefore meets the criteria for a derogation. Increasing the discharge limits for nitrogenous species, PAHs and cyanide until the closure of Appleby coke ovens in 2026 would be justified under Article 15(4) of the Industrial Emissions Directive.

8. Conclusions

A cost-benefit analysis has shown that the costs of achieving all the BAT-AELs at the biological effluent treatment plant for British Steel's coke oven effluent would be disproportionately high compared to the environmental benefits. This would therefore meet the requirements for a derogation under Article 15(4) of the Industrial Emissions Directive on technical grounds, i.e. the configuration of the plant on a given site, making it more technically difficult and costly to comply, and the limited operational lifetime of the coke ovens.

Although PAH concentrations in this scenario would exceed the relevant EQSs in the receiving waters, this would also be the case even if PAH levels in the effluent achieved the BAT-AEL.

9. List of abbreviations

BAT	best available techniques
BAT-AEL	BAT-associated emission levels
BAU	business as usual
BREF	BAT reference document
CBA	cost-benefit analysis
EA	Environment Agency
EQS	Environmental Quality Standard
IED	Industrial Emissions Directive
NPV	net present value
PAH	polycyclic aromatic hydrocarbon

10. References

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17. Environment Agency, "Water Appraisal Guidance; Assessing Costs and Benefits for River Basin Management Planning", May 2013
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Appendix 1 – Details of research programme

The historical development of cokemaking and effluent treatment at Scunthorpe means that the current BETP configuration is not optimal for the effluent composition and volume now requiring treatment. Some steps have already been taken to remedy this – in particular, the lease of three of the treatment cells to a third party has been terminated to allow them to be used as anoxic cells for denitrification of the effluent, as described in the BREF. However the atypical effluent composition at Scunthorpe still leaves other technical challenges.

The characteristic that has the greatest impact on the effectiveness of conventional biological treatment with integrated denitrification/ nitrification stages is the ratio of soluble chemical oxygen demand to total nitrogen. This has been investigated as part of the research programme carried out in an experimental pilot plant (with a total volume of 1 m^3) that is located on the BETP site at Scunthorpe. This initial work commenced in March 2015 and finished in December 2015 and the results are illustrated in Figure 1. Additional studies were carried out between January 2016 and June 2016, using two laboratory-based treatment units (each with a total treatment volume of 30 litres) at Tata Steel's Swinden Technology Centre and further work was undertaken following the closure of Dawes Lane coke ovens.

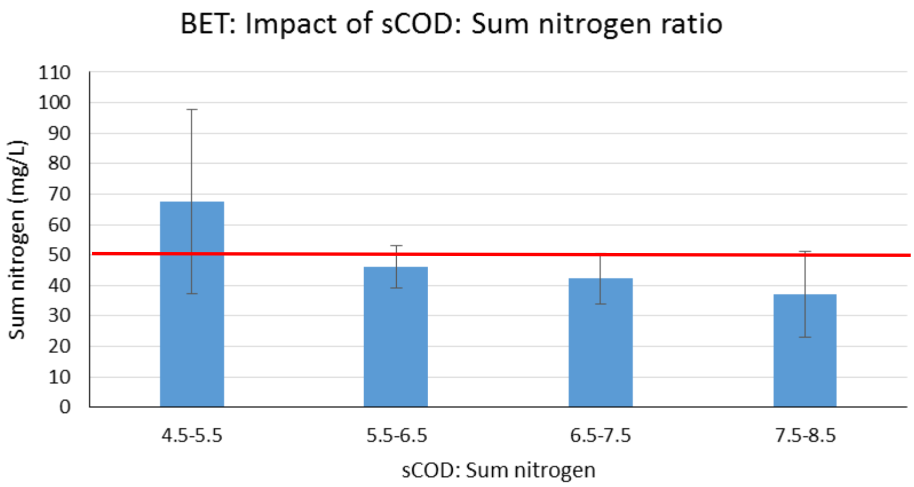

Figure: 1 Relationship between influent sCOD:TN ratio and effluent TN concentration

The pilot plant studies demonstrated that the ratio of soluble chemical oxygen demand (sCOD) to total nitrogen (TN = NH_3-N + SCN^--N + NO_3^--N + NO_2^--N) is critical in determining whether effective denitrification will occur. Figure 1 demonstrates that in order to consistently meet the BAT-AEL of 50 mg total nitrogen per litre, the sCOD:TN ratio should be >7.5 in order to provide a safe working headroom. With a sCOD:TN ratio in the range 7.5-8.5, the mean TN in the treated effluent was 37 mg/l. The average annual sCOD:TN ratios of BETP influent at Scunthorpe Works from 2014 to 2017 are summarised in Figure 2.

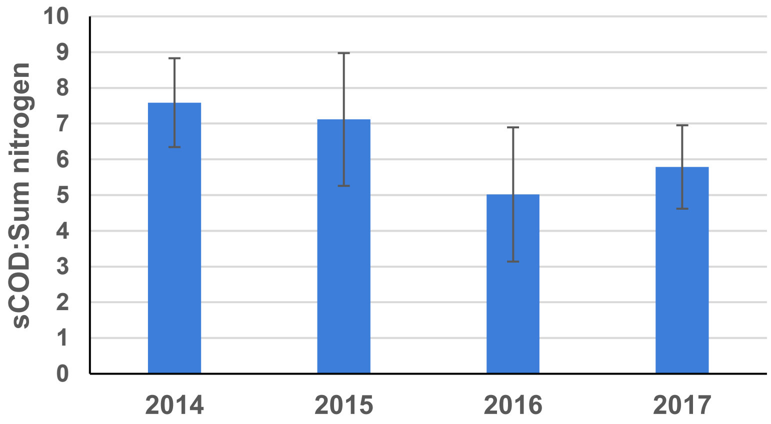

Figure 2: Annual average sCOD:TN ratio for influent at Scunthorpe Works BETP

As is evident from Figure 2, the sCOD:TN ratio fell well below the optimum range in 2016 and remained below the optimum in 2017. The change in the ratio in 2016 followed the closure of Dawes Lane coke ovens, which resulted in a decrease in the volume and strength of the waste water stream sent to the BETP. The subsequent increase in sCOD:TN in 2017 was due to the recommissioning of a coke oven battery at Appleby Coke Ovens, but the ratio is still substantially below the optimum range. The fall in the sCOD:TN ratio is attributable principally to a reduction in sCOD levels, rather than an increase in the TN concentration, as may be seen in Figure 3.

One potential means of controlling the raw effluent sCOD:TN ratio is the upstream ammonia stripping process which removes the major part of the ammonia in the raw effluent, reducing the NH_3-N concentration from typically 5,000 mg/l down to around 40-50 mg/l. However, further reduction in the NH_3-N concentration by steam stripping to compensate for the loss in sCOD is not practicable. In any case, thiocyanate, which is biologically degraded to ammonia, is the other major source of nitrogen but its concentration is not affected by ammonia stripping.

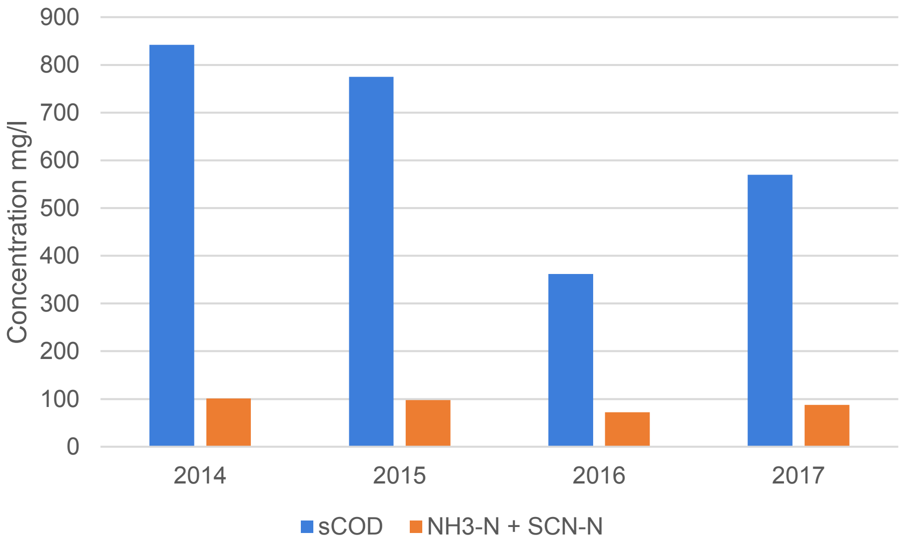

Figure 3 Variations in sCOD and NH_3-N + SCN^--N, 2014-2017

It can therefore be concluded that there is currently insufficient organic carbon to ensure consistent nitrogen removal and external organic carbon addition would be required to ensure compliance with the new 50 mg/l emission limit. In order to ensure consistent compliance with the emission limit it is necessary to ensure that the sCOD:TN ratio remains above 6.5 with an ideal ratio of at least 7.5.

There are various organic carbon compounds that could be used to supplement the intrinsic carbon content of the raw effluent in order to meet the required sCOD:TN ratio for efficient denitrification. The selection of a suitable source of organic carbon depends upon a number of factors as follows:

- It should be readily available and ideally locally sourced to minimise transport costs;
- It should be low cost;
- It should be available in a form that can be easily dosed into the effluent treatment system without the need for complex preparation methods;
- It should be available in a concentrated form to minimise transport costs;
- It should be easy to store;
- It should be safe to store and handle;
- It should be easily biodegradable;
- It should have a high organic carbon content;
- It should be soluble in or miscible with water.

Substances that have been considered as supplemental carbon sources are listed in Table 1.

Substance	Organic carbon, mg C/mg	COD, mg O_2/mg
Methanol	0.38	1.50
Ethanol	0.52	2.09
Acetic acid	0.40	1.07
Glucose	0.40	1.07
Glycerol	0.39	1.22

Table 1: Organic carbon content and COD of alternative carbon sources

Initially, glycerol was selected as a potential carbon source owing to the absence of health and safety concerns with its use and its ready availability. Treatment studies were carried out in a laboratory-scale reactor that was scaled according to the design expected for full-scale operation. Parameters such as hydraulic residence time (HRT) and alkalinity addition for nitrification had previously been optimised, and the system was operated at an sCOD:TN ratio of 8 to ensure that the overall carbon supply was sufficient to promote denitrification and enable an effective comparison to be made between control conditions (phenol dosing) and addition of glycerol. Figure 4 gives an overview of the findings observed.

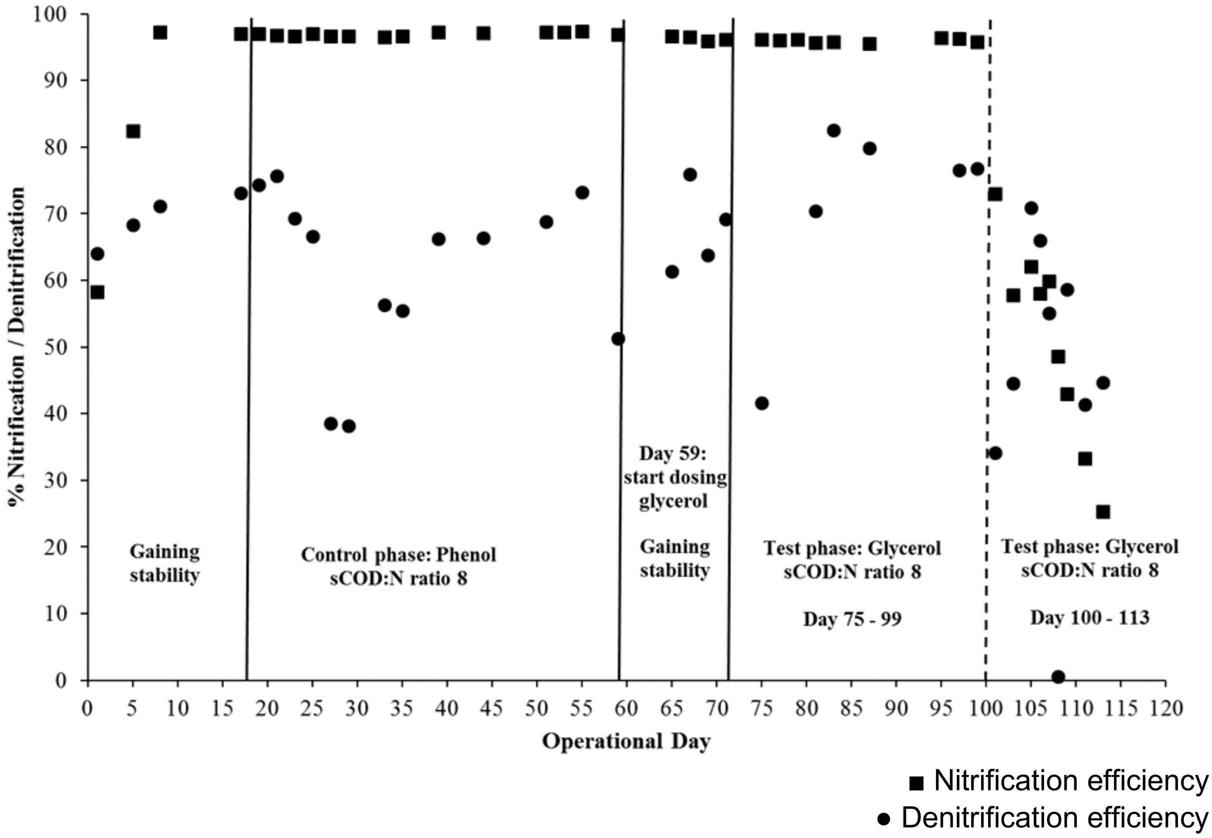

Figure 4: Nitrification and denitrification treatment efficiencies in the anoxic-aerobic laboratory-based treatment plant with phenol and glycerol as external carbon sources

The decline in treatment efficiencies from day 100 onwards was associated with a rapid decline in concentrations of the mixed liquor suspended solids (MLSS – the biomass containing the bacteria that treat the effluent). The MLSS concentration under control conditions (phenol) was maintained at an average of 2,165 mg/l. Initially with glycerol dosing, the mixed liquor suspended solids (MLSS) concentration remained stable at 2,235 mg/l (days 75 to 99), however, after 25 days of dosing with glycerol the average MLSS concentration declined to 1,730 mg/l (days 100 to 113). As a result of the declining MLSS, carryover of COD was observed from the anoxic to the aerobic tank. It is believed that this will have intensified the loss of slower-growing nitrifying bacteria in the aerobic tank leading to the rapid decline in nitrification. On the final day of operation the MLSS reached just 750 mg/l representing a 65% decrease in MLSS.

The research described above was focussed on measures required to incorporate an additional denitrification stage into the existing BETP configuration to reduce ammonia concentrations in the final effluent and hence achieve the BAT-AEL for nitrogenous species. However, as previously mentioned, the fundamentals of the different biological processes that occur during coke oven effluent treatment, and how they may interact, are not fully understood, and there is some evidence that treatment of other pollutants may also be affected by the current effluent composition. For example, the concentration of free cyanide in the final effluent is higher than the influent cyanide level on occasions and the reasons for this are still unknown.

Furthermore, there is a potential conflict between the measures necessary to reduce ammonia concentrations and those necessary to reduce PAHs. The PAH in the final effluent is largely associated with biomass that does not settle out in the clarifiers. One way to reduce the PAH content of the sludge may be to reduce the mean age of the biomass, and hence minimise the opportunities for the sludge to pick up PAHs. However, in order to build up a viable population of nitrifying bacteria to effectively treat the nitrogenous species, the solids retention time must be increased to, typically, 60 days. Again, bioaugmentation may be investigated as a potential means of increasing PAH degradation within the BETP.

Consequently, a derogation is sought in regard to free cyanide and PAHs (as well as nitrogenous species). The causes of the increased levels of cyanide and PAHs are not fully understood, but are linked to the technical characteristics of the installation.

Conclusions from research programme to date

- The composition of the cokemaking effluent at Scunthorpe has changed owing to the closure of Dawes Lane coke ovens so that the intrinsic soluble COD in the raw effluent is insufficient to meet the organic carbon demand required to consistently reduce concentrations of nitrogenous species in the final effluent to below the 50 mg/l BAT-AEL. As a consequence, an external source of carbon would be required to achieve the lower levels.
- Several sources of carbon have been considered and glycerol was selected for initial assessment of its capability to meet the carbon shortfall owing to its ready availability and the fact that it does not require COMAH registration.
- Laboratory trials have shown that glycerol is an ineffective carbon source owing to the systematic loss of biomass resulting in a 65% reduction in the MLSS which resulted in loss of nitrification (reduced from 97% to <30%) and denitrification (reduced from 62 to 41%) and hence in effluent TN in excess of the required 50 mg/l emission limit.