SUNDERLAND UTR FACILITY ENVIRONMENTAL PERMIT APPLICATION

Appendix BAT-OT 01

Assessment of Abatement Options

SLR Ref: 416.11075.00004
Version No: 1
October 2021

BASIS OF REPORT

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1.0 Introduction

SLR Consulting Ltd (SLR) has been instructed by Wastefront AS to prepare a bespoke Environmental Permit (EP) application for the proposed Sunderland Used Tyre Recycling (UTR) Facility, to be located at Extension Road, East End, within the Port of Sunderland, SR1 2NR (the site). The site will be operated by Wastefront Sunderland Limited (Wastefront).

The proposed facility will process up to 77,000 tonnes per annum (tpa) of end-of-life tyres by pyrolysis followed by distillation and refining to produce approximately 24,000 tpa of carbon black and 30,000 tpa of liquid products for use in tyre manufacture and synthetic fuels. Steel will be recovered as a by-product. Fuel gas is produced by the pyrolysis and distillation processes and is used solely as fuel to provide heat for the process, rather than as a target product.

As requested by the Environment Agency (EA) following pre-application advice, this document provides an assessment of the costs and benefits of abatement techniques suitable for the removal of contaminants from the combustion of the fuel gas burned at the facility.

1.1 Overview of the combustion of fuel gas

The pyrolysis process and naphtha distillation stages of the process produce a hydrocarbon rich gaseous by-product similar to refinery fuel gas, which is used as a fuel to heat the pyrolysers and carbon black dryers as an integral part of the process.

The raw fuel gas produced by the pyrolysers is scrubbed with caustic solution in a packed tower to remove H_2S, HCl and CO_2. Some of the cleaned gas is burned to provide heat for the carbon pellet dryers, some is blended with the fuel gas from the distillation stage and burned to heat the pyrolysers, and any remaining gas is used to fuel the Regenerative Thermal Oxidiser (RTO). The RTO is also used to treat the combustion gases from the pellet dryers and pyrolyser burners as well as the exhaust gases from combustion of distillate oil in the diesel generators. Natural gas is used as a start-up fuel for the pyrolysis heating system and is also used to supplement the RTO if required.

All combustion emissions are ultimately released from the facility via the RTO. The emissions from the RTO are cooled in a water quench tower followed by removal of oxides of sulphur and any remaining traces of HCl in a caustic scrubber tower, before the cleaned gases are released to atmosphere via the 30m high stack.

This assessment therefore considers the Best Available Techniques (BAT) for the abatement of pollutants from the RTO.

1.1.1 Raw Fuel Gas & Treatment

Fuel gas is produced from the tyre pyrolysers and the naphtha distillation stage.

Due to the relatively high concentrations of pollutants in the raw pyrolyser fuel gas, it undergoes treatment (described above) before use as a fuel to provide process heating.

The fuel gas stream produced from the naphtha distillation stage has relatively minor amounts of pollutants and is blended with the cleaned pyrolyser gas before the fuels are used for providing energy for the process.

The Refinery Bref describes refinery fuel gas as a low polluting fuel which generates little dust and low sulphur emissions (as the gas is cleaned before combustion) and with NO_x emissions much lower than the combustion of liquid fuels.

1.1.2 Combustion Exhaust Gases from the RTO

The unabated emission concentrations resulting from the RTO combustion are compared with typical refinery fuel gas unabated emissions in Table 1 below, together with the estimated emissions post abatement and the IED Annex VI emission limits. The range in emissions reflects the different RTO feedstock mix depending on the configuration of the process.

The unabated emissions of SO_2 are higher for the Wastefront process than typical refinery fuel gas because the RTO treats, in addition to the other feed streams, the exhaust gas from the diesel generators which contains elevated levels of sulphur. Another reason for the variation is that the refinery fuel gas emissions are based on 100% fuel gas combustion, whereas the RTO treats a mixture of fuel gas, natural gas, distillate oil and exhaust gases from all the on-site combustion sources.

Table 1 Comparison of Emissions

Pollutant	Typical Fuel Gas Unabated Emission[1] (mg/m^3)	Estimated RTO Unabated Emission (mg/m^3)	Estimated RTO Emission Post Abatement (mg/m^3)	Annex IV Emission Limit (mg/m^3)
SO_2	1 -20	198 - 423	4 - 7	50
NOx	<100	49 - 99	5 - 9	200
Particulate	1	<1	<1	10

[1] Table 3.56 of the Bref – assumes 100% fuel gas combustion

From the above, it can be concluded that:

- The estimated SO_2 emissions require abatement in order to meet the Annex IV limit
- The estimated emissions for NOx in the unabated exhaust gas are likely to be substantially lower than the Annex IV limit and are reduced to very low levels following wet scrubbing; and
- The particulate emissions are likely to meet the Annex IV limit in the unabated exhaust gas.

1.2 Assessment of BAT for Abatement Options

As part of the demonstration that BAT has been adopted for environmental protection, an assessment of the abatement options has been completed. This assessment should take into account both costs and environmental benefits to demonstrate why the method chosen is considered to be the most appropriate. However, there is currently very little published information on the performance of abatement techniques specific to the pyrolysis of tyres. Therefore, in line with the pre-application advice received from the EA the assessment is based on information sourced from:

- EA Guidance 'EA – Industrial Waste Management – Establishing a methodology that support the assessment of the impact of ATT processes' Ref ED13600100, Issue No1, 31st March 2021 ('the ATT guidance'); and
- the techniques described in the Mineral Oil and Gas Refining Bref ('the Refining Bref').

In accordance with the methodology set out in the H1 guidance, this cost/benefit study includes assessment, where relevant, of the following aspects:

- scope of available abatement options;

- scope of emissions and impacts;
- environmental impacts;
- costs; and
- selection of the Best Available Technique.

2.0 Scope of Available Abatement Options

2.1 Pollutants requiring control

The key pollutants of concern in the exhaust gases following combustion of fuel gas from tyre pyrolysis include:

- Acid Gases: SO_2, HCl and HBr;
- Nitrogen dioxide; and
- Tar & particulate.

From the information provided in Table 1, it is concluded that abatement of SO_2 will be necessary in order to meet the Annex VI emission limit. Accordingly, Wastefront propose to use a wet scrubbing technique for abatement. Other abatement options are available for SO_2 and therefore an options appraisal has been carried out to establish which of these represents BAT for the process.

The wet scrubbing is primarily designed for the removal of SO_2. However, in addition, it is effective in removing NOx from the flue gases. Based on the information in Table 1, the estimated emissions of NOx post wet scrubbing are very low. Although techniques exist for the abatement of NOx in exhaust gases, given the low NOx concentrations in the exist gas from the wet scrubber, it is considered that the benefits of any further abatement would be extremely marginal and the costs would be hugely disproportionate. Therefore, an appraisal of NOx abatement options is not considered necessary.

The presence of tar and particulate in fuel gas is identified as a potential issue in the EA's ATT guidance. However, the raw pyrolyser gas is cleaned in a wet scrubbing process before it is burned, which removes any tar or particulate present. As shown in Table 1, the emissions of particulate from fuel gas combustion are expected to be very low. As the exhaust gases from the RTO are also subjected to a wet scrubbing process, it is considered that an appraisal of further abatement options would be unnecessary.

The following sections consider an assessment of abatement options for acid gas removal.

2.2 Primary Control Measures

Primary control measures for the reduction of acid gas pollutants may include:

- Reduction of contaminants (such as sulphur and chlorides) in feedstocks; and
- Reduction of contaminants in the raw fuel gas.

2.2.1 Reduction of contaminants in feedstocks

The fuel gas composition resulting from tyre pyrolysis is dependent on the type of rubber used for the tyre manufacture. Sulphur and halides are also present in the additives used in tyre manufacture to provide elasticity and for vulcanisation and this leads to a relatively higher presence of these compounds in the fuel gas compared with other waste types.

However, the opportunity to reduce these contaminants from waste tyre feedstocks is very limited as these additives are a fundamental component of the manufacturing process. No techniques to reduce contaminants in the tyre feedstock are proposed.

2.2.2 Reduction of contaminants in the raw fuel gas

The EA's ATT guidance suggests that fuel gas burned within the process is not usually cleaned, as it is not intended as a target product.

However, the Refinery Bref suggests that fuel gas is commonly cleaned before combustion and the design of the Wastefront process includes a caustic wet scrubbing process to remove sulphur and halogen compounds. Besides reducing the risk of sulphur and halogen combustion products, this also has the advantages of protecting the longevity of the fuel combustion systems as well as removing any particulate or tar from the raw fuel gas.

2.3 Secondary Control Measures

Several secondary abatement techniques can be used to remove acid gas pollutants from the exhaust gases following combustion of the fuel gas which are considered and appraised in the following section.

3.0 Acid Gas Abatement Assessment

3.1 Available Options

A range of techniques are available for the removal of acid gases from combustion products. These fall into three main categories as described below, which form the options for appraisal.

Dry Scrubbing

Dry methods involve injection of powdered alkaline reagents, commonly sodium bicarbonate or calcium hydroxide, into the flue gas which react with acid gases. The solid residues are collected on the surface of bag filters and these residues form a filter cake within which a significant amount of the reaction between the reagent and acid gases takes place. Reagent dosing rate is usually higher than wet or semi-dry systems, to achieve the same low emission levels. Recirculation of the reagent / contaminant mix from the bag filter, combined with conditioning of the injected material enhances reactivity and reagent utilisation.

Semi-dry Scrubbing

Semi-dry systems add the alkaline reagent into the flue gas stream as an aqueous slurry, such as lime milk ("slaked lime"), generally by means of a rotary atomiser. Water evaporates from the slurry droplets, thus cooling the gases and resulting in dry reaction products that are typically removed by bag filter. Compared with dry processes, semi-dry processes are typically more efficient and require less sorbent. The semi-dry system typically has a higher power consumption than a dry system due to the additional atomiser, lime slaking and pumping equipment needed. As for dry scrubbing, the reagent and reaction products are collected on bag filters which act as a secondary site for reactions to occur.

Wet Scrubbing

Wet-scrubbing uses a re-circulated solution of either sodium hydroxide or calcium hydroxide, which is sprayed into the flue gas stream as fine droplets or onto inert packing material to provide good gas/liquid contact. Wet systems have a higher abatement performance than dry systems, with lower reagent consumption and solid waste generation. They also remove particulate and tar from the fuel gas. However, they produce effluent or concentrated caustic residues which require further treatment and which may place an effluent burden to the water environment.

3.2 Comparison of Techniques

Table 2 below provides a summary of the three abatement options which would be suitable for the removal of acid gas from the RTO exhaust gas. All three techniques can achieve high levels of acid gas removal and would be capable of meeting the emission limit values for SO_2, HCl and HF in Annex VI of the IED. The Air Emissions Risk

Assessment provided in Section 5 of this permit application also confirms that the emissions, assuming a worst case concentration in line with the emission limits values in Annex VI, will not result in exceedance of Air Quality Standards or unacceptable impacts on ecological receptors when received into the surrounding environment.

Table 2 Comparison of Acid Gas Abatement Techniques

Option	Performance of the Technique
Dry Scrubbing	• Removal rates of acid gases are approximately 80 – 85% (by mass)[1] • Reaction times are slower than wet systems so a longer residence time is required. • Powdered hydrated lime or calcium carbonate is injected into the flue gas and collects on the downstream bag filter. • Approximately 40% more reagent is required compared with semi-dry scrubbing and therefore greater amounts of waste residues are also produced. • Waste residues are hazardous and must be treated before disposal. • There is no requirement for plume reheat so energy use is relatively low compared with the other options. • This option has a lower capital cost than semi-dry or wet processes but has greater operating costs because of the greater amount of reagent used and amount of waste that needs treatment and disposal.
Semi dry Scrubbing	• Removal rates of acid gases are approximately 80 - 90% (by mass)[1]. • Alkaline reagent is sprayed as an aqueous solution, typically as lime milk. Water evaporates, allowing reagent products to be collected on the downstream bag filter and recirulated. Reaction rates can be low so reagent is typically re-circulated until replete. • Less reagent is used and less waste residue is produced than for dry scrubbing, but the residues are hazardous and must be treated for disposal. • Semi-dry systems need more energy for pumping and reheat for plume prevention than for dry scrubbing. • This option has higher capital costs than dry scrubbing due to pumping and reagent slurry recirculation costs. Operating costs are lower as reagent use and waste disposal costs are lower.
Wet scrubbing	• Removal rates of over 90 - 99% (by mass)[2]. Wet scrubbing systems also effective for removing tars and dust as well as some nitrogen oxide content. • The wet scrubbing technique proposed for Wastefront produces a residue of concentrated salts consisting of 40% solids, 60% liquids. The volume of residue is less than that produced by dry or semi dry scrubbing but is hazardous waste and must be treated for disposal. • Energy use for wet scrubbing is similar to semi dry systems as there are pumping requirements and reheat for plume prevention. • Wet systems tend to have a higher capital cost than dry or semi dry scrubbing because of the pumping and recirculation costs, but the cost of reagent use and waste disposal is lower.
[1] ATT Guidance [2] ATT guidance – two ranges are provided; the upper range is for spray towers.	

3.3 Scope of Emissions and Impacts

To identify BAT for acid gas abatement, all the potential environmental impacts associated with the operation of each candidate option need to be assessed, not simply the effects of emissions of acid gases.

Table 3 below lists the full range of environmental impact categories that need to be considered according to the H1 guidance and identifies those which are relevant to the options selected for this appraisal. The categories only need to be taken into account in the appraisal if there are differences in potential impact between the options.

Table 3
Identification of Relevant Environmental Considerations

Impact	Comments	Relevance
Emissions to Air	Significant differences between options. Techniques result in different releases of SO_2 HCl & HF that are significant for acid gas abatement options.	Y
Emissions to Water	No emissions to water from any of the options.	N
Noise & Vibration	Same for all options.	N
Odour	Same for all options.	N
Raw Materials	Potential differences in types & quantities of reagents used.	Y
Visual Impact	Same for all options.	N
Risk of Accidents	Similar for all options	N
Global Warming Potential	Potential differences in energy consumption and overall thermal recovery efficiency between options.	Y
Ozone Creation	Similar for all options.	N
Waste Generation & Disposal	Potential significant differences between quantities of waste generated by each option. All residues will be hazardous waste and require treatment.	Y

As identified in Table 3, the categories relevant to the options appraisal based on this assessment are:

- Emissions to air;
- raw materials;
- global warming potential; and
- wastes generation and disposal.

3.4 Environmental Impacts

This section provides a summary of the impacts of the three abatement options for each of the environmental impact categories identified above.

Little published information is available on the performance and cost of acid gas abatement systems for pyrolysis fuel gas combustion. Although some details are provided in the EA's ATT guidance and the Refinery Bref, it is considered that this is insufficient to carry out a comparison of the techniques using a quantitative technique such as the EA's H1 tool. Therefore, a simple qualitative assessment has been carried out to compare the relative performance of each technique against the four relevant environmental impact categories. This has been carried out by assessment of the following parameters for each type of environmental impact:

- Air quality performance is based on the relative performance of each technique for the removal of acid gases;
- Raw materials performance is based on the relative amounts of reagent required to achieve optimum acid gas removal;
- Waste generated is based on the amount of residues generated from each option only, as all residues are hazardous waste and would require treatment before recovery or disposal;
- Global Warming Potential is based on energy used, on the assumption that the same fuel is used (in the diesel generators) for all options which would produce carbon dioxide emissions.

The options are scored in order of relative performance in Table 4 below, where 1 is the best performer and 3 the least.

Table 4 Relative Performance of Abatement Options

Technique	Air Quality	Raw Materials	Waste Generated	Global Warming Potential	Overall score	Overall Ranking
Dry scrubbing	3	3	3	1	10	3
Semi-dry scrubbing	2	2	2	2	8	2
Wet scrubbing	1	1	1	3	6	1

3.5 Costs

There is little published information available on the costs of abatement for the techniques considered, especially for relatively smaller scale applications such as the Wastefront process, and for this reason a detailed costing to produce an annualised cost has not been carried out. The literature sources which are available (Waste Treatment Bref) suggest the following relative ranking of capital and operating costs:

Technique	Capital Cost	Operating Cost	Overall Score	Overall Ranking
Dry scrubbing	1	3	4	1
Semi-dry scrubbing	2	2	4	1
Wet scrubbing	3	1	4	1

The above scoring is a very simplistic assessment; in reality the ranking of annualised costs might differ due to the relative difference between capital and operating costs between each technique. However, the simple assessment indicates that the cost differences between techniques may not be significant.

4.0 Selection of the Best Environmental Technique

The following key conclusions have been reached from the foregoing information:

1. All abatement options considered would meet the emission limits within Annex VI of the IED. The detailed air dispersion modelling in Section 5 of the application also confirms that all options would result in emissions well within air quality standards, including taking background concentration into account, assuming a worst case emission value in line with Annex VI.

2. The simple ranking exercise indicates that wet scrubbing provides the best environmental performance in every category other than global warming.

3. A simple ranking of relative capital and operating costs has been carried out as there is a lack of published cost data for these processes. The simplified assessment indicates that there may not be significant differences between the options.

4. The options assessed all achieve the high degree of performance to meet the required mandatory standards and BAT-AELs. The main difference in environmental performance and cost-effectiveness between the options relates to the amount of residues and their disposal costs as well as energy use.

5. On the basis that wet scrubbing performs best in more environmental categories than dry or semi-dry scrubbing it is considered that this represents BAT for the proposed Wastefront facility.

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