Raw Materials

Introduction

The TEGCO Immingham Ltd Installation at Netherlands Way, Stallingborough, Grimsby, DN41 8DF is an Energy from Waste (EfW) process. The installation is designed to consume 320,000 Te/yr of Refuse Derived Fuel (RDF) based on 10 MJ/kg (LHV), producing: -

- 12 MW electrical export,
- 51 MW thermal export (60 Te/hr) as steam (no condensate return).

The installation is a Combined Heat & Power (CHP) plant sized and is designed to replace the steam and electricity currently generated by an existing CHP plant on an adjacent industrial plant. The existing CHP plant is reaching the end of its operational life and will be decommissioned when the installation is operational.

The need to continue to take waste in the event that steam and/or electricity cannot be exported (e.g. customer is shutdown), the installation is designed such that all steam generated at normal waste feed can pass through the turbine and condenser resulting in 24 MW electrical export.

A proportion of the RDF is sourced from local waste management companies and transported to the installation by road. The remaining is sourced from further afield and transported by rail to 1 of 2 local railheads and the final transfer from the railhead to the installation is by road.

The installation will operate continuously (24 hr/day & 7 day/week) for >8,000 hr/yr.

The installation consists of 2 off 20 Te/hr incineration lines (combustor, boiler & feed-water system) and a single turbine and air cooled condenser.

The installation is designed not to generate any waste water from the process during normal operation.

The installation is designed to be fully compliant with the 2019 European BREF for Waste Incineration (JRC 118637) and the associated BAT Conclusions published in the Official Journal of the European Union on 3rd December 2019.

Raw material safety data sheets are included in Appendix 2.

NO_X Abatement

The reagent used in the SNCR system is 40%wt urea solution.

An SNCR system can by operated with dry urea, urea solution, or aqueous ammonia solution. There are advantages and disadvantages with all options.

The Sector Guidance on Waste Incineration (EPR5.01) and 2019 BREF both consider that all options as suitable for NO_X abatement.

Aqueous Ammonia Solution

The use of ammonia solutions introduces additional management issues and risks compared to the use of urea. These include:-

- Significant health and safety issues associated with the use of/exposure to ammonia solution or vapour;
- Even at extremely low concentrations, ammonia vapour is extremely odorous resulting in issues both on and off site;
- Air quality legislation specifically addresses ammonia due to its adverse impact on human & animal health and ecosystems.
- Atmospheric storage tanks have to be fitted with suitable abatement (typically wet scrubbers using sulphuric acid). This introduces additional hazardous raw materials (sulphuric acid), potentially significant emissions to air, additional waste streams (ammonium sulphate solution), and operational equipment;

The main advantage is potentially lower Nitrous Oxide (a potent greenhouse gas) emissions.

Dry Urea

The use of Dry Urea introduces additional management issues and risks compared to the use of urea. These include:-

- Dry Urea is supplied in "bulk bags" introducing manual handling and storage issues;
- Dry urea needs to be made up into a solution prior to use as a reagent in an SNCR system;

Urea Solution

Urea has the following advantages: -

- The health, safety and odour issues associated with ammonia are avoided;
- Delivered by road tanker and blown into storage tank;
- No additional abatement equipment is required to prevent excessive emissions from atmospheric storage tanks;
- It has a wider effective operational temperature range (750 – 1,000°C) giving better & more consistent abatement performance.

The main disadvantage is the potential for slightly higher Nitrous Oxide emissions however these can be addressed with good process design and control.

Acid Gas Abatement Reagent Selection

The reagent used for acid gas abatement is Hydrated Lime ($Ca(OH)_2$).

A dry injection acid gas abatement system can be operated with Sodium Bicarbonate ($NaHCO_3$) or $Ca(OH)_2$.

The reagents have similar levels of abatement performance. However, the level of reagent use and therefore residue generation and disposal is different.

This requires a full assessment following the Horizontal Guidance note H1 methodology. The assessment is detailed in Appendix 1 and is summarised in Table 1 below.

Table 1 – Costs per Unit Hydrogen Chloride Abated

Item	Unit	$NaHCO_3$	$Ca(OH)_2$
Mass of reagent required	kg/kmol	106	85
Mass of residue generated	kg/kmol	80	103
Cost of reagent	£/tonne	240	185
Cost of residue disposal(1)	£/tonne	135(2)	135
Overall Cost	£/op. hr/kmol	36.25	29.57
Ratio of costs	N/A	1.23	1

Notes:

1. Excludes landfill tax,
2. No allowance is included for potential additional "pre-treatment" costs for Sodium based residues.

For HCl, the use of $NaHCO_3$ would lead to less FGCr generation than a $Ca(OH)_2$ based system, however this is significantly outweighed by the advantages of using $Ca(OH)_2$ as a reagent, which are: -

- $Ca(OH)_2$ has higher molar removal rates of acid gases than $NaHCO_3$, which is reflected in the reduced mass of reagent consumed;
- $Ca(OH)_2$ based FGCr has a lower leaching potential than $NaHCO_3$ based FGCr. Therefore, there are greater waste management options available for $Ca(OH)_2$ based FGCr. These include options for the recovery of materials from $Ca(OH)_2$ based FGCr, e.g. it can be recovered into substitute products displacing virgin materials. TEGCO conclude that the only currently 'available' option for the management of $NaHCO_3$ based FGCr is disposal in landfill.
- The reaction temperature for $Ca(OH)_2$ systems match well with the optimum adsorption temperature for carbon, which is dosed at the same point in the process;
- The $Ca(OH)_2$ system has a slightly lower global warming potential due to the reaction chemistry;
- The costs per kmol HCl abated are approximately 23% higher for a $NaHCO_3$ system than a $Ca(OH)_2$ system.

Auxiliary Fuel

Natural gas is used as the Auxilary/Support fuel

As stated in Article 50 (3) of the Industrial Emissions Directive (IED):

"The auxiliary burner shall not be fed with fuels which can cause higher emissions than those resulting from the burning of gas oil as defined in Article 2(2) of Council Directive 1999/32/EC of 26 April 1999 relating to a reduction in the sulphur content of certain liquid fuels (1) OJ L 121, 11.5.1999, p. 13., liquefied gas or natural gas."

Therefore, as identified by the requirements of the IED, the only available fuels that can be used for auxiliary firing are:

- Natural gas;
- Liquefied petroleum gas (LPG); or
- Gas oil.

Auxiliary/support firing will only be required intermittently however when firing large volumes of fuel are required.

Natural Gas

Natural gas has the following advantages: -

- There is a suitable high pressure gas main close to the installation so arranging supply is cost effective;
- Connection to mains supply: -
    - Eliminates the need to store a large inventory of flammable hydrocarbon at the installation;
    - Eliminates vehicle movement movements and risks associated with the supply of LPG/gas oil;
    - Ensures that unexpected disruption to supply is unlikely helping to ensure continuous operation.

Liquefied petroleum gas (LPG)

LPG is a highly flammable mixture of hydrocarbon gases and is readily available.

Significant inventory has to be maintained onsite and potentially significant additional traffic movements may be required to ensure adequate inventory is maintained at all times, especially start-up & shutdown.

LPG has to be maintained under pressure (in purpose designed storage vessels) to remain liquid at ambient temperature and pressure.

The site footprint is small meaning that gas storage cannot be easily segregated from other activities.

These factors mean that in the event of a fire at the site, there would be a significant risk of explosion/major fire should the LPG storage be affected.

Gas oil

Gas oil is a flammable hydrocarbon liquid that would have to be stored

Significant inventory has to be maintained onsite and potentially significant additional traffic movements may be required to ensure adequate inventory is maintained at all times especially, start-up & shutdown.

The site footprint is small meaning that gas oil storage cannot be easily segregated from other activities.

These factors mean that in the event of a fire at the site, there would be a significant risk of major fire should the gas oil storage be affected.

Small quantities of gas oil (diesel) is used for standby emergency equipment (Integral tanks in packaged fire pump and packaged generator)

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Appendix 1

1. Assessment of “Costs per Unit Hydrogen Chloride Abated”

Assessment of “Costs per Unit Hydrogen Chloride Abated”

Options Considered

This assessment only considers the two alternative reagents for a dry system for acid gas abatement, i.e. Sodium Bicarbonate ($NaHCO_3$) and Hydrated Lime ($Ca(OH)_2$).

Environmental Performance Hydrogen Chloride (HCl)

Emissions to Air

There is no change in emissions to atmosphere between the two reagents.

Both achieve the same level of abatement.

Deposition to Land

There is no difference between the two reagents.

Emissions to Water

There are no emissions to water associated with either reagent.

Photochemical Ozone Creation Potential

There would be no change to POCP for either reagent.

Global Warming Potential

$NaHCO_3$ has a higher optimum reaction temperature than $Ca(OH)_2$ meaning that less heat can be recovered in the boiler adversely affecting power generation and/or steam export.

This can be addressed adding additional heat recovery after the acid gas abatement system. Therefore, it has been assumed that there is no impact on global warming potential from this operational difference.

The reaction of $NaHCO_3$ with HCl (and Sulphur Dioxide (SO_2)) results in the generation of Carbon Dioxide (CO_2) directly increasing global warming potential.

The reaction of $Ca(OH)_2$ with HCl (or SO_2) does not result in the generation of CO_2, therefore there is no direct effect on global warming potential.

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$NaHCO_3$ has better solid handling properties than $Ca(OH)_2$ however $Ca(OH)_2$ is widely used and this is not considered a significant issue.

$NaHCO_3$ and $Ca(OH)_2$ react with the acid gases to produce alkaline salts as per the following reactions: -

$$NaHCO_{3(s)} + HCl_{(g)} \rightarrow NaCl_{(s)} + H_2O_{(g)} + CO_{2(g)}$$

$$Ca(OH)_{2(s)} + 2HCl_{(g)} \rightarrow CaCl_{2(s)} + 2H_2O_{(g)}$$

In order to promote the reactions above, excess quantities of $NaHCO_3$ or $Ca(OH)_2$ will be required. The excess reagent is lost in the residue. The "stoichiometric ratio" is the ratio between the quantity of reagent supplied and the theoretical quantity required to complete the reaction.

$NaHCO_3$ has a historically been used with significantly lower stoichiometric ratio than $Ca(OH)_2$.

The equipment vendor's operational data indicates the following: -

- $NaHCO_3$: A stoichiometric ratio of around 1.26 is used,
- $Ca(OH)_2$: A stoichiometric ratio of around 2.28 is used, which at first glance, appears to be a significant in terms of raw material use.

However the following factors also significantly impact raw material use: -

- $NaHCO_3$ has a higher relative molecular weight (84 viz 74);
- 1 kmol of $NaHCO_3$ reacts with 1 kmol of HCl whereas 1 kmol of $Ca(OH)_2$ reacts with 2 kmols of HCl.

The result is that the overall mass consumption of $NaHCO_3$ is actually 25% higher than $Ca(OH)_2$.

The reagent required to abate one kmol of HCl is calculated as 106 kg for $NaHCO_3$ and 85 kg for $Ca(OH)_2$.

Similarly, the reagent required to abate one kmol of SO_2 is calculated as 212 kg for $NaHCO_3$ and 169 kg for $Ca(OH)_2$ based on the following reactions: -

$$4NaHCO_{3(s)} + 2SO_{2(g)} + O_2 \rightarrow 2Na_2SO_{4(s)} + 2H_2O_{(g)} + 4CO_{2(g)}$$

$$2Ca(OH)_{2(s)} + 2SO_{2(g)} + O_2 \rightarrow 2CaSO4_{(s)} + 2H_2O_{(g)}$$

This means that conclusions based on raw material usage are equally valid for sulphur dioxide.

Waste Streams

The residue production rate for abatement of one kmol of HCl is calculated as 80 kg when using $NaHCO_3$ and 103 kg when using $Ca(OH)_2$.

Similarly, the residue production rate for abatement of one kmol of SO_2 is calculated as 186 kg when using $NaHCO_3$ and 233 kg when using $Ca(OH)_2$.

Comparing the FGCr resulting from the use of $NaHCO_3$ and $Ca(OH)_2$, those from $NaHCO_3$ have: -

- Higher leaching characteristics (increasing the risk of environmentally hazardous species being released),
- Significantly more limited waste management options.

Costs

There is little difference in capital cost between the two reagents abatement systems. However the higher operating temperature required for $NaHCO_3$ will result in a slight reduction in efficiency or increased capital to install additional heat recovery.

The purchase cost of $NaHCO_3$ is significantly higher than $Ca(OH)_2$, with $NaHCO_3$ costing almost 30% more than $Ca(OH)_2$ per tonne. This makes $NaHCO_3$ an uneconomic option in comparison to $Ca(OH)_2$.

The cost of disposing of the residue must also be considered due to the differences in quantity, and the availability of outlets. Currently TEGCO conclude that the only sensible outlet for $NaHCO_3$ based residues is disposal to landfill and this assessment is therefore based on disposal to landfill. $NaHCO_3$ based residues are more difficult to stabilise than $Ca(OH)_2$ residues, however for the purposes of this analysis the cost of disposal to landfill (including any required treatment required to achieve Waste Acceptance Criteria) has been considered to be the same for both residue streams. The landfill disposal cost quoted for $Ca(OH)_2$ based residues is £135/Te.

The operating costs for the two abatement options are compared below, using the equipment vendors data and expressed on the basis of abatement of one kmol of HCl are summarised in Table 1 below: -

Table 1 – Costs per Unit Hydrogen Chloride Abated

Item	**Unit**	**$NaHCO_3$**	**$Ca(OH)_2$**
Mass of reagent required	kg/kmol	106	85
Mass of residue generated	kg/kmol	80	103
Cost of reagent	£/tonne	240	185
Cost of residue disposal(1)	£/tonne	135(2)	135
Overall Cost	£/op. hr/kmol	36.25	29.57
Ratio of costs	N/A	1.23	1

Notes:

1. Excludes landfill tax,
2. No allowance is included for potential additional “pre-treatment” costs for Sodium based residues.

In the event that sensible recovery options for $Ca(OH)_2$ based residues are available and/or higher pre-treatment costs are incurred for $NaHCO_3$ based residues, this is will further increase the operational cost penalty of using $NaHCO_3$.

Conclusions

While the use of $NaHCO_3$ results in lower residue generation than a $Ca(OH)_2$ based system for HCl, this is significantly outweighed by the advantages of using $Ca(OH)_2$ as a reagent, which include: -

- Higher removal rates of acid gases than $NaHCO_3$, which is reflected in the quantities of reagent consumed;
- $Ca(OH)_2$ based FGCr has a lower leaching potential than $NaHCO_3$based FGCr;
- There are greater waste management options available for $Ca(OH)_2$ based FGCr. These include options for the recovery e.g. recovery into substitute products displacing virgin materials. TEGCO conclude that the only currently ‘available’ option for the management of $NaHCO_3$ FGCr is disposal in landfill;
- The reaction temperature for $Ca(OH)_2$ systems match well with the optimum adsorption temperature for carbon, which is dosed at the same time/location in the process;
- The $Ca(OH)_2$ system has a slightly lower global warming potential due to the reaction chemistry;
- The costs per kmol HCl abated are approximately 23% higher for a $NaHCO_3$ system than a $Ca(OH)_2$ system (& 21% higher for SO_2, see below).

Taking all of the factors discussed above into consideration, the use of $Ca(OH)_2$ is considered to be BAT for the installation compared to $NaHCO_3$.

Additional Cost Analysis

The following is included to demonstrate that the selection of $Ca(OH)_2$ as the BAT choice remains valid when considering SO_2 and over all acid gas abatement.

A similar analysis for SO_2 abatement is summarised in Table 2 below:-

Table 2 – Costs per Unit Sulphur Dioxide Abated			
Item	**Unit**	**$NaHCO_3$**	**$Ca(OH)_2$**
Mass of reagent required	kg/kmol	212	169
Mass of residue generated	kg/kmol	186	233
Cost of reagent	£/tonne	240	185
Cost of residue disposal(1)	£/tonne	135(2)	135
Overall Cost	£/op. hr/kmol	75.89	62.77
Ratio of costs	N/A	1.21	1
Notes: 1. Excludes landfill tax, 2. No allowance is included for potential additional “pre-treatment” costs for Sodium based residues.			

The overall operating cost of acid gas (HCl and SO_2) abatement per hour is summarised in Table 3 below.

Table 3 – Costs per Unit Acid Gas Abated(1)(2)			
Item	**Unit**	**$NaHCO_3$**	**$Ca(OH)_2$**
HCl Abatement Cost	£/op. hr/kmol	36.25	29.57
HCl Abated	kmol/hr	2.60	2.60
SO_2 Abatement Cost	£/op. hr/kmol	75.89	62.77
SO_2 Abated	kmol/hr	1.22	1.22
Total Cost	£/op. hr	186.53	153.38
Ratio of costs	N/A	1.22	1
Notes: 1. Excludes landfill tax, 2. No allowance is included for potential additional “pre-treatment” costs for Sodium based residues.			

Raw Materials

Appendix 2

Raw Material Safety Data Sheets

1. **Antiscalant,**
2. **Caustic Soda,**
3. **Chloric Acid,**
4. **Diesel,**
5. **Hydrated Lime,**
6. **Hydrochloric Acid,**
7. **Nitric Acid,**
8. **Powdered Activated Carbon,**
9. **RDF Type 3,**
10. **Urea.**