Bergmesteren
Raudsand AS

BAT Screening Report

Evaluation of Best Available Techniques

DOCUMENT HISTORY

Date	Revisions	Reasons for change
4/4/2017	0	Initial screening summary of BAT
12/9/2017	1	Updated with recent data from Stena
29/9/2017	2	Updated with recent data from BSH, and binder test results
23/10/2017	3	Updated with comments from internal hearing of draft Impact Assessment.

BAT Screening Report

Evaluation of Best Available Techniques

1.0. Objective

This report documents a screening exercise of Best Available Techniques (BAT) to treat, recover, and recycle primary waste streams at a possible national waste treatment installation located at Raudsand, Norway. Numerous techniques have been identified and are assessed using criteria stipulated in the EU commission reference documents (BREFs).

2.0. Background

The waste management industry is highly regulated in EU and Norway. Waste treatment installations contain operations for the recovery and or disposal of waste. Waste treatment installations are considered to provide services to society to handle their waste materials and sometimes these treatments generate products. More than 14 000 waste treatment installations exist just in the EU, including Norway (1).

The majority of the installations (over 9 900) use physio-chemical treatments applied to waste solids, waste water and sludges. Additionally, approximately 126 installations deal with treatment of inorganic waste (excluding metals), and 13 installations exist to treat waste acid/base chemicals (1).

Commonly applied techniques throughout the industry include

• generic management of installations, reception, acceptance, traceability, quality assurance, storage and handling, energy systems

• biological treatments such as anaerobic and aerobic digestion and off-site biotreatments

• physico-chemical treatments applied to waste waters, waste solids and sludges

• recovery of materials from waste such as regeneration of acids and bases, catalysts, activated carbon, solvents and resins as well as re-refining of waste oils

• preparation solid/liquid waste fuel from non-hazardous and hazardous waste

• emission abatement treatments to air, waste water and residues generated in the industry

One of the primary waste streams in Norway originates from the combustion process (incineration) of solid municipal waste. Such solid waste from incineration is typically called 'ashes'. Two types of ash are usually present; one called 'bottom ash', typically recovered at the bottom of the combustion chamber and another called 'fly ash' that is smaller in volume and collected from the combustion fumes. Filter ash is also generated if the treatment facility has this equipment installed.

Combustion ashes and flue-gas cleaning residues are one of the main waste streams treated by stabilization and solidification processes on waste treatment facilities. Other methods are vitrification, purification and recycling of some components (e.g. salts). Another method of treating combustion ashes involves the fusion of ash by plasma at very high temperatures in order to vitrify the structure (2). These are the methods that remain in focus for BMR at Raudsand.

Norway's current national site for hazardous waste treatment and disposal/storage, will be full in some years and have to close. One alternative site for a new 'next generation' national waste treatment installation is proposed at Raudsand.

3.0. BAT screening process

Over several years, Bergmesteren Raudsand AS (BMR) has been assessing various techniques to treat and recycle the primary hazardous waste streams managed in Norway (ashes, spent acid). This has included discussions with various companies in Norway, Europe, Australia, and the USA, as well as discussions with research and academic institutions in Norway and elsewhere. BMR continues to actively maintain these contacts as part of its ongoing process to develop methods and techniques for treatment / recycle, and to follow trends in technology advances, economic and social developments, and changes in scientific knowledge.

Due to the specific advantages and disadvantages of the Raudsand site, several techniques have remained in focus (e.g. physio-chemical) while others (e.g. biological treatments), have not been considered as candidates for the primary treatment process. It can be noted, however, that biological treatments of certain smaller volume waste streams are still deemed possible and potentially feasible at Raudsand.

The specific criteria or 'factors' used to screen waste treatment methods and technologies for Raudsand are found in several EU documents (2, 3, 4). These factors are summarized below (Fig. 1).

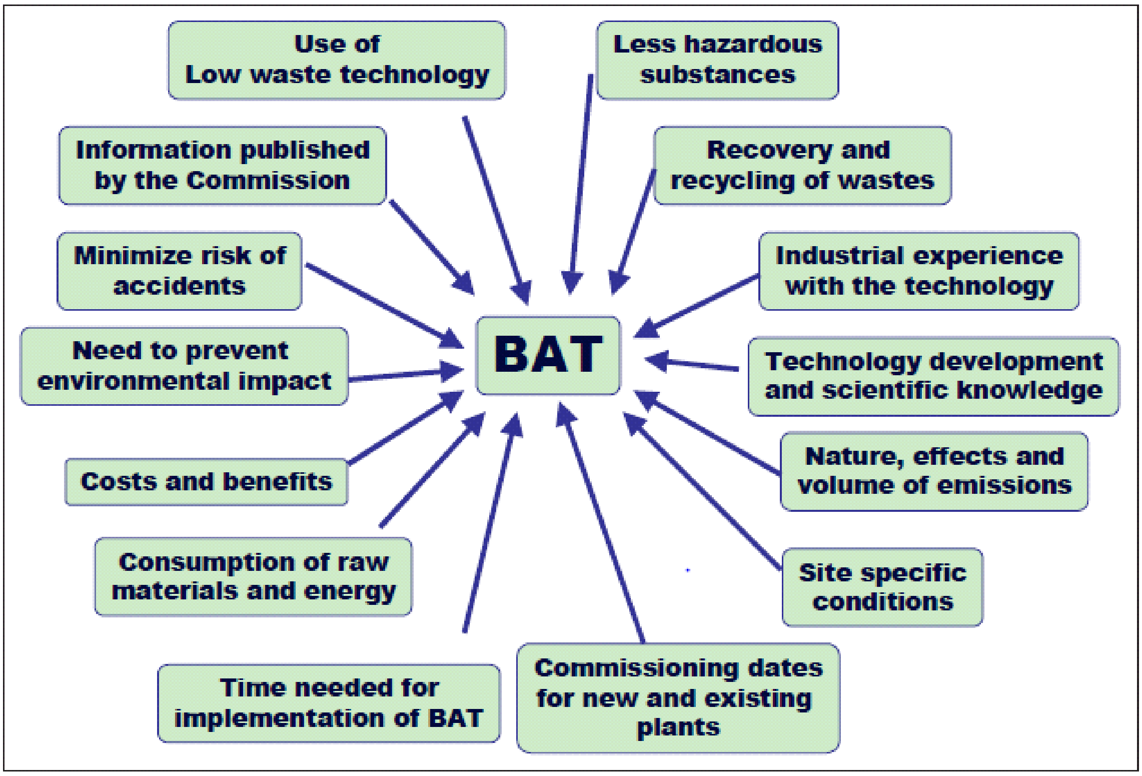

Figure 1. Criteria / factors relevant in the determination of BAT (5).

BMR, throughout 2017, will be conducting a Socio-economic & Environmental Impact Assessment of the proposed landfills and hazardous waste treatment and recycle facility at Raudsand. This BAT screening report reviews and assesses the possible methods and technologies (Best Available Techniques) found to be applicable to the Raudsand site, and further serves to support the ongoing Impact Assessment.

4.0. **Overview of applicable Best Available Techniques (BAT)**

BMR's screening process has lead to the following primary methods for treatment, recovery, recycle of ashes at Raudsand:

'Wet' processes:

1. Neutralization / stabilization using spent sulfuric acid from Kronos Titan, Norway

2. Neutralization / stabilization and salts recovery using hydrochloric acid (Halosep process)

3. Neutralization / stabilization and salts recovery using 'scrubber' fluid (minimized hydrochloric acid consumption) (Halosep process)

4. Neutralization / stabilization and salts recovery using spent sulphuric acid from Kronos Titan, Norway (Halosep process)

'Dry' processes / without acid:

5. Binder method for stabilization

6. Dry mixture of recovered used concrete and ashes

7. Vitrification by fusion of ash at very high temperatures, including further treatment for reuse

8. Neutralization of ashes by use and inclusion in cement / concrete

Additional processes for recovery / recycle:

9. FLUWA-FLUREC process to recover / reuse heavy metals

10. Electrolysis to recover / reuse the heavy metals

Currently elsewhere in Europe, large quantities of waste ash are simply deposited without any form of treatment directly into salt mines, while in Norway such waste has been treated over many years using a neutralization / stabilization process (Process nr. 1 above), using spent sulphuric acid. As a result of this process of mixing ash and acid a gypsum solid is produced containing heavy metals originating from the ash, while excess water is discharged to the sea (Oslo fjord) after treatment. This current practice (neutralization-stabilization of 2 waste streams) is proposed as the primary process for Raudsand and detailed in the Impact Assessment as a 'Base Case' only.

Using CO_2 as a means of neutralization to produce calcium carbonate is another possible method still under research, however there is currently no CO_2 source found in the Raudsand area.

Process nr. 1, 2, 3, 4, and 7 will all require approximately the same space and infrastructure. Each of these relevant processes for Raudsand have their inherent advantages and disadvantages. An overview of these, based on the EU BAT checklist (5), is summarized below in Table 1.

Table 1. Overview of process alternatives relevant to the Raudsand installation proposal.

Nr.	Process Description	Advantage	Disadvantage	Comment
1	Neutralization / stabilization using spent sulfuric acid from Kronos Titan, Norway	Tried, tested, known process. Solves spent acid challenge for	Increased volume of waste product, ie. need for increased disposal/storage	Current practice in Norway. Base Case for new installation

		society / Kronos Titan. Opertions cost /low OPEX.	volume. Difficult to recover/reuse heavy metals. Recovery efficiency in general.	in Impact Assessment. Currently assessed as BAT for stabilization only.
2	Neutralization / stabilization, including salts recovery using hydrochloric acid (Halosep process)	Increased materials recovery / reuse. Reduced volume for disposal / storage. Reduced gas produced/emitted. Lower investment compared to process nr.1.	Full scale process soon finalized	Work progressing with development by Stena Recycling (Denmark), full scale tests ongoing (2017)
3	Neutralization / stabilization and salts recovery using 'scrubber' fluid (minimized hydrochloric acid consumption) (Halosep process)	Simpler operations. Reduced need / cost for acid, lower OPEX.	Increased transport cost.	Work progressing with development by Stena Recycling (Denmark), full scale tests ongoing (2017)
4	Neutralization / stabilization and salts recovery using spent sulphuric acid from Kronos Titan, Norway (Halosep process)	Reduced volume for disposal / storage. Process can be developed and tested while operating process nr. 1 or 2.	Process not yet developed/tested.	
5	Binder method for stabilization	Simple chemistry, simple process, available materials. Economics. Can be developed at Raudsand.	Development not yet complete.	Confidential process BMR is developing. Positive results from tests. Several labs / companies contributing in

				development
6	Dry mixture of recovered used concrete and ashes	Investment low /CAPEX. Operations cost / OPEX low. Simple process.	No heavy metals recovered. Moderate stabilization.	
7	Vitrification by fusion of ash at very high temperatures, including further treatment for reuse	Exceptional recovery efficiency. Simple process. Could be an 'add on' to primary process.	Doesn't meet Kronos Titan needs, needing separate process. Not fully developed, as related to longterm binding of impurities in matrix.	
8	Neutralization of ashes by use and inclusion in cement / concrete	Investment low /CAPEX. Operations cost / OPEX low. Simple process.	No heavy metals recovered. Moderate stabilization.	
9	FLUWA – FLUREC	Proven method. Efficient heavy metal recovery, direct sale of metal products, less need for cavern disposal space, cleaner discharge water	Economics not completed yet.	
10	Electrolysis to recover / reuse the heavy metals	Increased recovery/reuse. Reduced gas production / emission. Pure metal products for sale. Process can be further developed / tested at Raudsand.	Development not yet complete.	

5.0. References

1. Integrated Pollution Prevention and Control, Reference Document on Best Available Techniques for the Waste Treatments Industries, August 2006.
2. Directive 2008/1/EC of the European Parliment and of the Council of 15 January 2008 concerning integrated pollution prevention and control. Official Journal of EU
3. Directive 2010/75/EC, Best Available Techniques (BAT) Reference Document for Waste Treatment, Industrial Emissions Directive, December 2015 (draft)
4. Directive 2010/75/EC, Best Available Techniques (BAT) Reference Document on Waste Incineration, Industrial Emissions Directive, May 2017(draft)
5. 'BAT Checklist,' IPPC Council Directive 96/61/EC, Annex IV, commonly known as the 'Integrated Pollution Prevention and Control Directive.'
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