



STATEMENT OF VERIFICATION

Technology: EVA mini

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The verification process, whose results are summarized in this Statement, complies with the EU-ETV General Verification Protocol and with the ISO Standard 14034 on Environmental Management: Environmental Technology Verification.

Verification Body

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Signed, 04/11/2022

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Signatory of EA, IAF and ILAC Mutual Recognition Agreements

1. TECHNOLOGY DESCRIPTION

Eva mini is an innovative system in which two processes are synergically combined to treat sewage sludge, namely:

1. Hydrothermal carbonization (HTC);
2. Gasification processes.

Eva mini aims at:

- Reducing by at least 80% the final material for disposal;
- Eliminating the gaseous atmospheric emissions and consequent odors from the hydrothermal treatment (HTC);
- Recovering water initially trapped within the sludge; and
- Allowing to adjust the process conditions (residence time between 0.5 to 5 hours, temperature between 180 to 250 °C) according to the characteristics of the sludge, in order to guarantee predetermined performances.

This system was developed in about five years, with a strong effort in R&D activities, and strictly collaborating with national and international universities and research centres. *Eva mini* has the capacity to process up to 500 t/a of sewage sludge.

Thanks to the valorisation of the syngas produced in the gasifier, if compared to the traditional sewage sludge disposal methods, a scale up of *EVA mini* is able to reduce the disposal cost up to 74%.

2. APPLICATION

Eva mini belongs to the ETV technology area *Water Treatment and Monitoring* since it is an integration to the existing wastewater treatment processes. However, *Eva mini* also crosses with other technology areas as it reduces significantly the waste production and, if extended with downstream dedicated technologies, it allows to recover valuable materials (such as ammonia, phosphorous, and metals), to produce hydrogen from the extracted ammonia as well as from the process water (excluding water competition), and to increase the biogas production in anaerobic digesters by controlled water recirculation.

2.1 MATRIX

Matrix	Purpose	Technologies and technical conditions
Wet biomass, such as sewage sludge from wastewater treatment plant from wastewater treatment plant with at least 30% of organic compound	<ul style="list-style-type: none"> • Drastic reduction of the waste while guaranteeing zero emissions from HTC • Production of syngas with high heating value • Recovery of byproducts with densified content of valuable materials 	<ol style="list-style-type: none"> 1) Sludge input at least 350 kg/d at about 75% moisture 2) Sludge hydration at solid/liquid ratio 11% 3) HTC at 25 bar(g) in the range 180-230 °C and 2-2.5 hours 4) Solid-liquid separation through evaporation at 140 °C and 0.1 bar(a), and subsequent vapor re-condensation, obtaining the "process water" stream 5) Continuous hydrochar gasification in fixed-bed updraft gasifier at 700-900 °C 6) Syngas burning (in torch or in boiler)

2.2 PURPOSE

The main purposes of *Eva mini* are:

- Drastic reduction of the waste while guaranteeing zero emissions from HTC;
- Production of syngas with high heating value; and
- Recovery of byproducts with densified content of valuable materials.

The matrix is sewage sludge as well as any other wet organic waste.

2.3 CONDITION OF OPERATION AND USE

The technical conditions targeting the performance claims are:

- Sludge input at least 350 kg/d at about 75% moisture;

- HTC time 2-2.5 hours at 180-230°C, 25 bar(g) of pressure and concentration solid/liquid ratio 11%;
- Continuous gasification at 800°/900°C.

2.4 VERIFICATION PARAMETERS DEFINITION SUMMARY

The performance parameters of *Eva mini* are:

1. Reduction of the final material to dispose by 85% or more (referred to the input sludge);
2. Non-hazardous solid waste;
3. Higher concentration of Fe, Ti, K, Na in the output ash than in the input sludge;
4. >50% of the mass input of Fe, Cu, Ti, Zn, Ca, K, Na is part of the output ash; and
5. Ammonia concentration in the liquid output >0.5 g/l.

3. TEST AND ANALYSIS DESIGN

Thanks to the data monitoring system and *Laumas CBL* compression weight cells installed on the tanks and evaporator, it's possible to calculate the amount of sludge and of re-hydration process water over a certain time. Each line of the HTC section, as well as the evaporator into which the treated slurry is discharged, operate batchwise Weight cells (by *AEB Italia srl*) are also placed underneath the container of the gasification bottom ash, which is the waste of *Eva mini*. The measured value enables to calculate the waste reduction referred to the input sludge. The temperature of the HTC reactors is measured by PT100 sensors. The recorded temperature values allow to verify the time and temperature of the HTC process, which in *Eva mini* can be adapted to cover a wide flexibility range (0.5-5 hours, 180-230 °C).

Samples of process water were sent to the Eco Research Laboratory and samples of input sludge and gasification ash are sent to *Ricerche e Analisi Lecher* laboratories for the evaluation of the other performance parameters.

3.1 EXISTING AND NEW DATA

Quality of the existing data provided by HBI has been positively evaluated. The existing data provided by HBI has been fully accepted. In view of our results, additional tests and measures were considered not necessary.

3.2 LABORATORY OR FIELD CONDITIONS

Laboratory analyses are performed by an ISO 17025-qualified Test Body (*Lercher Lab*, Salzano, Venice) with a proper quality management system in place

3.3 MATRIX COMPOSITIONS

The technology treats organic sludge from waste water treatment plant, after a partial drying process, with 75% of humidity and 54% of organic carbon component. However, this technology can be used for any kind of organic sludge of OFMSW.

3.4 TEST AND ANALYSIS PARAMETERS

The parameters analyzed are the mass reduction (through load cell and flow meter managed by the PLC) and the composition of sludge, ash and syngas (performed by an ISO 17025-qualified Test Body), the concentration of materials in eluate and the ammonia content of the process water

3.5 TESTS AND ANALYSIS METHODS SUMMARY

The test and analysis method of the parameter follow the following standards:

- CNR IRSA 2 Q 64 Vol 2 1984/Notiziario 2 2008 for the Humidity Content;
- UNI and EPA standard for the composition of sludge, ash, syngas and Concentration of materials in eluate; and
- The ammonia content of the process water is measured through KIT MACHEREY-NAGEL 0-05.

3.6 PARAMETERS MEASURED

The waste reduction is calculated as follows:

$$\text{Waste reduction [\% wt]} = \frac{\text{Cumulated sludge input [kg]} - \text{Cumulated ash [kg]}}{\text{Cumulated sludge input [kg]}} \times 100$$

Although *Eva mini* can operate continuously, for the calculation of this parameter it was operated batchwise, so that the calculation could be repeated at every stop of the plant. Other parameters (atmospheric emissions from HTC process, temperature flexibility of HTC, time flexibility of HTC, possibility to modulate the gaseous streams at the gasifier inlet,

production of liquid waste) can be proven by visual check or by temperature and time measures, and they do not require any calculation. The specific parameters have been selected according to the waste typology, the substance that are used and the production cycle that produced the waste. They do not contain hazardous substances in concentration such as to confer the danger characteristics reported in Annex III of Directive 2008/98/EC. They do not present extreme pH values (pH<2 or pH>11,5) fixed as limit values by Rule EC n. 1272/2008, Annex I, Part 3, and subsequent amendments for the HP8 risk attribution.

4. VERIFICATION RESULTS

FINAL MATERIAL REDUCTION

HBI collected the operating data of *Eva mini* in the period July-November 2021, while the *Eco Research Laboratory* measured the ammonia content in the process water in November 2021. The analysis on the input sludge and the output ash has been carried out by Ricerche e analisi Lecher in March 2022. In average, after HTC and Gasification process, the final reduction material is 94.3%

ASH and SLUDGE

Ricerche e analisi Lecher was commissioned to perform the analysis on the ash produced in the gasifier that must be sent to disposal. The ash has been classified as “non-hazardous waste” based on the analytic evidence, in accordance with Decision EU 955/2012 and Rule EEC/EU n. 1357/2014 and n. 997/2017 because: (1) They do not contain hazardous substances in concentration such as to confer the danger characteristics reported in attachment III of Directive 2008/98/EC, as replaced by Rule (EU) n. 1357/2014 of 18/12/2014; and (2) They do not present extreme pH values (pH<2 or pH>11,5) fixed as limit values by Rule EC n. 1272/2008 Attachment I part 3 and subsequent amendments for the HP8 risk attribution. The waste as regards the leaching test presents an eluate compliant to table 5 of Attachment 4 of Italian Legislative Decree dated 13/01/2003, n.36 (concentration limits in the elute for the landfill acceptance as non-hazardous waste).

Ricerche e Analisi Lecher was also commissioned to perform the analysis on the input sludge and the output ash to identify the concentration of determined elements. These analyses confirm that: (1) Higher concentration of Fe, Ti, K, Na in the output ash than in the input sludge; and (2) That >50% of the mass of Fe, Cu, Ti, Zn, Ca, K, Na is part of the output ash.

The following table reports the analyses of the process water for the determination of the dissolved total ammoniacal nitrogen (TAN).

Sample #	Sampling date	Analysis date	Method	TAN (mg/l)
1	Nov. 19 th , 2021	Nov. 22 nd , 2021	KIT MACHEREY-NAGEL 0-05	455
2	Nov. 22 nd , 2021	Nov. 22 nd , 2021	KIT MACHEREY-NAGEL 0-05	680

5. ADDITIONAL INFORMATION INCLUDING ADDITIONAL PARAMETERS

N/A

6. QUALITY ASSURANCE AND DEVIATION

Role	Inspector	Technical Expert	Rewriter	Proposer
Responsible	Giovanni D'ANGELO	Andrea MAFFINI	Luca MEOZZI	Daniele BASSO
Specific Verification Protocol	Draft	Draft	Review	Review and approve
Verification Report	Draft	Draft	Review	Acceptance
Statement of Verification	Draft	Draft	Review	Acceptance