



# STATEMENT OF VERIFICATION

CARBOREM TECHNOLOGY

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Signed, 22/12/2020

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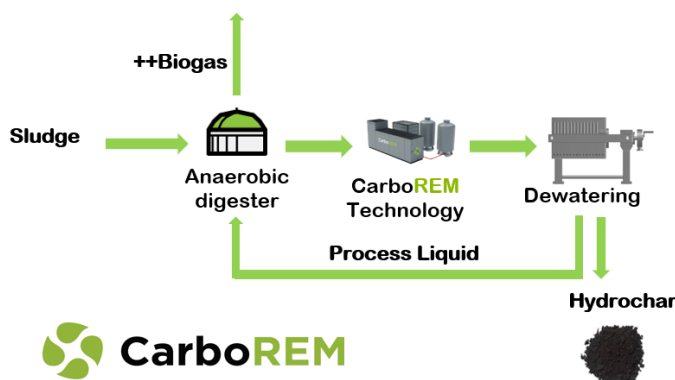
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## 1. TECHNOLOGY DESCRIPTION

Carborem technology is based on Hydrothermal Conversion (also called Hydrothermal Carbonization or HTC), an innovative process treating sewage sludge in a continuous mode at 180-190 °C and 9-14 bar, in about one hour. In Figure 1 is reported a simplified scheme showing a conceptual scheme of a common wastewater treatment plant including Carborem process.

The process, which is perfectly aligned with the trends in EU legislation on sewage sludge management<sup>1</sup>, aims at **sanitizing sewage sludge, reducing the amount of pathogens** and the **concentration of the total suspended solid**. After the HTC process, the treated sludge (namely HTC slurry) is mechanically dewatered in a centrifuge, obtaining mainly a liquid, that is used as a substrate into anaerobic digestion for biogas production or into the wastewater treatment plant. A minor part of the products is constituted by a solid product (called hydrochar), that is rich in carbon and phosphorus and may be potentially valorized as a soil improver in agriculture. Hydrochar is highly hydrophobic and can be dewatered more easily than sludge. As a result, higher % of dry matter content can be reached by using Carborem technology before a common dewatering system like centrifuge or filter press. The drop of the total suspended solid during the process and the higher dewaterability of hydrochar allows to reduce sludge by 50-70 wt.% compared to using the sole traditional dewatering system. Carborem technology, which is the objective of this EU ETV Verification, was implemented in Carborem plant, called “C700”, treating approximately 5,000 ton of sludge per year.

The figure below shows a conceptual scheme of a common wastewater treatment plant including Carborem process (left) and Carborem C700 plant (right).



## 2. APPLICATION

### 2.1 MATRIX

The technology could be applied to all the wet organic wastes (with moisture content > 50 wt.%). The process was tested for sewage sludge / digestate from winery making and dairy industry and from civil sludge.

### 2.2. PURPOSE

The purpose is to sanitize and reduce the volume of sludge to dispose of with a low energy demanding process. In about one hour the sludge is sanitized and converted into a liquid recycled into anaerobic digester and into a solid with no pathogens, rich in carbon and phosphorus and with reduced amount of polyaromatic hydrocarbons (PAHs).

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<sup>1</sup> European Union legislation on sewage sludge management (PDF Download Available). Available from: [https://www.researchgate.net/publication/261365754\\_European\\_Union\\_legislation\\_on\\_sewage\\_sludge\\_management](https://www.researchgate.net/publication/261365754_European_Union_legislation_on_sewage_sludge_management)

## 2.3 CONDITION OF OPERATION AND USE

Carborem technology is a continuous process. The sewage sludge/digestate is heated at 180°C-190°C at 9-14 bar for about one hour.

## 2.4 VERIFICATION PARAMETERS DEFINITION SUMMARY

Parameter	Claimed performance	Verified performance
Process time	50-60 min	57 min [54-60 min]
Addition of chemicals/oxygen	No use of chemicals/oxygen	No use of chemicals/oxygen
Carbon densification into hydrochar	70%	90%± 13% [77-102%]
Phosphorus densification into hydrochar	>70%	249%± 9% [248-251%]
Total suspended solid reduction (waste minimization)	30%	43.5% ± 6.3% [38-52%]
PAHs reduction into hydrochar	50%	73%± 4% [69-77%]
Escherichia Coli reduction	50%	100%± 0.3% [99.2-100%]
Methane consumption (per 760 liters of sludge treated)	6-7 m <sup>3</sup>	6.5±0.3 m <sup>3</sup> [6.2-6.7 m <sup>3</sup> ]
Electricity consumption (per 760 liters of sludge treated)	2-4 kWh	3.5±0.1 kWh [3.4-3.5 kWh]

## 3. TEST AND ANALYSIS DESIGN

### 3.1. EXISTING AND NEW DATA

The verification was based on existing data collected during the period March-October 2020.

### 3.2. LABORATORY OR FIELD CONDITIONS

Tests using Carborem technology were performed by the operators of Carborem using the C700 plant, wholly owned by Carborem and located at the wastewater treatment plant "Ex Distillerie Val D'Adige" in Mezzocorona (TN), in operation since December 2019. Testing and verification activities has been conducted by processing the sludge produced daily in the wastewater treatment plant.

### 3.3. MATRIX COMPOSITIONS

In the present verification the matrix is the sewage sludge/digestate from winery making and dairy industry and from civil sludge. The technology could be applied to all the wet organic wastes (with moisture content > 50 wt.%). The sludge entering the Carborem system passes through a thickener to reach about 4-5 wt.% of total suspended solid and through a filter, that removes the extraneous material.

More specifically, the digestate has the following characteristics:

- TSS: 44.5±0.5 g/l [range: 43.9-45 g/l]
- TOC: 30±4 %DM [range: 26-34%]
- Total Phosphorus: 14,100 ± 500 mg/kg<sub>DM</sub> [range: 13,600-14,600]
- PAHs: 4.30 ± 1.5 mg/kg<sub>DM</sub>
- Escherichia Coli: 66,667±38,793 MPN/g [range: 12,000-98,000]

### 3.4. TEST AND ANALYSIS PARAMETERS

The performance parameters and the methods used for their determination are listed below.

Parameter	Method	Code	Accreditation
Carbon content	Method for sludge and hydrochar: IR Spectrometer	UNI EN 15936 2012	ACCREDIA Accreditation n.: 0252 L; A UNI CEI EN ISO/IEC 17025:2018 1st issue date: 08/07/1999 Modification date: 23/05/2009 Expiring date: 23/06/2023
Total phosphorous content	Method for sludge and hydrochar: mineralization + ICP-OES	EPA 3051A 2007	ACCREDIA Accreditation n.: 0252 L; A UNI CEI EN ISO/IEC 17025:2018 1st issue date: 08/07/1999 Modification date: 23/05/2009 Expiring date: 23/06/2023
Total suspended solid	Method for sludge and slurry: Gravimetry	CNR IRSA 1 Q64 Vol 2 1984	ACCREDIA Accreditation n.: 0252 L; A UNI CEI EN ISO/IEC 17025:2018 1st issue date: 08/07/1999 Modification date: 23/05/2009 Expiring date: 23/06/2023
PAHs	Method for sludge and hydrochar: GC-MS	EPA 3550C 2007 + EPA 8270E 2018	Not accredited
Escherichia Coli	Method for sludge and slurry: MPN	IS 08.03/106 Rev.1 2015	Not accredited
Methane consumption	Gas meter	Product name: Quantometer QA1625GI Brand: Elster instrument	-
Electricity consumption	Electricity meter	Type: Acti 9 Product name: iEM3210 - 3P+N Brand: Schneider Electric	-
Process time	PLC time counter	Not applicable	-

### 3.5. TESTS AND ANALYSIS METHODS SUMMARY

The tests were performed by means of C700 plant of Carborem, using the operational parameters (flow, process temperature and pressure) reported in section 4.2.

The digestate was collected before each test from a storage tank for its characterization. Then, the sludge is pumped from the tank to a heat exchanger and then into a reactor, where is heated to 180±10 °C for about one hour by means of a diathermic oil boiler. After the process time, the treated sludge (namely slurry) is stored into another storage tank, where is collected for the laboratory analyses. Then, the slurry is dewatered by means of a centrifuge which allows the liquid-solid separation. The solid (called hydrochar) was collected and delivered to Ecoopera's lab for analyses.

The laboratory analyses performed on the collected samples (digestate, slurry and hydrochar) are the following: digestate (TOC, Total phosphorus, PAHs, TSS, Escherichia Coli); HTC Slurry (TSS, Escherichia Coli); and hydrochar (TOC, Total phosphorus, PAHs)

The samples were collected in the period 13/03/20 – 14/10/20. Each analysis was conducted at least on two samples of digestate, four samples of hydrochar and three samples of slurry collected at different times. The tests were conducted choosing different periods during the year in order to verify the claims even with different types of sludge.

The electricity, gas consumption and process time were determined by reading values in the analytical software developed by Carborem to monitor data of the plant.

### 3.6. PARAMETERS MEASURED

Test parameters and analysis parameters were described in section 3.4.

## 4. VERIFICATION RESULTS

### 4.1 PERFORMANCE PARAMETERS

The claimed and verified performance are listed below.

Parameter	Claimed performance	Verified performance
Process time	50-60 min	57 min [54-60 min]
Addition of chemicals/oxygen	No use of chemicals/oxygen	No use of chemicals/oxygen
Carbon densification into hydrochar	70%	90%± 13% [77-102%]
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Electricity consumption (per 760 liters of sludge treated)	2-4 kWh	3.5±0.1 kWh [3.4-3.5 kWh]

### 4.2 OPERATIONAL PARAMETERS

The performance parameters were obtained by heating sewage sludge at temperature of 180±10°C in the C700 plant of Carborem operating in a continuous mode. The flow rate used was in the range of 12 l/min±2 l/min.

Operational parameter	Value
Process Temperature	180±10°C
Process pressure	9-14 bar

Flow	12±2 l/min
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The slurry obtained by the process was sampled to determine Escherichia Coli and Total suspended solid content. This slurry was properly dewatered in a centrifuge in order to separate solid and liquid. The dewatered solid obtained was also sampled by Carborem operators to determine the total phosphorus, the total organic carbon and the PAHs. For each sampling of hydrochar and slurry, the inlet digestate was also collected as a reference.

Electrical and methane consumption, duration was also determined by using Carborem analytical software, which collects real time and historical data generated by the plant.

#### 4.3 ENVIRONMENTAL PARAMETERS

The only environmental parameter measured during each test is the ambient temperature of the entering sludge, which is  $24 \pm 3^{\circ}\text{C}$ . This parameter does not influence the performances parameters.

### 5. ADDITIONAL INFORMATION INCLUDING ADDITIONAL PARAMETERS

Additional information was reported in the verification report.

### 6. QUALITY ASSURANCE AND DEVIATION

The test and verification activities were planned and undertaken in order to satisfy the requirements on quality assurance described in the General Verification Protocol Version 1.3 developed for the EU ETV Pilot Programme. Test activities were undertaken in house by Carborem and some of the performance parameters (electrical, methane consumption, duration) were also determined by using Carborem analytical software, which collects real time and historical data generated by the plant. Laboratory analyses were performed by Ecoopera Soc. Coop., accredited according to the ISO 17025:2017 for methods in the area of analysis relevant for the verification process (Accreditation n° 0252L). The personnel and experts responsible for quality assurance as well as the different quality assurance activities are described in the following table.

Role	Inspector	Technical expert	ITR (by VB)	E-ITR	Proposer
Responsible	Giovanni D'ANGELO	Giovanni D'ANGELO	Laura MARTI	Andrea MAFFINI	Michela LUCIAN
EU-ETV Verification Task					
Specific Verification Protocol	Draft	Draft	Review	Review	Acceptance
Test System at test site	Audit	Audit	-	-	Acceptance
Verification Report	Draft	Draft	Review	Review	Acceptance
Statement of Verification	Draft	Draft	Review	Review	Acceptance