LIFE B2E4SustWWTP (LIFE16 ENV/GR/000298)

New concept for energy self-sustainable wastewater treatment process and biosolids management

Deliverable: A.1.3. Report with the characteristics of biosolids

Project Funded by the European Commission under the LIFE Framework Programme. Grant Agreement LIFE16 ENV/GR/000298

GENERAL INFORMATION

PROGRAMME	LIFE 2016
GRANT AGREEMENT NUMBER	LIFE16 ENV/GR/000298
PROJECT ACRONYM	LIFE B2E4sustainable-WWTP
DOCUMENT	A.1.3. Report with the characteristic of biosolids
START DATE OF THE PROJECT	1st September 2017
END DATE OF THE PROJECT	31st December 2022
DUE DELIVERY DATE	30/06/2020
DATE OF DELIVERY	30/06/2020
STATUS AND VERSION	FINAL
ACTION RELATED	A1
ACTION RESPONSIBLE	DEVISE
AUTHOR (S)	TUC
PARTNER (S) CONTRIBUTING	CETENMA, DEYAR

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1. Introduction

TUC, CETENMA, and DEYAR have investigated the characteristics of the biosolids produced from the experimental microscreen, which is installed in WWTP of Rethymno.

In detail, the parameters which have been studied are the followings:

- Moisture content
- Total Solids (TS)
- Volatile Solids (VS)
- Elemental composition (C, H, N, S, Cl)
- Higher Heating Value (HHV)

Also, the production of biosolids per day has been measured, taking into account that the daily flowrate of the wastewater will be 5000 m^3/d.

The ability of biosolids to form briquettes has been investigated by executed tests with a specified machine.

The results of the experimental measurements and calculations are analyzed within this report.

2. Biosolids characteristics

2.1 Moisture – TS – VS – Elemental analysis

TUC has of the biosolids produced from the microscreen. Also, TUC has sent samples of biosolids to CETENMA, so to have the opportunity to compare similar measurements from another laboratory.

The results regarding Moisture, TS, VS, and elemental analysis are showed in **Table 2.1.1**.

Table 2.1.1. Characteristics of biosolids from TUC and CETENMA analyses.

Parameter	Unit	Value	Average	Standard deviation
Moisture	%	66.8	**67.3**	**7.64**
		68.3		
		75.2		
		79.5		
		74.0		
		56.0		
		64.0		
		56.0		
		66.0		
TS	%	33.2	**32.7**	**7.64**
		31.7		
		24.8		
		20.5		
		26.0		
		44.0		
		36.0		
		44.0		
		34.0		
VS	% (d.b.)*	85.6	**84.5**	**1.31**
		85.6		
		85.9		
		85.0		
		83.0		
		82.0		
		85.0		
		84.0		

*d.b. = dry basis

Elemental analysis				
C	% (d.b.)	52.7 52.2 52.6	**52.5**	**0.216**
H	% (d.b.)	7.2 7.5 7.7	**7.5**	**0.205**
N	% (d.b.)	2.22 2.22 2.18	**2.2**	**0.019**
S	% (d.b.)	0.32 0.29 0.30	**0.30**	**0.012**
Cl	% (d.b.)	0.05 0.04 0.05	**0.05**	**0.005**

*d.b. = dry basis

2.2 HHV

TUC has conducted 11 measurements of the calorific value (HHV, MJ/kg) of the biosolids produced from the microscreen. Also, TUC has sent samples to CETENMA and CERTH (Centre for Research & Technology Hellas), in order to ensure the reliability of the results.

All measurements are summarized in the following **Table 2.2.1** (see ANNEX for further information).

Table 2.2.1. Biosolids production (wet and dry phase) per day (5000m^3 of wastewater).

Organization	HHV (MJ/kg)
TUC	22.955
	20.285
	19.673
	19.692
	20.622
	21.445
	20.717
	20.982
	19.762
	20.775
	20.644
Average	**20.687**
Standard deviation	**0.897**
CETENMA	23.760
	23.470
	24.400
Average	**23.877**
Standard deviation	**0.388**
CERTH	22.332
	22.329
	21.299
Average	**21.987**
Standard deviation	**0.486**

Minimum	**20.687**
Maximum	**23.877**
Average	**22.183**
Standard deviation	**1.310**

3. Biosolids quantification

The production of biosolids from the microscreen has been investigated by TUC, with the assistance of DEYAR.

The results are presented at **Table 3.1**.

Table 3.1. Biosolids production (wet and dry phase) per day (5000m^3 of wastewater).

Total incoming wastewater (m^3)	Produced biosolids (kg, wet phase)	Produced biosolids (kg, dry phase)	Produced biosolids (kg, dry phase)/m^3	Produced biosolids (kg, dry phase)/5000m^3
135	9.2	3.36	0.0249	124.37
135	10.3	3.35	0.0248	123.98
70	12.8	4.61	0.0658	329.14
60	6.3	2.27	0.0378	189.00
125	17.8	6.23	0.0498	249.20
108	18.2	6.73	0.0624	311.76
108	19.4	7.18	0.0665	332.31
190.8	34.8	12.88	0.0675	337.42
42	8.1	3.00	0.0714	356.79
66.7	12.2	4.51	0.0677	338.38
142	26.2	9.69	0.0683	341.34
		AVERAGE	**0.0552**	**275.79**

Preliminary trials with the use of coagulants have been performed (a special static mixer was used), but they did not indicate any significant increase in biosolids yield.

Tests with finer belt size pore openings and the addition of coagulants/flocculants for the prototype's microscreen will be performed during the trial testing of the pilot plant.

The manufacturer (DEVISE) will have promptly install the pilot microscreen and will have adequately prepare the site for the installation and testing with the coagulants' system. It must be noted that addition of coagulant needs a reaction vessel and special mixing arrangements.

The results of these tests will be included in the final version of Deliverable B.1.1 as recommended by EASME.

4. Briquetting tests

TUC's gasification system requires the use of briquetted biomass, so TUC executed successful tests, using biosolids generated from the experimental microscreen, to verify the ability of biosolids to form briquettes (**Figure 4.1**).

Figure 4.1. Production of well-shaped briquettes using a specified machine.

5. Annex

5.1 TUC analysis

Example with full calculations for the determination of the HHV of biosolids by TUC, using the XRY-1A Oxygen Bomb Calorimeter.

Υπολογισμοί	Συμβολισμοί	Σχόλια
1.517	ΔT - The temperature increase of calorimeter system after correction, °C;	ΤΥΠΟΣ 2
24.434	tn - The final temperature of main period, °C	Η επόμενη από την μέγιστη θερμοκρασία
22.886	t0 - The initial temperature of main period, °C	Η αρχική θερμοκρασία
-0.031380081	Δθ - The modified value of heat exchange between calorimeter-environment, °C	ΤΥΠΟΣ 3
-0.00075	Vn - The temperature change rate in the final period, °C/30s	Μέσος όρος διαφορών "final period"
-0.0045	V0 - The temperature change rate in the initial period, °C/30s	Μέσος όρος διαφορών "initial period"
24.436	θn - The average temperature in the final period, °C	Μέσος όρος θερμοκρασιών "final period"
22.886	θ0 - The average temperature in the initial period, °C	Μέσος όρος θερμοκρασιών "initial period"
26	n - Times to record temperatures in the main period	Αριθμός μετρήσεων "main period"
606.761	Σti - The temperature readings in sequence in the main period	Το άθροισμα των μετρήσεων "main period" χωρίς την t0
22955.43298	Q - Calorific value of sample, J/g	ΤΥΠΟΣ 4
41.4	ΣGd - the total heat produced by the additive, J	Θερμογόνος δύναμη (σταθερό=6000)*Μάζα σύρματος
1.0402	G - Weight of sample, g	Μάζα δείγματος (περίπου 1g)

ΤΥΠΟΣ 2

$$\Delta T = (t_n - t_0) + \Delta\theta$$

ΤΥΠΟΣ 3

$$\Delta\theta = \frac{V_n - V_0}{\theta_n - \theta_0}\left(\frac{t_n + t_0}{2} + \sum_{1}^{n-1} t_1 - n \cdot \theta_1\right) + n \cdot V_1$$

ΤΥΠΟΣ 4

$$Q = \frac{E \cdot \Delta T - \Sigma(G \cdot d)}{G}$$

No	Μέτρηση (°C)	Period
0	0.000	initial (οι μετρήσεις πριν το ignite)
1	0.000	
2	0.000	
3	0.000	
4	0.000	
5	0.000	
6	0.000	
7	0.000	
8	0.000	
9	0.000	
10	22.886	main (από το ignite μέχρι την μέγιστη θερμοκρασία)
11	23.18	
12	23.682	
13	23.92	
14	24.063	
15	24.151	
16	24.215	
17	24.265	
18	24.302	
19	24.332	
20	24.353	
21	24.375	
22	24.386	
23	24.396	
24	24.409	
25	24.412	
26	24.42	
27	24.421	
28	24.431	
29	24.428	
30	24.433	
31	24.432	
32	24.438	
33	24.438	
34	24.439	
35	24.440	
36	24.434	final (από την μέγιστη θερμοκρασία μέχρι το τέλος)
37	24.434	
38	24.438	
39	24.436	
40	24.437	

5.2 CETENMA analysis

RESULTS REPORT
WASTE CHARACTERIZATION

1. DESCRIPTION / SCOPE

Determination of several parameters on dried WWTP sludge (three samples).
Measured parameters:

- Moisture (M)
- Total solids (TS)
- Volatile solids (VS)
- High Heating Value (HHV)
- Low Heating Value (LHV)
- Elemental composition (C,H,N,S,Cl)

2. METHODOLOGY

Parameter	Method	Measures per sample
Moisture	Thermogravimetry – UNE-EN ISO 18134-1	3
Total Solids	Thermogravimetry - UNE-EN ISO 18134-1	3
Volatile Solids	Thermogravimetry - UNE-EN 14918	3
High Heating Value	Calorimetry – LECO AC500 - UNE 164001:2005 EX	2
Low Heating Value	Calculated from HHV and (C,H,N) - UNE 164001:2005 EX	1
Elemental Composition		1
- C, H, N	LECO 628 - UNE-EN ISO 16948	1
- S, Cl	UNE-EN ISO 16994	1

3. RESULTS

Parameter	Unit	Sample 1	Sample 2	Sample 3	Mean
M	%	2.29	2.02	2.08	2.13
TS	%	97.71	97.98	97.93	97.87
VS	% (w.b.)	83.65	83.85	84.09	83.86
SV/ST	%	85.6	85.6	85.9	85.7
HHV	kcal/kg (d.b.)	5675	5606	5828	5703
HHV	kcal/kg (w.b.)	5661	5594	5816	5690
C	% (d.b.)	52.7	52.2	52.6	52.5
H	% (d.b.)	7.2	7.5	7.7	7.5
N	% (d.b.)	2.22	2.22	2.18	2.2
S	% (d.b.)	0.32	0.29	0.30	0.30
Cl	% (d.b.)	0.05	0.04	0.05	0,05
LHV	kcal/kg (d.b.)	5288	5203	5414	5302
LHV	kcal/kg (w.b.)	5256	5175	5386	5272

w.b. – Wet basis
d.b. – Dry basis
M, TS, VS, HHV (d.b.), C, H, N, S and Cl are measured
HHV (w.b.), LHV (d.b.) and LHV (w.b.) are calculated

5.3 CERTH analysis

ΕΘΝΙΚΟ ΚΕΝΤΡΟ ΕΡΕΥΝΑΣ ΚΑΙ ΤΕΧΝΟΛΟΓΙΚΗΣ ΑΝΑΠΤΥΞΗΣ (Ε.Κ.Ε.Τ.Α.)
ΙΝΣΤΙΤΟΥΤΟ ΧΗΜΙΚΩΝ ΔΙΕΡΓΑΣΙΩΝ ΚΑΙ ΕΝΕΡΓΕΙΑΚΩΝ ΠΟΡΩΝ (Ι.Δ.Ε.Π.)

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Ημερ. Έκδοσης έκθεσης : 16/5/19 Αρ. Πρωτοκ. : 39

ΑΠΟΤΕΛΕΣΜΑΤΑ ΔΟΚΙΜΩΝ

ΚΩΔΙΚΟΣ ΔΕΙΓΜΑΤΟΣ : **262096**
ΟΝΟΜΑΣΙΑ ΕΠΙΣΗΜΑΝΣΗ : **Sample _1**

ΑΝΑΛΥΣΗ: **CALORIFIC_VALUE** **Gross Heat of Combustion MJ/Kg**

ΣΤΟΙΧΕΙΑ ΑΝΑΛΥΣΗΣ	ΑΠΟΤΕΛΕΣΜΑ	ΜΟΝΑΔΕΣ	ΑΠΑΙΤΗΣΗ ΔΟΚΙΜΗΣ
Gross Heat of combustion	22.3323	MJ/Kg	ASTM D 4809
OPERATOR	Maria Miltsi		ASTM D 4809

Ημερ. Έκδοσης έκθεσης : 16/5/19 Αρ. Πρωτοκ. : 39

ΑΠΟΤΕΛΕΣΜΑΤΑ ΔΟΚΙΜΩΝ

ΚΩΔΙΚΟΣ ΔΕΙΓΜΑΤΟΣ : **262097**
ΟΝΟΜΑΣΙΑ ΕΠΙΣΗΜΑΝΣΗ : **Sample _2**

ΑΝΑΛΥΣΗ: **CALORIFIC_VALUE** **Gross Heat of Combustion MJ/Kg**

ΣΤΟΙΧΕΙΑ ΑΝΑΛΥΣΗΣ	ΑΠΟΤΕΛΕΣΜΑ	ΜΟΝΑΔΕΣ	ΑΠΑΙΤΗΣΗ ΔΟΚΙΜΗΣ
Gross Heat of combustion	22.329	MJ/Kg	ASTM D 4809
OPERATOR	Maria Miltsi		ASTM D 4809

Ημερ. Έκδοσης έκθεσης : 16/5/19 Αρ. Πρωτοκ. : 39

ΑΠΟΤΕΛΕΣΜΑΤΑ ΔΟΚΙΜΩΝ

ΚΩΔΙΚΟΣ ΔΕΙΓΜΑΤΟΣ : **262098**
ΟΝΟΜΑΣΙΑ ΕΠΙΣΗΜΑΝΣΗ : **Sample _3**

ΑΝΑΛΥΣΗ: **CALORIFIC_VALUE** **Gross Heat of Combustion MJ/Kg**

ΣΤΟΙΧΕΙΑ ΑΝΑΛΥΣΗΣ	ΑΠΟΤΕΛΕΣΜΑ	ΜΟΝΑΔΕΣ	ΑΠΑΙΤΗΣΗ ΔΟΚΙΜΗΣ
Gross Heat of combustion	21.2997	MJ/Kg	ASTM D 4809
OPERATOR	Maria Miltsi		ASTM D 4809