





European Union European Regional Development Fund REGION OF CENTRAL MACEDONIA MANAGING AUTHORITY O.P. Region of Central Macedonia

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Autonomous system for remote control of anaerobic CSTR reactors

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Acknowledgments

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Introduction

Production of organic wastes

Ineffective management

Anaerobic Digestion is a process:

- performed by a large number of microorganisms
- organic carbon is converted to carbon dioxide and methane in the absence of oxygen
- consists of four consecutive stages: hydrolysis, acidogenesis, acetogenesis and methanogenesis

Success of anaerobic digestion various parameters:

- oxygen
- temperature
- pH
- hydraulic retention time (HRT)
- substrate composition
- organic loading rate (OLR)
- . C/N ratio
- concentration of volatile fatty acids (VFA)
- nutrients, trace elements, toxic compounds, ammonia

GHG emissions

Promising & continuously developing method of utilisation of organic waste is its anaerobic treatment









Even **if** all parameters could be recorded

Logging data

Monitoring as many of these critical factors as possible is **necessary**



Introduction

 Connection between Computers – Humans – Things

• "Things": anything that creates a network (such as a device) and can exchange data with other devices through the network





https://tenor.com/el/view/embedded-security-for-internet-of-things-gif-25502017

other devices & systems

Internet

or other communication protocols



Aim of this study



Examine the accuracy of

Biogas Methane Temperature

Reactor equipped with respective **sensors** and **devices**

- Connected to a **Raspberry Pi**
- Measurements are sent to a cloud platform



Identical reactor

Fed with the same organic waste
Measurements are obtained manually by using conventional methods

Materials and Methods



Control of



Remote monitored

Experimental setup



Biogas

Methane





Manually monitored

Materials and Methods



The connection of the gas counters was made to the **RasPi 3 computer through its analog inputs**

Experimental setup

Through RasPi 3, all data was sent to a cloud loT platform where it was stored, examined and exported



Cloud IoT platform

	ThingsBoard	Dashboards > EGKE Biogas dashboard		
♠	Home	EGKE Biogas dashboard	EGKE Biogas dashboard 👻	
‹· ›	Rule chains			
*	Customers	New Timeseries table History - from 2022-05-01 15:41:00 to 20	Q [] Timeser	
₽	Assets	Timestamp 🧅 biogas_counter	Timestam	
[•0	Devices	2022-05-31 15:12:20 1220	2022-05-3	
D	Device profiles	2022-05-31 13:32:07 1219	2022-05-3	
٢	OTA updates	2022-05-31 11:44:13 1218	2022-05-3	
	Entity Views	2022-05-31 10:57:13 1217	2022-05-3	
Ĵ.	Edge instances	2022-05-31 08:33:33 1216	2022-05-3	
Ŷ	Edge management 🛛 🗸	2022-05-31 05:37:06 1215	2022-05-3	
	Widgets Library	2022-05-31 03:23:21 1214	2022-05-3	
	Dashboards	2022-05-31 01:39:46 1213	2022-05-3	
Ð	Version control	1 – 10 of 200 < <	< > >I	
(Audit Logs			
ıl.	Api Usage			
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Study period of 58 days (2 HRT), after the achievement of steady state conditions

Biogas & Methane production



Temperature fluctuation

Reactor	Biogas (mL d ⁻¹)	Methane (mL d ⁻¹)	Temperature (°C)
R1	414.35	253.15	36.76
R2	396.25	242.42	36.75
Relative Difference	4.57%	4.42%	0.02%

No significant differences between the remote and the manually operating reactors



Lack of uniformity of the substrate used

Inhomogeneity of the inoculum

Monitoring of AD process by IoT - enabled technologies





Significant advantages related to conventional methods

. Remote control of important process parameters

- . Early warning indicators at any time
- . Monitoring of multiple reactors working simultaneously
- **Data security** through the storage ability to the cloud or local (memory card)
 - Creation of a database that can be easily viewed and processed
 - . Low cost of additional equipment

Conclusions

- Effective and low-cost system for monitoring important process parameters of anaerobic digestion has been proposed
- Results of **biogas and methane** production were similar to both anaerobic reactors
- Significant **temperature** fluctuations between the two reactors were not observed

As technology is constantly evolving...

- (e.g. pH, NH_3 etc.)

 More and more advanced and precise sensors could be connected to the proposed monitoring system for the surveillance of multiple parameters

 Automatic feeding operation could be achieved by controlling the reactors peristaltic feeding pumps through programming the RaspPi







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