EVALUATION OF BIOPLASTICS BIODEGRADATION UNDER SIMULATED LANDFILL CONDITIONS

BERİVAN ÜLGER-VATANSEVER,

TURGUT T. ONAY, BURAK DEMIREL

INSTITUTE OF ENVIRONMENTAL SCIENCES

BOĞAZIÇI UNIVERSITY

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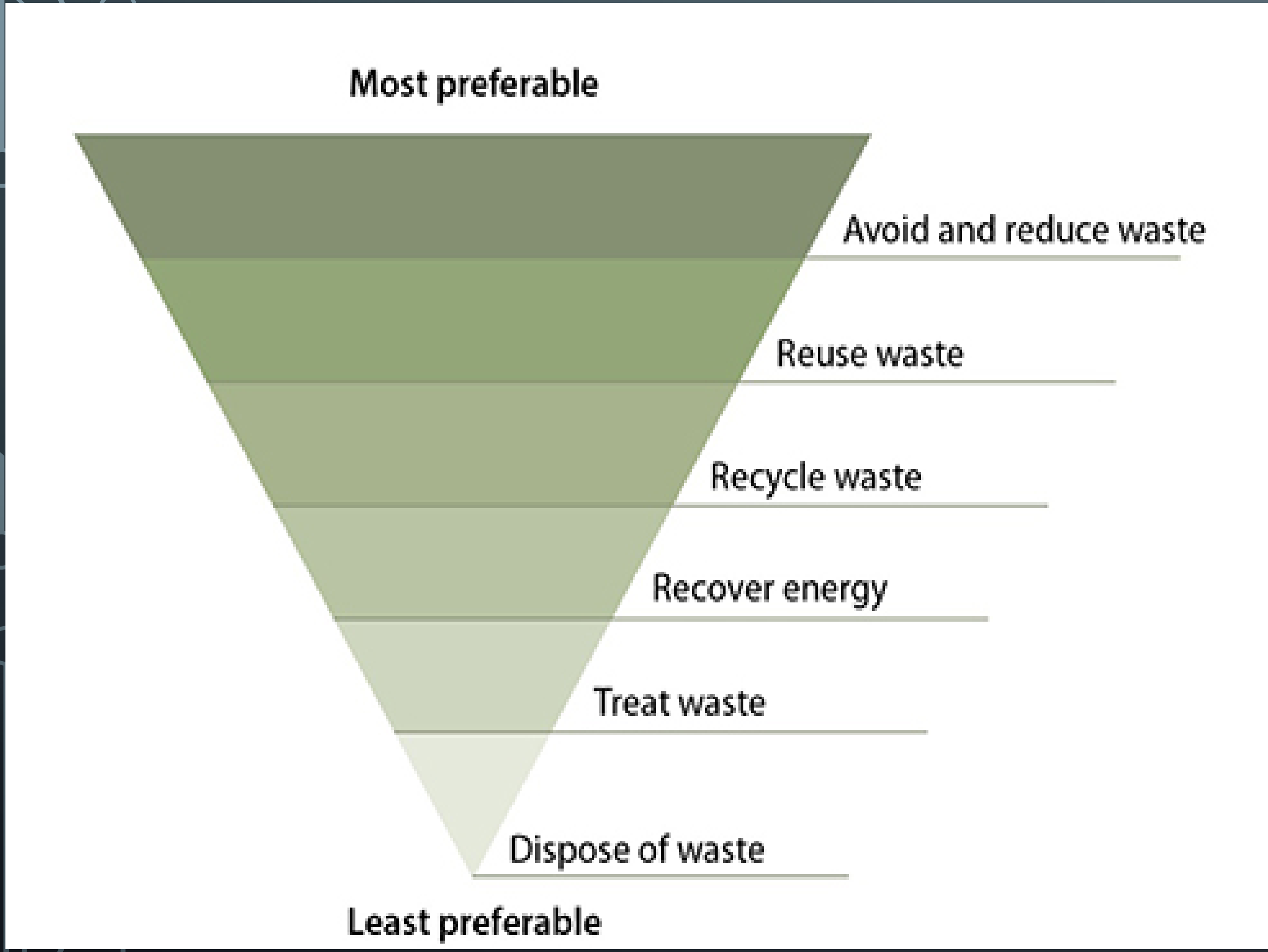
OUTLINE

- Background
- Objectives of the Study
- Materials and Method
- Results
- Conclusion

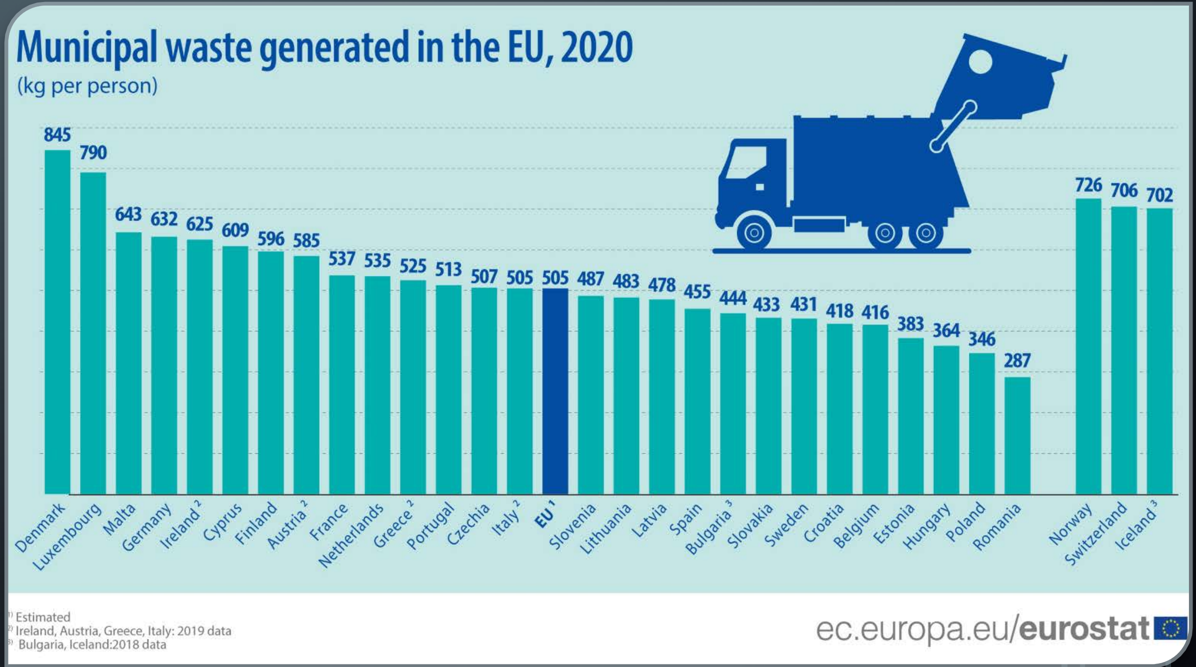
MUNICIPAL SOLID WASTE (MSW) MANAGEMENT



Waste Managmenet Hierarchy (EPA)

Inappropriate management leads to increasing environmental issues such as;

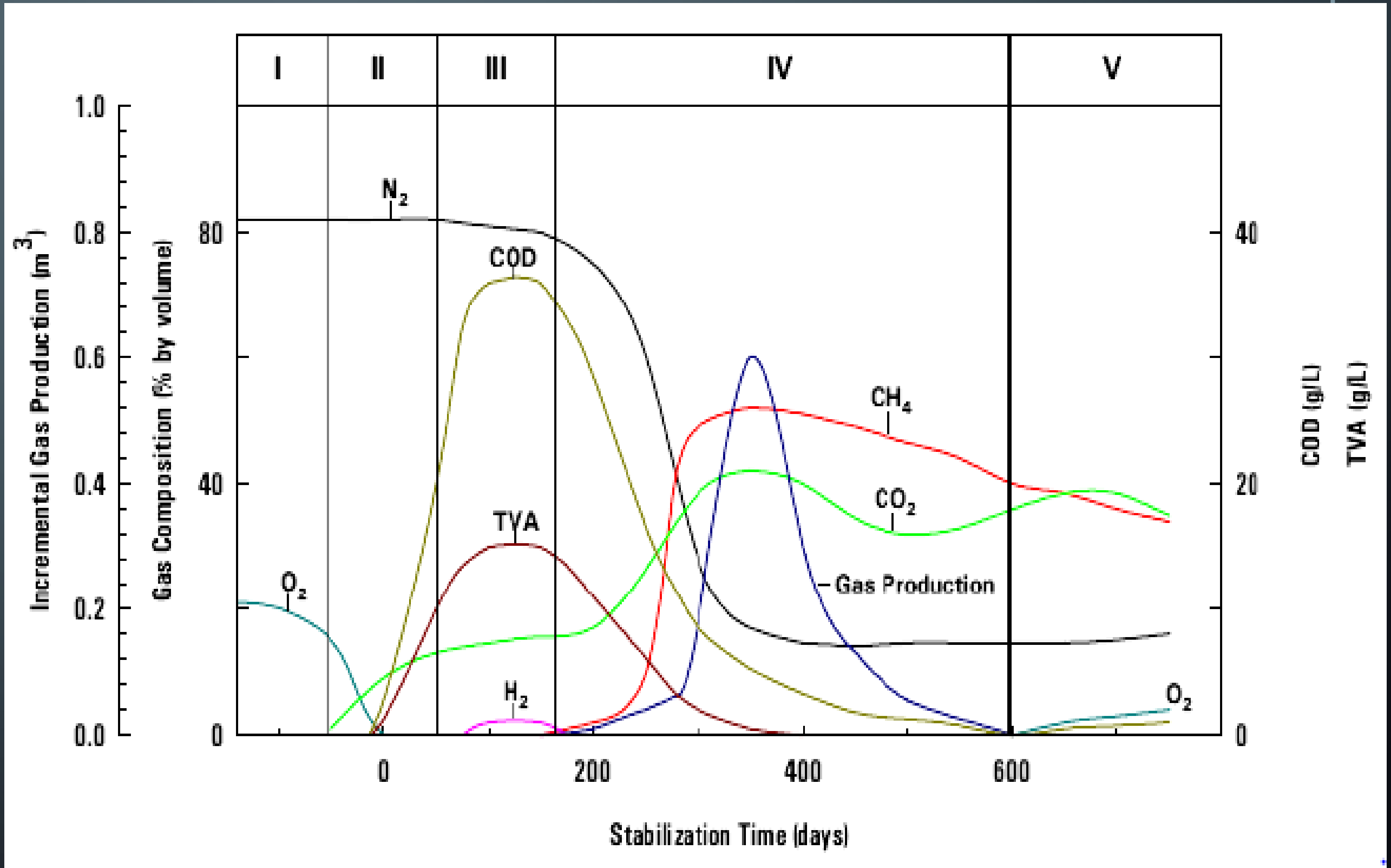
- the depletion of resources and ozone layer,
- global warming,
- the health problems of living organisms etc.

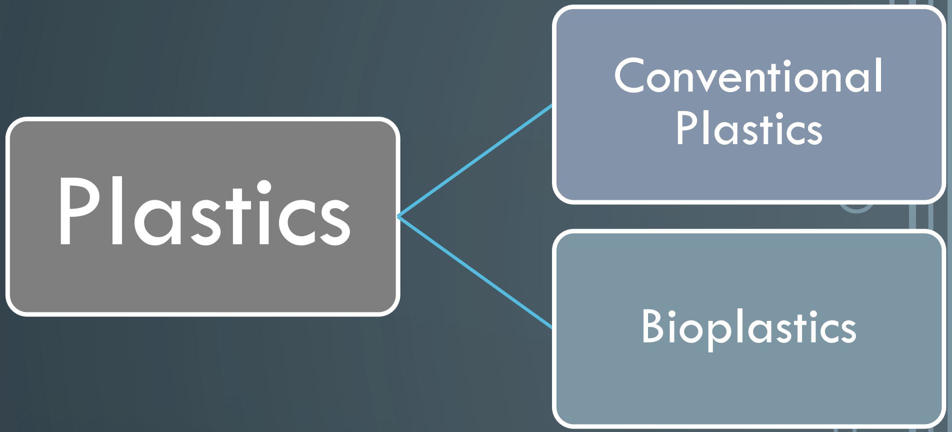


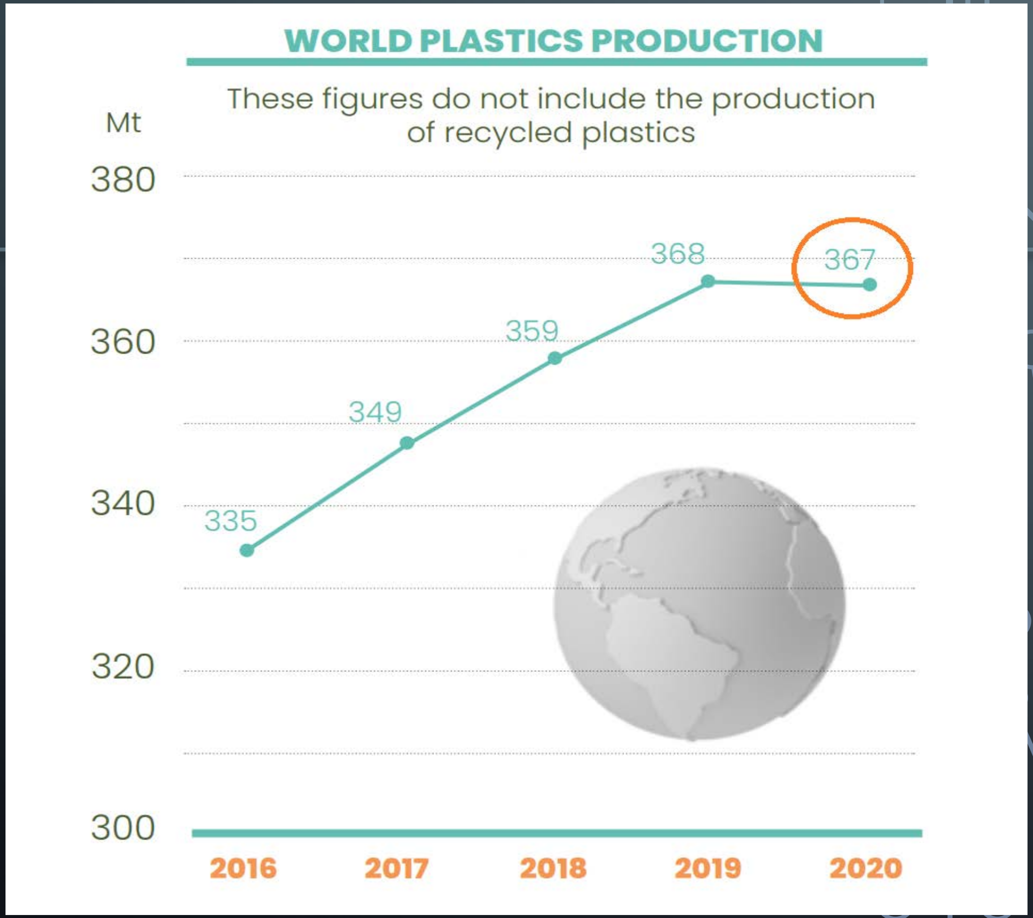
The pathway of MSW stabilization

The degradation of solid wastes in landfill sites takes place in five phases;

1. Initial adjustment
2. Transition
3. Acid formation
4. Methane fermentation
5. Final maturation







Mt: Million tonnes

CONVENTIONAL PLASTICS

Plastics are;

- applicable
- cost-effective
- resistant
- long-lasting

Utilized in numerous applications;

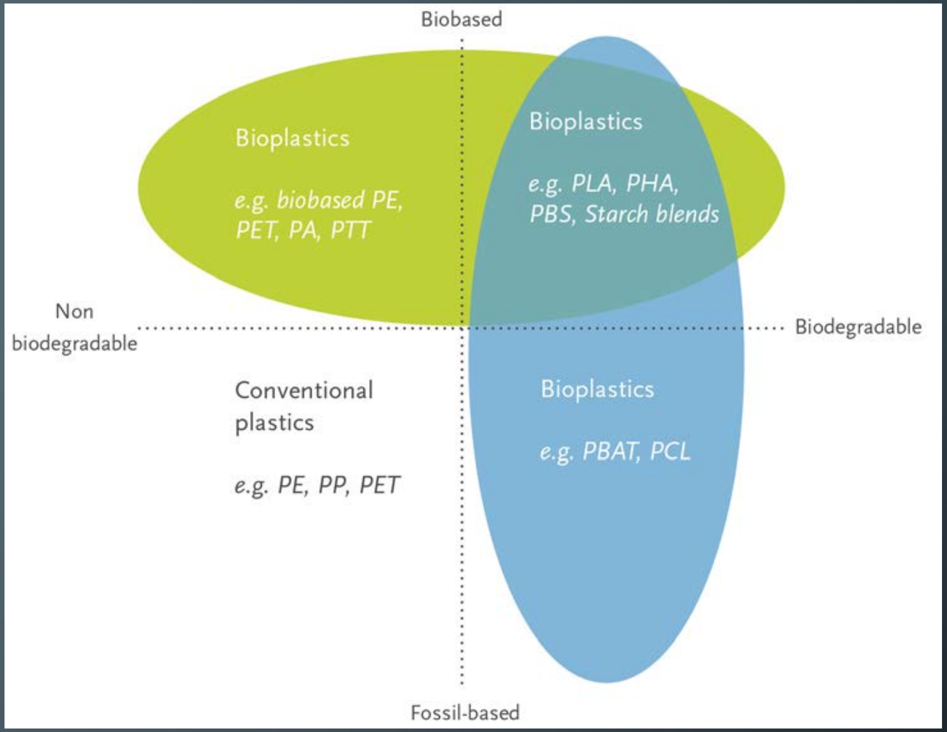
construction, packaging, transportation etc.

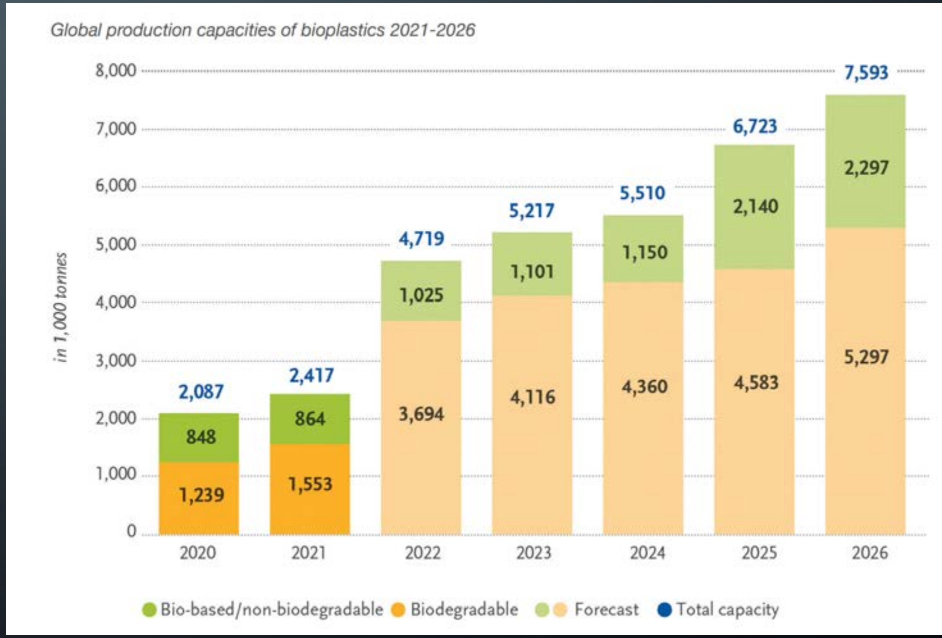
Remain in the environment for many years.

BIOPLASTICS

The polymers that are comprised of renewable materials such as plants and/or can undergo biodegradation or composting

- **Bio-based Plastics** → the materials that are produced from biomass, which can be cellulose, corn or sugarcane. i.e. bio-polyethylene terephthalate (PET), bio-polypropylene (PP).
- **Biodegradable Plastics** → the plastics that can be broken down to organics and gases. i.e. polyhydroxy butyrate (PHB), polycaprolactone (PCL).



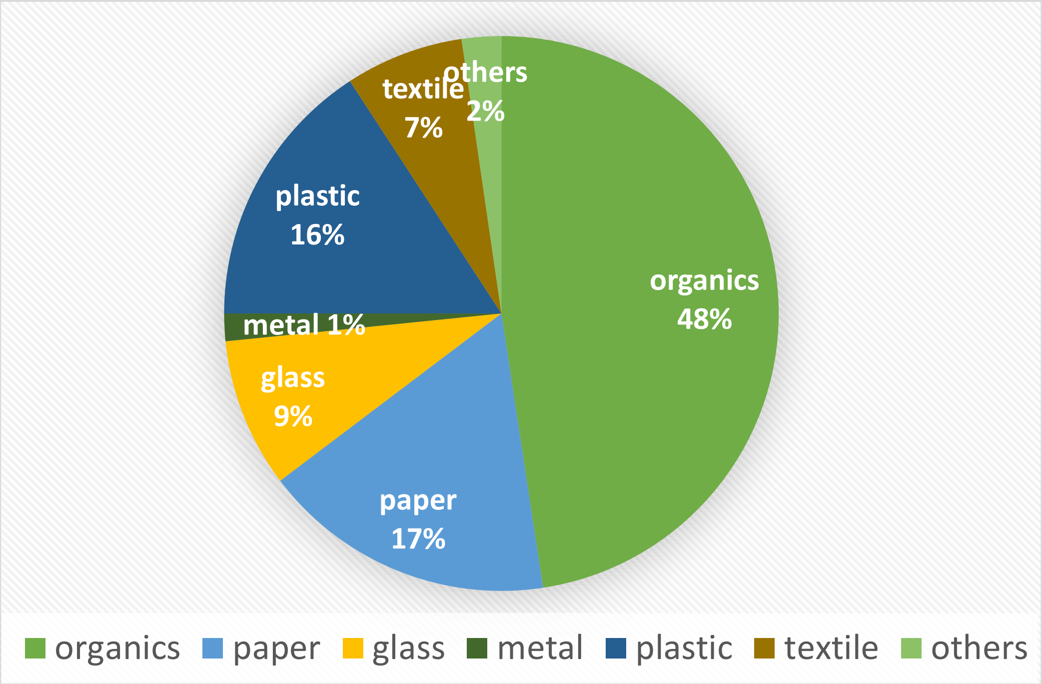


**thousand tonnes

OBJECTIVES

- Evaluation of the fate of bioplastics and their biodegradability under landfill conditions,
- Observation and comparison of the impacts of the different landfill waste stabilization stages on bioplastics' biodegradation potential,
- Investigation of the leachate and landfill gas characteristics,
- Assessment of landfilling as a disposal method for bioplastics.

MATERIALS & METHODS



MSW samples were obtained from Odayeri landfill site, an operating landfill site of İSTAÇ (İstanbul).

- ✓ separated to identify the average composition
- ✓ shredded in order to contribute to the moisture transfer.

- ✓ 19 kg of solid waste mixtures were prepared for each reactor
- ✓ Representative samples of 1 kg were taken from each mixture to determine the moisture content and other initial characteristics

SIMULATED LANDFILL REACTORS LOADING

- 18 kg MSW, 1.5 L seed sludge and 2 PLA cups for each reactor
- 5 L of water was added to each reactor to reach field capacity.

All reactors commenced operation;

- at the same time,
- under aerobic conditions
- in 25-28°C temperature-controlled room

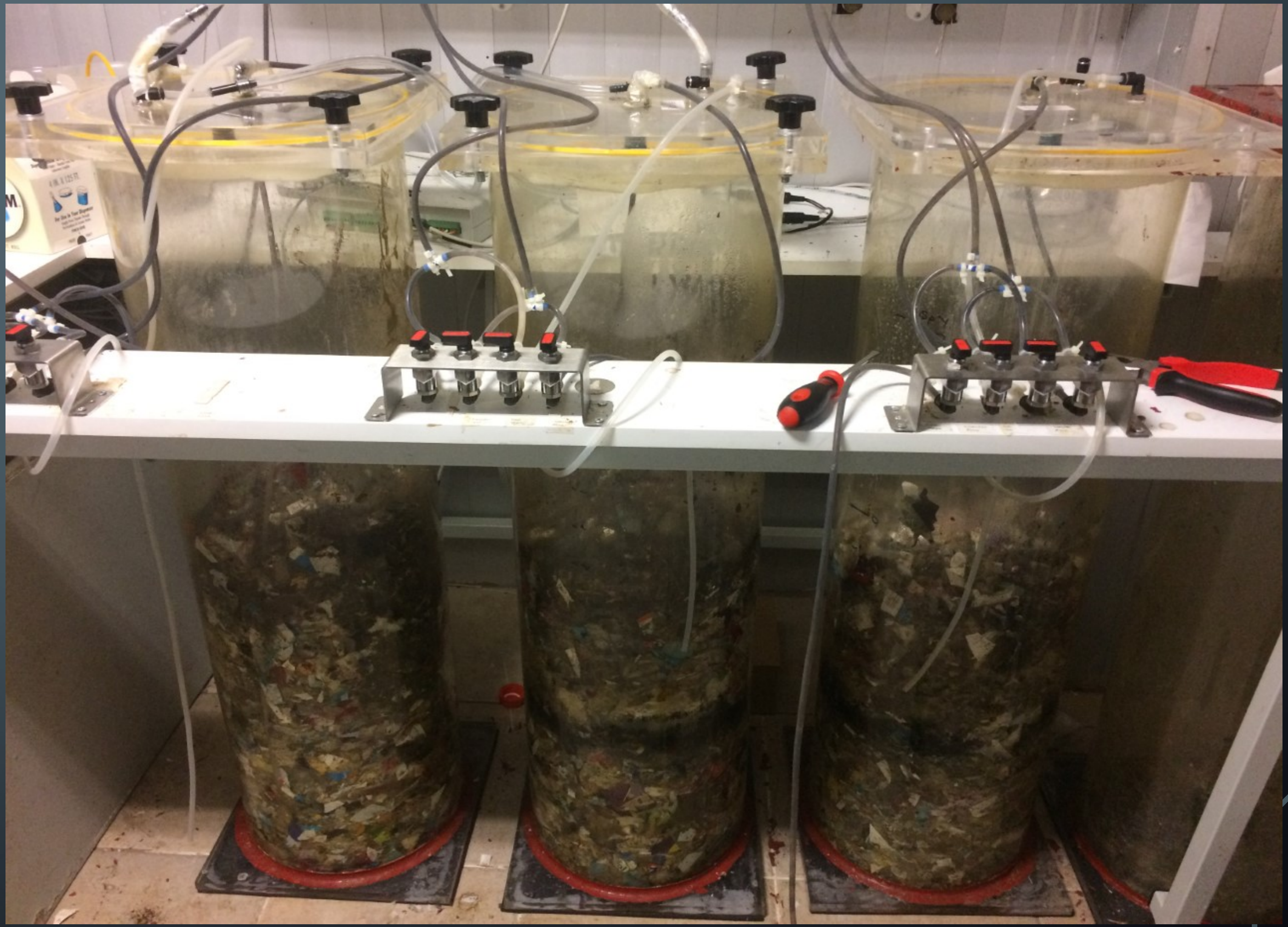
Content of the reactors

Reactor	MSW content	Seed Sludge	PLA Cups
Reactor 1 (R1)	18 kg	1.5 L	Cup 1 and Cup 2
Reactor 2 (R2)	18 kg	1.5 L	Cup 3 and Cup 4
Reactor 3 (R3)	18 kg	1.5 L	Cup 5 and Cup 6

Experimental Set-up

Phase 1:

- The lids were opened for 30-45 minutes daily to get the reactors be exposed to ambient aeration
- After 2 month-operation, R1 was stopped



- Phase 2:
- R2 and R3 were converted to semi-aerobic by **closing the lids** and **flushing nitrogen** into reactors
- The room temperature was adjusted to 35±2°C to provide mesophilic waste decomposition
- Approximately 50 days later, second reactor (R2) was discontinued.

Phase 3:

- R3 was converted to strictly anaerobic by complete nitrogen purge on day 106.
- All the connections were sealed with silicone and partly insulation tape to ensure that it was airtight.
- The last reactor was operated for approximately 295 days under anaerobic conditions to simulate anaerobic phase that was the longest phase in landfills.

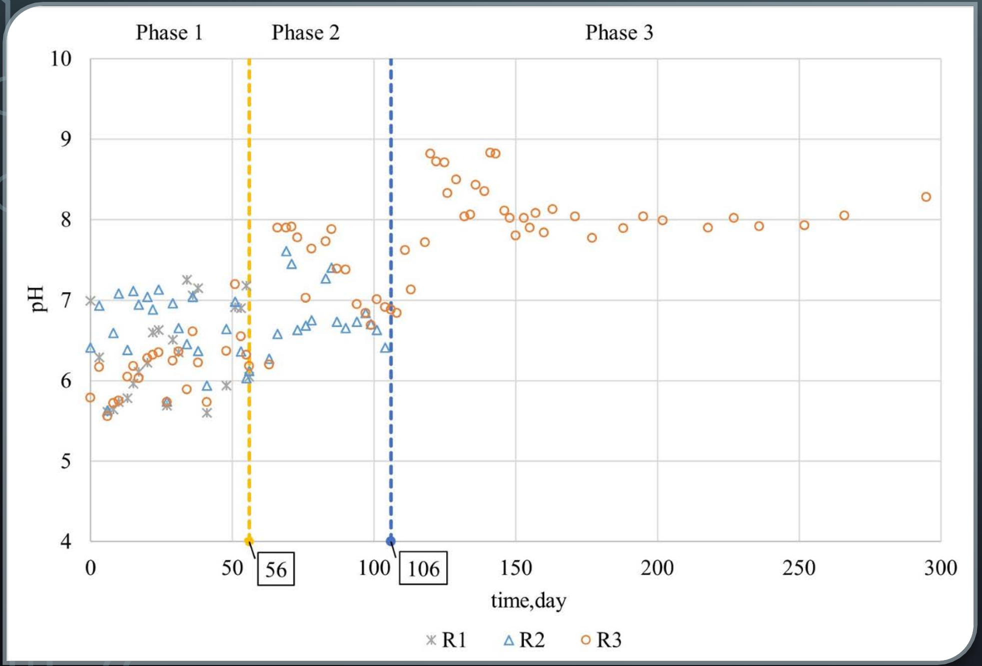
Experimental schedule

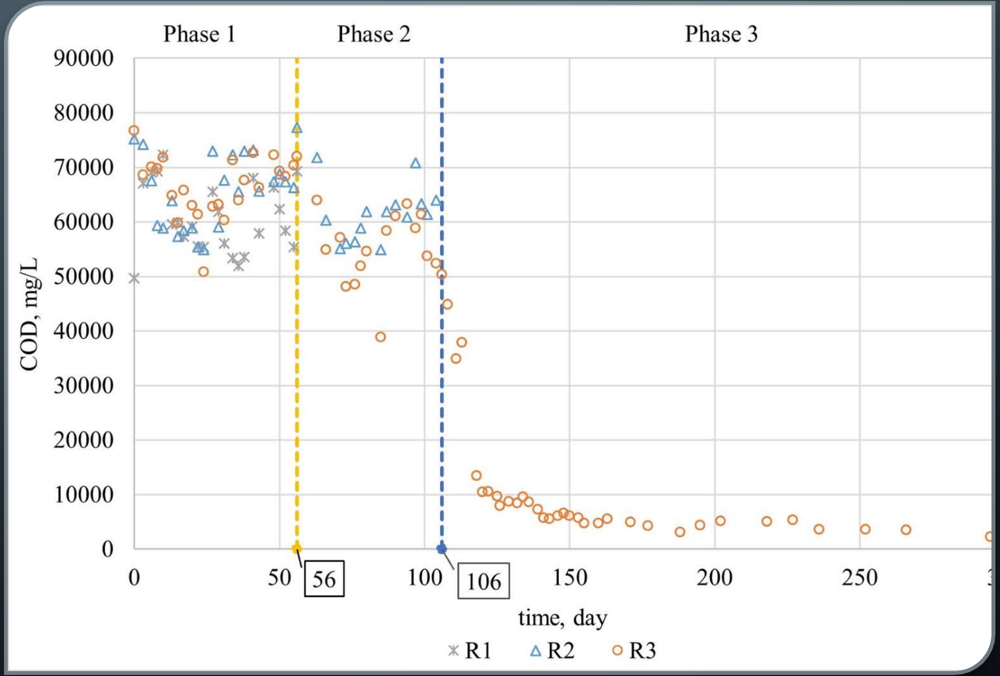
Parameter	Frequency	Method	Devices
pH	Cont.		WTW pH Meter
Temperature	Cont.		Automation system
ORP	1/week	2580 B Method (APHA, AWWA, WEF, 1998)	ORIAN SA520 pH meter
COD	3/week	5220 D Method Closed Reflux, Colorimetric (APHA, AWWA, WEF, 1998)	HACH COD digester; HACH DR/3 Spectrophotometer
Volatile Fatty Acids (VFA)	1/month	Gas Chromatography	Agilent GC-FID
Alkalinity	1/week	2320 B Method Titration (APHA, AWWA, WEF, 1998)	-
TKN	2/month	4500 Method (APHA, AWWA, WEF, 1998)	HACH Digester
NH_4-N	2/month	4500 E Method Titration (APHA, AWWA-WEF-1998)	Gerhardt Vapodest Distillation device
Total Phosphorus	2/month	4500-P E Method Ascorbic acid (APHA, AWWA, WEF, 1998)	HACH Digester
Orthophosphate	2/month	4500-P E Method Ascorbic acid (APHA, AWWA, WEF, 1998)	HACH DR/3 Spectrophotometer
Chloride	2/month	4500-Cl B Method argentometric (APHA, AWWA, WEF, 1998)	-
Sulfate	2/month	4500-SO_4^{-2} E Method turbidity (APHA, AWWA, WEF, 1998)	HACH DR/3 Spectrophotometer
Heavy metals	2/year	ASTM 3010	Perkin Elmer ICP-OES/ Perkin Elmer AAS
Gas volume	Cont.	Milligas counter	Hengstler Milli Gas Counter
CH_4, CO_2, O_2, N_2	3/week	Gas chromatography	Agilent 6850 Series II GC

Results and Discussion

Parameter	R1 (day 0)	R2 (day 0)	R3 (day 0)	R1 (day 56)	R3 (day 295)
TS (%)	36.8	36.6	43.6	43.3	36.7
VS (%)	27.6	28.1	33.8	24.8	18.1
Moisture Content (%)	63.3	63.4	56.4	57.7	63.3
Carbon (%)	36.1	37.54	36.4	22.28	24.43
Nitrogen (%)	2.53	1.94	2.3	3.48	2.17
Hydrogen (%)	4.6	4.95	4.5	2.74	2.9
C/N ratio	14.27	19.35	15.83	6.41	11.26

Initial and Final Characteristics of Solid Waste

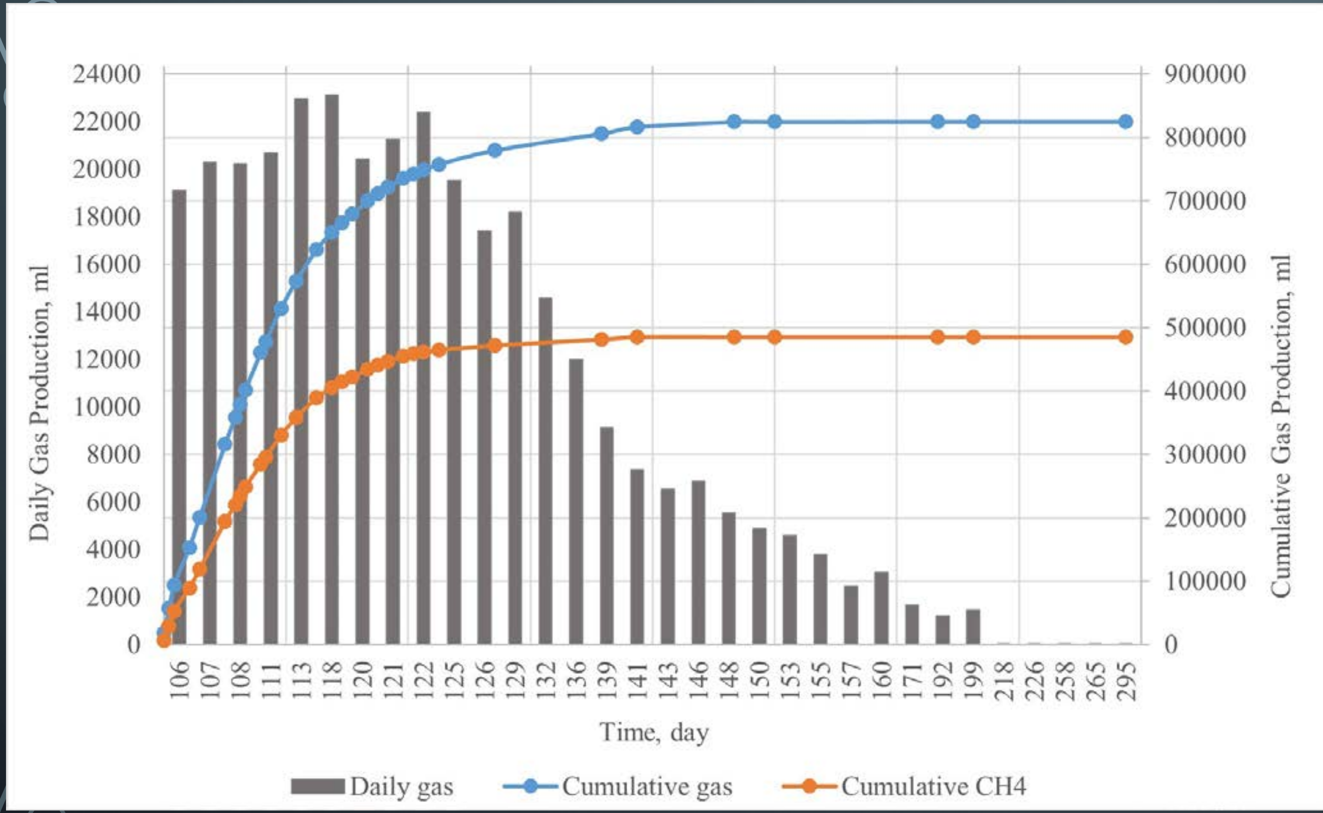




pH values and COD concentrations of Leachate

GAS PRODUCTION AND GRAVIMETRIC RESULTS

Daily and Cumulative Gas Production in R3



Weighing Results

Cup	Initial weight	Final weight	% change
Cup 1	12.1490	12.1474	0.013%
Cup 2	12.0730	12.0623	0.089%
Cup 3	12.0490	12,0345	0.12%
Cup 4	12.0990	12,0860	0.10%
Cup 5	12.1160 g	10.5611	12.8%
Cup 6	12.5610	10.8403	13.7%

MSW in R1 on day 56

MSW in R2 on day 106

MSW in R3 on day 295

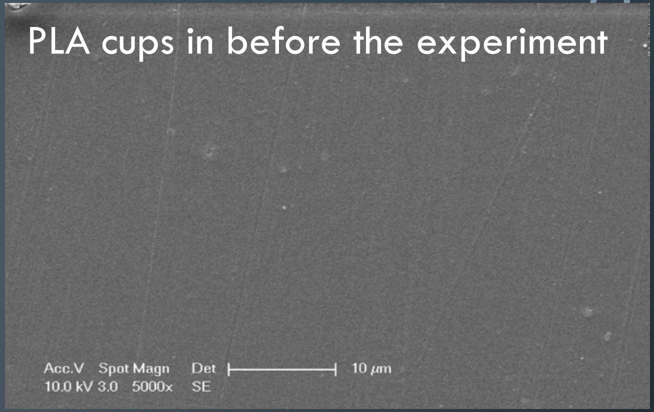
PLA cups in R1 after 56-day operation

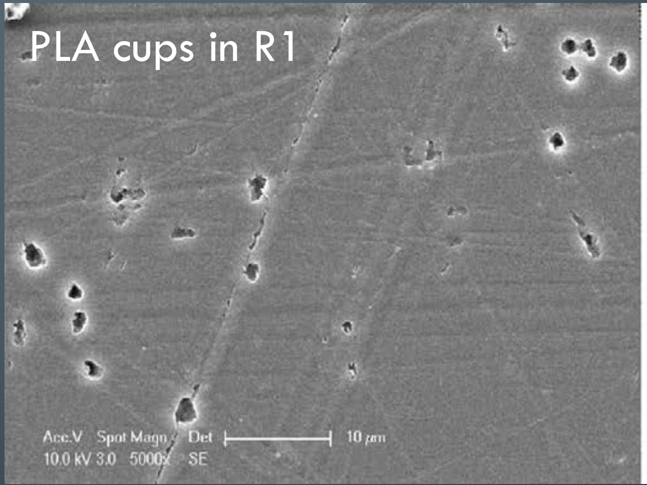
PLA cups in R2 after 106-day operation

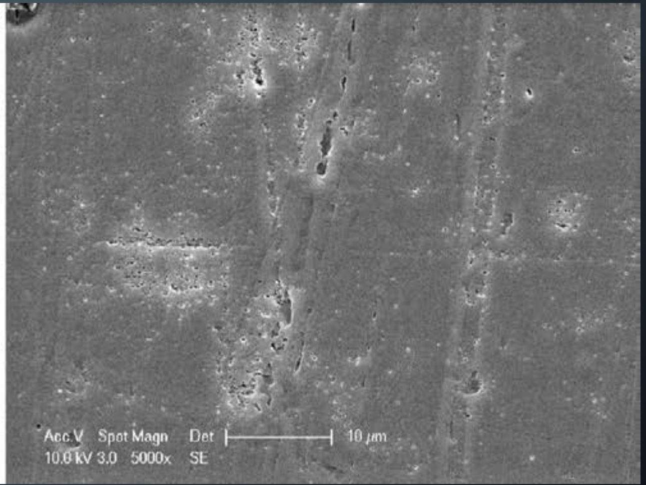
PLA cups in R3 after 295-day operation

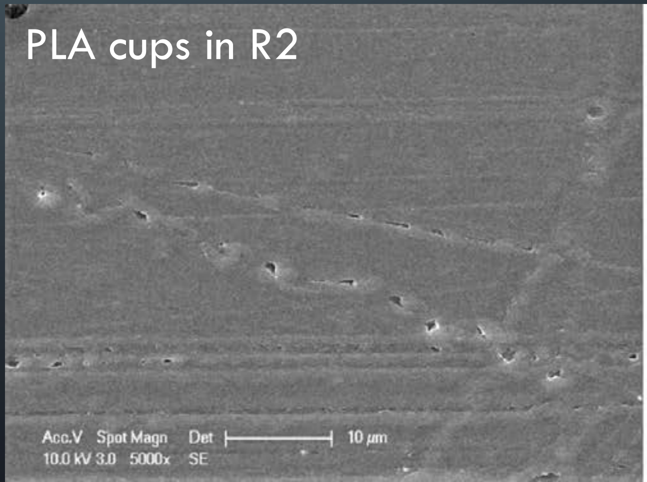
SCANNING ELECTRON MICROSCOPE (SEM) RESULTS

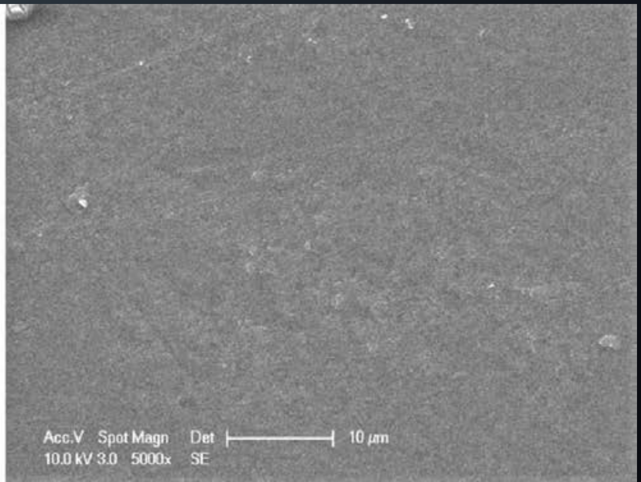
- The images of samples were enlarged 1000 to 5000 times for each sample.
- The surface of plastics was smooth and scatheless before the experiment.
- PLA cups seemed to undergo biodegradation in aerobic phase more than they did in semi-aerobic phase.
- This can be a result of additional waiting time in the aerobic reactor.
- The residence time of PLA cups under aerobic conditions was extended independently of the experimental procedure, in order to observe its possible effects on bioplastics biodegradation.







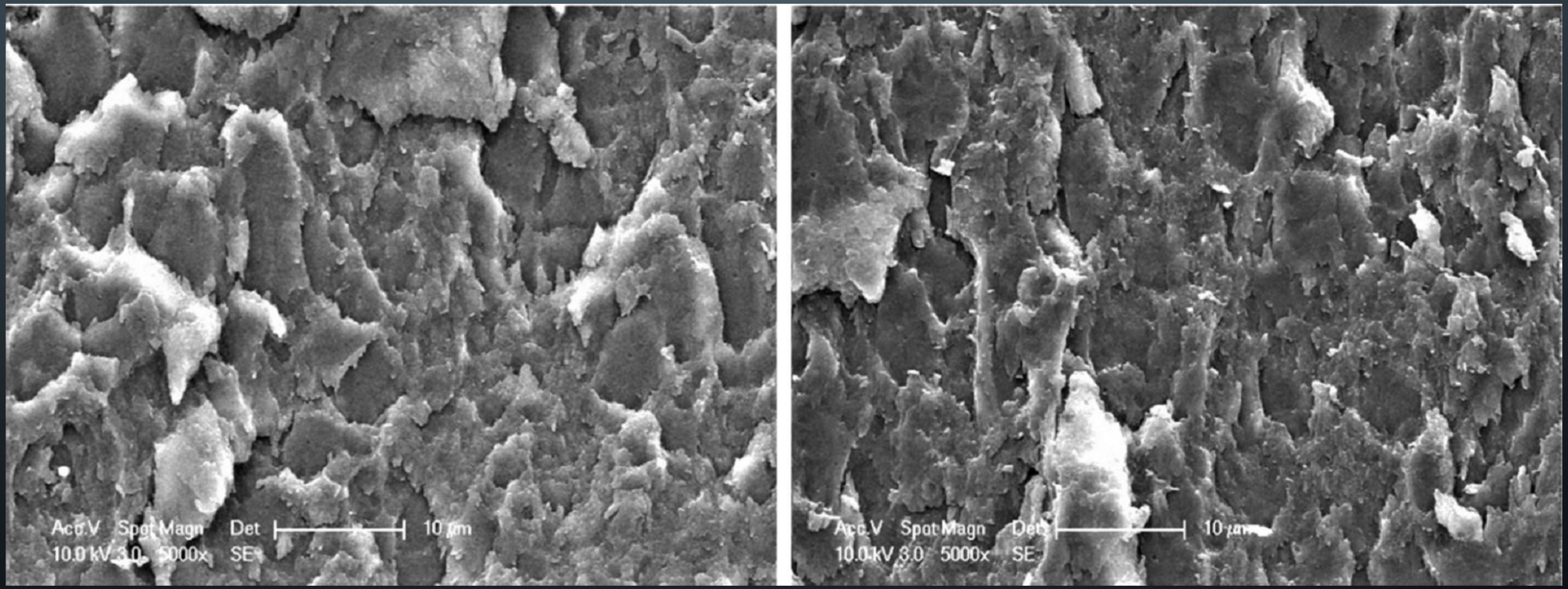




SCANNING ELECTRON MICROSCOPE (SEM) RESULTS

- It can be concluded that most of the changes in the surfaces took place during the last phase of waste stabilization (anaerobic phase).
- As it can be seen in following figure, the surfaces of cups were highly rough and damaged.
- Deep holes, cracks and cavities were observed on the surface.

PLA cups in R3



CONCLUSIONS

For the first two phases, no remarkable changes were recorded on bioplastic cups.

However, the cups decreased 13% in weight under strictly anaerobic conditions.

Anaerobic conditions caused **gravimetric changes** and **visual and microscopic** alteration.

The cups were much **softer and whiter** after anaerobic phase compared to others.
Their surface was **damaged and rough**, according to the microscopic results.

Microscopic results also show if plastics were exposed to londfilling longer, they could experience more biodergadation.

The study was limited to time; similar procedures can be applied for longer periods to understand better the behavior of these polymers.

Considering their more environmentally friendly characteristics compared to conventional plastics, these polymers may contribute to the **waste minimization** in the long term and can fit in zero waste approach.

THANK YOU FOR LISTENING