Universität Rostock Traditio et Innovatio

Mecklenburg Vorpommern MV tut gut.

EUROPÄISCHE UNION
Europäischer Fonds für regionale Entwicklung

Microwave discharges and ultrasonic – A synergy as the next generation of biomass disintegration?

Kuhlow, T., *Schönherr, K., Burgstaler, J., Wiedow, D. & Kanswohl, K.*

Baltic Bioeconomy Days
Plenary Session 4:
"Innovative Approaches for the Deployment of Biomass Resources"

Structure

- Project „KombiMax“ – Combination and Maximization – An overview
- Ultrasonification pretreatments in science and practise
- Cold plasma - Micowave discharges
- Experimental design
- Summary and Conclusion

Project „KombiMax“ – Combination and Maximization

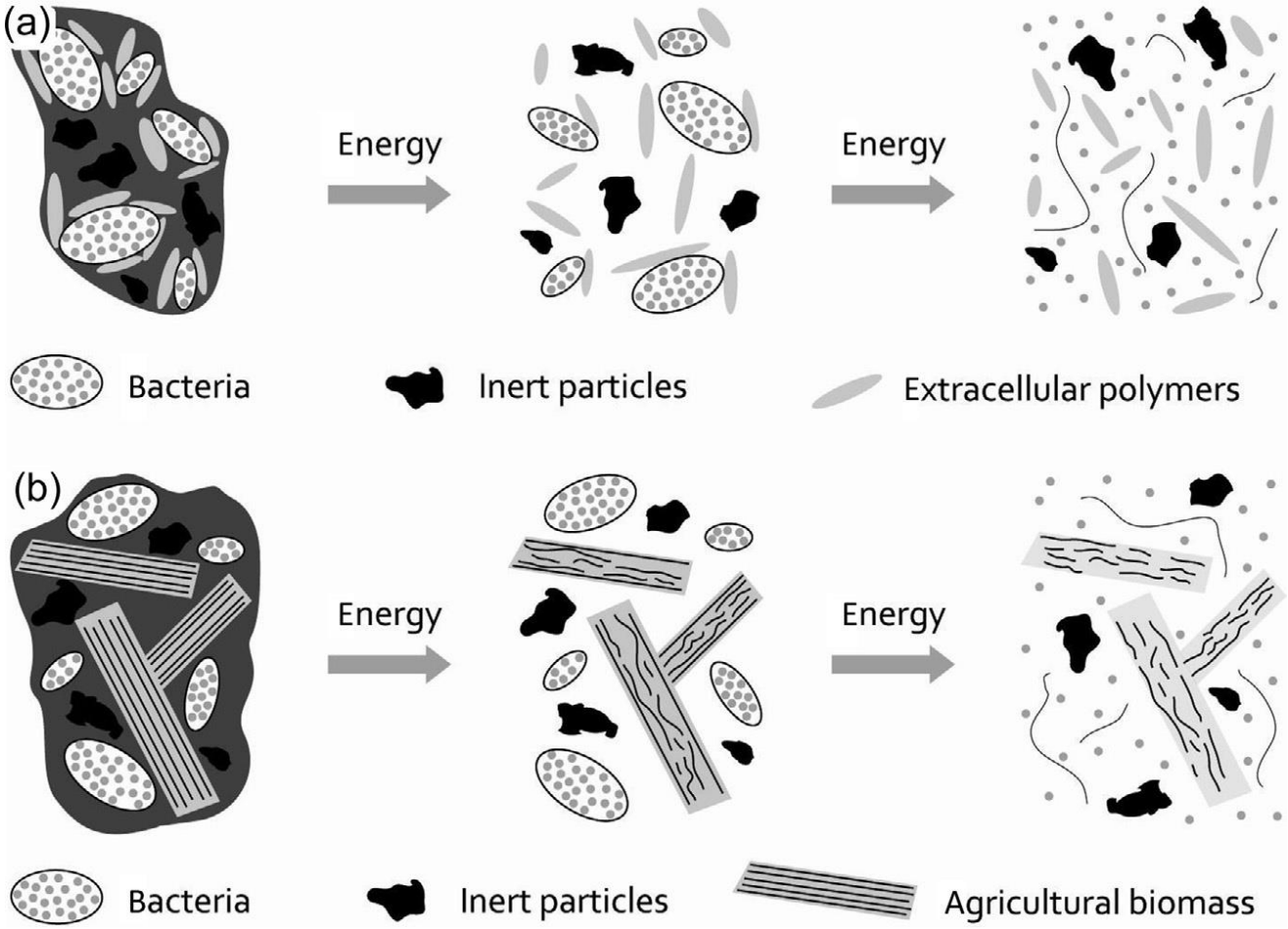
- KombiMax is a network-project between:
  - Chair of Agrartechnology and Process Engineering, University of Rostock (AUF)
  - Leibniz Institute for Plasma Science and Technology (INP)
  - Power Recycling Energyservice GmbH (PRE)
- The aim of the project is the development of a combination device for the targeted physicochemical modification of ingredients in suspensions by ultrasonic and cold plasma.
- Two different plasma sources are compared with each other.

Project „KombiMax“ – Combination and Maximization

- Investigation on effects of substrate disintegration from the combined application of ultrasound and microwave plasma, also called *"sonoplasma”.*
  - Reaction space for the two technologies must be researched and designed.
- The synergetic effect of both processes should improve the substrate disintegration and the associated efficiency of biogas plants.
- Verification of the effectiveness by various laboratory analyses are used to demonstrate the physical and chemical conversion of the material.
- Process-determining parameters are elaborated which serve as indices of successful disintegration.

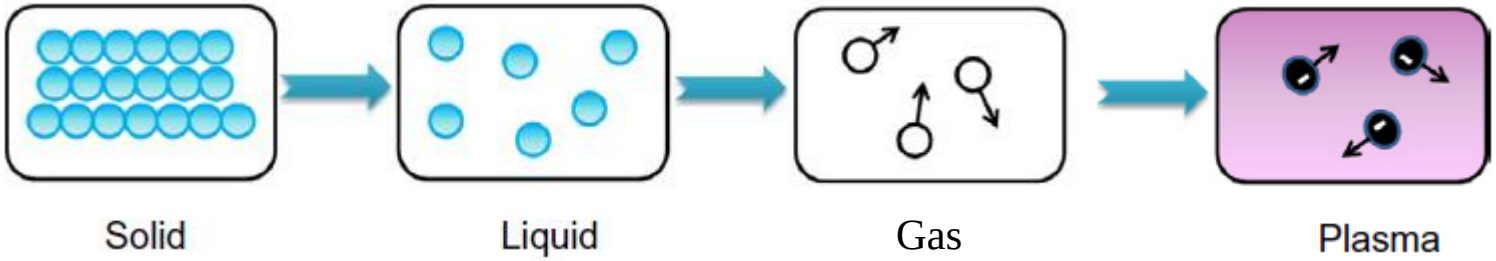
Ultrasonification in science and practise

- Hydrolysis as the most rate limiting step in anaerobic digestion systems[10].
- Ultrasonic is a physical pretreatment with high energy impact to the medium by cavitation forces and secondary effects.
  - Dynamic processes with microjets (> 100 m/s) and shockwaves up to 10^3 MPa generate extremely high shear forces which cause in an emulsification and dispersion of solid particles[3].
- Various high-performance ultrasound techniques are available on the market.
  - No direct comparability of the technologies because of different ultrasonic methods.
  - Ultrasonic treatments are an energy intensive process with economical consequenses.



Effect of ultrasound on (a) the disintegration of biomass and (b) the disintegration of biomass at agricultural biogas plants (Source: Neis (2015)).

Cold plasma - Microwave discharges

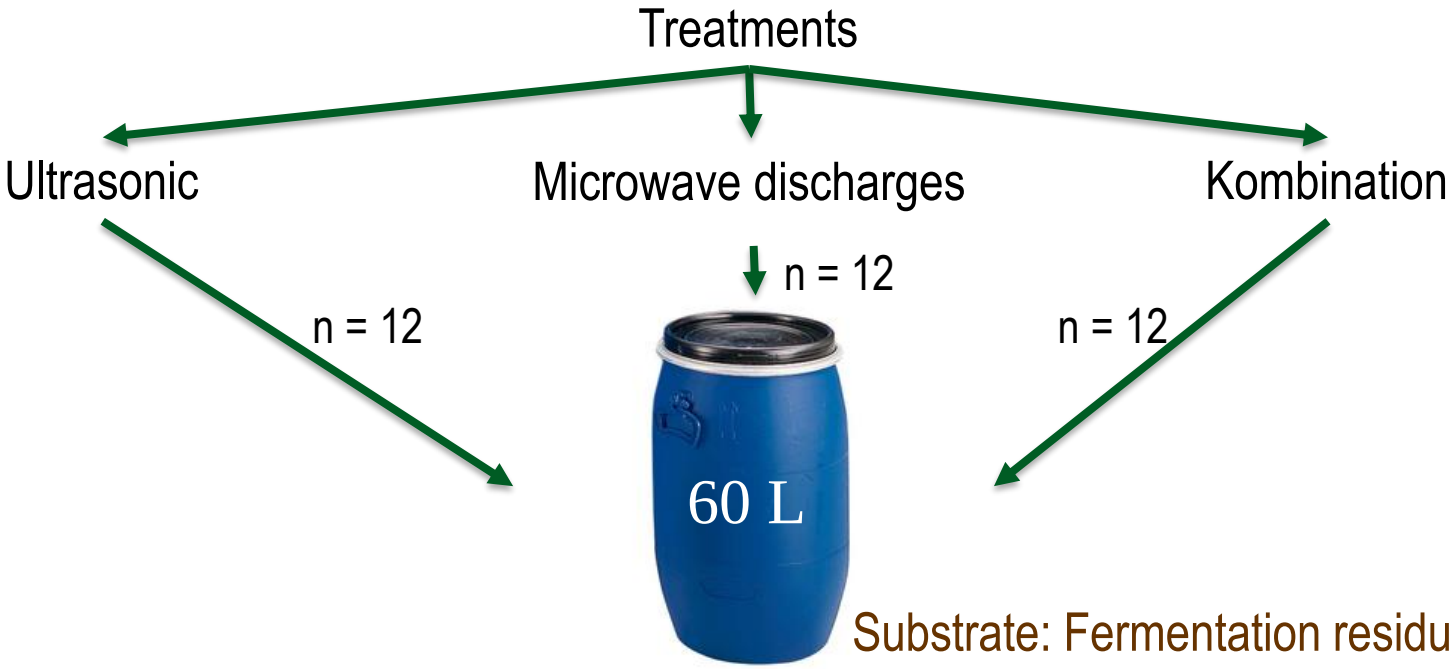


By adding enough energy to any material, we can eventually produce a gas of electrons and ions. This fourth state of matter is referred to as "plasma."

- In liquids, there is a high inflow of molecules from the substrate into the plasma
  - High density of active particles such as atoms, radicals (O_2^-, H_2O_2, OH^-) and charged particles
  - Physicochemical formation prosses of reaction products[11]
- Low pressure areas through ultrasonic waves facilitate the generation of plasma
  - Enhancement of radical emissions, organic disintegration and energy efficiency[9]

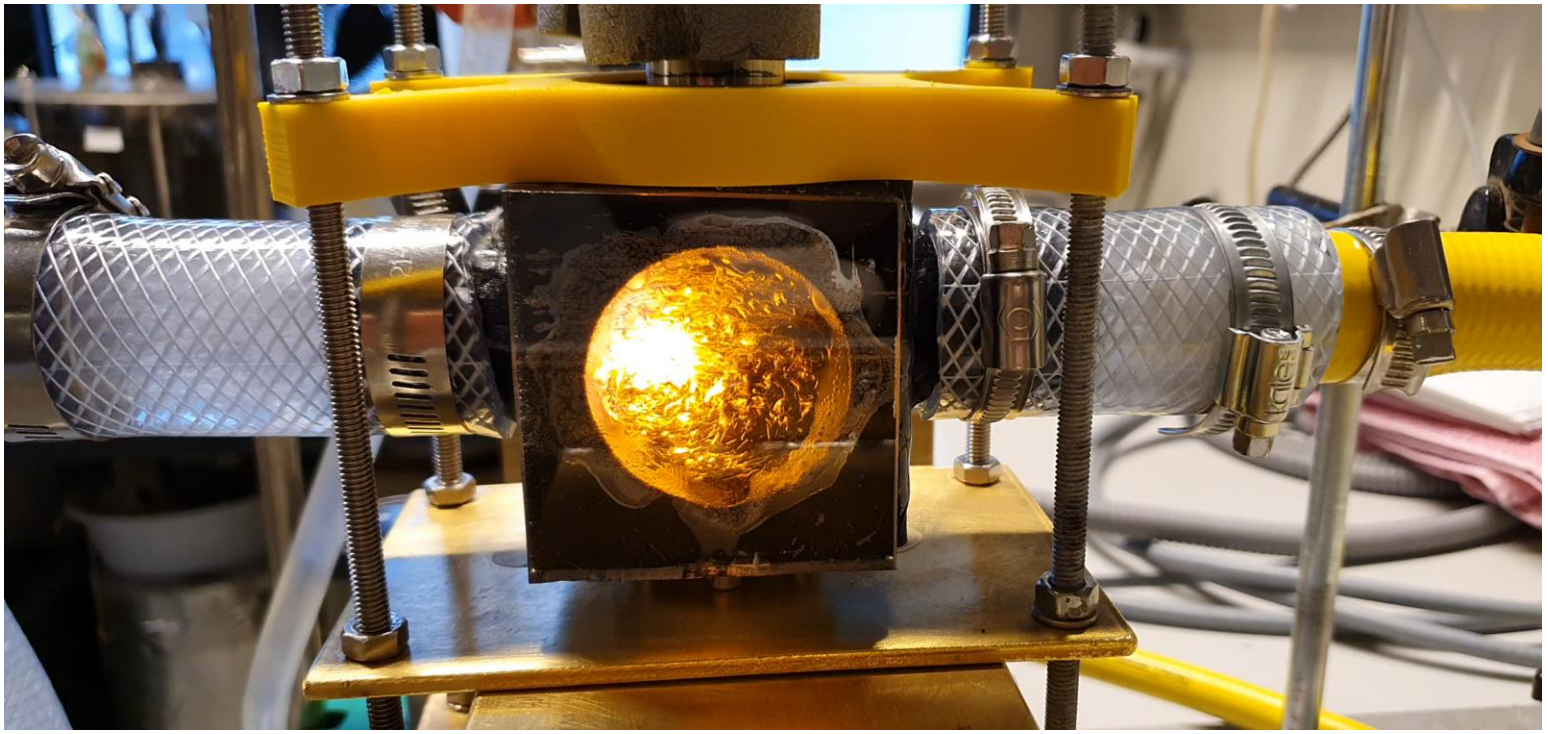
Source: Misra et al. (2016)

Experimental design



- Take samples in defined intervals from 0 to 90 min
- Process monitoring by measurements of temperature, pH and EC

Experimental design



Microwave plasma ignitions in fluent saltwater (Source: Kuhlow (2020), AUF)

Experimental design – Lab analysis

- Neutral-Detergent-Fibre (NDF) -> Hemicellulosis, Cellulosis, Lignin
- Acid-Detergent-Fibre (ADF) -> Cellulosis, Lignin
- Acid-Detergent-Lignin (ADL) -> Lignin
- Particle size fractionation
- Chemical oxygen demand (total and solved COD)
- Viscosity
- Dry matter content and organic dry matter content (crude ash)

- *Total organic acids*
- *Ammonia*
- *Biogas and methane yield*

} **Sebarate experimental design**

Summary and Conclusion

The synergy of cold plasma and ultrasonic leads to…

- Optimization of hydrolysis
- Utilization of originally non-degradable biomass in biogas plants by cavitation and radical production
- Increase of biodegradation by bacteria – increasing biogas yield
- Improvement in the treatment efficiency of biomass for biogas plants compared to the state of the art
- When fertilizing with fermentation residue treated in this way, less methane is released into the atmosphere

Universität Rostock Traditio et Innovatio

Thank you very much for your attention!

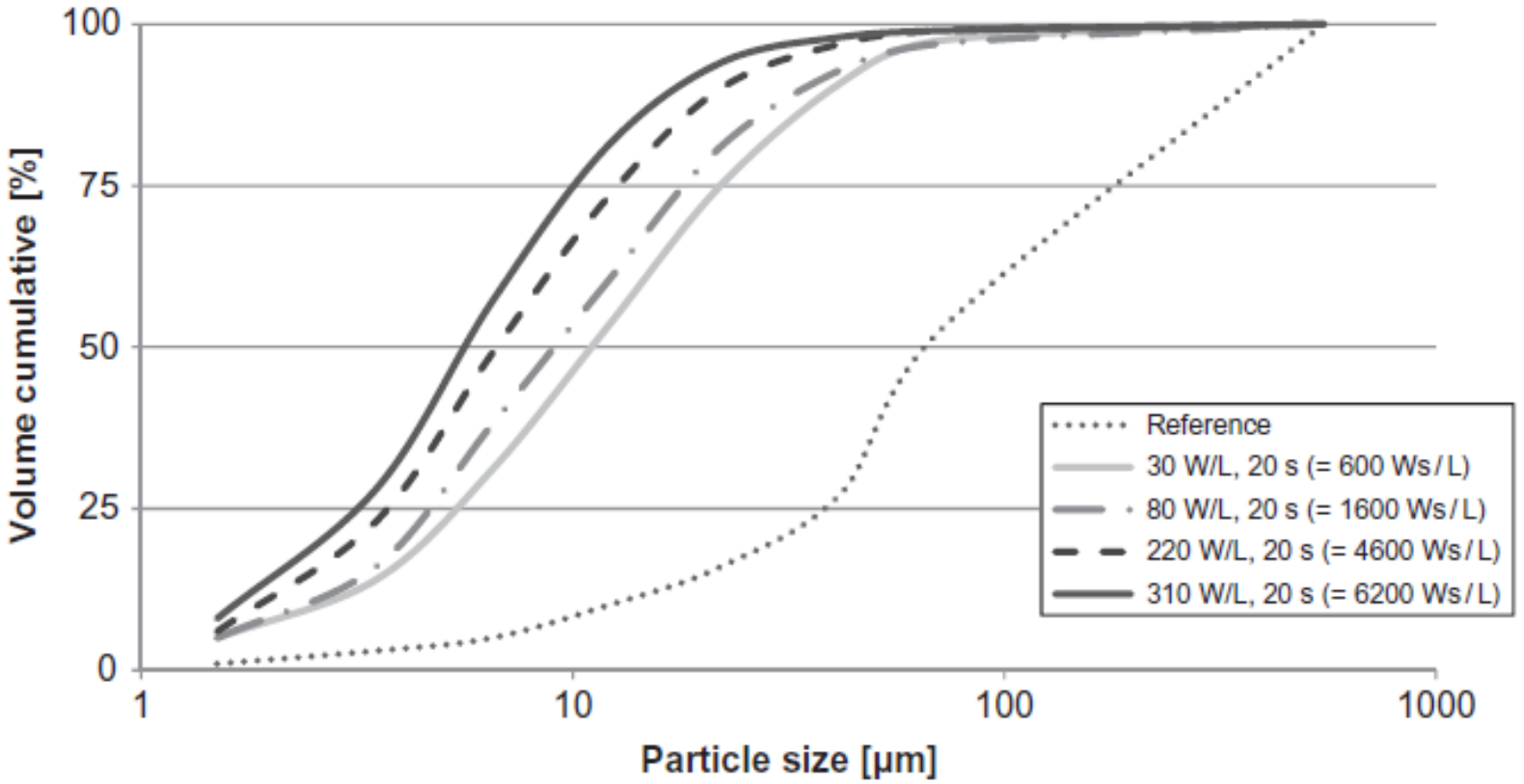
EUROPÄISCHE UNION
Europäischer Fonds für regionale Entwicklung

Mecklenburg Vorpommern
MV tut gut.

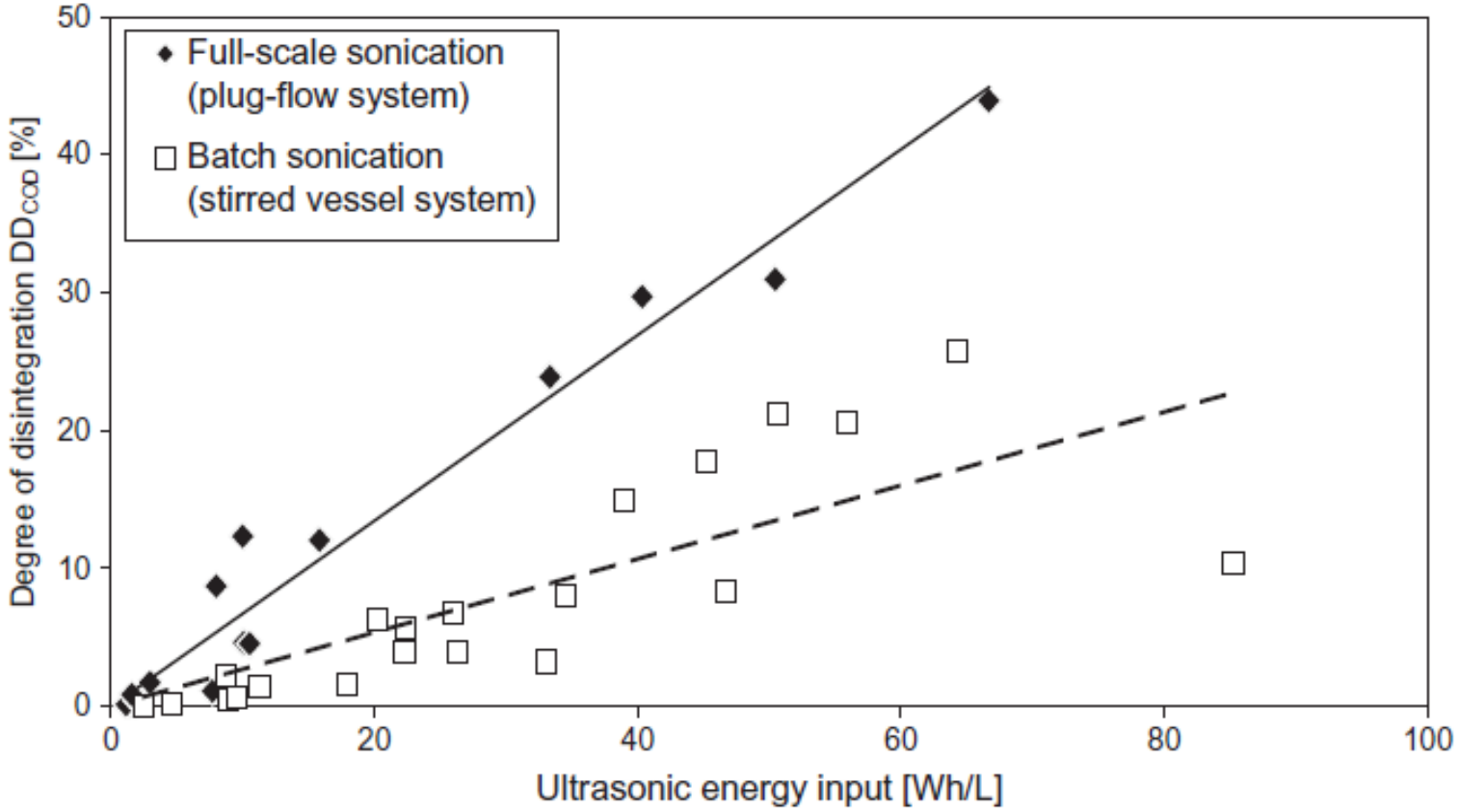
This project is co-financed by the European Union from the European Regional Development Fund.

Operational Programme Mecklenburg-Vorpommern 2014-2020

- Investment in growth and employment



Impact of sonication on particle size distribution of a wastewater treatment Effluent (Source: Neis (2015)).



Sludge cell disintegration in full scale continuous plug-flow type ultrasonic reactor as compared to batch type sonication using the same sonotrode system (Source: Neis (2015)).

Sources

(1) Ashokkumar, M. (2011). The characterization of acoustic cavitation bubbles - An overview. In: Ultrasonics Sonochemistry; 18: 864–872.

(2) Kaltschmitt, M., Hartmann, H. & Hofbauer, H. (2016). *Energie aus Biomasse. Grundlagen, Techniken und Verfahren.* 3. Aufl. Berlin - Heidelberg: Springer Vieweg. ISBN: 978-3-662-47437-2.

(3) Luo, J., Fang, Z. & Richard, L. S. Jr. (2014). Ultrasound-enhanced conversion of biomass to biofuels. In: Progress in Energy and Combustion Science; 41: 56-93.

(4) Miesra, N. N., Schlüter, O. & Cullen, P. J. (2016*). Cold Plasma in Food and Agriculture - Fundamentals and Applications*. 1. Aufl. London - Elsevier Inc..

(5) Neis, U. (2015). The use of power ultrasound for wastewater and biomass treatment. In: Gallego-Juarez, J. & Graff, K.. *Power Ultrasonics*, 1. Aufl.: Elsevier: 973-996.

(6) Show, K .Y., Mao, T., Tay, J. H. & Lee D. J. (2006). Effects of ultrasound pretreatment of sludge on anaerobic digestion. In: J Residuals Sci Tech; 3: 51-59.

(7) Scheminski, A., Krull, R. & Hempel, D. C. (1999). Oxidative treatment of digested sewage sludge with ozone. In: Water Sci Technol; 42: 151-158.

Sources

(8) Suslick, K. S. & Skrabalak, S. E. (2008). Sonocatalysis. In: Ertl, G., Knözinger, H., Schüth. F. & Weitkamp, J. (Hrsg.). *Handbook of heterogeneous catalysis*. 2. Aufl. Weinheim: Wiley-VCH Verlag GmbH & Co. KG. ISBN: 978-3-527-31241-2.

(9) Takahashi, T., Takada, N. & Toyoda, H. (2014). Synergistic effect of microwave plasma and ultrasonic wave on decomposition of organic compounds in water. In: Japanese Journal of Applied Physics: 53: 07KE01.

(10) Tiehm, A., Nickel, K., Zellhorn, M. & Neis, U. (2001). Ultrasonic waste activated sludge disintegration for improving anaerobic stabilization. In: Water research; 35(8): 2003-2009

(11) Wang, B., Sun, B., Zhu, X., Yan, Z., Liu, Y. & Liu, H. (2013). Degradation of Methylene Blue by Microwave Discharge Plasma in Liquid. In: Contrib. Plasma Phys; 53: 697-702.

(12) Zou, S., Wang, X., Chen, Y., Wan, H. & Feng, Y. (2016). Enhancement of biogas production in anaerobic co-digestion by ultrasonic pretreatment. In: Energy Conversion and Management; 112: 226-235.