The Chair of Waste Management and Emissions
The aim of research and education at the Chair of Waste Management and Emissions is to assure resource conservation and climate protection in a sustainable manner. Within this context, material flows that come waste as result of the use of resources, their treatment processes, along with the emissions from waste treatment plants, are considered in a holistic manner. The topic of biological waste air purification is dealt in a special department within the chair. The main emphasis is on the fundamental waste management processes, which serve as cornerstones for sustainable resource management, span from the generation of waste and its avoidance, over the preparing for re-use of recovery of materials and energy from waste, up to the environmentally sound disposal of wastes and the control of the associated emissions. The courses are specially tailored for the German taught Environmental Engineering program, Civil Engineering program and the international Master of Science Program “Air Quality Control, Solid Waste and Waste Water Process Engineering – WASTE”.

The working groups represent the research priorities of the chair. The working group Circular Economy and Waste Management Systems is led by Dipl.-Geol. Detlef Clauß and the working group Biological Processes in Closed Loop Recycling Management is in charge of M. Sc. Claudia Maurer. Dr.-Ing. Gerold Hafner leads the working group for Resource Management and Industrial Recycling and Dr.-Ing. Dipl. Chem. Martin Reiser is responsible for the Emissions working group.

Research is focused on the following fields:

- Modeling, simulation and evaluation of waste management systems and concepts as well as potential estimations taking into consideration resource conservation and climate protection.
- Biotechnological waste treatment processes (composting, anaerobic digestion), concentrating specially on process modelling and simulation of anaerobic systems, process optimization and regenerative flexible energy recovery from organic waste and renewable resources.
- Surveys on food waste generation and development of food waste reduction strategies.
- Laser based methods of measuring methane emissions from area sources and model-based load observations.
- Stabilization of landfills by in-situ aeration.
- Waste Treatment from Waste Management Facilities.
- Analysis of wastes and emissions.
- Examination and evaluation of decentralized disposal systems for the joint treatment of solid waste and waste water, as well as energy recovery (zero waste and wastewater processes e. g. in tourist areas, on islands).
- Infrastructure development for future megacities of tomorrow, particularly in developing and emerging countries. Scientific support of the implementation of sustainable material management systems and waste treatment technologies.
- Recovery of Phosphorus form sewage sludge by thermo-chemical procedures.

The Chair of Waste Management and Emissions is a member of several cooperation projects as well as competence networks, e.g. the Competence Centre Environmental Engineering Stuttgart (Kompetenzzentrum für Umweltschutz Region Stuttgart, KURS e.V.) and several standardization committees as well as scientific advisory boards of the federal state of Baden-Württemberg, Federal Ministries and the EU. As a result, it has established numerous contacts and cooperation agreements with several research institutions, public waste management authorities, private enterprises and ministries. Cooperation with foreign universities and research institutions has been established through international research projects.

Activities in Education

The chair’s staff including lecturers, researchers and external readers, holds lectures covering several study courses and supervises students from different academic programs. From winter semester 2008/09 the diploma programs Civil Engineering and Environmental Engineering have been converted to Bachelor and Master Programs. The following modularized courses are now being offered:

Bachelor of Science Program Civil Engineering and Environmental Engineering:
- Waste Management and Biological Air Purification
- Lecture Series in Environmental Management

Master of Science Program Civil Engineering:
- Master course “Waste Treatment Engineering”

Master of Science Program Environmental Engineering:

International Master Program “WASTE” (established in 2002):
- Sanitary Engineering, course Solid Waste Management
- Mechanical and Biological Waste Treatment
- Design of Solid Waste Treatment Plants
• Independent Study
• Biological Waste Air Purification and Adsorption
• International Waste Management
• Industrial Waste and Contaminated Sites
• Sanitary Engineering: Practical Class
• Measurement of Air Pollutants

International Master Program “Infrastructure Planning” and “WAREM”:
• Sanitary Engineering, Solid Waste Management
• Ecology III

Seminars, laboratory work, design exercises and excursions supplement the lectures.

International

Cooperation agreements in research and education through the ERASMUS program of the EU and the promotion of the Federal Ministry of Education and Research and the DAAD have been established with the following universities: Tampere University of Technology (Finland); Dokuz Eylûl University, Izmir (Turkey); Akdeniz University, Antalya (Turkey); Pamukkale University, Denizli (Turkey); Middle East Technical University, Ankara (Turkey); University of Salerno (Italy); Technical University of Temesvar (Romania); University of Thessaloniki (Greece); University of Guangxi, Nanjing (China); Southwest Jiaotong University, Chengdu (China); University of Sains Malaysia, Penang (Malaysia); Addis Abeba University, Addis Abeba (Ethiopia); Universidad Catolica Boliviana “San Pablo”, La Paz (Bolivia).

Furthermore, several staff members of the chair are active and associated lecturers of other institutions worldwide. It is important to highlight the activities of lecturers in the Master program EDUBRAS MAUI, held in cooperation with the Universidade Federal do Paranã in Curitiba (Brazil) and the Indo-German Centre for Sustainability at the IIT Madras in Chennai (India) as well as several winter and summer schools.

Conferences

Beyond research and academic activities, the chair is involved in the continuing educations and advanced training of professionals. Worth mentioning here in particular are the “Bioabfallforum”, the “Deponieforum” and the “Ressourceneffizienz- und Kreislaufwirtschaftskongress” 2018 and 2019 in association with the Ministry of Environment, Climate Protection and Energy of Baden-Württemberg and the LUBW as well as the Scientific Conference of the DGAW in cooperation with several universities.

Committees

Staff members are also involved in several committees including academic councils, professional associations and advisory boards. Prof. Kranert is the chairman of the Joint Commission of Environmental Engineering, the manager of this study program is Dipl.-Biol. Andreas Sihler. Prof. Kranert is also member of the committees of the Environmental Engineering and WASTE study programs. From April 1st, 2011 to March 31st, 2013 Prof. Kranert was the Dean of the Faculty for Civil and Environmental Engineering. Besides, Prof. Kranert is member of the Alumni associations KONTAKT e.V. and WASTE Club.

In addition, Prof. Kranert is an active member of several professional associations and committees. These include the German Institute of Standardization (DIN), the Association of German Engineers (VDI e.V.), the Society of Engineers for Water Management, Waste Management and Agricultural Infrastructure (Bund der Ingenieure für Wasserwirtschaft, Abfallwirtschaft und Kulturbau BWK), the working group for the Valorization of Municipal Solid Waste (Arbeitskreis zur Nutzbarmachung von Siedlungsabfällen ANS e.V.), the German Association for Water, Waste Water and Waste DWA e.V.), the Re Tech e.V., the ORBIT Association, the European Compost Network (ECN) and the Federal Compost Quality Association (Bundesgütegemeinschaft Kompost BGK). Prof. Kranert is the chairman of the Quality Committee of the BGK, the chairman of the Trustees of the Professors of the Waste Disposal Association for the German waste management companies (EdDE e.V.) and a member of the Sustainability Advisory Board of Baden-Wuerttemberg.

Additionally, the chairholder serves as referee for several research funding institutions, scholarship foundations and accreditation agencies. Furthermore, several staff members play a leading role in the Competence Centre “Environmental Engineering” (Kompetenzzentrum Umwelttechnik – KURS e.V.).
For the German subject Area coordinators and visiting professors there are corresponding counterparts on the Indian side at IIT Madras.

The IGCS Centre coordinators are Prof. Reicherter (RWTH Aachen University) and Prof. B. S. Murty (IIT Madras). The Area of Waste Management at IGCS is represented and coordinated by Prof. Martin Kranert. Since August 2019, Dr. Gabriela Garcés works as Associate and Post-Doc at IGCS in fields of coordination and research on this theme.

At IGCS, the focus of sustainable waste management is on advancing the development of strategies and technological processes, in the frame of interdisciplinary research that considers the circular economy, reuse approaches, energy recovery, social aspects and water (resources) protection. Organic and inorganic waste are on focus, as both represent a challenge in Indian cities. Research topics are the potential of organic waste, waste separation, aerobic (composting) and anaerobic (biogas production) processes and the products from these treatment steps. Research also include assessing the impacts of plastic waste in coastal areas in urban regions and management approaches to reduce and reuse plastic material.

In addition to biochemical, microbiological and process-orien-
ent questions, networking with the IGCS topics on energy, water and land use plays an important role. The projects are to be implemented at various scales - from laboratory scale to technical scale, and to provide recommendations for decision-makers.

One challenge is the adaptation of solutions to the prevailing situation in India and the widely differing socio-economic structure between rural and urban areas. An essential aspect is to deepen Indian-German scientific cooperation and to intensify the link between theory and practice.

Winter Schools organized at the IIT-Madras in February/March and Summer Schools held at universities in Germany in June/July enable young scientists from India and Germany to learn and work together on sustainability topics. In 2018, the Summer School took place at RWTH Aachen University and in 2019 at the TU Dresden.

In 2019, the Winter School was held at IIT Madras on the topic of “Sustainable Waste Management”, organized and directed by Prof. Martin Kranert together with Prof. Ligy Philip. Besides lectures by Prof. Kranert on “Strategies for Sustainable World Waste Management” and by his researcher Philipp Fuchs on „Management of Food Waste“, a project workshop was organized on „Food Waste Quantification and Development of Optimization Measures“.

As part of activities for networking and dissemination of research knowledge, the IGCS team had an active participation at two conferences and a winter school: i) Presentation on “Waste Management for Resilient Cities and a gender perspective“ at the World Congress of the International Solid Waste Association, Bilbao, Spain (Oct. 2019); ii) Presentation on “Waste Management in a Circular Economy, Practices in Germany“ at the 9th Icon SWM, International Conference on Sustainable Waste Management towards Circular Eco-
In preparation of Dr. Gabriela Garcés role as visiting professor at the Faculty of Civil Engineering at IIT Madras, she held a presentation on “Sustainable waste and water management for healthy ecosystems”.

In addition, various activities were carried out to strengthen transdisciplinary cooperations and build synergies. These include the co-organization of the Seminar: The Future is Round! Empowering Women in Recycling and the Circular Economy - Women of Waste (WOW), supported by the International Solid Waste Association, at the ISWA Congress in Spain (Oct. 2019). The online participation at the 3rd Indian Dialogue on Green Urban Practices, organized by the IGCS Land Use Team (Dr. C. Woiwode) in Pune, India (Dec. 2019) focused on the exchange of knowledge for project development.

In the frame of projects on Peri-urban areas and land management (Prof. Chella Rajan, IIT Madras), discussions were held on the integration of waste management issues. The Centre is also addressing plastic waste management issues in coastal urban areas in India, for which concepts studies are under development. This is conducted in accordance to the DST-funded project at IIT Madras on the topic „Climate Change Impacts on Coastal Infrastructure and Adaptation Strategies“. A master thesis has recently started to evaluate and assess plastic waste on beaches in Chennai.

In 2019, two Master Theses have been successfully completed on the topics of Waste Management in Coastal Areas and the Implementation of Composting in Urban and Peri-urban Areas, as well as joint publications were published in peer-reviewed journals.

Conferences - Seminars - Colloquia

Deponieforum 2019
Participants: about 170
www.deponieforum.de

Bioabfallforum 2019
02-03.Juli 2019, Alte Reithalle, Hotel Maritim Stuttgart
Participants: about 200
www.bioabfallforum.de

Deponieforum 2018
20.03.2018, Konferenzsaal 1+2, Willy-Brandt-Straße 41, Ministerium für Umwelt, Klima und Energiewirtschaft Baden-Württemberg
Participants: about 130
www.deponieforum.de

Bioabfallforum 2018
Participants: about 150
www.bioabfallforum.de
Therefore and for a better consciousness of bioeconomy in society as well as to help it gain more public attention, the following ideas are developed and presented in this concept study:

- Creating a bio-economy identity,
- Modular basic concept,
- House of Bioeconomy (Science Center): a place where bioeconomy can be experienced and grasped, interactively, instructively and entertainingly be presented and where companies can be connected by means of brandlands (Bioeconomy Lighthouse),
- Modules for bioeconomy on the move: trade fairs, international building exhibitions, garden shows, consumer fairs etc. (diversification),
- Modules for schools and training of craftsmen and consumers,
- Digital offers: App for bioeconomy „Bionaut”, and so on.

The authors plead for a modular and flexible system for the House of Bioeconomy. A cluster of overseas containers is favored and proposed for the realization of this House of Bioeconomy. The app „Bionaut” is intended to accompany a steadily growing community on its way from the fossil to the biogenic regenerative age. This change has to be perceived positively and is intended to generate pleasure and joy in new and environmentally friendly processes and products.

The House of Bioeconomy could support a positive development of bioeconomy and carry its goals and products into society. Children and young people in particular would be the ideal target group to bring about social change and create a broad awareness for regenerative products, across all social classes (multipliers). Mobile units such as science trucks could carry the message into schools or craft industries and companies.

The present concept study provides the basis for decisions on which elements should be followed up. Based on these ideas, concrete projects can be worked out and developed in detail. This requires the involvement of the respective actors including the relevant companies. Topics to be clarified in detail:

- Architecture
- Total scope
- Stationary or mobile
- Locations: Hall, new building, squares, etc.
- Construction of the modules: overseas containers, wooden pavilions, 3D printing rooms
- Determination of the contents and thematic priorities: Exhibitions, experiments, laboratories, showrooms, nature trails, etc.
- Steps of implementation
- Detailed costs: investment, operation, etc.
- Infrastructure
- Partner companies with brandlands and sponsors, etc.
To implement the ideas, it is necessary to develop and plan detailed concepts for the individual projects. The overall scope must be defined, locations must be examined and detailed plans must be drawn up. It has to be determined which bioeconomy topics will ultimately be implemented, whether the House of Bioeconomy will be modular and mobile or only stationary at one location.

Planning with modules would allow the House of Bioeconomy to grow successively and would make the temporary mobilization of some parts into the country possible. For its implementation, locations have to be found: new buildings with modern architecture, industrial wasteland, squares, „old“ factory halls, exhibition halls and so on.

The possibilities for the connection of the different parts have to be discussed with companies: brandlands, sponsoring, sponsorships for schools and training containers.

Furthermore, a schedule has to be drawn up for the possible mobile use of the pavilions at public exhibitions, major events or bioeconomy days to ensure that the „bioeconomy on wheels“ can be used economically.

Authors
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Andreas Sihler
Detlef Clauß
Juliane Gasse

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Institute for Sanitary Engineering, Water Quality and Waste Management at the University of Stuttgart

Claus Lämmle
Carl Lämmle
Bueroplasz, Neukirchen-Lauterbach (Pleißе)

Created: June 2018

Funded:
Minister of the Environment, Climate Protection and the Energy Sector Baden-Wuerttemberg

Project funding:
Project Management Agency Karlsruhe
Baden-Wuerttemberg Programs (PTKA-BWP)
Bioeconomy
Prof. Dr.-Ing. Martin Kranert was a member of the following scientific committees, conferences and congresses:

2019

- Ressourceneffizienz- und Kreislaufwirtschaftskongress Baden-Württemberg 2019
  Stuttgart, 23.-24.10.2019 (member of advisory board)

- iRRC Waste to Energy 2019 – International Conference on Waste to Energy,
  Vienna, Austria, 14.-15.10.2019

- Sardinia 2019
  17th International Waste Management and Landfill Symposium, S. Margarita di Pula, Sardinien, 30.09.-04.10.2019

- 7th International Conference of Euro Asia Civil Engineering Forum (EACEF 2019)
  Stuttgart, 30.09.-02.10.2019

- Bioabfallforum Baden-Württemberg 2019
  Bioabfall – Rohstoff mit steigendem Wert. (Scientific direction), Stuttgart, 02.-03.07.2019

- 9. Wissenschaftskongress Abfall- und Ressourcenwirtschaft der DGAW
  TH Amberg-Weiden, 14.-15.03.2019

- Deponieforum 2019
  Ausbau der Deponie-Infrastruktur – eine Schwerpunkt- aufgabe. (Scientific direction) Stuttgart, 28.03.2019

- Waste Safe 2019
  6. International Conference on Solid Waste Management
  In South Asian Countries, Khulna (BGD), 23.-24.02.2019

- 16. Münsteraner Abfallwirtschaftstage
  Münster, 12.-13.02.2019

2018

- Ressourceneffizienz- und Kreislaufwirtschaftskongress Baden-Württemberg 2018
  Karlsruhe, 17.-18.10.2018 (member of advisory board)

- Venice 2018
  International Symposium on Energy for Biomass and Waste, Venice, Italy 15.-18.10.2018

- Recy & Depotech 2018
  Konferenz der Montanuniversität Leoben, Austria, 07.-09.11.2018

- 2. International Congress of Urban Water and Wastewater Management
  Uksay 2018, Denizli, Turkey, 25.-27.10.2018

- iRRC Waste to Energy 2018
  International Conference on Waste to Energy, Vienna, Austria, 01.-02.10.2018

- Bioabfallforum Baden-Württemberg 2018
  Verwertung von Bioabfällen – Hohe Qualität und Märkte. (Scientific direction), Stuttgart, 12./13.06.2018.

- 8. Wissenschaftskongress Abfall- und Ressourcenwirtschaft der DGAW
  BOKU Vienna, Austria, 15.-16.03.2018

- Deponieforum 2018
  Deponie – Auslaufmodell oder unverzichtbares Element? (Scientific direction) Stuttgart, 20.03.2018

Garces Sanchez, Gabriela (2019)
ISWA World Congress 2019, WOW Session
Session by Women of Waste (WOW): The Future is Round! Empowering Women in Recycling and the Circular Economy.
## Prizes and Awards

### 2019

<table>
<thead>
<tr>
<th>Name</th>
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<th>Event</th>
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### 2018

<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
<th>Event</th>
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<tbody>
<tr>
<td>Karoline Owusu-Sekyere</td>
<td>Improving the e-waste management conditions in Agbogbloshie through a Material Flow Analysis.</td>
<td>DGAW Science Award and Audience Award 2018</td>
</tr>
<tr>
<td>Year</td>
<td>Title</td>
<td>Student</td>
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<tr>
<td>2019</td>
<td>Landfill Mining Management and Cost-Benefit Analysis</td>
<td>Tingfeng Song (WASTE)</td>
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<tr>
<td></td>
<td>Literature Review on methods used to determine and analyze</td>
<td>Enny Carolina Arevalo Padron</td>
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<td></td>
<td>microplastics in terrestrial ecosystems</td>
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<td></td>
<td>Urban Mining and Circular Economy in Asia</td>
<td>Lichun Lin (WASTE)</td>
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<tr>
<td></td>
<td>Literature Review of different direct and indirect</td>
<td>Jorge Vinueza (WASTE)</td>
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<td></td>
<td>techniques applied in the world for coffee by-products composting</td>
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<td></td>
<td>and the relationship with emissions produced</td>
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<td>2018</td>
<td>Assessment of Potential Agricultural Waste Utilization in the Region</td>
<td>Katherine Hasan (WASTE)</td>
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<td>of Malang, East Java, Indonesia</td>
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<td></td>
<td>Influence of Selected Processing Parameters on Black Soldier Fly</td>
<td>Cecille Marie Cessar (WASTE)</td>
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<td></td>
<td>Larvae Performance</td>
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<td>Recycling of Batteries</td>
<td>Noshin Nower (WASTE)</td>
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<td></td>
<td>Recycling of Rare Earth Elements in permanent magnets</td>
<td>Christina Christadoulou</td>
</tr>
<tr>
<td></td>
<td>Small incineration plants for Health Care Waste</td>
<td>Diana Capozza Tebaldi</td>
</tr>
<tr>
<td>Year</td>
<td>Title</td>
<td>Author</td>
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</tr>
<tr>
<td>2019</td>
<td>Avoidance possibilities of food waste generation in commercial kitchens in the Greek hospitality sector – case study of hotels in Heraklion, Greece</td>
<td>Stefan Hadlaczky (UMW)</td>
</tr>
<tr>
<td></td>
<td>Eigenschaften, Aufbereitung und Verwendung von Gärresten</td>
<td>Fabian Klasen (UMW)</td>
</tr>
<tr>
<td></td>
<td>Food Management im Gastgewerbe: Digitale Ansätze zur Messung und Reduzierung von Lebensmittelabfällen (Schwerpunkt Buffet)</td>
<td>Marlene Scholz (UMW)</td>
</tr>
<tr>
<td></td>
<td>Abfallsituation in Kairo und Optimierung der Wertstofferkassung im Bringsystem</td>
<td>Jasmin Saad (UMW)</td>
</tr>
</tbody>
</table>
### Master Theses

**Construction and commissioning of filter break detection and single particle definition in the cleaning system EcoCcore through Piezo Particle Sensor**

Kang Sheng Tan (WASTE)
Supervision: Dipl.-Ing. M. Rapf; Prof. Dr.-Ing. M. Kranert; M. Irion, Ecoclean GmbH

**Hydrothermal Carbonization of Biomass for Biochar production and its applications**

Buket Durmaz (WASTE)
Supervision: Dr.-Ing. K. Fischer

**Investigation on the behaviour of polyethylene films during aerobic and anaerobic degradation of biowaste**

Paula Dholio Silveira (WASTE)
Supervision: Dr.-Ing. K. Fischer

**Management of used tryes in Colombia**

Paula Fernanda Santa Chacon (WASTE)
Supervision: Dr.-Ing. K. Fischer

**Paper Recycling, case study Egypt**

Eslam Abdelraouf (WASTE)
Supervision: Dr.-Ing. K. Fischer

**Pharmaceutical Waste Management, Regulations, Hazards and Options of Treatment**

Nidal Safarini
Supervision: Dr.-Ing. K. Fischer

**Recording and Analysis of Food Waste in Food Processing in Bavaria**

Jun Shao (UMW)
Supervision: Dipl.-Ing. D. Leverenz; Dipl.-Ing. G. Hafner

**Recycling potential of lithium-ion batteries generated by electromobility at the end of life**

Xiaochun Zhou (UMW)
Supervision: Dipl.-Ing. G. Hafner

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**Anpassung des Umweltmanagementsystems der Pressmetall Gunzenhausen GmbH an die neue ISO 14001.2015**

Felix Kiemle (UMW)
Supervision: Prof. Dr.-Ing. M. Kranert

**Entwicklung einer Methodik zur Bilanzierung, Bewertung und Reduktion von lebensmittelgebundenen Verpackungsabfällen und der damit korrelierten Kohlenstoffdioxidemissionen in der Außer-Haus-Verpflegung am Beispiel einer Frühstücksbuffetbilanzierung**

Sebastien Hofer (UMW)
Supervision: Prof. Dr.-Ing. M. Kranert; Dipl.-Ing. D. Leverenz

**Entwicklung und Umsetzung eines Umweltkennzahlensystems für einen Automobilzulieferer**

Esma Namli (UMW)
Supervision: Prof. Dr.-Ing. M. Kranert

**Methodenentwicklung zur Bewertung und Optimierung von Lebensmittelverlusten und –abfällen**

Melchior Werner Weinmann (UMW)
Supervision: Dipl.-Ing. G. Hafner

**Nachhaltiges Einkaufen bei der EnBW Energie Baden-Württemberg AG**

Carolin Beez (Extern)
Supervision: Philipp Fuchs, M. Sc.

**Adaptation of Municipal Solid Waste Infrastructure to Climate Change in Coastal Areas – Chennai Region**

Muraleedharan Bramishan (WAREM)
Supervision: Prof. Dr.-Ing. M. Kranert

**Analysis and evaluation of food waste at catering events through the application of a waste tracking tool**

Bernardo Guavara (UMW)
Supervision: Dipl.-Ing. D. Leverenz; Prof. Dr.-Ing. M. Kranert

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<table>
<thead>
<tr>
<th>Master Theses 2018</th>
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<tbody>
<tr>
<td>Waste treatment with Black Soldier Fly larvae – reducing performance variability through biowaste formulation</td>
</tr>
</tbody>
</table>
| Cecille Marie Cassar (WASTE)  
Supervision: Dr.-Ing. K. Fischer |
| VOC und Geruchsprobleme in China |
| Qiaoying Zhang  
Supervision: Dr.-Ing. K. Fischer |
| Analysis of the influence of changes in atmospheric pressure on landfill gas emissions |
| Marjan Petreski (WASTE)  
Supervision: Prof. Dr.-Ing. M. Kranert; Dr.-Ing. M. Reiser |
| Emissions of Nitrous Oxide from coffee plants (WASTE) |
| Jorge Vinueza (WASTE)  
Supervision: M. San Martin Ruiz (M.Sc.), Dr.-Ing. M. Reiser |
| Wissenschaftliche Untersuchungen zur Optimierung der Abluftreinigungsanlage bei der Herstellung von Ersatzbrennstoff für die Zementindustrie |
| Ronja Mozer (UMW)  
Betreuung: Dr.-Ing. M.Reiser, Leonie Wittmann M.Sc. |
| Ursprung und Entwicklung des theoretischen Verlaufs der Hauptkomponenten von Deponiegas mit Einordnung aktueller Deponien |
| Yuzhang Dong (UMW)  
Betreuung: Dr.-Ing. M. Reiser, Imke Wessel M.Sc. |
| Ermittlung der Gesamtkohlenstoff-Emissionen aus einer kombinierten Vergärungs- und Kompostierungsanlage |
| Christoph Ehler  
Betreuung: Dr.-Ing. M. Reiser |
| Capturing renewable energy from wastewater and bio-waste treatment of light industry in China |
| Qing Wang (UMW)  
Supervision: Prof. Dr.-Ing. M. Kranert |
| Management von medizinischen Abfällen in China |
| Guan Chong (UMW)  
Supervision: Dr.-Ing. K. Fischer |
| Materialgesundheit – Hintergrund und Perspektiven |
| Pascal Kepper (UMW)  
Supervision: Prof. Dr.-Ing. M. Kranert; Marcel Özer (Drees & Sommer) |
| Analysis of the influence of changes in atmospheric pressure on landfill gas emissions |
| Marjan Petreski (WASTE)  
Supervision: Prof. Dr.-Ing. M. Kranert; Dr.-Ing. M. Reiser |
| Biogas as a natural gas substitute in the agricultural sector of Ukraine |
| Andrii Kolesnyi (WASTE)  
Supervision: Dr.-Ing. K. Fischer |
<table>
<thead>
<tr>
<th>Thesis Title</th>
<th>Author</th>
<th>Supervisor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biological removal of micropollutants from chemically pre-treated sewage treatment plant effluent – laboratory test and reactor development</td>
<td>Thi Thu Hien Nguyen (WAREM)</td>
<td>Dipl.-Ing. G. Hafner; Dipl.-Ing. M. Rapf</td>
</tr>
<tr>
<td>Characterisation of wastewater sludges from food processing industries for procedural consideration of available disposal routes</td>
<td>Peyman Sabokroohieh (WAREM)</td>
<td>Prof. Dr.-Ing. M. Kranert</td>
</tr>
<tr>
<td>Chemical Recycling of post-consumer mattress materials</td>
<td>Savina Padumane Yogish (WAREM)</td>
<td>Dr.-Ing. K. Fischer</td>
</tr>
<tr>
<td>Chlorine in Cement Manufacturing using Co-processing of Waste</td>
<td>Marouane Merizak (WAREM/MAUI double degree)</td>
<td>Dr.-Ing. K. Fischer</td>
</tr>
<tr>
<td>Co-Fermentation of food waste with olive oil mill wastewater</td>
<td>Nikolaos Papastefanakis (WAREM)</td>
<td>Dr.-Ing. K. Fischer</td>
</tr>
<tr>
<td>Comparison of biowaste and compost composition, management and quality analysis in Stuttgart and Kurdistan Region of Iraq (KRI)</td>
<td>Rzgar Al-bewani (WAREST)</td>
<td>Dipl.-Ing. L. Böhme; Dipl.-Geol. D. Clauß; Prof. Dr.-Ing. M. Kranert</td>
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Phosphorus recovery by high temperature reduction of sewage sludge ash

Fatah Naji

Supervisor: Prof. Dr.-Ing. Martin Kranert, Universität Stuttgart
Co-Supervisors: Prof. Dr.-Ing. Kerstin Kuchta, Technische Universität Hamburg
Prof. Dr.-Ing. Renatus Widmann, Universität Duisburg Essen

Abstract

Approximately 85 M-% of the world’s phosphate resource is processed into fertilizers. Alternative uses include pesticides, cleaning agents, foods, flame retardants, oil additives, and it is used in the metalworking industry as well. Phosphorus is increasingly in demand within the high-tech industry and is used, for example, as a dopant in the semiconductor and solar cell industry, in nano-engineering, in lithium-iron-phosphate batteries, and in LEDs.

The estimated availability of the resource phosphorus has a range of approximately 115 to 350 years. As phosphates are fossil and irreplaceable and occurrences with low heavy metal and uranium contents are becoming increasingly scarce, the importance of secondary phosphorus sources such as meat and bone meal, sewage sludge and sewage sludge ash is steadily increasing. Sewage sludge produced in Germany contains 0.1 to 1.2 M-% phosphorus and sewage sludge ash 5 to 10 M-% phosphorus. The Federal Environment Agency assumes a phosphorus recovery potential in Germany of 50,000 Mg of phosphorus per year from sewage sludge, which could replace about 50% of the volume of phosphorus fertilizer imported into Germany. The total an-
nual sludge ash available in Germany contains about 19,000 Mg of phosphorus per year, which could theoretically replace 12.6% of the phosphorus of the fertilizer used annually in Germany.

Together with the federal states, the Federal Government developed a phosphorus strategy for Germany under the auspices of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). The new version of the Ordinance on the Reorganisation of Sewage Sludge Recycling in Germany (Sewage Sludge Ordinance - Abf-KlärV) came into force on 3rd October 2017. This requires wastewater treatment plants above a certain size to recover phosphorus from wastewater streams such as sewage sludge at the end of the transitional period.

In addition to a large number of wet-chemical processes that recover phosphates from the sewage sludge, the process water of a sewage treatment plant or from sewage sludge ash in the form of fertilizers (usually magnesium ammonium phosphate) can be used as fertilizer as well. It should be noted that so far none of the thermochemical processes have gone beyond the development of pilot plants.

White phosphorus P4 has the highest economic value of all phosphorus products and serves as a precursor for many chemical products. This is produced by thermochemical reduction of raw phosphates in the arc furnace. The only known plants of this kind are operated in China, Kazakhstan, the United States, Vietnam and India, which reflects Europe’s dependence on imports. In 2012, Thermphos International, based in Vlissingen (Netherlands), which had the last white phosphorus producing plant (electric arc furnace) in Europe, filed for insolvency.

The aim of this dissertation is the development of a thermochemical process for phosphorus recovery from secondary raw material sources and its ecobalance assessment. In contrast to wet-chemical processes (currently state of the art), higher phosphorus yields can be achieved with this process. High phosphorus yields can be reached despite high iron contents in phosphorus sources. The thermochemical reduction of sewage sludge ash (RecoPhos process) to obtain white phosphorus or thermal phosphoric acid takes place in the InduCarb reactor. This is a bulk bed reactor that can be inductively heated to temperatures around 2,000°C. It is filled with a susceptor material and has already been tested for the recovery of zinc from steel mill dusts.

If the sewage sludge ash melt flows through the bulk, the shear and elongation of the melt and the formation of thin films favor the reduction and volatilisation of phosphorus from the melt compared to the arc furnace. This results from the larger specific surface area and the associated higher contact with the reductive atmosphere and the shorter diffusion and convection paths from the melt into the gas phase. In this way, the probability of contact between elemental phosphorus and iron can be reduced, thus minimizing the formation of ferrophosphorus and the associated losses compared to phosphorus generation in the arc furnace.

The laboratory plants developed have confirmed that phosphorus can be selectively separated from the sludge ash and transferred to the gas phase. Thus, the suitability of sewage
sludge ash as secondary phosphate ore has been proven. Continuous operation (input and output) was determined as process management. It was shown that graphite, anthracite or coke are suitable susceptor materials, but for reasons of economy and availability coke has clear advantages. Calculations showed that for the recovery of 1 Mg phosphorus from KSA about 1.5 Mg carbon is required as a reducing agent, which was confirmed by the experiments.

The experiments carried out at the pilot plant have shown that by setting the basicity between $B_1 = 0.8$ to $1.1$ in combination with a sufficiently long residence time and reactor temperatures of about $1,600^\circ$C, over 99% of the phosphorus can be separated from the sewage sludge ash. The by-product slag then has good cement hydraulic properties and the phosphorus losses due to the formation of ferrophosphorus do not exceed the calculated equilibrium concentration of phosphorus in iron. It was also shown that the iron oxides contained in the sewage sludge ash can be almost completely reduced and transferred to the metal phase (> 99%). In addition to iron oxides, chromium and zinc oxides are also reduced. Volatile metals that precipitate the gas phase include zinc, lead and cadmium.

On the basis of the pilot plant it could be proven that the input materials can be fed into the process as supplied (dusty, lumpy). In this way, compared to the phosphorus production in the arc furnace and comparable thermochemical processes, no complex and expensive pelletizing plant has to be installed upstream.

The ecobalance shows that the process has ecological advantages over thermochemical phosphorus production in the arc furnace. The identified improvement potentials can be expanded through suitable strategies and measures. Positive effects can be achieved by increasing the efficiency of the induction unit. Furthermore, the use of hot or even molten sewage sludge ash can significantly reduce energy requirements and environmental impacts. The switch to renewable energies also has a significant positive impact on the environmental balance; in particular on the global warming potential and the ozone depletion potential. By using industrial waste instead of expensive technical products, the ecological balance can also be improved. For example, waste such as ash, dust and slag from thermal processes can be used as flux and substitute raw materials such as lime (hydrate) or sand. Waste containing carbon can be used as a reducing agent or, if suitable, as a susceptor material. However, the utilization of by-products also has an influence on the ecobalance. The largest mass flow of by-products is the slag produced. Therefore, the use of slag as a product is a decisive factor for ecologically sensible operation. However, this is only possible if the slag can be used in the cement industry, for example, and has a positive effect on the cement hydraulic properties.

The marketability of the slag produced is decisive for the economic operation of the plant. This represents the highest mass flow in the output of the plant. The break-even analysis showed that with a revenue of €3,000 per Mg phosphorus, the market price of the slag must be higher than €30 per Mg for an economic operation of the plant. This seems unrealistic given the current market situation. If the slag is removed without costs or proceeds, the price for recycling phosphorus must be above €4,800, in order to reach the profit zone. The power requirement offers further savings potential. Further profit potential lies in the marketing of processed ferrophosphorus, which must be available in a marketable quality, in a high-quality phosphorus product and in waste treatment for example of waste produced by thermal plants.
Development of methods to provide basic data for material and material flow investigations in waste management

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Abstract

The aim of the method development was to provide case-specific basic data for material and material flow analyses in waste management. For this purpose, an extensive data model was developed and a database was designed and implemented, which is divided into two major parts: a waste management material database (AM-DB) and a waste management technology database (AT-DB). The AM-DB stores raw literature data on materials relevant to waste management and the AT-DB stores the technical parameters for simulating the process sequence of technical processes.

The focus of the work was on the case-specific provision of basic data on the composition of waste with identification of the chemical-physical characteristics contained in the individual waste fractions. For this purpose, several methods were developed which make it possible to generate an aggregated Material-Basic-Matrix (MBM) from the raw literature data in the AM-DB. Based on selection and aggregation criteria, this contains weighted mean values for the stored waste fractions and chemical-physical parameters. In addition, a standardization to uniform reference values is carried out. From this MBM, one or more so-called Input-Material-Substance-Matrices (I-MSM) can be generated for specific cases of application. This is achieved by modeling the waste composition by selecting the waste fractions contained in the waste and specifying the percentage by mass of the model waste, supplemented by selecting the relevant substances or chemical-physical parameters. The I-MSM thus generated contains the specific basic data, representing the input into a waste management system or a waste technology scenario, consisting of the waste composition with identification of the associated chemical-physical parameters and based on the previously specifically selected and aggregated raw waste data from the literature.

Besides, this approach was supplemented by additional methods to provide analog basic data after mechanical processing. To reach this goal, simulation models for modeling plants using mechanical material flow separation were integrated. This allows to combine any set of technical processes of a mechanical waste treatment plant in order to simulate the material flows for each process stage and the plant as a whole. In this way, a tracking of origins, paths, and remains of the materials in the system input is possible. The associated substance flows and chemical-physical characterizations result from the respective material compositions in the output streams of the simulated processes. The result of this modeling of a specific material flow processing then again provides case-specific basic data with identification of the waste composition according to fractions, substances and the chemical-physical characterizations.

The developed methods have finally been implemented using an example from municipal waste management. This was a hypothetical scenario in which municipal waste was first modeled and described using an I-MSM as described above. This I-MSM was then used as input flow into a process aiming on mechanical flow separation, in which several technical processes are connected in series as process steps. The output flows from this exemplary process configuration are described by the respective Material-Substance-Matrix (MSM). Afterwards, these specific basic data are available for waste material and substance flow analyses and can be used as a basis for the classification, evaluation and optimization of the investigated waste management system. The integration of further technical systems into such a system analysis can be carried out by using transfer factors and transfer formulas for waste materials and chemical substances that can be stored in the database. This is demonstrated by an example.

To sum up, it has been possible to develop a methodology that makes it possible to provide the desired case-specific basic data for material and substance flow investigations. The methods developed here are also suitable for programming software with database connection.

From a scientific point of view, the new methodology provides an important addition to the implementation of waste management material and material flow analyses. With the possibility to create detailed case-specific basic data, this existing gap is closed. In addition, a tool was developed to build up an extensive database with basic waste management data. It is already possible to compose a typical municipal waste with relevant chemical-physical characteristics using the basic data entered in the databases as examples. As soon as the data basis has reached a certain level, a more detailed modeling of waste composition and chemical-physical characterization can be carried out.
Figure 1: Methodologies to be developed as objectives of the dissertation
Figure 2: Methodology II-1 for generating the „Material-Base-Matrix“ (MBM)

Figure 3: Modelling of technical processes in waste management, schematic illustration
## Co-Supervision of Dissertations and Habilitations

### 2019

**Solid Organic Waste Characterisation and Management in India**

Christopher Josef Speier

**Supervisor:** Dr.-Ing. habil. Dirk Weichgrebe, Gottfried Wilhelm Leibniz Universität Hannover

**Co-Supervisor:** Prof. Dr.-Ing. Martin Kranert, Universität Stuttgart
Prof. Dr. Regina Maria de Oliveira Barros Nogueira, Gottfried Wilhelm Leibniz Universität Hannover

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**Dissertation**
### Co-Supervision of Dissertations and Habilitations

#### 2018

**Development of a two-stage high pressure anaerobic digestion system for biomethane production**

*Entwicklung eines zweistufigen Hochdruckfermentations-Verfahrens zur Biomethanproduktion*

**Dr. sc. agr. Andreas Lemmer**

**Supervisor:** Dr. Hans Oechsner, Universität Hohenheim  
**Co-Supervisor:** Prof. Dr. T. Jungbluth, Universität Hohenheim

**Combined Hydrogen sulfide and Carbon dioxide removal process for Biogas upgrading**

Karen Jenifer Rajavelu  
**Supervisor:** Prof. Dr. Martin Denecke, Universität Duisburg-Essen  
**Co-Supervisor:** Prof. Dr.-Ing. Martin Kranert, Universität Stuttgart

**Habilitation**

**Combined energy and phosphorus recovery from black water, co-substrates and urine**

Karen Mouarkech  
**Supervisor:** Prof. Dr.-Ing. Heidrun Steinmetz, Technische Univ. Kaiserslautern  
**Co-Supervisor:** Prof. Dr.-Ing. Jörg Longdong, Bauhaus-Universität Weimar  
**Co-Supervisor:** Prof. Dr.-Ing. Martin Kranert, Universität Stuttgart

**Erweiterte Prozessbewertung von Biogasanlagen unter Berücksichtigung organoleptischer Parameter und Erfahrungswissen**

Laura Katharina Weitze  
**Supervisor:** Prof. Dr.-Ing. Eckhard Kraft, Bauhaus-Universität Weimar  
**Co-Supervisor:** Prof. Dr.-Ing. Martin Kranert, Universität Stuttgart

**Dissertation**

**Removal of pharmaceutically active compounds from treated effluent using heterogeneous photocatalysis under visible light**

Anupama Surenjan  
**Supervisor:** Prof. Ligy Philip, Research Guide, IIT Madras, Chennai, Indien  
**Co-Supervisor:** Prof. T. Pradeep, Dept. of Chemistry, IIT Madras, Chennai, Indien

**Erweiterte Prozessbewertung von Biogasanlagen unter Berücksichtigung organoleptischer Parameter und Erfahrungswissen**

Laura Katharina Weitze  
**Supervisor:** Prof. Dr.-Ing. Eckhard Kraft, Bauhaus-Universität Weimar  
**Co-Supervisor:** Prof. Dr.-Ing. Martin Kranert, Universität Stuttgart

**Biologische Wasserstoff-Methanisierung in Hochdruck-Rieselbetrektoren für Power-to-Gas Konzepte**

Timo Ulrich  
**Supervisor:** Prof. Dr. Thomas Jungbluth, Universität Hohenheim  
**Co-Supervisor:** Prof. Dr.-Ing. Martin Kranert, Universität Stuttgart

**Dissertation**
2019


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2018

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Investigation on the behaviour of plastics during biological treatment of organic waste

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Analysis of E-Waste Management Conditions in Agbogbloshie through a process based MFA

Karoline Owusu-Sekyere (2019):
Quantification of food waste and identification of food waste management strategies in bakeries

Karoline Owusu-Sekyere (2019):
Improving the waste management conditions in Agbogbloshie through a Material Flow Analysis

Gabriela García-Sanchez (2019):
Waste Management for Resilient Cities and a gender perspective.

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Hildemar Mendez (2019):
Investigation on the behaviour of plastics during biological treatment of organic waste

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9th Icon SWM, International Conference on Sustainable Waste Management towards Circular Economy, Bhubaneswar, India, 27.11.2019.
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Martin Kranert (2018):
Biologische Abfallverwertung – Herausforderungen und Perspektiven.

Martin Kranert (2018):

Martin Kranert (2018):
Kreisläufe schließen – Ausgangsstoffe und Produkte der Bioabfallwirtschaft.

Philipp Fuchs (2018):
Food Waste Reduction using RESOURCEMANAGER-FOOD.
Posters

2019


2018


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Biological Processes in the Circular Economy
Biological Processes in the Circular Economy

High-value utilization of organic waste (fermentation, composting) is an important element in order to ensure a high share in the supply of renewable energy in Germany as well as to achieve the desired energy policy objectives of the federal and state government.

This working area focuses on processes for the biological treatment and conditioning of organic waste. Furthermore, flexible energy production and the use of renewable raw materials is also one main emphasis of the working area.

Core competencies of the working area are:

- The identification of optimal pathways in the exploitation of the resulting products from the fermentation and composting process (biogas, digestate, compost)
- Utilization and balancing of organic waste and their streams for the provision of raw material for the bioeconomy
- The investigation of physical and chemical material properties of organic waste and waste materials in general and in particular, digestate and compost
- Balancing of pollutants and impurities in technical systems
- The technical evaluation of treatment processes in large-scale fermentation plants

The methodological approaches for the technical-economic evaluation are based on measurements at the organic waste treatment plants, experimental test series and model-based calculations.

Controlling Mechanism of Hyper Grease and Saline Biowaste Codigestion

“Controlling Mechanism of Hyper Grease and Saline Biowaste Codigestion” Project is designed to identify the potential and possible concepts for co-fermentation of food waste and sewage sludge and its practical implementation and investigation in China in lab scale. This will be accomplished by intensive cooperation of Chinese and German partners, yielding very valuable knowledge exchange and intensifying existing long-term collaboration.

In this project, a concept for separate collection and pretreatment of food waste was developed. Series of experiments of co-fermentation was conducted in lab-scale fermentation reactor at Southwest Jiaotong University. Batch tests and continuously tests aim to find out the maximized biogas yield and best proportion of food waste. At the same time, the experiments of flexible biogas production were conducted with demand oriented feeding management. Furthermore, the potential to save energy by fermentation of sewage sludge and food waste are estimated. Similarly, the potential to reduce climate relevant emissions (GHG) from sewage sludge and food waste on the landfill, by valorizing it as substrate for
fermentation, was calculated as well. During this project, 2 workshops were held in Chengdu for experience exchange and results discussion. Besides, students exchange and joint scientific articles realize a high level know-how-transport between China and Germany.

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<th>Funding Institution:</th>
<th>Science and Technology Bureau of Sichuan Province, China</th>
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<tr>
<td>Contact:</td>
<td>Prof. Dr.-Ing. Martin Kranert</td>
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<td>Claudia Maurer, M.Sc.</td>
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<td>Dipl.-Ing. Jingjing Huang</td>
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<td>Duration:</td>
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**Optimization Potentials at Fermentation Plants for Biowaste in Baden-Württemberg**

The aim of the project is to develop a solid database with key figures on established concepts of fermentation plants for biowaste. The database is intended to support project development and planning decisions in the expansion of fermentation capacity and to identify optimization potentials.

For several years the utilization of biodegradable waste in fermentation plants is increasing. This development makes it necessary to evaluate the best use of the substrate and to identify the optimization potential - for existing plants as well as for the design of new plants. Currently there is a lack of reliable data for a longer period regarding the suitability of the concepts for the respective substrates and the actual performance of the systems.

In the project „Optimization Potential in Solid Waste Biogas Plants in Baden-Württemberg“ a comprehensive, objective, reliable database is therefore to be created by implementing an extensive measurement, sampling and data collection program. A comprehensive database with information on various concepts for process operation, energy and material flow balances, analyzes of substrates and product qualities should assist planners and operators within project development and planning decisions. In addition the optimization potential, such as higher energy efficiency, targeted substrate use, increased energy and resource efficiency, is to be discovered.

This project is funded by the Ministry of Science, Research and the Arts of the State of Baden-Württemberg (Az: 33-7533-10-5/99/1) and takes part in the BBW-ForWerts graduate program.

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<th>Funding Institution:</th>
<th>Ministerium für Wissenschaft, Forschung und Kunst Baden-Württemberg; Forschungsprogramm Bioökonomie Baden-Württemberg</th>
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<td>Contact:</td>
<td>Prof. Dr.-Ing. Martin Kranert</td>
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<td>Dipl.-Ing. Anna Fritzsche</td>
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Research

**SepaFlex – Co-Fermentation of Separated Biowaste Press Water in Sewage Treatment Plants for Flexible Energy Generation**

The separate, demand-oriented energetic utilisation of the liquid and solid components of Biowaste represents an innovative concept to use domestic biowaste for energy production at low cost through existing waste utilisation capacities. By pressing off the liquid components of the biowaste, the biowaste press water (PW) can be used in digestion towers of municipal sewage treatment plants for the demand-oriented supply of biogas. The separated, hardly degradable solid components of the pressed biowaste (aBA) can be efficiently utilized in existing composting plants.

Due to the high proportion of readily degradable organic matter and the resulting good accessibility of the nutrients for the micro-organisms is ideally suited to be used as a co substrate in digestion towers. Due to the significantly higher energy content and the rapid degradability in comparison to sewage sludge, very high performance gradients can be achieved with the Biogas production. Through targeted co-fermentation of PW, it is therefore possible to achieve, in addition to a significant increase in the biogas production of a wastewater treatment plant, a flexible adaptation of the Biogas production to the own energy demand and if necessary beyond that to the electricity grid possible. The aim of the pilot and demonstration project is to develop a cost-effective process concept for the flexible energetic use of biowaste. The suitability of the PW for flexible energy use is to be assessed. Biogas production in digestion towers of municipal sewage treatment plants and the recycling of the aBA in composting plants can be examined under practical conditions and the technical as well as economic possibilities and framework conditions of the procedure in pilot operation by the ISWA and LFKW of the University of Stuttgart together with the biowaste recycler BEM Umweltservice GmbH, and validated. The IER evaluates the concept in the context of the future electricity system, including system services.

**Funding Institution:**
Bundesministerium für Wirtschaft und Energie

**Contact:**
Prof. Dr.-Ing. Martin Kranert
Claudia Maurer, M.Sc.
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**Partners**
BEM Umweltservice GmbH
Institut für Energiewirtschaft und Rationelle Energieanwendung, Universität Stuttgart
Lehr- und Forschungsklärwerk ISWA

**Duration:**
09/2018 - 06/2022
Process-oriented Optimization of Straw Co-digestion System in Sichuan Province

China as one of the largest country producing crop straw, in 2017, the total resource of straw reached 1.02 billion tons. At present, China is vigorously promoting and improving the straw collection and storage system and accelerating the comprehensive utilization of straw utilization. However, open burning occurred still in a small part of rural areas in China, which not only causes waste of natural resources but also causes environmental pollution. Straw anaerobic fermentation is an important way to realize the recycling of agricultural resource and reduce its pollution in the environment.

As part of the stems and leaves of crops, straw is a multi-purpose renewable biomass source. Its main components include cellulose, hemicellulose and lignin. Among them, lignin is one of the recognized hard-to-degrade substances because of its stable spatial structure, which is difficult to be degraded by microorganisms. In order to make full use of straw for anaerobic fermentation, it is necessary to carry out pre-treatment on straw before anaerobic fermentation to improve the efficiency of biological transformation.

Chinese and German side in the project will carry out technical cooperation and research in the field of anaerobic co-digestion, in which the straws are used as raw material with different substrates, the optimized reaction control parameters are explored to maximize the biogas production rate and the utilization mode of fermentation product is also optimized.

This project is designed to character the quantity and quality of straws in Sichuan Province and find out the optimal pretreatment method for straws. Furthermore, the system of straw anaerobic co-digestion is optimized to improve the biogas production rate and the mathematical modeling for demand-oriented biogas production is established. The best scheme of digestate reuse is determined from the aspect of technical, economic and social benefits. Besides of the technical cooperation of both parties, academical exchanges, such as the exchange of researchers and students, the co-publication of research results and the launching of seminars, are expected to be achieved.

The main research contents inclusive Investigations of quantity and quality of straws in Sichuan Province, literature review of straw utilization status in Sichuan Province, experiments on anaerobic co-digestion technology of straws with different substrates and comprehensive utilization technology of digestate. Based on the experimental results, combined with the actual case, the anaerobic co-digestion system designed in this study is evaluated comprehensively.
Joint project: RUN – Rural Urban Nutrient Partnership
Subproject “material flows”

The aim of the project is to use secondary resources (black water, kitchen waste and green waste) and to use them to produce design fertilizers, biogas, biochar and biopolymers. Various technical processes will be investigated and evaluated. The project partners develop a concept from these technologies and implement them in a pilot plant in Heidelberg in the Patrick Henry Village district. The concept pursues the goal of creating a community between town and country, in that secondary resources of a town or a district can cover part of the fertilizer needs of the surrounding farmers for food production in order to save fossil resources.

The working area „Biological Processes in the Circular Economy“ focuses on the RUN project on material flows and biogas potential. For this purpose, a material flow analysis of the above-mentioned secondary raw material flows is created in order to show the behavior of carbon, nitrogen, phosphorus and potassium and the substitution potentials in different utilization paths. The data and results of other project partners who examine the various technologies will be partially evaluated. Furthermore, the material flows mentioned are investigated in a laboratory biogas plant as mono- and co-substrates for their biogas and energy potential. The evaluation criteria for the suitability of the material flows for energy production in this project is above all the ecological added value with regard to insect-friendly planting areas in the urban area.

In the „RUN“ project, a comprehensive data basis for testing in the pilot project is therefore created. The different recycling paths are made comparable so that potentials for the application can be derived. This research work is supported by the Ministry of Education and Research as part of the funding program „Agricultural Systems of the Future“.

Funding Institution:
Ministry of Education and Research

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EMS
Emissions
Emissions

If it stinks to others, then our colleagues are in their element. In the „Emissions“ (EMS) department, it is dealt with almost anything gaseous that leaks out of anything. Preferential at waste treatment plants, landfills and sewage treatment plants, but also other emissions are „welcome“.

At waste treatment plants, the issues “acceptance” and “gaseous emissions” are often strongly coupled. On the one hand, it is a matter of nuisance avoidance or compliance with thresholds, on the other hand also of resource conservation and sustainability. Therefore, the minimization of emissions of climate-relevant gases in the disposal and recycling of waste remains an important area of research. In the work field EMS, the prevention of methane formation and methane monitoring are currently an important focus. This research is applied to work on reducing the aftercare of waste landfills, reducing emissions at the MBT and to the further development of measurement methods for methane.

In cooperation with companies and authorities, there was a frequent demand for existing gas analysis options during the reporting period. The range of devices available extends from classical methods such as gas chromatography with mass spectrometer and flame ionization detector to more „unusual“ methods such as olfactometry, laser absorption spectrometry and “sniffing port” (GC-MS-o). Our work is embedded in both the scientific-technical and the economic context. Our experience is incorporated into national and international regulations.

Main areas of research:

- Aerobisation of landfills
- New methods for quantifying methane emissions
- Investigation of emissions from waste treatment plants
- Analysis of odors and odorous substances by means of olfactometry and gas chromatographic methods (“sniffing port” (GC-MS-o))
Measurement of methane emissions at landfill surfaces to estimate the success of stabilization measures

The quantification of methane emissions from municipal solid waste landfills is effected by calculations of methane production potentials and collected methane amounts in the gas collection system. However, not by measurements telling something about the emitted methane load. Annually 11,000 Gg-CO₂-eq equivalents originate from landfilling (UBA, 2013). A reduction by 500-2,500 Gg-CO₂-eq equivalents per year through landfill aeration is a declared aim of the Federal Republic of Germany.

A successful aeration can lead to up to 90% reduction of methane formation potential (BMUB, 2014). Until today, the main point for the determination of the landfill gas emissions is a calculation. This calculation is based on various assumptions as the amount of waste in place, degradability of waste in place, methane concentration of collected landfill gas, age of waste and efficiency of landfill gas collection system. Additionally, regular inspections with the FID monitor, showing that the methane concentration on the landfill surface are low. From this approach, an emission projection is generated. With the indirect remote sensing technology TDLAS (Tunable Diode Laser Absorption Spectroscopy) a line concentration measurement with infrared spectroscopy is done. The first measurement, the background measurement, is carried out in wind direction in front of the landfill which is important for the correction of the actual concentration measurement in wind direction behind the landfill. Together with ambiance parameters like temperature, pressure and surface roughness as well as wind data (wind direction, turbulence, etc.) the measured line concentrations are used in the computer based modelling program WindTrax. This program calculates via a backward Lagrangian stochastic model the source strength, clearly spoken the emissions in terms of g/s. In the next three years, methane emission measurements will take place at four landfills. Additionally, for all four landfills, the methane production potential will be calculated. In parallel, an aeration measure will be installed. From this approach, a triple gain of knowledge is expected: first: verification of the aeration measure, second: measurement based investigation of the efficiency of the landfill gas collection system and third: determination of the actual emitted methane load.

The elementary gain of knowledge is that for the first time a measurement based determination of the efficiency of the landfill gas collection system is carried out.

Funding Institution:
DBU-Stipendienprogramme, Promotionsstipendium

Contact:
Imke Wessel, M.Sc.
Dr.-Ing. Martin Reiser

Duration:
01.07.2017 – 30.06.2018

Aculated methane amount, produced in the landfill body. Calculated according to EPER-model Germany
European harmonisation of methods to quantify methane emissions from biogas plants (“Metharmo”)

Biogas plants emit methane. Known major sources are leakages, pressure relief vents, gas utilization devices and open storage tanks. For reaching climate protection targets it is essential to quantify the emissions from greenhouse gas emitting sources. The results enable to determine the environmental impact of a technology and to gain knowledge of the value of emission mitigation strategies. To date, no common European standard is established to measure the overall emission rates of methane from biogas plants. The objective of the project is to harmonize some first national approaches for the quantification of emissions to a common procedure.

Quantitative emission control of fugitive methane emissions is not mandatory for biogas plants in Europe. Nevertheless, methane is a potent GHG and its emissions contribute to climate change. For life-cycle analyses (LCA) estimated standard values are commonly used. First national attempts have been undertaken to perform measurements to quantify total methane emissions from biogas plants. The precise quantification of emission sources at biogas plants is an outstanding challenge since the emissions are heterogeneous and time variant.

There are in principle three types of sources: leakages, area sources like open storage tanks and exhaust gas/air. While measurements on site often focus on one type of these sources, remote measurements cover the overall emission plume. The methods for evaluation in use at different institutions in Europe are still not standardized and deliver different results.

The determination of methane losses directly relates to economic plant improvements and resource efficiency as mitigation measures come into play at the point where emission quantities are known. The environmental compatibility of the biogas economy can only be proofed if emission rates can be determined in a verifiable way. In addition, the possibility to evaluate the environmental impact of biogas plants gives the chance to raise public acceptance of this branch of bioenergy, especially if energy crops are used as a part of the substrate.

Based on two measurement campaigns with simultaneous executions of all measuring teams in the consortium, the different measuring methods were evaluated and harmonized. In the future methane emissions from biogas plants can be quantified comparably throughout Europe with the help of a guiding document.

Funding Institution:
Fachagentur Nachwachsende Rohstoffe e.V. (FNR)

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Project Partner:
Deutsches Biomasseforschungszentrum gemeinnützige GmbH (DBFZ), Institut für Abfallwirtschaft, Universität für Bodenkultur Wien (BOKU), Zentralanstalt für Meteorologie und Geodynamik (ZAMG), Energiforsk – Swedish Energy Research Centre (EF), Research Institutes of Sweden (RISE), JOANNEUM RESEARCH FORSCHUNGSGESELLSCHAFT MBH (JR), Avfall Sverige (AS), Technical University of Denmark (DTU), Boreal Laser Inc. (Boreal), Bioenergy 2020+ GmbH, National Physical Laboratory (NPL) (Unterauftrag)

Duration:
03/2016 - 02/2018
Evaluation and reduction of methane emissions from different European biogas plant concepts

In the project, different plant concepts in the particular countries are classified, and the emission sources are separated into components following particular country specific approaches. From that, a quantification system for representative EFs of the evaluated plant concepts in Europe will be elaborated by using the harmonized measurement data from the measurement series within the project, as well as additional data sources, e.g. from previous measurements, third parties or operator surveys. This extended knowledge base on CH₄ emissions of the respective biogas technology will improve the database of the national GHG inventories.

Another main target of the project is the development of emission reduction concepts for the examined plants, by altering plant organization or operation, e.g. changes in biogas storage management, feeding strategies and/or stirring strategies. Besides, the positive effect on the GHG balance, the reduced CH₄ emissions caused by such concrete measures also improve the overall energy efficiency and productivity of the existing plants and, hence, their cost-effectiveness. After the application of the developed mitigation concepts, the success in reducing CH₄ emissions will be evaluated. From that, a cost-benefit analysis will be elaborated for the particular mitigation measures.

Additionally, a European position paper including a general overview over the emissions and possible mitigation strategies for European biogas plants will be edited.

According to the Swedish and Danish voluntary systems, the national biogas associations develop national voluntary systems for emission mitigation in the biogas sector and analyze its implementation in the particular country. The voluntary systems shall be concluded between the association and the plant operators consisting of own investigations performed by the plant operators on a regular basis, external monitoring by third parties (e.g. accredited laboratories), and a regulation for the documentation of the emission measurements. Additionally, a European voluntary system for emission mitigation in the biogas sector including the minimum requirements from the national voluntary systems and recommendations for the implementation of a national voluntary system in other European countries will be elaborated.
Chair of Waste Management and Emissions

Research

Joint project: Energy-efficient exhaust air treatment in mechanical-biological waste treatment plants 2, EnAB 2
Subproject: Effects of modified plant operation on exhaust gas flows and evaluation of alternative exhaust gas cleaning systems

Mechanical-biological waste treatment (MBT) is used as a basic technology for municipal solid waste treatment. The technology has the specific aim to stabilize the organic waste prior to landfilling.

To guarantee aerobic conditions during biological degradation, a high ventilation rate is necessary. The process gases are loaded with pollutants, which should be reduced to German limit values before emission into the atmosphere. Often, regenerative thermal Oxidation (RTO) is used. To keep up the oxidation process, additional fuel is necessary.

The research and development project “Energy-efficient exhaust air treatment 2” (EnAB2) aims at a significant reduction of energy demand on MBT plants. As an outcome of the previous project, the reduction of the energy demand of the aeration of the heaps and the exhaust gas cleaning are promising. The RTO is used as a central solution of an exhaust gas mixture of numerous processes, which influence its composition. To achieve the aim, technical aspects of exhaust gas treatment and operational aspects of all interacting processes are relevant.

As a result of the previous project, it might be possible to reduce the specific energy demand of mechanical-biological waste treatment by 25%.

In the context of this project, the exhaust gas streams from 15 rotting tunnels should be divided due to their different levels of air pollution and should be treated in alternative cleaning systems. In consequence, the volume flow rate to the RTO will be reduced. For this purpose, a new bypass pipe will be built. In addition, a control algorithm will be developed to use automatic flaps to supply the exhaust gas to the suitable cleaning system.

Funding Institution:
Bundesministerium für Wirtschaft und Energie (BMWi), Forschungszentrum Jülich GmbH (PTJ)

Contact:
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Dr.-Ing. Martin Reiser

Project Partner:
I.A.R.-Institut für Aufbereitung und Recycling der RWTH Aachen, Materialkreislauf- und Kompostwirtschaft GmbH & Co. KG (Großefehn), PlasmaAir AG (Weil der Stadt)

Duration:
11/2015 - 02/2018

Air pollution of total hydrocarbon for both rotting phases
Measurement verification of the success of stabilization measures at landfill projects funded by NKI (MÜDSE)

From landfilling there are annually 11 000 Gg CO₂-equivalents generated [UBA 2013]. A reduction of these emissions by 500-2 500 Gg CO₂-equivalents is a stated aim of the federal republic of Germany. So far, a calculation is the center of the determination of landfill gas emissions. This calculation is based on certain assumptions including the amount of landfilled waste, the degradability of landfilled waste, the methane content of collected landfill gas, the age of the landfill, and the performance of the landfill gas collection system.

The planned project covers three measurement scenarios at two landfills in the county of Waldshut in the state of Baden-Württemberg. Each measurement includes the execution of three measurement methods simultaneously at two landfills. These measurement methods are: 1°) Inverse Dispersion Method (TDLAS-measurement, measurement of the wind field, and computer based modelling), 2°) CHARM (Helicopter based gas detection system based on Infrared Laser), 3°) FID-field measurements (concentration measurement directly on landfill surface). The first measurement scenario will be the baseline measurement. With this measurement, the status quo will be determined. The second scenario verifies the measurement methods. A direct comparison of the three different measurement methods will be done in “cold-torch” state. The third scenario has the aim to evaluate the by the NKI promoted and at the landfills installed climate protection measures. The aim of the project is it, to evaluate and optimize with the help of three different measurement methods stabilization measures promoted by the NKI.

Landfill with GF2 and Ultrasonic anemometer

Funding Institution:
Projekträger Karlsruhe, KIT-EDU, Silke Bohrmann

Contact:
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Dr.-Ing. Martin Reiser

Duration:
01.04.2018 – 31.05.2020
Sustainable management of coffee by-products and determination of emissions rates during the application of fertilizers for greenhouse gases

The purpose of this study is to develop an experimental methodology for the sustainable management and improved treatment of coffee by-products for the production of organic fertilizer, for the usage in agricultural crops including coffee plantations. In addition, to identify the behavior and distribution of emissions during the fertilization process and the treatment of coffee by-products, where these two aspects are considered the most relevant for greenhouse gas (GHG) emissions in the coffee sector. Agriculture is the fourth cause of global GHG emissions with the non-CO2 gases among them, including N2O and CH4. These gases have a global warming potential of 265 and 28 for N2O and CH4, respectively, therefore it is of utmost importance the proper management and treatment in agriculture.

The methodology to be developed will be implemented in the Cooperativa de Caficultores y Servicios Múltiples de Tarrazú R.L. COOPETARRAZU R.L. (San Marcos de Tarrazú, San José, Costa Rica). Due to the great interest and utility, it represents for the Cooperative in the face of the challenge of providing sustainable management to coffee by-product residues and its potential for the reduction of GHG emissions during its production and harvest cycle. The main beneficiaries at the end of this project will be the coffee producers and the coffee sector, enhancing the economy and sustainability by being able to implement good practices for the environment.

Within the framework of the proposed project, experiments are performed to explore and optimize high temperature processes using by-products from coffee and other organic waste materials, with the aim of creating a nutrient-rich fertilizer as a soil amendment. The compost produced will be tested in field trials on coffee plantations, which may reflect its impact on soil fertility and agricultural productivity.

Consequently, this project aims to improve the composting treatment that coffee by-products currently receive. As well as the verification of GHG during composting and during the fertilization process in coffee plantations, giving the coffee sector in general as well as its community, the opportunity to receive a positive environmental impact where it is intended to reduce GHG emissions, odors and pathogens generated during the actual mill processes. The gases were extracted for the analysis using Fourier-Transform Infrared Spectroscopy (FTIR), meanwhile, in Costa Rica the emissions where performed using a portable detector gas analyzer in chambers for the composting piles.

It is important to estimate GHG emission rates as they are the flow of a pollutant expressed in weight per unit of time and are necessary to calculate an emission factor, which is a representative value that attempts to relate the amount of a pollutant released into the atmosphere with an activity associated with the release of that pollutant. The detection of gaseous emissions during the process of composting coffee by-products is one of the most important tools to meet the challenge of reducing GHG emissions and odor emissions. Gas concentrations act as indicators, indicating biological degradation and thus lead to optimization possibilities. For this reason, the first two phases of the project are crucial in order to obtain the emission factors associated with coffee.
activity in coffee plantations and in their treatment of coffee by-product residues.

The project will address 5 main impacts directly: environmental, economic, technological, commercial, and business, without neglecting that the main objective is to obtain a product from a residue, allowing the Cooperative to initiate a bio economy as a basis for sustainable development while is providing at the same time, a waste treatment with low emissions.

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<td>Dr.-Ing. Martin Reiser</td>
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<td>Project Partners</td>
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<td>Coffee Institute of Costa Rica (Icafe), CoopeTarrazú, Costa Rica</td>
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Chair of Waste Management and Emissions

Resources Management and Industrial Waste

With our help there’ll be not much left for your bin

Concerning problems from industry and public bodies, RIK’s expertise covers the preparation of material and substance balances, development of management systems and technical processes to prevent, recycle and treat all kinds of wastes and residues. With most of its projects, RIK aims to turn waste management in real closed loop recycling management.

Currently we are working on the following topics:

• Sustainable management and use of the resource "food": We sum up and balance the amounts of disposed food and food waste in Germany and develop out of these prevention measures and action plans for policy-makers. We are developing a standardized method for the classification and evaluation of new food management approaches, which shall be later established all over Germany and Europe.

• Recovery of phosphorus from sewage sludge ash: In an EU-funded cooperative project we help to develop an innovative thermo-chemical process by which sewage sludge ash can be turned into phosphorus and other useful products. RIK’s contributions to the project are firstly the performing of experiments as well as the management of input and output materials.

• Renewable energy and energetic use of waste streams ("waste to energy"): We develop concepts to use unavoidable wastes in an ecologically and economically optimal way to substitute fossil energy.

• Wet oxidation of liquid hazardous wastes/industrial wastewaters: We perform experiments with real wastewaters, thus evaluate the feasibility of AOP treatment, and subsequently set up overall treatment concepts from the point of origin to the canal.

• Pyrolysis of organic residues: Various organic residues can be transformed into coke and energy-rich gas by means of pyrolysis. Adapted to the according local conditions, concepts and reactors for pyrolysis recycling including gas treatment are developed and tested.

• Further fields of activity: Resources in wastes, residues and anthropogenic deposits; treatment and utilization of sewage sludge; treatment and disposal of solid, pasty and liquid industrial wastes; microbial regeneration of adsorbents; waste adequate special analysis and test methods; sampling of solid, pasty and liquid wastes.

Research topics:

• Waste and resources management in industry and public bodies
• System optimization by material and substance balancing
• Food and food waste balances and prevention strategies
Avoidable and unavoidable food waste: A holistic management approach for urban environments

The quantities of food waste, both avoidable and unavoidable, generated daily in urban environments in the EU are a major challenge. On the one hand, due to the pressure that the production and management (disposal) of food waste imposes on the various resources, the environment and the economy, and on the other hand, the legal requirements for the reduction and utilization of food waste have to be implemented within the framework of the circular economy.

A promising solution is the holistic management system for food waste of A2UFood, in which all relevant aspects are included. These are the reduction of avoidable food waste, the material use of unavoidable food waste as raw material and the proper utilization of the remaining unavoidable food waste.

The A2UFood project focuses on the hospitality sector (hotels and restaurants).

The innovative character of the project is the use of modern tools, such as a software to support families in reducing avoidable food waste, a software / hardware tool to reduce avoidable food waste in restaurants and hotels, a restaurant that offers a second chance to eat unused food, a biorefinery where unavoidable food waste is recycled into bio-plastics (production of compostable bags), and a series of state-of-the-art autonomous composting plants where the recycling is done on site to produce a soil improver.

The results are expected to be the reduction of avoidable food waste, the use of unavoidable food waste as a raw material, and the environmentally friendly and economic utilization of the remaining unavoidable waste. Furthermore, all experiences, knowledge, information and data will be publicly available, so that the A2UFood concept can be transferred and applied to other urban environments.

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<tr>
<td>Municipality of Heraklion, United Association of Solid Waste Management in Crete (ESDAK), University of Crete, Technological Educational Institute of Crete, Harokopio University Athens, Enviroplan Consultants &amp; Engineers S.A. - ENVIROPLAN S.A.</td>
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ELOFOS - Efficient Lowering of Food Waste in the Out-of-Home Sector

The aim of the proposed project is to contribute to the reduction of food losses and waste along the whole food supply chain, and in particular in the gastronomy considering direct pre-chains. For this purpose, a representative overview of the food waste generated in the out-of-home sector is given in relation to the quantities consumed. In this process, existing data from statistics and samples are collected and expanded by measurements in hotel kitchens with the RESOURCEMANAGER-FOOD, an innovative tool for waste quantification and management developed in earlier projects. In a field analysis, experts from further facilities of the restaurant and catering sector are interviewed and in addition to that, restaurant guests are polled regarding sensory aspects as well as regarding additional factors influencing food waste generation, which are important for future strategies for waste minimization and valorization of wastes. The RESOURCEMANAGER-FOOD is going to be refined while involving producers and suppliers. Especially producers of products with a particularly high environmental impact will be involved, such as sausages, meat and fish. On the basis of the collected data, an interface optimization and a demand analysis will be conducted to ensure a more sustainable food production. This interface optimization also includes, in particular, planning security as well as the standardization of units / containers in which the foodstuffs are offered by the suppliers or are demanded by the out-of-home consumption. This also includes the development of standardized procedures for the conversion of units.
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Circular Economy and Waste Management Systems

Waste is a potentially valuable material in the wrong place. This statement is the central principle of many activities of our municipal solid waste section. Focal points are avoidance, utilisation and environmentally friendly treatment of municipal and commercial waste.

The increasing scarcity and costs of raw materials makes recycling and waste management in the area of municipal waste to an important element within the resource economy. The collection and recycling of secondary raw materials are at the forefront. The necessary systems are becoming increasingly complex. Existing systems must be in terms of efficiency, but also in terms of citizen-friendly, checked and optimized. This requires, amongst others, to identify the existing potential and properties of the material flows.

Research topics:
- Conceptual development and analysis of systems in the Circular Economy and Waste Management
- Disposal systems in the international waste management
- Analysis of material flows
Microplastic particles defined as MP < 5 mm, are seen as a threat to the environment. However, little research focuses on the input paths and possible influence that MP have on the terrestrial ecosystem. To the knowledge of the authors, the possible contamination of soils due to the introduction of MP through organic fertilizers coming from biowaste treatment facilities has been so far hardly recorded.

Project part 6: Aerobic composting and anaerobic digestion

The goal of the project is to investigate how macroplastics (> 5 mm) entering the biowaste treatment facilities through the collection of municipal organic waste behave during their biological treatment in a laboratory scale frame. The main question to be answered is the extent to which plastics age as a result of the process and therefore fragment into MP due to mechanical stress, temperature and retention time.

In order to investigate the behavior of plastics during the aerobic and anaerobic processes, the following treatment plants have been built and conditioned to answer the research questions of the project (Figure 1).

During the retention times of three, six and 12 weeks, the following process parameters will be measured: temperature, pH, total solids, volatile solids carbon to nitrogen ratio, and the concentration of CO₂ in the compost tumbler. Additionally to these, the gas volume and the gas content (CO₂ and CH₄) are also recorded in the anaerobic treatment plant.

After the mentioned retention times, samples are taken to examine the condition of the plastics. Analyses such as the size spectrum of the plastics, the macro and microscopic aspects and the hydrophobicity of the surface were additionally carried out. These analyses lead us to a basic understanding of the biological influence of the processes on the plastic films. Found changes or fragmentation of the plastic could be a first indication of a microbial and mechanical attack.

Funding Institution: BWPLUS

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Claudia Maurer, M. Sc.
Duration:
01.04.2019 – 31.03.2022
Joint Venture: Nutrition Partnership for a sustainable agriculture: „Rural Urban Nutrient Partnership (RUN)“

Within the project coordination of the Institute for Sanitary Engineering, Water Quality and Solid Waste Management (ISWA) of the University of Stuttgart, researchers of different fields of study work together with industry partners to find new ways to close the nutrient cycle between urban and rural areas.

The world needs an efficient handling with resources, which includes the agricultural sector, where new ways for a sustainable food production are to be found. This not only applies to production and economic sectors, but rather to a change in the consumption behaviour of urban inhabitants as well as innovative biowaste and household waste water treatment technologies. In the project RUN researchers work with two partners from the industry and one associated practice partner on the development of a concept to close the nutrient cycle through nutrient partnerships between urban inhabitants and farmers. RUN is one of eight projects of the research project “Agrarsysteme der Zukunft (sustainable agricultural systems)” as part of the “national research strategy BioÖkonomie 2030 (bio economics 2030)”. The Ministry for education and research (BMBF) supports the project with round about 4.2 Million Euros for three years.

RUN Sub Project Logistics:

Regarding the ongoing digitalisation and, thanks to online retailing, increasing transporting expenditures for goods and services, new logistical systems have to be implemented. Autonomous Systems are already in use in production logistical processes (e.g. warehouse logistics) and in the future should be used in distribution logistical processes as well (e.g. Amazon, Hermes). Next to Concepts, like tube systems, these concepts shall, be implemented and evaluated on reverse logistical processes in urban areas. The goal is the development of new concepts, which empower circular economy thinking especially for organic household waste. To achieve that, acceptance of these logistical systems (comfortable, user friendly) by the users (households) is key. Only if these are guaranteed, bigger amounts of organic waste from households with higher quality can be collected and returned into the nutritional cycle. In case of non – tube based systems should be researched if “on demand” – systems or other business practises are suitable for RUN.

The goal of the sub project “logistics” is the development and evaluation of systems for the collection and the transport of kitchen waste and black water.

For that, a literature review regarding existing systems and
systems which are in the phase of testing has been made. To allow an easier distinction between the concepts, the categories “transport” and “collection” had been defined. Sub categories are “Concept 0: conventional systems”, “Concept I: tube systems” and “Concept II: (partly-) autonomous operating systems” (see Figure 1). In collaboration with the working group Biological Processes in the Circular Economy (BVK) from ISWA, a design kitchen waste (DKW) has been put together. The composition, as seen in Figure 2, has been set by the help of a literature review and own tests. For DKW water content, nutritional con-

<table>
<thead>
<tr>
<th>Physical- and Chemical Parameters</th>
<th>Freeze Dried</th>
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<tbody>
<tr>
<td>Phosphorus (P) mg/kg</td>
<td>2.220</td>
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<tr>
<td>Potassium (K) mg/kg</td>
<td>156</td>
</tr>
<tr>
<td>Total Nitrogen (Nges.) %</td>
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<tr>
<td>Aluminium (Al) mg/kg</td>
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<td>Chrom (Cr) mg/kg</td>
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<td>Iron (Fe) mg/kg</td>
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<tr>
<td>Copper (Cu) mg/kg</td>
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<tr>
<td>Nickel (Ni) mg/kg</td>
<td>0.52</td>
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</table>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Water Content %</td>
<td>69,2</td>
</tr>
<tr>
<td>Loss on ignition %</td>
<td>95,6</td>
</tr>
<tr>
<td>Dry matter content %</td>
<td>30,8</td>
</tr>
<tr>
<td>Microbiological degradable organic substance (AT4) mol CO2/g Trockenmasse</td>
<td>320</td>
</tr>
</tbody>
</table>

Figure 2 Composition of the Design Kitchen Waste (own research, (Bolzonella et al. 2003; Hübsch und Adlwart 2017; Kegebein 2006))

Figure 3 Experiment to Concept I
Research

tent and heavy metal content has been evaluated (see Table 1). This waste should allow the replicability of experiments.

With the DKW an experiment to Concept I: Tube systems was implemented, in which the waste was shredded by an ordinary kitchen waste shredder and transported via a sub pressure tube system (see Figure 3).

To evaluate and improve the process the parameters water consumption, electrical energy demand for shredding and grain size distribution were determined.

Literature


Funding Institution:
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