Circular Economy
What are you doing?
POSTERS
**POSTER PRESENTATIONS**

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<td>Andrea Winterstetter, VITO (Belgium)</td>
<td>WEEE collection and recycling. A resource classification approach for the circular economy.</td>
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<td>Manuel Brey, Verinsur (Spain)</td>
<td>Hydrothermal liquefaction for production of crude-oil from solid and liquid surfactant waste.</td>
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<td><strong>16.10 – 16.20</strong></td>
<td>Kazuo Kmura, Univ. Waseda (Japan)</td>
<td>Evaluation of industrial landfill sites for potential as urban mines.</td>
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<td>Pierre Menger, Tecnalia (Spain)</td>
<td>Cindercebm – a circular business model for urban construction.</td>
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<td><strong>16.20 – 16.30</strong></td>
<td>Jose Cristiano Model, UFRGS (Brazil)</td>
<td>Chemical characterization of spent Lithium-ion batteries to recover Lithium and Cobalt.</td>
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<td>Jonathan Torrez, UPNA (Spain)</td>
<td>Valorization of Aluminium saline slags.</td>
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<td>Mª Dolores Bovea, Univ. Jaume I (Spain)</td>
<td>Preliminary analysis of the internal cost of the waste management system in developing countries: a Brazilian case study.</td>
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<td>Francisco Corona, CARTIF (Spain)</td>
<td>Nutrient and carbon recovery for more efficient agriculture in Europe.</td>
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<td>Bianca Ramalho Quintaes, COMLURB (Brazil)</td>
<td>Analysis of anaerobic digestion technologies for the treatment of organic fraction of MSW.</td>
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<td><strong>08.30 – 08.40</strong></td>
<td>Ana Cunha, LIPOR (Portugal)</td>
<td>Organic composts effect on lettuce and strawberry productivity and in Vit C and pigments content as quality parameters.</td>
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<td>Renato Ribeiro Siman, Federal University of Espírito Santo (Brazil)</td>
<td>Influence of waste picker organizations and selective waste collection on sustainability indicators.</td>
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<td>Yahaya Yakubu, Africa Environmental Sanitation Consult (Ghana)</td>
<td>Feasibility study on mobile sorting and composting facility.</td>
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<td><strong>08.40 – 08.50</strong></td>
<td>Bianca Ramalho Quintaes, COMLURB (Brazil)</td>
<td>Investigation on characteristics of sludge generated in the primary treatment of landfill leachate.</td>
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<td>Ana Andrés, University of Cantabria Berta Galán (Spain)</td>
<td>Influence of input streams con the CDW recycling performance of advanced treatment plants.</td>
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<td>Jang Hyun Kang, College of Engineering, Kangwon National University (South Korea)</td>
<td>Optimization of Cobalt and Iron supplement for enhancing biogas production from food waste in mesophilic and thermophilic anaerobic digestion.</td>
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<td><strong>08.50 – 09.00</strong></td>
<td>Mitsuo Yoshida, International Network for Environmental and Humanitarian Cooperation (Japan)</td>
<td>Development of solid waste management and its national strategy in Palestine.</td>
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<td></td>
<td>Valeria Ibáñez, Univ. Jaume I (Spain)</td>
<td>Comparative analysis of the recovering practices implemented in Brazilian cities.</td>
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</table>
11.00 – 11.10
Marcos Latorre, Imecal (Spain) – PERCAL project: chemical building blocks from versatile MSW biorefinery.
Carmen Macías, Univ. Cantabria (Spain) - Depolymerization of sulfate polysaccharides obtained from green algae to study the extraction of the Ulvan bioproduct.
Catarina Almeida, LIPOR (Portugal) – LIPOR’s compost Life Cycle Analysis.

11.10 – 11.20
Ednel Silva, Univ. Federal do ABC (Brazil) – Evaluation of mass reduction treatment technologies with the purpose of the life extension of Sao Paulo’s municipal sanitary landfill.
Marta Braulio Gonzáló, Univ. jaume I (Spain) – Waste management indicators that contribute to sustainable cities: an analysis from a circular perspective.
Purvra Tavri, Independent Consultant (UK) - A collaborative reuse model for surplus food materials.

11.20 – 11.30
Rodrigo Pontiggia, Benito Roggio Ambiental (Argentina) – From electronic waste to plasmonic response gold nanoparticles.
Inazio Irigoien, UPNA (Spain) – Pilot project on circular bioeconomy of organic wastes at local scale with social and training dimension.
Tiago Faria, Efacec (Portugal) – Energetic comparison of two sorting plants.

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08.20 – 08.30
Santiago Pecotche, Impactos Ambientales (Argentina) – Characterization of the solid waste of the City of Ushuaia, Tierra del Fuego, Argentina.
Rahma Al Riyami, be’ah (Oman) – Be’ah’s circular economy initiatives.
Steffen Blume, GIZ & Andreas Lindau, Geocycle (Germany) - Guidelines on pre- and co-processing of waste in cement production.

08.30 – 08.40
Luis Alberto Rojo, ESWET (Germany) - Continuous Mercury emission and process monitoring.
Hélder Marques, LIPOR (Portugal) - Education by Art: proposal for the concretization of an Art biennial with recycled materials.
Ana Andrés, University of Cantabria (Spain) - Ecotoxicity of alternative potential precursors in alkaline activation processes.
Evangelos Terzis, Univ. Athens (Greece) – Assessment of electric and electronic equipment stock in Greek households.

08.40 – 08.50
Jose Manuel Baraibar, Viuda de Sainz (Spain) – Consideration of circular economy criteria in the design of technical solutions for landfills. The extension of the Artigas landfill in the municipality of Bilbao.
Winie Evers, University of Southern Denmark / Odense Waste Management (Denmark) - WEEE penta helix: co-creating a waste less infrastructure.
Yuan Meng, School of Environment, Tsinghua University (China) - Amine-modified sorbents for CO2 capture: screening appropriate temperatures for inhibiting O2 induced deactivation.
Carol Maione, Univ. Michigan (USA) - Plastics at sea in ecotourism sites in Zanzibar, Tanzania.

08.50 – 09.00
Hideaki Kurishima, Shibaura Institute of Technology (Japan) – Survey on awareness of food loss caused by consumer behaviors and feasibility of improvement behaviors.
Caterina Coll Lozano, Imecal (Spain) – Urbiofin project: demonstration of an integrated innovative biorefinery for the transformation of MSW into new biobased products.
Joseph Donahue, ABT Associates (USA) - The climate benefits of a proposed anaerobic digester: a US case study from Naucalpan, Mexico.
10.30 – 10.40
Miguel Varela Pérez, Teimas Desenvolvimento (Spain) – ZERØ, strategic tool for corporate circularity.
Robert Dick, SCS Engineers (USA) - Severe weather impacts on solid waste disposal facility operations.
Chiara Magrini, Univ. Bologna (Italy) – The role of eco-labelling in plastic packaging circularity.

10.40 – 10.50
Esther San José, CARTIF (Spain) – The spherical urban forest.
Karim Khodier, Montanuniversität Leoben (Austria) – Result reliability in comparative solid waste processing experiments.
Liang Zhang, SUS Environment (China) - The operation and regeneration of low temperature SCR catalysts in waste incineration plants.

10.50 – 11.00
Oliver Gohlke, Dublix Technology (Denmark) - Engineered solutions for the “tuning” of existing waste-to-energy plants.
Ashiya Otwong (Thailand) - Legal obstacles for circular economy: a case study of illegal dumping in Thailand.
Isabell Eickhoff, University of Rostock (Germany) - Press waste fermentation from mixed household waste.
WEEE COLLECTION AND RECYCLING - A RESOURCE CLASSIFICATION APPROACH FOR THE CIRCULAR ECONOMY

Andrea Winterstetter¹, Ulrich Kra¹
¹VITO, 200 Boeretang, 2400 Mol, Belgium
²Institute for Water Quality and Resource Management, Technische Universität Wien, Karlsplatz 13/226, 1040 Vienna, Austria

Abstract: ‘Waste of electrical and electronic equipment’ (WEEE) contains a broad range of valuable materials to be potentially recovered under a circular economy regime. This study analyses a) how the collection and sorting of WEEE under different boundary conditions drives the economics of recycling and b) what the United Nations Framework Classification for Resources (UNFC) approach can do for a circular economy. Case study 1 is located in a high-income EU country and yields a net-present value of €96,000 (120 €/t collected PCs). Case study 2 is located in a low-income country with a net-present value of €36,000 (360 €/t collected PCs). The economic viability in case study 1 is driven by high labour cost for manual dismantling and the avoided cost for disposal alternatives. Case study 2 involves higher societal costs as more PCs are subject to improper disposal practices. Further research on best practice examples of WEEE collection systems across the EU is ongoing.

Key words: WEEE, Collection, Resource Classification, Circular Economy, H2020 project COLLECTORS

1. Introduction

The transition to a sustainable circular economy requires sound knowledge on the future availability of secondary resources. Waste of electrical and electronic equipment (WEEE), or ‘e-waste’, is one of the fastest growing waste streams, at 3-5% per year. This potential ‘urban mine’ contains valuable resources, such as (precious) metals and rare earth elements. The Directive on waste of electrical and electronic equipment (WEEE Directive), updated in 2012, sets incremental targets on several aspects: minimum rates for separate collection, recovery and recycling/preparing for re-use. Moreover, it calls for improved reporting of volumes collected and better enforcement of legislation [1]. This paper aims at showing a) how the collection and sorting of WEEE under different boundary conditions impact the economics of recycling, and b) how the United Nations Framework Classification for Resources (UNFC) approach can be of use in pathing the way towards a circular economy [2].

2. Methods & Materials

Taking the example of end-of-life personal computers (PC), two hypothetical case studies, one located in a high-income and one in a low-income EU country, are classified under UNFC [3]. The UNFC is a global standard for communicating the availability of resources for markets. The UNFC categorizes recoverable quantities based on three criteria, namely “knowledge on composition” (G-axis), “project and technical feasibility” (F-axis) and “socioeconomic viability” (E-axis), with scores from 1 (‘best’) to 3. As under UNFC only defined ‘mining’ projects can be classified [3], arbitrary system boundaries of a city of 1 million inhabitants and a time span of 1 year were chosen.

2.1. Two hypothetical WEEE collection & recycling case studies

In case study 1 end-of-life PCs are collected and treated in a high-income EU country, while case study 2 reflects the situation in a low-income EU country with poorly enforced WEEE related legislation and low collection rates (cf Table 1).

Table 1: Recovering materials from end-of-life PCs for two different case studies [cf 4].

<table>
<thead>
<tr>
<th>Specific condition Type</th>
<th>Case study 1 High-income EU member state</th>
<th>Case study 2 Low-income EU member state</th>
</tr>
</thead>
<tbody>
<tr>
<td>Legal, institutional, organizational &amp; societal structures</td>
<td>PCs have to be collected and treated under EU WEEE directive (1)</td>
<td>PCs are assumed to have similar composition &amp; weight</td>
</tr>
<tr>
<td>Different options for dismantling</td>
<td>Full compliance with EU laws, High public awareness, Good infrastructure, High collection rate of obsolete PCs: 0.8 kg(cap/a) =&gt; 800 t PCs/a</td>
<td>Weak compliance with EU laws, Low public awareness, Weak infrastructure, Active informal sector, Low collection rate of obsolete PCs: 0.1 kg(cap/a) =&gt; 100 t PCs/a</td>
</tr>
<tr>
<td>Costs</td>
<td>Mechanical treatment &amp; further manual dismantling</td>
<td>Manual dismantling</td>
</tr>
<tr>
<td></td>
<td>Costs for transport from collection point, sorting &amp; dismantling</td>
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</table>
3. Results

Case study 1 is graded with G1, as the waste stream’s volume and composition as well as the extractable resource potential with known technologies can be estimated with a high level of confidence. In contrast, case study 2 is graded with G2, i.e. medium level of confidence, due to the involved informal sector, implying high uncertainties about the collected quantities and quality.

The WEEE directive defines the minimum standards for collection and treatment. In contrast to case study 2, which is graded with F2, in case study 1 European legislation is implemented via a well-functioning Extended Producer Responsibility scheme and is therefore graded with F1: The infrastructure and public awareness for PC collection exists, while in case study 2 the PC collection infrastructure is poor and the public awareness on the importance of WEEE recycling is low. The obsolete PCs are manually dismantled, with only economically interesting materials being extracted, while the residues are assumed to be illegally dumped.

Both case studies yield positive economic results, and are therefore graded with E1 due to positive NPVs. The Net Present value (NPV) for case study 1 is 96,000 € (120 €/t collected PCs), while case study 2 yields 36,000 € (360 €/t collected PCs) which is due to significantly lower labor costs for manual dismantling. Further, avoided disposal costs in case study 1 are high, due to strict regulations and requirements for disposal alternatives. Case study 2 involves higher social and environmental costs due to higher quantities subject to unsound recycling and disposal practices. Thus, the overall categorization for case study 1 is E1F1G1 and case study 2 obtains E1F2G2 [4]. Moving project 2 up from F2 to F1 and from G2 to G1 requires increasing WEEE collection rates in terms of quantity and quality, for instance, by stopping WEEE exports, scavenging and illegal dumping, by improving the WEEE collection infrastructure, and by increasing public awareness on source separation. For case study 1, reducing taxes on labor related to WEEE recycling would improve the economics even further.

4. Conclusions

This work compared two WEEE recycling case studies embedded in different societal, legal, institutional and organizational structures, including a) the European and national WEEE legislation and its enforcement, b) public awareness and collection behavior and c) the collection and recycling infrastructure. All these factors have an impact on the amount of recoverable materials as well as (avoided) costs and revenues, and hence finally the economics of recycling and material valorization. The UNFC results can be of use in pathing the way towards a circular economy by communicating the opportunities and barriers for developing material recovery projects. Especially in light of changing properties of waste streams and volatile commodity prices, they can facilitate the dialogue between producers, the recycling sector and political decision makers to identify potential needs for governmental support and / or changes in legislation or better enforcement of existing laws.

While this study presented two hypothetical cases, the currently ongoing H2020 project COLLECTORS [5] aims at comparing different real-life waste collection systems across the EU in order to identify best practice examples with respect to recyclable outputs, and to support the implementation of better-performing systems.

References

E-WASTE COLLECTION & RECYCLING: A RESOURCE CLASSIFICATION APPROACH FOR THE CIRCULAR ECONOMY

Andrea Winterstetter, Dirk Nelen, Ivo Vanderreydt, Kévin Le Blévennec
VITO – Flemish Institute for Technological Research, Belgium
Assessment & Development of Value Networks for the Circular Economy - Sustainable Materials Management Unit
Andrea.winterstetter@vito.be, +32 14 33 51 51

What can resource classification do for the Circular Economy?

This serves the Circular Economy by:
1. Looking at waste management projects & systems with a focus on resource recovery,
2. Providing decision support for resource recovery projects for different stakeholders,
3. Making future assessments (prospective) or evaluate past measures (retrospective),
4. Communicating the impact of key factors under different boundary conditions.

A resource classification approach for the assessment of waste collection & sorting systems with respect to recycling quality

To achieve high quality recycling it is essential to adjust and manage waste collection and sorting accordingly:

1. Communicate the results by using UNFC
   - Translate the previous results into categories on one of the three axes of UNFC (EQ-G, FI-H, FI-E)
   - Communicate the impact key influencing factors on the recycling quality
   - Understand potential trade-offs between higher collection rates, waste quality, cost, benefits and enivronments

2. Evaluate socioeconomic parameters for two points in time (before and after the measure)
   - Perform a Cost-benefit analysis from a specific stakeholder perspective, including:
     - Benefits from secondary products
     - Direct costs for collection, sorting & recycling, disposal of non-recyclables & treatment of hazardous components
     - Investment cost for measures to increase quantities & quality of collected waste (check also cost effectiveness)
     - Avoided disposal costs
     - Measured external social and environmental effects (e.g. results from Life cycle assessment)

3. Assess recoverable materials as a function of collection & sorting for two points in time (before and after the measure)
   - Identify measures (to be) taken to increase waste collection quantities & waste quality
     - E.g. measures to increase frequency and convenience of collection, security of scale: amenity sites, or information campaigns on source separation

4. Select and define a 'resource recovery project'
   - Select a waste stream & describe: location, origin, volume, composition, share of recyclables, non-recyclables & hazardous substances
   - Define system boundaries, e.g. temporal, geographic
   - Understand the current collection systems and value chain
   - Micro Scale Material Flow Analysis

5. Evaluate the results & feedback
   - Communicate the results by using UNFC

What can resource classification do for the Circular Economy?

A Resource Classification Approach

Five steps to assess measures (to be) taken to increase quantities and quality of collected waste with respect to recycling quality

The H2020 project COLLECTORS aims to identify and highlight existing good practices of waste collection and sorting for high quality recycling. It focuses on three waste streams: paper and packaging, waste electrical and electronic equipment (WEEE), and construction and demolition waste.

Define goal, project & system boundaries

Case study 'Cirtilat' in France for the collection of small WEEE & IT items

Identify measures taken in the past to increase WEEE capture rates & check impact on the economics of recycling from a PRO's perspective

Increased security at civic amenity site & increased public awareness led to:
- Increased collection quantities
- Reduced uncertainty on waste quality

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Retrospective assessment of measures taken to increase waste collection

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COMMERCIAL AND INDUSTRIAL SOLID WASTE FLOWS AND THEIR POTENTIAL FOR A CIRCULAR ECONOMY MODEL IN BUENOS AIRES METROPOLITAN REGION, ARGENTINA

L.V. Sosa \(^1(1,2)\), S.L. Galvan \(^1(1,2)\), S.L. Lusich \(^3(1)\), R.O. Bielsa \(^1(1)\)

1: Instituto del Comurbano, Universidad Nacional de General Sarmiento, J.M. Gutierrez 1150, 1613 Los Polvorines, Provincia de Buenos Aires, Argentina.
2: Consejo Nacional de Investigaciones Científicas y Tecnológicas, Argentina.

Abstract: Buenos Aires Metropolitan Region is a mega city in Latin America facing great environmental challenges as sustainable solid waste management through a circular economy model. Regarding this model, commercial and industrial solid waste (C&IW) management (nonhazardous) was ruled in 2013 to increase source separation, recycling and material and energy recovery. In this work, input flows of C&IW and their physical and chemical properties are studied when entering to a C&IW management center with the first solid recovered fuel (SRF) production plant in the region. Field work was done in October and November 2017 to quantify and analyze C&IW flows to increase material and energy recovery towards circular economy. Results show that 6% wt. of C&IW, that now is disposed, has potential to SRF production and this is a sustainable way to manage plastic and paper waste that has no demand in recycled material market in Argentina.

Key words: Buenos Aires Metropolitan Region, Commercial and industrial waste, Circular economy, SRF production.

1. Introduction

In Buenos Aires Metropolitan Region (BAMR) solid waste generation has increased more 50% in the last 20 years. Nowadays 17,000 tons per day of municipal solid waste (MSW) is generated and it is estimated that 5,000 tons per day of commercial and industrial nonhazardous waste (C&IW) is generated according to statistical data from CEAMSE between 2009 and 2017 \([1]\). C&IW was managed with MSW till 2012, but in 2013 a new regulation was approved for C&IW generators because landfills were near to collapse. Since 2013, C&IW generators are obliged to separate C&IW between two fractions (recyclable and nonrecyclable), and contract collection, treatment and final disposal through private companies that should be registered.

One of the registered companies for CIW management is focused in this work because solid recovered fuel (SRF) is produced in its center. This SRF is produced using 3% of input CIW and is sold to clinker production as a way to recover energy from waste. In this work, we carried out a field study in this center to identify and quantify C&IW input streams that can be used to produce SRF to increase energy recovery and decrease final disposal.

2. Materials and Methods

The BAMR is a mega city in Latin America covering an area of 3,760 km\(^2\) and it counts with 40% of the industries in Argentina. Our field work was carried out in October and November 2017 in the mentioned CIW management center in BAMR. In this center, input CIW is weight, visually inspected, and its manifest is checked according to regulations. SRF class 2 \([2]\) is produced and delivered weekly to cement plants for coprocessing. During our field study, CIW streams were classified in five categories: suitable for SRF production, not suitable for SRF production, recyclable to MRF, potential to SRF and potential to SRF with pretreatment. For those CIW classified as potential, composition estimation was made by visual confirmation, photographic record and cargo manifest.

In order to take the representative samples of streams classified as potential for SRF production plant and to prepare the samples for laboratory analysis, sampling and sample preparation were performed according to the European Committee for Standardization standard methods for SRF \([3]\). C&IW steams were analyzed in our laboratory using UNE standard methods of analysis of SRF: moisture content \([4]\), ash content \([5]\), chlorine content \([6]\), gross and net calorific value (NCV) \([7]\).

3. Results

During our field study, we noted that this CIW management center received CIW from 26,596 generators but waste from about 30 generators were used to formulate SRF. The reason behind this was that this waste has mainly composed of one type of material and was almost without any mixtures of organics. According to our data and laboratory results, CIW from another 280 generators could be added to CIW suitable to an SRF plant if CIW was to be source separated. The main components in CIW potential to SRF were paper, nonwoven fabric, rubber and foam material, textiles, wet paper and plastic labels and their characteristics determined in our laboratory are shown in Table 1.
Table 1: Properties of main components of potential streams of C&IW for SRF production

<table>
<thead>
<tr>
<th>Laboratory sample identification</th>
<th>MAIN COMPONENTS</th>
<th>Moisture content (wt. %)</th>
<th>Ash content (wt. %)</th>
<th>Gross calorific value (GCV) dry basis (MJ kg⁻¹)</th>
<th>Net calorific value (NCV) dry basis (MJ kg⁻¹)</th>
<th>Chlorine dry basis (wt. %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>P001</td>
<td>DRY LABELS (paper)</td>
<td>2.90 ± 0.10</td>
<td>14.43 ± 0.09</td>
<td>15.70 ± 0.01</td>
<td>14.00 ± 0.01</td>
<td>0.17 ± 0.04</td>
</tr>
<tr>
<td>P006</td>
<td>NON-WOVEN FABRIC</td>
<td>2.00 ± 0.20</td>
<td>0.52 ± 0.06</td>
<td>21.10 ± 0.20</td>
<td>19.40 ± 0.29</td>
<td>0.19 ± 0.03</td>
</tr>
<tr>
<td>P011</td>
<td>NON-WOVEN FABRIC</td>
<td>0.11 ± 0.02</td>
<td>1.88 ± 0.04</td>
<td>46.16 ± 0.27</td>
<td>44.80 ± 0.27</td>
<td>0.28 ± 0.10</td>
</tr>
<tr>
<td>P042</td>
<td>PAPER</td>
<td>4.50 ± 0.40</td>
<td>3.10 ± 0.04</td>
<td>17.80 ± 0.05</td>
<td>15.70 ± 0.49</td>
<td>0.13 ± 0.03</td>
</tr>
<tr>
<td>P016</td>
<td>RUBBER AND FOAM MATERIAL</td>
<td>0.59 ± 0.06</td>
<td>0.29 ± 0.08</td>
<td>59.9 ± 0.49</td>
<td>58.60 ± 0.49</td>
<td>0.18 ± 0.02</td>
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<tr>
<td>P024</td>
<td>TEXTILE/PLASTIC (wet)</td>
<td>5.00 ± 0.20</td>
<td>6.17 ± 0.02</td>
<td>36.46 ± 0.44</td>
<td>33.30 ± 0.04</td>
<td>0.16 ± 0.01</td>
</tr>
<tr>
<td>P048</td>
<td>TEXTILE/PLASTIC (wet)</td>
<td>0.92 ± 0.13</td>
<td>2.13 ± 0.04</td>
<td>21.66 ± 0.36</td>
<td>20.20 ± 0.33</td>
<td>0.14 ± 0.04</td>
</tr>
<tr>
<td>W035</td>
<td>WET PAPER AND PLASTICS</td>
<td>66.73 ± 2.67</td>
<td>27.50 ± 1.14</td>
<td>22.30 ± 0.29</td>
<td>21.50 ± 0.19</td>
<td>0.30 ± 0.003</td>
</tr>
<tr>
<td>W031</td>
<td>WET LABELS (plastic wet)</td>
<td>84.44 ± 0.83</td>
<td>31.0 ± 0.40</td>
<td>12.50 ± 0.71</td>
<td>11.50 ± 0.39</td>
<td>0.11 ± 0.03</td>
</tr>
<tr>
<td>W027</td>
<td>WET PAPER</td>
<td>84.83 ± 8.59</td>
<td>7.20 ± 0.14</td>
<td>32.76 ± 0.64</td>
<td>31.90 ± 0.62</td>
<td>0.23 ± 0.07</td>
</tr>
</tbody>
</table>

Regarding our laboratory results on samples of C&IW and quantities related to these samples, we found that these C&IW streams can be added to those used now to produce SRF. Then, SRF production can be almost doubled and the decrease in waste to final disposal should be achieved.

It should be underlined that most of these streams of C&IW are not recycled in the region because technological limitations and / or lack of demand of recycled materials. Most of this waste is generated in plants where glass beverage bottles are washed (wet labels), in paper mills that use recycled paper (wet paper and plastic), from car assembly plants come the car mats and isolation materials (rubber and foam materials), and diapers and towels industry generate textiles and nonwoven fabrics.

4. Conclusions

The commercial and industrial solid waste was studied in Buenos Aires Metropolitan Region through a field study in a waste management center including the first SRF production plant of the region. It was found that input streams from industries (as car assembly plants and paper mills) had only one component and were well separated. These streams could be divided in a dry stream that showed parameters that met the requirements of SRF class 2 and a wet stream that should be mixed to produce acceptable SRF. Commercial waste was identified in the field study, but materials were not source separated so they were not considered suitable for SRF production.

Another important outcome of this work is that production of SRF with this commercial and industrial waste in the region does not compete with material recovery facilities but does complement the solid waste management system by recovering energy from waste towards a circular economy.

Acknowledgements

This work has been sponsored by Argentina National Agency of Scientific and Technological Promotion (Projects FITR 2013-0021 and DTEC 2013-017) and CONICET (doctoral fellowships of S.L. Galvan and L.V. Sosa).

References

1. Introduction
This work was carried out in a commercial and industrial nonhazardous waste (C&IW) management center located in Buenos Aires Metropolitan Region (BAMR), Argentina. BAMR counts with 40% of the country’s industries and it is estimated that 5,000 tons per day of commercial and industrial nonhazardous waste (C&IW) was generated between 2009 and 2017. The final destination of this C&IW is mainly the landfill, but a fraction is derived to produce solid recovered fuel (SRF) for clinker production as a way to recovery energy from waste. Currently, SRF is produced using only 3% of input C&IW. The aim of this work is to identify and quantify new C&IW input streams: that can be used to produce SRF for increase energy recovery and decrease final disposal.

2. Materials and Methods
Our field work: Period: October-November 2017
Site: C&IW management center in BAMR, Argentina (Figure 1).
Method: see Figure 2

Figure 1: BAMR and C&IW Management Center location.

3. Results
During the field work, a total of 22,000 tons of C&IW reached the management center, and were classified according to Figure 3.

Figure 2: Summary of method.

Main components of potential fraction were: rubber and foam materials, natural fiber and nonwoven fabric, plastic (hard and soft). Main components of potential with treatment were: wet paper, plastic labels and leather. Its properties are presented in Figure 4 and Table 1.

Most of these waste streams are not recycled in the region because technological limitation and/or lack of demand of recycled materials. The streams studied here had only one component and were well separated at source.

4. Conclusions
The waste streams studied in a C&IW management center in Buenos Aires, Argentina, could be divided in: a) a dry stream with parameters that could be used to produce a SRF that met the requirements of a SRF class 2; and b) a wet stream that should be mixed to produce an acceptable SRF. If both streams were incorporated into the production of SRF, it could be almost doubled.

Another important outcome of this work is that production of SRF with this C&IW in the region does not compete with material recovery facilities but does complement the solid waste management system by recovering energy from waste towards a circular economy.

Acknowledgements
This work has been sponsored by Argentina’s National Agency of Scientific and Technological Promotion (Projects FrmT 2012-0021 and DTEC 2013-027) and CONICET (doctoral fellowships of S.L. Galvan and L.V. Sosa).
HYDROTHERMAL LIQUEFACTION FOR PRODUCTION OF CRUDE-OIL FROM SOLID AND LIQUID SURFACTANT WASTE.


1: Departamento de Ingeniería Química y Tecnología de Alimentos/ Facultad de Ciencias, Universidad de Cádiz, Instituto IVAGRO, 11510 Puerto Real (Cádiz), Spain.
2: Departamento de Tecnologías del Medio Ambiente/ Facultad de Ciencias del Mar y Ambientales, Universidad de Cádiz, Instituto IVAGRO, 11510 Puerto Real (Cádiz), Spain.
3: Verinsur. S.A., CA-3113 km.13, 11408, Jerez de la Frontera (Cádiz), Spain.

Abstract: Hydrothermal liquefaction (HTL) is a promising thermal treatment suitable for valorization of a large variety of organic waste. Unlike other treatments such as pyrolysis or gasification, HTL can be applied to those waste that are produced on aqueous medium, being unnecessary a previous drying pre-treatment. This technology is more suitable for non-biodegradable waste and for those waste classified as dangerous that can not be treated or recovered by conventional methods. HTL can produce a liquid fuel alternative to fossil fuels or as a starting point to obtain products of industrial interest (phenols, furfurals, etc). In the present work HTL is applied to solid and liquid surfactants waste using a 300 ml stirred batch reactor. The effect of temperature, concentration and time of reaction is studied, obtaining up to 20% crude yield, with a High Heating Value (H.H.V) higher than 6.000 cal/g in most cases.

Key words: Hydrothermal Liquefaction, HTL, surfactants, crude, high pressure water, valorization.

1. Introduction

The industrial production of surfactants generates tons of solid and concentrated liquids wastes. At present, the management of this waste is complicated and expensive, so it is necessary to find alternative solutions to this problem.

Hydrothermal liquefaction is a thermal treatment in which the reaction medium is mainly water, generally at temperatures of 250-370 °C and high pressures of 50-200 bar, in absence of oxygen. Despite the process must occur within a liquid phase, the process admits the presence of solids in suspension or particles <10mm. The organic compounds present in the waste are largely transformed into a set of products that result in what is called crude or “oil”. Parameters such as the final temperature of liquefaction, reaction time, rate of heating of the waste, type of solvent medium, pH of the reaction medium, presence of hydrogen donors or catalysts, can be determining factors in the amount of crude produced and its quality.

Minowa et al [1] studied cellulose decomposition in hot-compressed water concluding that the highest oil yield is achieved with 300ºC during short periods of reaction time. Other authors like Saqib Sohail Toor et al. [2] also studied HTL over various biomasses reaching oil yields from 5% to 61%. Based on the literature, the present study focused on three variables, concentration, temperature and reaction time, over industrial surfactants wastes, obtaining a 16% oil yield with a heating value of 7.500 cal/g in the best case.

2. Experimental

2.1. Materials and method.

Autoclave Engineers AISI 316 stirred batch reactor of 300 ml of volume that supports a max 220 bar at 350 ºC. This reactor is surrounded by a cylindrical heater of 1.2 kW and the temperature can be set with ± 2 ºC a temperature controller (ICP, model TC21).

Once the reactor is filled with 150 ml of waste solution, the reactor is purged and initially pressurized to 28 bar with nitrogen gas to avoid wet oxidation of the waste and to ensure that the reaction occurs in liquid phase when temperature reaches 290, 300 or 310ºC. The stirring is set to 440 rpm during the heating step and during the reaction time. Then the reactor is cooled down before taking a gas sample that will be analyzed using a Hewlett Packard HP 6890 PLUS gas chromatograph, and the reactor is depressurized. The solid and liquid products are recovered for analysis. The char present in the effluent is vacuum filtered using glass fiber filter. The crude is obtained as result of evaporating the filtered effluent during 30 minutes at 70°C in a IKA IV10 rotavapor.

The measure of Higher Heating Value was performed using an isoperibolic oxygen pump Parr 6400 Calorimeter.

2.2. Results and discussion.

The main results obtained are shown in table 1.
<table>
<thead>
<tr>
<th>Experiment</th>
<th>Feed COD (g/l)</th>
<th>Temperature (°C)</th>
<th>Reaction time (min)</th>
<th>Max Pressure (bar)</th>
<th>Oil Yield (%)</th>
<th>Oil H.H.V (cal/g)</th>
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<td>7.553</td>
</tr>
<tr>
<td>6</td>
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<td>1</td>
<td>96,5</td>
<td>16,5</td>
<td>7.619</td>
</tr>
</tbody>
</table>

*Table1: Experiments with liquid surfactants. *Acetone was added for recovering substances from reactor walls.

The best results were found for surfactants in liquid phase. Solid surfactants didn’t generate crude in these operation conditions, so the corresponding experiments are not shown.

Temperature above 300°C decreased oil yield and H.H.V. Instead, at 290°C oil yield decay is negligible while H.H.V is the same. Different values of concentration do not make significant change in the generated oil, so it is recommended do not dilute the feed in excess to save energy heating less amount of water.

The increase of reaction time enhances the yield, but significantly reduces oil H.H.V. In the experiment number 2 the use of acetone to recover part of the fixed effluent in the wall of the batch reactor decreases the heating value of the final crude.

3. FAQ

• What are the products of interest generated by this technology?
  - The main product is crude and little amounts of char and gases (CO₂, H₂, CO, CH₄) are also produced. Another advantage is that the waste COD is reduced.

• What kind of waste is the most suitable for applying this technology?
  - Being a process in which water is the reaction medium, the most appropriate waste for this technology consists of an aqueous liquid with a moisture content of more than 85%. Regarding the solids content, although the waste may include solids in suspension or particles <10 nm. The organic concentration must be high (>5%), preferably with low content of salts and halogenated products, to avoid corrosion.

• Is this technology profitable from an economic point of view?
  - Our data suggest that with less than 20% of the crude produced, a continuous reactor could be self-sufficient energetically at industrial scale.

4. Conclusions

Hydrothermal liquefaction technology has shown good results over liquid surfactants wastes. Solid surfactants could not be converted to oil using the same operating conditions.

The best results, without the addition of any additive, were obtained for liquid residue of surfactants (process waters) at 300 °C of temperature and 100 bar of maximum pressure, during a reaction time between 1 and 3 minutes. Preliminary results show that an industrial scale HTL continuous reactor could be self-sufficient energetically with less than 20% of the crude produced.

Acknowledgements

The authors thank Verinsur S.A for technical assistance and sponsorship, as well as for supplying the surfactants industrial wastes. Also thank the “Catedra UCA Verinsur” for the project “Estudio de la licuefacción hidrotérmica en proceso continuo aplicado a residuos gestionados por la empresa Verinsur, S. A.” Ref. Code: 18DGUECAP2.

References

HYDROTHERMAL LIQUEFACTION FOR PRODUCTION OF CRUDE-OIL FROM SOLID AND LIQUID SURFACTANT WASTE.


1) Departamento de Ingeniería Química y Tecnología de Alimentos, Facultad de Ciencias, Universidad de Cádiz. juanmrm portela@uca.es
2) Departamento de Tecnologías del Medio Ambiente/ CATÉDRA VERINSUR-UBA de Investigación y Tecnología Industrial. Facultad de Ciencias del Mar y Ambientales, Universidad de Cádiz.
3) Verinsur S.A., Jerez de la Frontera, Spain.

Introduction

Hydrotermal liquefaction (HTL) is a promising thermal treatment suitable for valorization of a large variety of organic waste. Unlike other treatments such as pyrolysis or gasification, HTL can be applied to those waste that are produced on aqueous medium, being unnecessary a previous drying pre-treatment.

HTL can produce a crude oil alternative to fossil fuels or as a starting point to obtain products of industrial interest (phenols, furfural, etc.).

The industrial production of surfactants generates tons of solid and concentrated liquids wastes.

In this work HTL is applied to solid and liquid surfactants waste, focusing on three variables, concentration, temperature and reaction time.

Materials and method

Autoclave Engineers AISI 316 stirred batch reactor of 300 ml of volume.

Reaction occurs in liquid phase when temperature reaches 290, 300 or 310°C. The stirrer is set to 440 rpm during the heating and the reaction steps. Then the reactor is cooled down before taking a gas sample. Finally the reactor is depressurized.

The solid and liquid products are recovered for analysis.

The crude is obtained as result of evaporation.

The measurement of Higher Heating Value (H.H.V) was performed using an isoperibolic oxygen pump Parr 6400 Calorimeter.

Discussion

The main results obtained are shown in table 1.

The best results were found for surfactants in liquid phase. Solid surfactants didn’t generate crude in these operation conditions, so the corresponding experiments are not shown.

The initial waste is a 4,557 cal/g dry liquid surfactant. Temperature above 300°C decreased oil yield and Higher Heating Value (H.H.V).

Instead, at 290°C oil yield decay is negligible while H.H.V is the same.

Different values of concentration do not make significant change in the generated oil, so it is recommended do not dilute the feed in excess to save energy heating less amount of water.

The increase of reaction time enhances the yield, but significantly reduces oil H.H.V.

In the experiment number 2 the use of acetone to recover part of the fixed effluent in the wall of the batch reactor decreases the heating value of the final crude.

Conclusions

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Solid surfactants could not be converted to oil using the same operating conditions.

The best results, without the addition of any additive, were obtained for liquid residue of surfactants (process waters) at 300 °C of temperature and 300 bar of maximum pressure, during a reaction time between 1 and 3 minutes.

In the best case, a 16% oil yield with a heating value over 7,500 cal/g is obtained.

Table 1: Experiments with liquid surfactants.

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<th>Feed/COD (g/l)</th>
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<th>Max Pressure (bar)</th>
<th>Oil Yield (%)</th>
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The industrial production of surfactants generates tons of solid and concentrated liquids wastes. The crude is obtained as result of evaporation. Hydrothermal liquefaction (HTL) can produce crude oil suitable to fossil fuels or as a starting point to obtain products of industrial interest (phenols, furfural, etc.).

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Figure 1. Simplified scheme of the process.

Figure 2. High Heating Value of crude obtained for each experiment.
Abstract: This research consists of establishing a non-destructive exploration method of concentrated rare metal zones in landfills and evaluating the potential of urban mining. For this purpose, we focused on an industrial landfill site in Japan. After conducting experiments to capture the basis of Induced Polarization (IP) phenomena using apparatus, IP survey was conducted at the site. Drilling was also carried out at potential sites. The concentrations of metals with the cores and the existing chemical forms were also investigated. As a result, rare metals coexisting with iron sulfide which strongly affects the IP phenomenon became clear. Namely, it is possible to discover potential zones of high grade rare metal via the use of IP survey. Furthermore, based on the maximum concentration of rare metals with the core sample, the degree of potential as urban mines was determined. The above approach can be one method of evaluation for landfill mining possibility.

Key words: industrial landfill site, induced polarization, rare metal, urban mine, grade ratio.

1. Introduction
Currently, consumption of rare earth metals is rapidly increasing in the world. Before recycling became widespread in Japan, various types of untreated electronic waste were buried in landfill. However, metal elements are rarely detected in leachate from landfill sites (Kamura, 2002). This means that valuable metals remain trapped in the landfill. Landfills in Japan consist mainly of incineration ash. As rainwater permeates the fills easily, various components are dissolved in pore water from waste. Furthermore, the organic matter decomposes at the early and middle stages of landfill, so the temperature of the landfill often exceeds 50 ° C. Under such conditions, certain elements may migrate in the landfill. Therefore, we focused on an industrial landfill site. Using drilled core samples, we clarified the content and chemical form of several metals. In addition, we developed a non-destructive three-dimensional exploration system that adopts resistivity and induced polarization (IP) measurement, and identified the iron sulfide concentration zone that strongly influences the IP phenomenon. Based on these results, we made clear the position of rare metal concentrated zones and its mining potential. Thus, the process of recovering rare metals enriched in fills can be regarded as a type of urban mining.

2. Method

2.1. Site characterization
An experimental site consists of five blocks. They were all constructed in a form of an artificial pond with a rubber sheet at the bottom and infilled. The total landfill period amounted to about 27 years, from 1982 to 2009. Ash and sludge were mainly disposed into the pond and the thickness was about 6 m. The concentrations of metals in leachate from each block have not exceeded the environmental quality standard values.

2.2. Concentration and chemical forms of metals
Each drilled core was classified according to the fill materials, and then samples were taken from each section for elemental analysis. One gram of fill sample was separated from each section and decomposed using hydrochloric acid and nitric acid. Then, using the filtered solution, the element concentrations in each sample were measured by inductively coupled plasma-atomic emission spectrometry and inductively coupled plasma-mass spectrometry. Furthermore, in order to clarify the chemical forms of metal species existing in the fills, analysis with a sequential extraction method (Tessier et al., 1979) was performed.

2.3. Prospecting for metal enriched zone in landfills
The experiments are composed of a laboratory test and a field prospecting. The former is a fundamental experiment to reveal the correlation between IP phenomenon and FeS content. The latter is a field measurement using resistivity and IP methods.
3. Results

3.1. Concentration of rare metals
The elements with high concentration were as follows: Cr 5199 mg/kg, Ni 14924 mg/kg, Ba 16820mg/kg, Ce 6325 mg/kg, La 3589mg/kg. In addition, the element Sb and the rare earth elements, La, Nd, and Dy were present in the recent disposed zone.

3.2. Chemical forms of metals by sequential extraction
The characteristics of the fraction ratios for each metal are summarized as follows: Cr, Nd, Ba, and Pb were relatively high in the residual fraction, and extremely high for the deep samples collected. In particular, Cu had a high proportion of organic matter as well as a high residual fraction. Ce and La had a high oxide fraction in the shallow sample, but the deep sample, mostly contained the residual fraction. Fractionation for Mn, Co, Ni, Sr, and Zn tended to be variable.

3.3. Relationships between the PFE value and chargeability and Fe concentration
There is a correlation between the Fe concentration and the PFE values over the range of a few percent to 10%. The correlation between chargeability and Fe concentration is similar.

3.4. Field experiment
Four survey lines were set and the resistivity and the chargeability were measured. As an example, the vertical cross-sectional and the horizontal cross-sectional profiles of chargeability obtained are shown in Fig.1. The former reflected mainly locations of the vertical section along the survey line and the latter locations of 2.5 m in the horizontal plane. Zones showing a high chargeability exceeding 200 mv/V occurred intermittently in the fills. These zones were dominant in the range X = 0 to 20 and Y = 0 to 20 horizontally and for a profile of 2.5 m depth vertically.

Fig.1 Chargeability profile. (a) vertical, (b) 2.5m depth.

4. Discussion
In order to evaluate the quality of elements contained in urban mines, the ratio of the elemental concentration in E-waste to the grade of natural ore is used. This is called "grade ratio" (Harada et al., 2001). When the grade ratio shows more than 1, waste is considered possible for urban mines. Therefore, in this study, the ratio of element concentration contained in the drilled core sample to the crude ore grade was calculated to evaluate the quality of the metal contained in the landfills. In case of being calculated using the maximum concentration, the elements with the magnitude ratio exceeding 1.0 were V, Ni, Ba, La and Ce. In Ce, the ratio calculated from the average concentration also exceeded 1.

5. Conclusion
Recycling of rare metals in electronic waste has been actively researched and developed in recent years, but there are few studies on metal recovery from the fills at the final disposal site. Japan as an industrial country has developed and manufactured electrical and electronic equipment using enormous amounts of resources and has disposed of it after use. In order to create a sustainable society, it is an attractive proposal to recover and recycle these precious and scarce metal resources from landfill sites.

References
K. Kamura, Relationships between electrochemical properties of leachate and resistivity of strata in the landfill site consisting mainly of combustion residuals, Environ. Geol. 41, 537-546, 2002.
**Background:** The earth has finite natural resources, but the consumption of rare earth metals is increasing rapidly. Before recycling became widespread in Japan, crushed or incinerated electronic waste parts were buried in landfills. However, metallic elements are seldom detected in leachate from landfills, implying that valuable metals remain in landfill sites.

**Purpose:** Examining of evaluation methods of a landfill site that could be used as an "urban mine".

**Methods:** In this study, we focused on a controlled landfill sites, called site F. The site consisted of five blocks, F1 to F5, as shown Table 1.

1. To determine the contents and chemical forms of valuable rare metals in landfills.
2. To identify the metal enriched zones in landfills using non-destructive prospecting methods.

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1. To determine the contents and chemical forms of valuable rare metals in landfills.
2. To identify the metal enriched zones in landfills using non-destructive prospecting methods.

**Fe is very predominant in landfills. → IP effect is correlated with FeS content. → IP effects are measured as targeting the Fe concentrated zone.**

**ORP of leachate**

Shallow zone: -200mV
Deep zone: -400mV

Some metals are affected by the internal atmosphere of the landfills.

**On possibility of using the landfill as an urban mine**

<table>
<thead>
<tr>
<th>Block</th>
<th>Landfill period</th>
<th>land capacity (m³)</th>
<th>main disposal metals</th>
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<tbody>
<tr>
<td>F1</td>
<td>1982-1988</td>
<td>3,700</td>
<td>ash, sludge, construction waste material (concrete, etc.)</td>
</tr>
<tr>
<td>F2</td>
<td>1988-1990</td>
<td>3,700</td>
<td>ash, sludge, construction waste material (concrete, etc.)</td>
</tr>
<tr>
<td>F3</td>
<td>1990-1993</td>
<td>3,000</td>
<td>ash, sludge, dust.</td>
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<tr>
<td>F4</td>
<td>1993-2000</td>
<td>3,000</td>
<td>ash, sludge, dust.</td>
</tr>
<tr>
<td>F5</td>
<td>2001-2006</td>
<td>1,700</td>
<td>ash, sludge, construction waste material (pulpboard, etc.)</td>
</tr>
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</table>

**Certain rare metals are present at higher contents in landfill material than in naturally occurring ores. The IP method is an effective tool for visualizing zones with high rare metal content nondestructively. Based on the approach, a basic evaluation of a landfill site that could be used as an “urban mine” was accomplished.**
CINDERCEBM – A CIRCULAR BUSINESS MODEL FOR URBAN CONSTRUCTION


1 Fundacion tecnalia research & innovation -
2 Fundacio benefico-docente gomez-pardo
3 The Slovenian National Building and Civil Engineering Institute
4 Instytut ekologii terenow uprzemyslowionych
5 Technische universiteit delft
6 kplusv

Abstract: CINDERELA is a four-year project being implemented under the flagship of the H2020 EU programme with an overall objective to make urban construction sector more resource efficient and thus contribute to the overarching goal of the circular economy of reducing the use of Raw Materials. CINDERELA will deliver a business model accompanied by technological solutions and a pool of knowledge that will enable the use of locally/regionally available secondary raw materials (SRM) recovered from waste streams available in urban and semi-urban areas in construction applications. Therefore, beginning its work in June 2018 under the coordination of the Slovenian National Building And Civil Engineering Institute (ZAG), a multidisciplinary consortium of 13 partners from 7 countries will be working together to design and demonstrate under real conditions a circular economy business model dedicated to the urban construction sector called CinderCEBM.

Key words: Cinderela, CinderCEBM, Secondary Raw materials (SRM)

1. Introduction

Urban and semi-urban areas generate large volumes of wastes such as construction and demolition waste, waste from industrial processes (e.g. different types of slags) or waste from municipal services (e.g. sewage sludge or heavy fraction of municipal waste) which could become sources of valuable secondary raw materials (SRM) of use for urban construction purposes as substitutes of virgin materials. However, this potential is not sufficiently explored, resulting in tons of valuable resources dumped on landfills only because there are no specialized knowledge nor technologies, nor enabling regulatory frameworks and, first of all, no business practices that would stimulate construction companies to benefit from this potential.

The objective for the project is to design and demonstrate under real conditions a circular economy business model dedicated to the urban construction sector called CinderCEBM. The aim of this model is to enable production of construction materials using Secondary Raw Materials (SRM) recovered from different waste types available in urban and semi-urban areas and their use in urban construction services in a technically feasible and economically viable way. To facilitate the business model, CINDERELA will develop and provide a digital platform in a form of a one-stop-shop called CinderOSS as a companion tool to CinderCEBM.

2. CinderCEBM – a circular business model for urban construction

At the heart of the CINDERELA project is a product driven business model, in short CinderCEBM. CinderCEBM shall enable turning unused waste into SRM that can be applied in the construction sector.
New value chains

Setting up new waste-to-products flows requires new business practices. CinderCEBM can be adapted by new or existing construction entrepreneurs to create a business that contributes to a circular construction sector. The main business practice will involve collecting waste, its processing for recovery of materials or use in full as SRM, and finally their application for manufacturing construction products fit for purpose. All steps are supported by LCA studies and relevant certification. As such, current manufacturers of construction materials are the main target of the CinderCEBM.

Sustainable values

By changing the current practices in urban waste management and consumption patterns of the construction sector, CinderCEBM is intended to deliver economic, environmental and social benefits to a broad range of stakeholders and actors along the supply and value chains. The economic value will be created for construction entrepreneurs by reducing potential costs of manufacturing construction materials. This is made possible thanks to full or partial substitution of virgin materials by cheaper, quality certified SRM available at local/regional level. Economic value will also be created for waste holders currently dumping the waste (i.e. burden) as these would become an asset, i.e. with a value on a market. CinderCEBM will provide environmental values to the urban construction sector by improving its environmental performance in terms of reduction of resource consumption, waste generation and equivalent CO2 emissions. For local and regional authorities, the environmental benefits of CinderCEBM will consist in optimized use of resources and locations that are currently associated with waste. Finally, in terms of social values, it is expected that CinderCEBM will strongly contribute in job creation.

CinderOSS: a one-stop-shop to support the business model

CinderCEBM focuses on a product-driven business which includes ongoing learning about users and new techniques to build better products and facilitate their implementation. For that purpose, CINDERELA will offer a digital tool in form of a one-stop-shop (CinderOSS).

CinderOSS will act as a knowledge hub for construction companies interested in implementing the CinderCEBM. To cover a large variety of topics, CinderOSS will be divided into four modules:

- production & construction module which provides information on SRM-based construction products characteristics (in the form of a BIM-library), where to get these products and how to use them;
- research & development module which collects new knowledge on current and future development of SRM (construction product) technologies;
- market & legal module which builds market and legal information provided in the CEBM with certification, administrative procedures and specific knowledge on the economic environment of EU-28 countries
- interactive ecosystem platform called the CINDERELA Digital Business Ecosystem which facilitates tracking and selling of waste and resources as well as communication with potential partners.

Demonstration

Both the business model and the digital platform will be developed and tested in real environments using a series of pilots and large-scale demos involving production and testing of SRM based construction materials and their implementation in real world construction projects. Testing and validation activities with the involvement of stakeholders will ensure that the business model is operational in real conditions and CinderOSS provides useful and market relevant support needed to enable this model.

4. Conclusions

The model will enable production of construction products using Secondary Raw Materials (SRM) recovered from different waste types available in urban and semi-urban areas and their application in urban construction services in a technically feasible and economically viable way. The SRM based construction materials will include manufactured aggregates, soil and building composites.
New Circular Economy Business Model for More Sustainable Urban Construction

CINDERELA develops and demonstrates a circular economy business model (CinderCEBM) aided by a One-Stop-Shop digital environment (CinderOSS) to help construction companies find how they can profit and deliver value to clients thanks to turning secondary raw materials (SRM) recovered from urban waste streams into construction materials for building and civil engineering applications.

CinderOSS:
- Provides a digital environment enabling setting of circular business models depending on regional/local conditions, together with information on SRM availability and the associated stakeholders.
- Delivers evidence-based knowledge on the enabling framework conditions for design, production and use of SRM-based construction materials.
- Helps build confidence in SRM-based construction materials by providing reliable test data on their performance based on testing protocols meeting the needs of construction sector requirements.

CinderOSS and CinderCEBM are built upon and validated in real environments under six DEMO pilots:
- Phosphorous extraction as a step in a cascade recycling of sewage sludge as SRM.
- Manufacture of SRM-based construction products for building and civil engineering applications.
- Geotechnical works with the use of SRM-based materials to revitalise a degraded area.
- Construction of a building with SRM-based construction materials.
- Construction of a road with SRM-based construction materials.
- 3D printing of a building component involving combination of robotic 3D printing and recycled plastic waste.

Contact Information:
Ainara Garcia Uriarte
ainara.garcia@tecnalia.com

CINDERELA Project
@CinderH2020

www.cinderela.eu
Abstract: Lithium-ion batteries (LIBs) are widely used in portable electronics devices due to their high energy density and low weight when compared to the other types of batteries. The useful life of LIBs is about two years. So, a collection system and recycling process is necessary, since only in Brazil are generated around 500 ton/year. In this work, five battery models were used. The batteries were manually disassembled to be characterized by SEM, FRX, DRX and ICP-OES. The elements present in higher content in cathode material are lithium and cobalt, making this waste very interesting as raw material.

Key words: WEEE, Lithium-ion Battery, Recycling.

1. Introduction
The increasing consumption of portable electronics, especially mobile phones, entails an inherent demand for batteries; in Brazil, 241 million of cell phones lines were in operation in September 2017 while the population was 209 million. LIBs work as a galvanic cell, composed by an anode (graphite powder layed on a copper sheet holder), a cathode (lithium-cobalt oxide - LiCoO$_2$ - layed on an aluminum sheet holder) and an electrolyte that allows ion exchange. In view of the large amount of electronic waste generated by the LIBs damaged or obsolete, it is of great interest to develop ecologically and economically viable recovery technologies for LiCoO$_2$. This project intends to use hydrometallurgical processes in order to recover the metals of interest. The first step is the characterization of this waste, presented in this work, and the second stage will be the use of ionic liquids. One way to increase the efficiency in the leaching process is pre-treating the material with ionic liquids to remove the polyvinylidene fluoride (PVDF). PVDF is used as a cathode powder binder on sheet holder and makes leaching difficult by keeping LiCoO$_2$ sticking to aluminum.

2. Methodology
For this work, 400 batteries were collected, of different brands and models, from technical assistance stores of cell phones. For this characterization step, a battery model (with more units out of the 400 collected batteries) for each brand was chosen: Samsung (EB-BG530CBB), LG (BL-53YH), Nokia (BL-5C), Motorola (GK-40) and Apple (616-00042). All five representative samples were manually disassembled for separation and subsequent characterization of the components as shown in Figure 1.

Figure 1. The five batteries models chosen to characterization process (a) and one of them after manual disassembly (b).

The main component of interest is the cathode powder, as it must contain lithium and cobalt. The cathode powder (LiCoO$_2$) was manually removed by scraping from the aluminum sheet; the microstructures were verified in scanning electron microscopy (SEM) (Phenom Pro-X). The XRD analysis was performed on a X-ray diffractom-
eter (Siemens BRUKER AXS D-5000 (θ-θ)) while XRF was performed on Thermo Scientific Niton XL3t. After, the cathode powder was digested in a microwave oven, according to EPA method 3051and analysed via ICP-OES (Agilent Technologies 5110).

3. Results

In the elementary analysis of the cathode powder composition, cobalt, lithium, manganese and aluminum were chosen because they are the probable components as the literature points out. After analysis by SEM, XRD and XRF the presence of these elements were verified and then quantified by ICP-OES, as presented in Table 1.

Table 1. Analyzed elements present in the cathode powder of lithium-ion batteries (wt%).

<table>
<thead>
<tr>
<th>Sample</th>
<th>Al</th>
<th>Co</th>
<th>Li</th>
<th>Mn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samsung</td>
<td>0.14</td>
<td>47.40</td>
<td>6.37</td>
<td>ND</td>
</tr>
<tr>
<td>LG</td>
<td>0.08</td>
<td>44.90</td>
<td>5.83</td>
<td>ND</td>
</tr>
<tr>
<td>Nokia</td>
<td>0.06</td>
<td>38.57</td>
<td>5.33</td>
<td>ND</td>
</tr>
<tr>
<td>Motorola</td>
<td>0.26</td>
<td>46.34</td>
<td>3.47</td>
<td>ND</td>
</tr>
<tr>
<td>Apple</td>
<td>0.03</td>
<td>42.82</td>
<td>5.19</td>
<td>ND</td>
</tr>
</tbody>
</table>

4. Conclusions

For all models of analyzed batteries, cobalt and lithium represent the major metals present in the cathode powder. The presence of aluminum is probably related to the manual scraping process that was performed on the aluminum sheet. Some literature indicates that the manganese may be present at the cathode, but in the material analyzed in this work the manganese was not detected. The amount of lithium and, especially, cobalt present on the cathode justifies further studies in order to enable a more efficient removal for subsequent leaching process. The next step of this work will be the use of ionic liquids to improve the processes of removal and leaching of cathode powder.

Acknowledgements

The authors would like to thank CAPES, CNPq and Finep for their financial support.
Chemical characterization of spent lithium-ion batteries to recover lithium and cobalt
José Cristiano Mengue Model
Roni Tiago Stein, Hugo Marcelo Veit


INTRODUCTION
The increasing consumption of portable electronics, especially mobile phones, entails an inherent demand for batteries; in Brazil, 241 million of cell phones lines were in operation in september 2017 while the population was 209 million. LIBs work as a galvanic cell, composed by an anode (graphite powder layer on a copper sheet holder), a cathode (lithium-cobalt oxide - LiCoO₂ - layed on an aluminum sheet holder) and an electrolyte that allows ion exchange. In view of the large amount of electronic waste generated by the LIBs damaged or obsolete, it is of great interest to develop ecologically and economically viable recovery technologies for LiCoO₂.

OBJECTIVE
Use hydrometallurgical processes in order to recover the metals of interest. The first step is the characterization of this waste, presented in this work, and the second stage will be the use of ionic liquids as pretreatment.

METHODOLOGY
In this work, 400 batteries were collected, of different brands and models. All five representative samples were manually disassembled for separation and subsequent characterization of the components as shown in Figure 1.

RESULTS
In the elementary analysis of the cathode powder composition, cobalt, lithium, manganese and aluminum were chosen because they are the probable components as the literature points out. After analysis by SEM (Figure 3), XRD and XRF the presence of these elements were verified and then quantified by ICP-OES, as presented in Table 1.

DISCUSSION
For all models of analyzed batteries, cobalt and lithium represent the major metals present in the cathode powder; manganese was also detected but in a lower quantity. The presence of aluminum is probably related to the manual scraping process that was performed on the aluminum sheet. The amount of lithium and, especially, cobalt present on the cathode justifies further studies in order to enable a more efficient removal for subsequent leaching process. The next step of this work will be the use of ionic liquids to improve the processes of removal and leaching of cathode powder.

ACKNOWLEDGEMENTS
The authors would like to thank for their financial support.

Table 1. Percentage mass of elements present in the cathode powder of lithium-ion batteries

<table>
<thead>
<tr>
<th>Sample</th>
<th>Al</th>
<th>Co</th>
<th>Li</th>
<th>Mn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samsung</td>
<td>0.14</td>
<td>47.4</td>
<td>6.37</td>
<td>1.43</td>
</tr>
<tr>
<td>LG</td>
<td>0.08</td>
<td>44.9</td>
<td>5.83</td>
<td>1.28</td>
</tr>
<tr>
<td>Nokia</td>
<td>0.06</td>
<td>38.57</td>
<td>5.33</td>
<td>1.52</td>
</tr>
<tr>
<td>Motorola</td>
<td>0.26</td>
<td>46.34</td>
<td>3.47</td>
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<td>1.40</td>
</tr>
</tbody>
</table>

E-mail: jose.model.jc@gmail.com
Mobile: +55 51 994473232
VALORIZATION OF ALUMINUM SALINE SLAGS
INAMAT-Science Department, Los Acebos Building, Public University of Navarra, Campus of Arrosadia, 31006 Pamplona, Spain

Abstract: Due to its composition and possible interaction with the environment, the saline aluminum slags generated in aluminum recycling processes are classified as hazardous wastes and must be deposited in controlled landfills. The management of this type of wastes supposes important economic costs for the industries, reason why its valorization could be the best solution. This work presents the studies that our research group have carried out to obtain materials that can be applied in environmental solutions such as adsorbents and metal catalysts.

Key words: aluminum saline slags, hazardous wastes, industrial waste valorization, adsorbents, catalysts.

1. Introduction
Aluminum saline slags are hazardous wastes generated during secondary aluminum melting processes. In these processes, NaCl and KCl are used to cover the aluminum melt scrap or dross to reduce the melting temperature; protect the aluminum against oxidation; dissolve, absorb, and allow the metal oxides and other impurities to easily be separated from the metallic aluminum. From the composition of the saline slags generated, the fraction known as non-metallic products, NMP, is the most important, with a content of various oxides between 20 to 50 wt.%. Metallic aluminum, flux brines and other components in smaller proportions are also present. In general, saline slags are managed by separation of their components for possible recovery or by storage in controlled landfills. In a first step, the aluminum metal is separated from the material by crushing and screening. The waste is treated with water to separate the soluble and insoluble fractions, generating a new solid waste containing less salt and a saline solution containing the salts to be recovered. The composition of this new solid waste varies and depends on the nature of the materials used for the recycling treatment. The applications are limited due to the heterogeneous composition, reason by which the waste is sent for landfill. The fact that aluminum saline slags are a mixture of oxides means that these materials can be used for direct applications such as inert filling for construction, road paving, mortar components, inert filler in polymer composites, mineral wool, etc. Aluminum can also be recovered as a high-value-added product and used to synthesize materials such as pure alumina, hydroxides, among others. In the present study, saline slags generated during aluminum recycling processes was used as alternative aluminum source for the synthesis of materials applied as adsorbents and catalysts for the removal of organic contaminants found in waste-water systems and for the catalytic valorization of CO₂.

Acknowledgements
The authors are grateful for financial support from the Spanish Ministry of Economy, Industry and Competitiveness (AEI/MINECO), the European Regional Development Fund (ERDF) and the Government of Navarra through projects MAT2016-78863-C2-1-R and P1017 CORRAL. MY thanks Government of Navarra for technologists recruitment. AS, JJTH and LS thank MINECO and UPNA for pre-doctoral grants. AG also thanks Santander Bank for funding through the Research Intensification Program.

References
The objective of the work was to present the current situation as regards the management and valorization of aluminum saline slags, also known as aluminum salt cake or salt slag. Aluminum saline slags are produced by the secondary aluminum industry and during the aluminum scrap/dross melting processes. The amount of salina slag generated in these operations can vary between 30 and 50% of the metal produced, that is, between 300 and 600 kg per ton of aluminum. This waste contains about 3-8 wt. % metallic aluminum, 20-50 wt. % oxides, such as aluminum oxide (also referred to as nonmetallic products), 20-75 wt. % flux brikes, and other components in smaller proportions. Due to their composition and possible reaction with water, saline slags are classified as hazardous and are included in the European List of Wastes, which means that they must be deposited in landfills or in secure deposits. Salt cake is a by-product which can be recovered provided the process is economically viable. Direct applications such as inert filling for construction; road paving, mortar components; aluminum salts; inert filler in polymer composites, adsorbents, mineral wood, etc., have been reported.

**VALORIZATION OF ALUMINUM SALINE SLAGS**

**A. Gil, A. Segovia, J.J. Torrez-Herrera, L. Santamaría, M. Yoldi, E.G. Fuentes-Ordoñez, S.A. Korili**

* INMAT-Science Department, Los Acoitos Building, Public University of Navarra, Campus of Arrosadía, 31006 Pamplona, Spain

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**Comparison of the steps involved in the separation of the components**

<table>
<thead>
<tr>
<th></th>
<th>Wet process</th>
<th>Dry process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preparations of the material</td>
<td>This is a simple wet and dry process.</td>
<td>This is a simple wet and dry process.</td>
</tr>
<tr>
<td>Grinding, screening, and separation</td>
<td>No water is consumed.</td>
<td>No water is consumed.</td>
</tr>
<tr>
<td>Leaching of the solid</td>
<td>Only performed in the wet process.</td>
<td>Only performed in the wet process.</td>
</tr>
<tr>
<td>Dissolution</td>
<td>The water/salt sludge mixture is an important factor.</td>
<td>The water/salt sludge mixture is an important factor.</td>
</tr>
<tr>
<td>Treatment of gases</td>
<td>The gases emitted upon reaction of water with the solid, typically H, NH, PH, HS, and CH, must be treated.</td>
<td>The gases emitted upon reaction of water with the solid, typically H, NH, PH, HS, and CH, must be treated.</td>
</tr>
<tr>
<td>Abstraction, absorption, condensation</td>
<td>Water consumption depends on the solubility of the solid.</td>
<td>Water consumption depends on the solubility of the solid.</td>
</tr>
<tr>
<td>Recovery of the salt</td>
<td>Evaporation and crystallization</td>
<td>Evaporation and crystallization</td>
</tr>
<tr>
<td>Management of the solid wastes</td>
<td>This is a common step in the wet and dry processes.</td>
<td>This is a common step in the wet and dry processes.</td>
</tr>
<tr>
<td>Additional processes</td>
<td>Waste transport</td>
<td>Waste transport</td>
</tr>
<tr>
<td>Water transport</td>
<td>This is a common step in the wet and dry processes.</td>
<td>This is a common step in the wet and dry processes.</td>
</tr>
</tbody>
</table>

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**VALORIZATION AND APPLICATIONS OF ALUMINUM DROSS AND NONMETALLIC PRODUCTS (NMPs)**

The use and applications of aluminum waste depend on the chemical composition of the oxides and the chloric content. The main phase detected is alumina. It can be used in direct applications such as inert filling for construction; road paving, mortar components; aluminum salts; inert filling in polymer composites, adsorbents, inert filler in polymer composites, adsorbents and mineral wool. Aluminum can also be recovered as a high-value-added product and used in the synthesis of materials such as pure alumina, salts, molecular sieves, zeolites, and hydroxides. These last materials can be used as adsorbents and catalysts.

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**Acknowledgements** This work was funded by the Spanish Ministry of Economy, Industry and Competitiveness (AELM/INECO), and the European Regional Development Fund (ERDF) through project MAT2016-78869-C2-R, S. thanks Universidad Pública de Navarra for a pre-doctoral grant. AG also thanks Santander Bank for funding through the Research Intensification Program.
PRELIMINARY ANALYSIS OF THE INTERNAL COSTS OF THE WASTE MANAGEMENT SYSTEMS IN DEVELOPING COUNTRIES. A BRAZILIAN CASE STUDY

V. Ibáñez-Forés(1), C. Coutinho-Nóbrega(2), L. de Figueiredo-Lopes(3), M.D. Bovea(1)

1: Department of Mechanical Engineering and Construction, Universitat Jaume I, Avda. Vicent Sos Baynat s/n 12071 Castellón de la Plana, Spain
2: Department of Civil and Environmental Engineering, Universidade Federal da Paraíba, Campus Universitário I, 58051-900 João Pessoa, Brazil
3: School of Sciences and Technology, Federal University of Rio Grande do Norte, 59078-970 Natal, Brazil

Abstract: This study aimed to identify how internal (operating and maintenance) costs are distributed along the life cycle stages of waste management systems in developing countries based on case applied to João Pessoa (Brazil). All the economic flows of inputs and outputs produced throughout the considered six waste management stages (selective/mixed waste collection, classification, material recovery, transport and landfilling) were collected from the primary data that came mainly from the municipal authorities for the urban cleaning company in the city of João Pessoa. The results show that, although the selective collection of recyclable waste is the most expensive stage per ton handled in each life cycle stage, globally the landfilling stage is the most expensive one given the amount of waste currently deposited in it.

Key words: Waste management, operational and maintenance costs, Brazilian National Policy on Solid Waste.

1. Introduction

Since the Brazilian National Policy on Solid Waste [1] came into force, waste management systems in Brazil have moved towards incorporating the selective collection of recyclable materials, among other improvement aspects. João Pessoa is one of the pioneering Brazilian municipalities to implement municipal strategies to promote selective collection and improve their classification facilities to increase its waste recovery rates [2].

Waste recovery provides both economic and environmental benefits as it reduces landfilling waste processing, and generates recycled secondary raw materials [3, 4]. However, since operational and maintenance costs, called internal costs, represent more than 80% of the economic burdens associated with managing one ton of waste [5] it is fundamental to identify the economic hot-spots of waste management systems.

This work aimed to perform a preliminary analysis of the economic assessment of the municipal solid waste management (MSWM) system in developing countries, specifically in João Pessoa (Brazil), by analysing the internal costs generated in each management stage. For this purpose, an economic inventory of the system’s life cycle was set up, based on primary sources of information to assess the system’s performance in a reliable, traceable and representative manner. Based on the collected data, the system stages that involved the highest internal costs were identified by comparatively analysing the cost distribution throughout the system’s life cycle.

2. Methodology

The initial applied methodology stage was data collection, which included making the Life Cycle Inventory (LCI) for João Pessoa’s waste management system, the scope of which is shown in Fig. 1. This helped identify the waste management system’s characteristics and all the economic flows of inputs and outputs produced throughout the six considered stages: I) Selective waste collection; II) Classification Facilities or sorting units; III) Mixed waste collection; IV) Material Recovery Facility; V) Final transport; VI) Landfillings. For this purpose, we combined the primary data, which were collected directly from the municipal authority for the Special Urban Sanitary Management of João Pessoa (EMLUR) [2] with the secondary data published by different institutional organisations: Instituto Brasileiro de Geografia e Estatística-IBGE; Prefeitura Municipal de João Pessoa-PMJP; Sistema Nacional de Informação sobre saneamento-SNIS, etc.

Secondly, internal (operational and maintenance) costs were calculated not only as the unitary cost of managing one ton of waste in each MSWM system stage, but also globally as the cost of managing one ton of MSW/inhabitant-year through all the MSWM system’s life cycle stages. Then the economic results were compared by analysing the distribution of costs along all six considered life cycle stages.
3. Results and Conclusions

Figure 2 compares the distribution of the internal costs in all the life cycle stages of the waste management system in João Pessoa. This allows accurate economic knowledge about the system to be acquired by identifying the most expensive stages after considering, on one hand, the cost of managing one ton of waste in each stage (Fig 2.a) and, on the other hand, the cost of the global management of one ton of MSW generated in this city (Fig. 2b).

The results showed that, although the selective collection of recyclable materials (I. Selective waste collection) was the most expensive stage per managed ton in each stage (see Fig. 2a), the landfilling stage (VI. Landfilling) was where more money was currently being invested per ton of MSW/inhabitant-year managed by the system after taking into account the rates of waste collection carried out in the city (see Fig 2.b). Therefore, improving the waste recovery rates would seem crucial for not only improving the system’s environmental performance, but also for making waste management more profitable.

Acknowledgement

The authors are grateful to the Universitat Jaume I (Project UJI-A2018-11) for funding for this study

References


Waste recovery provides both economic and environmental benefits as it reduces landfilling waste processing and generates recycled secondary raw materials [1, 2]. However, since operational and maintenance costs, called internal costs, represent more than 80% of the economic burdens associated to the management of waste [3], it is critical to identify the economic hot-spots of waste management systems.

This study aims at performing a preliminary analysis of the economic assessment of a municipal solid waste (MSW) management system, by focusing on its internal costs. The city of João Pessoa (Brazil) is selected as a case study, since it is one of the first Brazilian cities to promote selective waste collection in order to increase its waste recovery rates.

The applied methodology consists of analysing the economic characteristics of the MSW management system implemented in João Pessoa, by means of determining all the economic flows of inputs and outputs produced throughout the following six stages: I) Selective waste collection; II) Classification Facilities or sorting units; III) Mixed waste collection; IV) Material Recovery Facility; V) Final transport; VI) Landfilling.

For this purpose, primary data collected directly from the municipal authority for the Special Urban Sanitary Management of João Pessoa (EMLUR), were combined with secondary data published by different Brazilian public institutions: Instituto Brasileiro de Geografia e Estatística-IBGE; Prefeitura Municipal de João Pessoa-PMPJ; Sistema Nacional de Informação sobre Saneamento-SNIS, etc.

Secondly, internal (operational and maintenance) costs were calculated:
- globally as the cost of managing one ton of MSW/inhabitant-year through all the MSW management system's life cycle stages, and
- unitary cost of managing one ton of waste in each MSW management system stage.

The results showed that the selective collection of recyclable materials (I. Selective waste collection) was the most expensive stage per ton of waste (see Fig 2a). There is no significant distinction among the costs due to the sorting units and the material recovered facility located at the landfilling site, since they have similar activities. Nonetheless, when accounting the annual costs, the landfill (VI. Landfilling) is where higher costs were incurred per ton of MSW/inhabitant-year, after taking into account the rates of waste collection carried out in the city (see Fig 2b).

By analysing the cost distribution by activities (see Fig. 3), it was identified that transportation and labor costs were the most expensive activities for almost all stages of the life cycle of the MSW management system. It can be observed that the cost of the stage I (selective waste collection) is mainly due to the fuel consumption included in transportation costs. The same occurs in stages III (mixed waste collection) and V (final transport to recyclers), although these stages present higher labor costs than stage I. Infrastructure costs (considered in the “others” category) are only significant for the stage VI (landfilling).

Conclusions

It can be concluded that improving the waste recovery rates would seem crucial for not only improving the system’s environmental performance, but also for making waste management system more profitable from an economic point of view.
NUTRIENT AND CARBON RECOVERY FOR MORE EFFICIENT AGRICULTURE IN EUROPE

F. Corona (1),(2), D. Hidalgo (1),(2), J.M Martín Marroquín (1),(2)

1: CARTIF Centro Tecnológico, Boecillo, Valladolid, 47151, Spain
2: ITAP Institute, University of Valladolid, Valladolid, 47010, Spain

Abstract: NUTRI2CYCLE project will use an integrated approach to enable the transition from the current (suboptimal) nutrient household in European agriculture to the next-generation of agronomic practices, characterized by an improved upcycling of nutrients and organic carbon. NUTRI2CYCLE starts from existing N-P-C flows and farm management systems and will propose, test and implement more mature and sustainable farm prototypes including innovative technologies to better close the loops. These prototypes will serve as an innovation engine to further extrapolate the farm level impact to regional and European level impact.

Key words: Nutrient recovery, Phosphate, Nitrogen, Organic carbon, Organic Waste Integral Management

1. Introduction

Intensified European agriculture is crucial for the EU food supply and self-sufficiency, but it also generates environmental challenges related to GHG emissions and nutrient related pressure (eutrophication). In addition, European agriculture is under economic pressure due to its high dependency on import of primary nutrients and energy. Nitrogen (N) has been highlighted as one of the three “planetary boundaries” that have been exceeded beyond supportable levels alongside climate change and biodiversity loss. Phosphorus (P) has been highlighted and was placed on the “Critical Raw Material” list by the European Commission, considering the European continent is dependent on import to secure its own agricultural production (and hence food security). Carbon has been insufficiently investigated and even overlooked in past nutrient oriented research, yet N-, P- and C-cycles are intertwined and need to be examined within a single methodological framework.

NUTRI2CYCLE addresses the current gaps in the N, P and C cycles of different European agricultural systems and the related environmental problems by implementing optimized management systems whilst having a positive trade–off with productivity, quality and environmental impact.

2. Objectives

NUTRI2CYCLE aims to (i) benchmark mass flows of nutrients, organic carbon and GHG-footprint, (ii) provide an assessment frame (toolbox) for evaluating potential impact of proposed innovations, (iii) actively support concepts, techniques and scenarios put forward in EIP-Operational Groups, (iv) optimize these (+ in consortium developed) scenarios using the toolbox, (v) showcase the most promising developments via prototypes and demos. Finally, using the experience gained at a local/regional scale, NUTRI2CYCLE will elaborate strategic scenarios to identify the effect of these innovations at European scale.

Better nutrient stewardship engaging all actors across the value chain as envisaged in NUTRI2CYCLE will increase the C, N and P recycling rate significantly and will improve the overall sustainability and innovation capacity of European agricultural systems.

3. Methodology

European agriculture is still characterized by a high overall contribution to GHG emission, a sub-optimal retrieval of valuable organic carbon and insufficiently efficient re-use of major plant nutrients (NPK) within agro-system boundaries. The project is drafted under the general model & assumption that the two classical agro-pillars (plant production and animal husbandry) need to implement optimized management system aimed at better nutrient stewardship and mitigation and a more sustainable connection can be made between these two pillars in regard to nutrient, energy and carbon cycles by integrating farm-scale processing techniques and principles. This triangle model for reconnecting carbon/nutrient/energy flows between conventional agro-pillars (plant & animal) requires a third pillar: processing and treatment of agro-biomass.
4. Results

Through the results obtained in NUTRI2CYCLE, it is expected to establish more C-, N- and P-efficient agro ecosystems by introducing effective combinations of existing technologies and high-potential innovations in nutrient recycling technologies, thus improving the sustainability of European farm systems, reducing negative impacts on water, air, climate and soil quality.

Acknowledgements

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 773682 (NUTRI2CYCLE project).
**INTRODUCTION**

Plant production and animal husbandry have intensified independently over the last century.

Crucial to EU food supply and self-sufficiency

Environmental challenges and economic pressure

Import of primary nutrients and energy

**INNOVATIONS**

Aim to focus on new innovations (min TRL 4-5) or are currently market ready (TRL 7-9) but only locally available:

- A high potential for improving nutrient use efficiency, carbon recycling, energy cycling, greenhouse gas emission mitigation
- Technical feasibility
- Cost
- Easy to use

**OBJECTIVE**

**NUTRI2CYCLE** addresses the current gaps in the N, P and C cycles of different European agricultural systems and the related environmental problems by implementing optimized management systems whilst having a positive trade-off with productivity, quality and environmental impact.

To improve nutrient & carbon cycles within agricultural systems a third pillar is required:

**METHODOLOGY**

- Total project budget: 7,048,003.75 €
- UE contribution: 6,850,050.50 €
- Duration: October 2016 – December 2019

**ACKNOWLEDGEMENTS**

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 773682
THE STUDY OF ASH DEPOSITION FORMATION IN MUNICIPAL SOLID WASTE INCINERATION USING CFD SIMULATION

H.L. Du (1), J. Huang (1), H. You (1), L. Bai (1), J. Xie (1), Y. Cao (1), Y. L. Shen (1)

1: Research Institute, Shanghai SUS Environment Co., LTD, Songqiu Road 9, 201700 Shanghai, China

Abstract: The municipal solid waste (MSW) incinerators have been widely used in China in recent years. In this work, Ash deposition in a 750t/d MSW incinerator in China has been studied. Characteristics of ash deposition from different locations in the combustion chamber have been analyzed. The serious slagging has been formed at head of the front arch and upper parts of the rear arch. The lower parts of the rear arch have less ash deposition than the upper parts.

The combustion process of incinerator has been studied by numerical simulation. The results indicate that the flue gas temperature is very high near the head of the front arch and upper parts of the rear arch. The fly ash in the flue gas will be melted and slagging can occur at locations with the high temperature. With the temperature decreasing, there is less ash deposition in the furnace wall.

Key words: Ash deposition, Municipal solid waste incinerator, Numerical simulation.

1. Introduction

In recent years, with the amount of municipal solid waste growing fast, there are more and more Waste to Energy (WtE) plants put into operation in China[1]. However, MSW is a mixture of inhomogeneous materials with high ash content and complex chemical compositions. During the combustion process of MSW in incinerator, a large fraction of the inorganic elements will volatilize and transform through complex chemical reactions. Part of the MSW, its combustion residues and generated ashes will be entrained by inlet air through the fuel bed, into finally the flue gas. These volatiles and entrained fine fuel/ash particles in the flue gas can lead to formation of deposits on heat transfer surfaces[2]. With accumulation and sintering of the ash deposits, the heat transfer can be significantly hampered, decreasing the energy conversion efficiency of the WtE plant[3]. So the characteristics of ash deposition formation in MSW incinerator should be analyzed in order to understand ash deposition formation processes.

In this paper, the ash deposition data of a 750t/d MSW incinerator in China has been collected for analysis. Numerical simulations based on FLIC[4] and Fluent have been applied in this study. Characteristics of combustion process of incinerator and temperature field in MSW incinerator have been analyzed by numerical simulation.
2. Part of the Result

Figure 1 Comparison of numerical simulation data with incinerator slagging

Acknowledgements
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References
The study of ash deposition formation in municipal solid waste incineration using CFD simulation

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1: Shanghai SUS Environment Co., Ltd., Songqiu Road 9, 201700 Shanghai, China

Introduction

In recent years, with the amount of municipal solid waste growing fast, there are more and more Waste to Energy (WTE) plants put into operation in China(1). However, MSW is a mixture of inhomogeneous materials with high ash content and complex chemical compositions. During the combustion process of MSW in incinerator, a large fraction of the inorganic elements will volatilize and transform through complex chemical reactions. Part of the MSW, its combustion residue and generated ashes will be entrained by inlet air through the fuel bed, into finally the fly gas. These volatiles and entrained fine fuel/ash particles in the fly gas can lead to formation of deposits on heat transfer surfaces(2). With accumulation and sintering of the ash deposits, the heat transfer can be significantly hampered, decreasing the energy conversion efficiency of the WTE plants(3). So the characteristics of ash deposition formation in MSW incinerator should be analyzed in order to understand ash deposition formation processes.

In this paper, the ash deposition data of a 75t/d MSW incinerator in China has been collected for analysis. Numerical simulations based on FLUENT(4) and Fluent have been applied in this study. Characteristics of combustion process of incinerator and temperature field in MSW incinerator have been analyzed by numerical simulation.

Fig. 1 Change of annual energy output of WTE power plants in Mainland China

Ash deposition formation in incinerator

The serious slugging has been formed at head of the front arch and upper parts of the rear arch. The lower parts of the rear arch have less ash deposition than the upper parts. The combustion gas above the combustion zone gets has been blown off near the throat. And a lot of heat has been released at the top of the combustion chamber. The fly ash in the fly gas has been melted and slugging can occur at locations with the high temperature. When the flow suction of the combustion chamber shrinking near the throat, the head of the front arch and upper parts of the rear arch have been scourd by high temperature fly gas. So the serious slugging has been formed near the throat.

Fig. 3 Ash deposition formation in different locations in the combustion chamber

(a) Slugging in front arch

(b) Slugging in rear arch

CFD simulation about combustion process of incinerator

The combustion process of incinerator has been studied by numerical simulation. In dry zone, the fuel has been dried and the local temperature is lower. In combustion zone, with the temperature continuously increasing on the fuel bed, combustion process turns into the rapid combustion zone. In burnout zone, the residual carbon has been wrapped by ash layer and resolved slowly.

The combustion gas such as CO reacts with secondary air, releasing a large amount of heat and increasing furnace temperature. The temperature near the secondary air outlet of the front arch has been increased significantly, and the temperature at the upper part of the rear arch is higher. The fly ash in the rise gas will be molten and slugging can occur at locations with the high temperature.

There is a high correlation between slugging distribution and temperature distribution.

Fig. 4 Numerical simulation data of incinerator

(a) Temperature of furnace

(b) Velocity of furnace

Fig. 5 Comparison of numerical simulation data with slinger slugging

Conclusions

- The serious slugging has been formed at head of the front arch and upper parts of the rear arch.
- The lower parts of the rear arch have less ash deposition than the upper parts.
- The fly ash temperature is very high near the head of the front arch and upper parts of the rear arch. The fly ash in the fly gas will be molten and slugging can occur at locations with the high temperature. With the temperature decreasing, there is less ash deposition in the furnace wall.

References


Acknowledgements

The works are financially supported by Project: National Key R&D Program of China (grant number: 2018YFE0109600). We would like to express our sincere thanks to Ningbo Mingzhou municipal solid-waste-to-energy plant for their supports and helps.
ANALYSIS OF ANAEROBIC DIGESTION TECHNOLOGIES FOR THE TREATMENT OF ORGANIC FRACTION OF MUNICIPAL SOLID WASTE

F.B. Cordeiro, M.J.O.C. Guimarães, J.C. Campos

UFRJ, Federal University of Rio de Janeiro, Technology Center, School of Chemistry. 149 Av. Athos da Silveira Ramos, E206, 21941-909, Rio de Janeiro, Brazil.

Abstract: The main negative aspects of the landfills are, even with the systems of collection and flare of the biogas generated, a significant portion of the biogas is not extracted by these systems, being emitted into the atmosphere. Therefore, it is important to highlight the relevance and impact of decreasing the disposal of organic materials in landfills, associate with the need to find effective ways to manage the organic fraction of the municipal solid waste, which would contribute to reduce the greenhouse gas emissions, as well as to increase the lifespan of the landfills. In the present study, it is demonstrated the management of solid urban waste in Brazil, specifically in Rio de Janeiro city, and it was implemented a set of evaluation indicators in order to select the most suitable technology for the implementation of a solid urban waste treatment unit in the city of Rio de Janeiro.

Key words: Anaerobic digestion technologies, organic fraction, municipal solid waste, residues management.

1. Introduction

Although solid waste management in Brazil has historically been treated as a sanitary and public health issue, its management has only recently been understood as a cross-cutting theme, due to its potential relation with biogas projects aiming at the reduction of gas emissions greenhouse effect and generation of energy [1].

Methanisation and conversion of organic wastes into methane has been a worldwide technological alternative for the energetic valorization of the organic fraction of urban solid waste (OFUSW), having been successfully applied to different types of waste and effluents worldwide. Especially in European countries, the consolidation of this technology was necessarily accompanied by regulation of the markets associated with the generation of energy and income from organic waste and its by-products - biogas and bio-solid (agricultural or energy) - a crucial factor for this technology to be implemented and also consolidated in Brazil [1].

As a result, it is possible to highlight the importance of the decrease in the disposal of organic materials in landfills, culminating in the need to find effective ways to treat the organic fraction of Municipal Solid Waste (MSW), contributing both to the reduction of greenhouse gas emissions, as well as for an increase in the useful life of a landfill.

To evaluate the dry and extra dry anaerobic digestion technologies available for the treatment of OFUSW, using information from available technologies in the literature.

2. Methodology

Five biomethanisation technologies were evaluated, which were chosen because they were supplied by companies consolidated in the market, have a large number of plants built, proven experience in the development of projects of MSW treatment units, are trademarks solid and global players.

A group of indicators was used to evaluate the biomethanisation technologies. The weights of each indicator are decided based on the impact that would have on the MSW of Brazil, that is, according to the degree of importance that each indicator has when considering the implementation of a certain technology in the country. The data for the calculation of the indicators were obtained in the websites of the companies holding the technologies and in other publications.

- Indicator I1 - Total capacity of treating wastes;
- Indicator I2 - Average plant capacity;
- Indicator I3 - Representative in Brazil;
- Indicator I4 - Need for pre-treatment of waste
- Indicator I5 - Types of waste to be treated;
- Indicator I6 - Generation of effluents in the process that need treatment.

3. Results and Discussion

2.1. Municipal Solid Waste in Brazil – a overview

In Brazil, the population had a total MSW generation of almost 214,405 t a day in the country [2]. The amount of MSW collected in 2016, there was a slight improvement compared to the previous year in the collection coverage index, totaling 71.3 million tons or 91% for the country. In spite of this, it was evidenced that 7 million tons of waste were not collected and thus had an improper destination [2].

Regarding the final disposal, about 41.7 million tons of MSW collected went to landfills, while almost 30 million tons of MSW were inadequately disposed (as open dump sites) [2]. The practice of inadequate final disposal of MSW still occurs in all Brazilian regions and states, where there are 3,331 (59.8%) municipalities still making use of these sites [2].

2.2. Evaluation of Indicators

The extra dry technology of anaerobic waste digestion proved to be the best to be implemented in Brazil, the complexity of the urban solid waste management scenario in the Rio de Janeiro city indicates a favorable scenario for this application. As an example, there is the case of Methanisation at the EcoParque do Caju (located in Rio de Janeiro city), where a pilot project of an anaerobic extra dry digestion technology is being installed in methane tunnels.

4. Conclusions

An extra dry technology of anaerobic digestion presented the best result in the evaluation of the indicators of this work with a view to application in the Brazilian reality. This fact creates good expectations as to the results to be obtained in the methanisation pilot plant that is being implemented in the city of Rio de Janeiro, which will contribute both to the reduction of greenhouse gas emissions and to the increase in the life of the landfill. In addition, these results will serve as a basis for a better understanding of the characteristics of MSW in Brazil, which could contribute to the installation and scale up of new plants.

Acknowledgements

To Methanum Company.

References


1. INTRODUCTION

Although solid waste management in Brazil has historically been treated as a sanitary and public health issue, its management has only recently been understood as a cross-cutting theme, due to its potential relation with biogas projects aiming at the reduction of gas emissions greenhouse effect and generation of energy [7]. Methanisation and conversion of organic wastes into methane has been a worldwide technological alternative for the energetic valorization of the organic fraction of urban solid waste (OFUSW), having been successfully applied to different types of waste and effluents worldwide. Especially in European countries, the consolidation of this technology was necessarily accompanied by regulation of the markets associated with the generation of energy and income from organic waste and its by-products - biogas and bio-sold (agricultural or energy) - a crucial factor for this technology to be implemented and consolidated in Brazil [4].

As a result, it is possible to highlight the importance of the increase in the disposal of organic materials in landfills, culminating in the need to find effective ways to treat the organic fraction of Municipal Solid Waste (MSW), contributing both to the reduction of greenhouse gas emissions, as well as for an increase in the useful life of a landfill.

The objective of this work was to evaluate the dry and extra dry anaerobic digestion technologies available for the treatment of OFUSW, using information from available technologies in the literature.

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- Indicator I - Total capacity of treating wastes;
- Indicator II - Average plant capacity;
- Indicator III - Representatives in Brazil;
- Indicator IV - Need for pre-treatment of waste;
- Indicator V - Types of waste to be treated;
- Indicator VI - Generation of effluents in the process that need treatment.

- Each indicator was assigned a score between 0 and 1;
- 0 for the best condition, and 1 for the worst condition;
- For the Indicator, the result would be a number, the grades were calculated according to the best observed result.

3. RESULTS AND DISCUSSION

3.1 Municipal Solid Waste in Brazil – a overview

- In Brazil, the population had a total MSW generation of almost 214,405 t a day in the country [4].
- The amount of MSW collected in 2016, there was a slight improvement compared to the previous year in the collection coverage index, totaling 71.3 million tons or 91% for the country. Despite this, it was evidenced that 7 million tons of waste were not collected and thus had an improper destiny [4].
- Regarding the final disposal, about 41.7 million tons of MSW collected went to landfills, while almost 30 million tons of MSW were inadequately disposed (as open dump sites) [4]. The practice of inadequate final disposal of MSW will occur in all Brazilian regions and states, where there are 3,331 (59.8%) municipalities still making use of these sites [4].

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An extra dry technology of anaerobic digestion presented the best result in the evaluation of the indicators of this work with a view to application in the Brazilian reality. This fact creates good expectations as to the results to be obtained in the methanisation pilot plant that is being implemented in the city of Rio de Janeiro, which will contribute both to the reduction of greenhouse gas emissions and to the increase in the life of the landfill. In addition, these results will serve as a basis for a better understanding of the characteristics of MSW in Brazil, which could contribute to the installation and scale up of new plants.

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An extra dry technology of anaerobic digestion presented the best result in the evaluation of the indicators of this work with a view to application in the Brazilian reality. This fact creates good expectations as to the results to be obtained in the methanisation pilot plant that is being implemented in the city of Rio de Janeiro, which will contribute both to the reduction of greenhouse gas emissions and to the increase in the life of the landfill. In addition, these results will serve as a basis for a better understanding of the characteristics of MSW in Brazil, which could contribute to the installation and scale up of new plants.

REFERENCES


ACKNOWLEDGEMENTS

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ORGANIC COMPOSTS EFFECTS ON LETTUCE AND STRAWBERRY PRODUCTIVITY AND IN VIT.C AND PIGMENTS CONTENTS AS QUALITY PARAMETERS

A. Teixeira (1)*, C. Santos (2)*, J. Oliveira (2), S. Abreu (2), R. Oliveira (1,3,4), A. Cunha (1,3,4,5)

1: Department of Biology, University of Minho, Campus de Gualtar, 4710-057 Braga, Portugal.
2: Lipor, Baguim do Monte 4435-996 Porto, Portugal.
3: Centre for the Research and Technology of Agro-Environmental and Biological Sciences (CITAB), University of Minho, Campus de Gualtar, 4710-057 Braga, Portugal.
4: Centre of Biological Engineering (CEB), University of Minho, Campus de Gualtar, 4710-057 Braga, Portugal.
5: Centre of Molecular and Environmental Biology (CBMA), University of Minho, Campus de Gualtar, 4710-057 Braga, Portugal.

* First co-authors with equivalent participation in the present work

Abstract: Food wastes headed to landfills is still greater than desired and the long use of agrochemicals lead to agricultural and health problems. Composting could be a way of giving a new and valued purpose to those wastes paving the way to a more sustainable agriculture and global attitude towards resources (re)use. In this study, organic composts N and G in different concentrations were used to fertilize lettuce and strawberry in a field experiment. Statistical differences were found between treatments in tissue turgidity, photosynthetic pigments and anthocyanins content. Also, vitamin C have increased in lettuce with compost N (10 ton/ha) and in strawberry with compost G (5 ton/ha). Overall, the compost N showed better results at the lowest concentration tested, suggesting that for each crop optimizing the type and concentration of compost is important not only to improve productivity and quality but also to fine tune the amount of compost added to the soil.

Key words: Waste, organic composts, humic substances, composting, lettuce, strawberry.

1. Introduction

Society is very inefficient with respect to waste recycling and reuse, since a large part of the by-products and residues are discarded with negative environmental impacts, and only a fraction is channeled back to the economic system. According to Food and Agricultural Organization (FAO), 1/3 of all food produced ends up discarded [1]. In the specific case of European Union, in 2016, about 2.6 million tonnes of waste were produced [2]. These numbers clearly claim that waste use and management should be a priority. Composting could be an effective technique to increase sustainability in waste management and a way to string a link in the circular economy of the agrifood chain. The wasted food should be deviated from the landfills to composting centers, where the end product could help to fertilize agricultural fields [3]. Humic substances, present in composts, are highlighted as a valuable group of molecules, due to their effects on the physical, chemical and biological properties of the soil and plant fertilization [4]. In the context of this work, we evaluate the effect of two organic composts (G and N), widely used commercially, at 5 and 10 ton/ha, on the productivity and quality of strawberry (Fragaria ananassa var. San Andre-as) and lettuce (Lactuca sativa L.). Leaf area/number, number of stems, number/volume of fruits were used as indicators of crop productivity. At the end of the experiment, relative water content (RWC), photosynthetic pigments, vitamin C and fruit anthocyanins contents were also evaluated. Statistical analysis was performed running one-way ANOVA and Newman-Keuls post-tests using GraphPad Prism version 5.1 for Windows (GraphPad Software, La Jolla California USA, www.graphpad.com).

2. Results

Results obtained with lettuce (Table 1), show that the lowest concentration of compost N (5 ton/ha) induced the largest foliar area (171 ± 23.2 cm²), while N at 10 ton/ha exhibit more leaves per plant (24.3 ± 2.62) (data not shown). The RWC was higher in lettuce grown with compost N, but relatively to pigments it was compost G (at 5 ton/ha), the treatment where the highest content in carotenoids was observed. For vitamin C, however, no significant differences were detected (Table 1). In the case of strawberry, preliminary results show that plants grown with compost N (especially at 5 ton/ha) produced more fruits (data not shown) and bulkier (Figure 1.A). With respect to vitamin C concentration (Figure 1.B) strawberries produced with compost G exhibited higher contents of ascorbic acid (P = 0.0055), than those produced with compost N. Similarly, the content of anthocyanins (expressed in mg of cyanidin-3-O-β-glucoside equivalents, C3g) was higher on G (5 ton/ha) but also on N at 10 ton/ha (Figure 1.C). However, after a preliminary shelf-life test at different temperatures, strawberries grown with compost G presented earlier fungal contamination than those grown with N compost (data not shown).
Table 1. Effect of the compost G and N on the physiological and quality variations of lettuce (Lactuca sativa). Percentage of turgidity, content of total chlorophyll and carotenoids (µg/g FW) and the concentration of ascorbic acid (mg/g FW) were the analyzed parameters. Each value represents a mean of at least 3 measures ± SD. For each parameter and treatment, mean values with different letters are statistically different.

<table>
<thead>
<tr>
<th>Physiological parameters</th>
<th>G5 ton/ha</th>
<th>N5 ton/ha</th>
<th>N10 ton/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>RWC (%)</td>
<td>95.7 ± 0.68a</td>
<td>97.8 ± 1.05b</td>
<td>98.4 ± 1.06b</td>
</tr>
<tr>
<td>Chl total (µg/g FW)</td>
<td>1073 ± 300.2a</td>
<td>943.5 ± 114.5a</td>
<td>597.6 ± 159.7a</td>
</tr>
<tr>
<td>Carotenoids (µg/g FW)</td>
<td>267.4 ± 65.48a</td>
<td>232.2 ± 29.36b</td>
<td>143.27 ± 21.28b</td>
</tr>
</tbody>
</table>

Quality parameters

<table>
<thead>
<tr>
<th>Arcorbinic acid equivalents (mg/g FW)</th>
<th>G5 ton/ha</th>
<th>N5 ton/ha</th>
<th>N10 ton/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.233 ± 0.071</td>
<td>0.214 ± 0.052</td>
<td>0.239 ± 0.0382</td>
</tr>
</tbody>
</table>

Figure 1. Effect of the compost G and N on the physiological (A) and quality variations (B-C) of strawberry (Fragaria ananassa). Fruit volume (A), ascorbic acid equivalents (B) and cyanidin-3-O-β-glucoside equivalents (C) were the analyzed parameter. Each value represents a mean of at least 3 measures ± SD. For each parameter and treatment, mean values with different letters are statistically different.

3. Conclusions

Different composts result in significant differences in crop productivity and quality, what, at a larger scale, may result in large economic gains. Our results show that compost N, formed with urban domestic wastes, promote the best results, highlighting the potential of these kind of practices and the importance of involving the population in a global simple effort. Current studies are focused on specific properties of humic substances. Extracts enriched in humic acids and fulvic acids obtained from composts are being chemically characterized and antimicrobial tests are underway to evaluate their activity as biostimulants and biofertilizers.

Acknowledgements


References

ORGANIC COMPOSTS EFFECTS ON LETTUCE AND STRAWBERRY PRODUCTIVITY AND IN VIT. C AND PIGMENTS CONTENTS AS QUALITY PARAMETERS

A. Teixeira, T. C. Santos, G. J. Oliveira Jr., S. Abreu Jr., R. Oliveira, and A. Ciuha

1. Department of Biology, University of Minho, Campus de Gualtar, 4710-057 Braga, Portugal.
2. ICPAA, University of Minho, Campus de Gualtar, 4710-057 Braga, Portugal.
3. ICPAA, University of Minho, Campus de Gualtar, 4710-057 Braga, Portugal.
4. CTA, University of Minho, Campus de Gualtar, 4710-057 Braga, Portugal.
5. Centre for the Research and Technology of Agro-Environmental and Biological Sciences (CTAEB), University of Minho, Campus de Gualtar, 4710-057 Braga, Portugal.

INTRODUCTION

Society is very inefficient with respect to waste recycling and reuse. According to Food and Agricultural Organization (FAO), 1/3 of all food produced ends up discarded [1]. Composting could be an effective technique to increase sustainability in waste management and a way to string a link in the circular economy of the agri-food chain, where the end product could help to fertilize agricultural fields [2]. Humic substances, present in composts, are highlighted as a valuable group of molecules due to their effects on the physical, chemical and biological properties of the soil and plant fertilization [3].

In the context of this work, we evaluate the effect of two commercially widely used organic composts, G and N, on the productivity and quality of strawberry and lettuce.

MATERIAL AND METHODS

Plant material, composts and field trial: Fragaria ananassa (strawberry, var. San Andreas) and Lactuca sativa (lettuce, var. wonder of the 4 seasons) were planted in soils with compost G and N at 5 and 10 ton/ha and followed for 7 weeks (Figure 1).

Measured parameters:

Leaf area, number and number/volume of fruits were measured as indicators of productivity parameters and only the results for the last week of the experiment are represented.

At the end of the experiment, physiological parameters (relative water content [4] - RWC - and photosynthetic pigments concentration [5]) were measured. Additionally, quality parameters, such as vitamin C [6], anthocyanins content [7] and strawberry shelf-life were also evaluated.

RESULTS

Results obtained with lettuce (Table 1), show that N 5 ton/ha induced the largest fertilizer area (171 ± 23.2 cm²), while N 10 ton/ha exhibit more leaves per plant (24.3 ± 2.62). The RWC was higher in lettuce grown with compost N, but concerning pigments, it was compost G the treatment where the highest content in carotenoids was observed. In the case of strawberry (Figure 2), plants grown with compost N (especially at 5 ton/ha) produced more fruits (data not shown) although no significant differences were observed with respect to their volume (5 ft ton/ha: 9.98 cm³; N 5 ton/ha: 11.5 cm³; N 10 ton/ha: 11.1 cm³: Figure 2A).

Table 1. Effect of the compost G and N on the productivity, physiological and quality variations of lettuce. Each value represents a mean of at least 3 measures ± 1 SD. For each parameter, mean values with different letters are statistically different.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>G 5 ton/ha</th>
<th>N 5 ton/ha</th>
<th>N 10 ton/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productivity parameters</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fertilizer area (cm²)</td>
<td>116.2 ± 25.7a</td>
<td>171 ± 23.2b</td>
<td>149.4 ± 16.2a</td>
</tr>
<tr>
<td>Number of leaves</td>
<td>21 ± 4.08b</td>
<td>22.3 ± 3.79b</td>
<td>24.3 ± 2.63b</td>
</tr>
<tr>
<td>Photosynthetic parameters</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chlorophyll (µg/g FW)</td>
<td>1071 ± 360a</td>
<td>943 ± 114.5b</td>
<td>597 ± 159.2a</td>
</tr>
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<td>Carotenoids (µg/g FW)</td>
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<tr>
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<td></td>
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<tr>
<td>Ascorbic acid equivalents (mg/g FW)</td>
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<td>0.239 ± 0.0382a</td>
</tr>
</tbody>
</table>
INFLUENCE OF WASTE PICKER ORGANIZATIONS AND SELECTIVE WASTE COLLECTION ON SUSTAINABILITY INDICATORS

J.L.N. Zon (1), C.J. Leopoldino (1), W.M.R. Günther (2), G.R. Besen (2), L.H. Yamane (1), R.R. Siman (1)

1: Department of Environmental Engineering, Technological Center / Federal University of Espírito Santo, Fernando Ferrari Avenue 514, 29075-910, Vitória, Brazil.
2: Department of Environmental Health, Faculty of Public Health / University of São Paulo, Av. Dr. Arnaldo, 715 - 01246-904, São Paulo, Brazil.

Abstract: In order to meet the requirements of the Brazilian National Policy on Solid Waste, in addition to the need to know the factors that interfere in the development of selective waste collection and the waste picker organizations, it becomes important to understand the correlation between these factors, both with each other and with the environment in which are inserted. In this sense, this paper evaluates the selective waste collection programs and municipal waste picker organizations in the state of Espírito Santo, Brazil, in relation to sustainability indicators and their correlations. To that end, 24 municipalities were selected, evaluated by their selective waste collection programs, and 23 waste picker organizations, on which questionnaires were applied to obtain the necessary data for the calculation of the indicators of sustainability. Statistical analyses were used to identify the correlation between the Indicators of Sustainability and correlation analyzes were applied to study the normality distribution.

Key words: Indicators of Sustainability, Selective Waste Collection, Waste Picker Organizations.

1. Introduction

In Brazil, with the approval of the National Policy on Solid Waste (NPSW), instituted by Federal Law No. 12,305 of 2010, the municipalities are obliged to implement and improve the selective waste collection (SWC) with integration of waste picker organizations (WPO) into the Integrated Solid Waste Management (ISWM) municipal systems [1], but the inclusion of recyclable waste pickers in the selective waste collection is not, in fact, integrated with the ISWM. Thus, while in theory legislation supports waste picker organizations and promotes reuse and recycling as a sustainable solution for waste, in practice many challenges still need to be overcome [2]. Municipalities, in general, face technical and administrative difficulties to perform selective waste collection in a universal and efficient way, as well as to relate to RMPOs as service providers [3].

In this sense, Dias [4] emphasizes that, with the lack of consistent information about the performance of selective waste collection with waste pickers, waste management is compromised, limiting the possibilities of social inclusion. Therefore, the use of sustainability indicators as a tool for planning, monitoring and evaluation contributes to the performance of selective waste collection and WPO programs towards sustainability.

Additionally, knowledge about the factors that interfere in the development of the selective waste collection and the waste picker organizations, it becomes important to understand the correlation between these factors, both among themselves and with the environment in which they are inserted. This knowledge can aid in the decision-making processes for the application of public policies aiming at the improvement of services related to waste.

2. Material and Methods

This research analyzed 24 municipal selective waste collection programs and 23 WPO using sustainability indicators in order to understand the performance of municipal SWC programs and WPO in relation to sustainability. For this, 10 Indicators of Sustainability of the Selective Collection (ISSC) and 16 Indicators of Sustainability of the Organizations of Collectors (ISOC) were analyzed using descriptive statistics. For that, means and frequencies were calculated to analyze the value of each of the indicators in relation to sustainability.

In order to identify the correlation between different aspects pertinent to the development of the SWC and the WPO, statistical analyzes of the peer-to-peer correlation between the data (Sustainability Indicators, time of existence of the WPO and size of the municipalities) were carried out together with the construction of graphs obtaining correlation coefficients. For the application of the correlation analyzes, the normality of the quantitative data was previously verified through the Shapiro-Wilk statistical test. For the samples that presented a Normal distribution, the Pearson correlation was used and for the Sustainability Indicators that did not present a normal distribution, the Spearman correlation was used. Statistical tests were performed at a significance level of 5% with the aid of the free software PAST.
3. Results and discussion

ISSC analysis: among the 24 selective waste collection programs surveyed, it was observed that 58% of the municipalities presented "very favorable" results regarding sustainability for the indicator "legal instruments in the relation of the city with service providers of selective waste collection". This result can be explained by the fact that the contract for the provision of the service is an indispensable item since it offers security to the city hall as contractor of the services. The other ISSCs did not obtain "very favorable" results in relation to sustainability.

ISOC analysis: among the 23 RMPOs studied, "favorable results" were observed in terms of sustainability for the indicators "regularization of the organization" (83%), "self-management" (74%), "training of the organization" (57%) and "tailings rate" (52%). For these four Indicators of Sustainability, the satisfactory results observed are due to the fact that the State government offered to the WPO of the ES, through Aderes, when they were in the structuring phase, besides the support that the local governments also grant to the RMPO. Still, "very favorable" results were observed in 78% of WPO in relation to the "gender ratio" indicator and in 48% of WPO in relation to "turnover". The satisfactory results for these two indicators are related to the organizational issues that are developed in the work practice and through training. The other ISOCs, however, did not obtain "very favorable" results in relation to sustainability.

Correlation analyzes: the results of moderate direct correlation and information from the literature showed that the average income of the members of the organizations (Socioeconomic aspect) and that the working conditions, health and safety tend to influence the rotation (Organizational aspect). The literature also indicated other influencing factors, such as sex and age of the associates. It was highlighted that, despite these factors, a great determinant for the permanence of the pickers in the organizations is the difficulty of finding another better job. Direct moderate correlation of indicators of diversification and quality of WPO partnerships (Institutional aspect) with the environmental conditions of work within the sorting centers were observed, and moderate direct relations of the training indicators of the WPO (Organizational aspect) with the conditions of work in the collection of dry waste and with health and safety conditions. Infrastructure deficiency was highlighted as a limiting factor for improving working conditions. It was highlighted the relevance of external support in the expansion of the niches of activities of the organizations when verifying correlations between the quality indicator of the partnerships, which represents the contribution made possible by the partners, and the indicator of diversification of activities and services performed (Organizational aspect). The correlations among the legal aspects of organizations have indicated that the more regularized the organization, the greater the fulfillment of the requirements for its hiring. In the evaluation of the influence of the aspects that influence the average income of the associated collectors and the efficiency of the selective waste collection and of the WPO, the expected correlations were not statistically verified. For productivity, there were no correlations with training and self-management data.

4. Conclusions

Despite the efforts made to implement selective waste collection programs and to structure WPO after the establishment of NPSW, municipalities still face several difficulties regarding the integrated management of solid waste. The present research showed that the municipalities of the Espírito Santo, Brazil, need to improve the management of solid waste, especially with regard to selective waste collection and recycling. The results indicated the intercorrelation between socioeconomic, organizational, legal, institutional and working conditions, health and safety, through the verification of moderate correlations, indicating, however, the existence of external influencing factors. For some analyzes, the existence of correlation was not statistically verified, although the literature presents a contrary idea. Despite the internal correlations between the aspects, the study highlighted crucial factors in the evolution of the selective waste collection systems integrated to the WPO: existence of a market for recyclables, system coverage and access to marketable waste

References


Influence of Waste Picker Organizations and Selective Waste Collection on Sustainability Indicators

Jéssica L.N. Zon\(^{a}\), Chaila J. Leopoldino\(^{a}\), Wanda M.R. Günther\(^{a}\), Gina R. Besen\(^{a}\), Luciana H. Yamane\(^{a}\), Renato S. Siman\(^{a}\)

\(^{a}\) Department of Environmental Engineering, Technological Center / Federal University of Espirito Santo, Fernando Ferrari Avenue 213, 29070-910, Vitória, Brazil.

\(^{b}\) Department of Environmental Health, Faculty of Public Health / University of São Paulo, Av. Dr. Arnaldo, 715 – 01248-906, São Paulo, Brazil.

Abstract

In Brazil, the National Policy on Solid Waste (NPWS), instituted by Federal Law no. 12.953 of 2013, the municipalities are obliged to implement and improve the selective waste collection (SWC) with integration of waste picker organizations (WPO) into the Integrated Solid Waste Management (ISMW) municipal systems [1], but the inclusion of recyclable waste pickers in the waste collection service is not in line with the ISWM. Thus, while in theory, legislation supports waste picker organizations and promotes reuse and recycling as a sustainable solution for waste, in practice many challenges still need to be overcome [2].

Introduction

In Brazil, the National Policy on Solid Waste (NPWS), instituted by Federal Law no. 12.953 of 2013, the municipalities are obliged to implement and improve the selective waste collection (SWC) with integration of waste picker organizations (WPO) into the Integrated Solid Waste Management (ISMW) municipal systems [1], but the inclusion of recyclable waste pickers in the waste collection service is not in line with the ISWM. Thus, while in theory, legislation supports waste picker organizations and promotes reuse and recycling as a sustainable solution for waste, in practice many challenges still need to be overcome [2].

Results and discussion

Analysis of Indicators of Sustainability of the Selective Collection (ISCC)

Among the 24 selective waste collection programs surveyed, it was observed that 58% of the municipalities presented “very favorable” results regarding sustainability for the indicator “legal instruments in the region of the city with sanitary guidelines to selective waste collection”.

This result can be explained by the fact that the contract for the provision of the service is an indispensable item since it offers security to the city hall as contractor of the services. The other ISCC did not obtain “very favorable” results in relation to sustainability.

Materials and methods

This research analyzed 24 municipal selective waste collection programs and 23 WPO using sustainability indicators in order to understand the performance of municipal SWC programs and WPO in relation to sustainability. For this, 20 Indicators of Sustainability of the Selective Collection (ISCC) (Table 1) and 2 indicators of Sustainability of the Organization of collection (ISOC) (Table 2) were analyzed using descriptive statistics. For that, mean and frequencies were calculated to analyze the value of each indicator in relation to sustainability.

In order to identify the correlation between different aspects relating to the development of the SWC and the WPO, statistical analyses of the pair-to-pair correlation between the data (Sustainability indicators, times of existence of the WPO and size of the municipalities) were carried out together with the creation of graphics obtaining correlation coefficients.

For the application of the correlation analysis, the normity of the quantile data was previously verified through the Shapiro-Wilk statistical test. For the samples that presented a normal distribution, the Pearson correlation was used and for the Sustainability indicators that did not present a normal distribution, the Spearman correlation was used. Statistical tests were performed at a significance level of 5% with the aid of the software R.ES.

Analysis of Indicators of Sustainability of the Organizations of Collection (ISOC)

Among the 23 WPO studied, “favourable” results were observed in terms of sustainability for the indicators “regularization of the organization” (RISYS) and “self-management” (RISYS), “training of the organization” (RISYS) and “training of the collectors” (RISYS).

For the five indicators of sustainability, the satisfactory results obtained were due to the fact that the State of Espírito Santo implemented a strategy called “Training Kit” through Advocacy, when they were in the outreach phase. Moreover, the support that the local governments also grant to the WPO, SLP, “very favorable” results could have been observed in 78% of WPO in relation to the “gender ratio” indicator and in 48% of WPO in relation to “hours per week”.

The satisfactory results for those two indicators are related to the organizational issue that are developed in the same process and through training. The other ISOC, however, did not obtain “very favorable” results in response to sustainability.

Correlation analysis

The results of moderate direct correlation and information from the literature showed that the average score of the members of the organization (Socioeconomic aspect) and that the working conditions, health and safety (WPS) influenced the retention (Organizational aspect).

The literature also indicated other influencing factors, such as the age and size of the association. It was highlighted that, despite these factors, a great determinant for the permanence of the pickers in the organization is the difficulty of finding another better job.

Direct moderate correlation of indicators of diversification and quality of WPO partnerships (Organizational aspect) with the environmental conditions of work, the working conditions, direct and indirect relations of the training indicators of the WPO (Organizational aspect) with the conditions of work in the collection of SWC and with health and safety conditions (Infrastructure deficiency was highlighted as a limiting factor for improving working conditions).

It was highlighted the relevance of external support in the expansion of the range of activities of the organization when verifying correlations between the quality indicator of the partnerships, which represent the contribution made possible by the authorities, and the indicator of diversification of activities and services performed (Organizational aspect).

The correlations among the legal aspects of organization have indicated that the more regulated the organization, the greater the fulfillment of the requirements, for both, in the evaluation of the influence of the aspects of the average income of the associated collectors and the influence of the selective waste collection and of the WPO. The expected correlations were not statistically verified. For productivity, there were no correlations with training and self-management data.

Conclusions

Despite the efforts made to implement selective waste collection programs and to structure WPO after the establishment of NPWS, municipalities still face several difficulties regarding the integrated management of solid waste.

The present research showed that the municipalities of the Espirito Santo, Brazil, need to improve the management of solid waste, especially with regard to selective waste collection and recycling.

The results indicated the interrelation between socioeconomic, environmental, legal, institutional and working conditions, health and safety, through the verification of moderate correlations. Inflating, however, the existence of external influencing factors. For some analyses, the existence of correlation was not statistically verified, although the literature presents a considerable correlation.

Despite the internal correlations between the aspects, the study highlighted crucial factors in the adoption of the selective waste collection systems integrated to the WPO existence for a market of recyclables, system coverage and access to marketable waste.

References

FEASIBILITY STUDY ON MOBILE SORTING AND COMPOSTING FACILITY

Y. Yakubu1; R. T. Bekai1,3; G. Atakorah2; E. K. Addae4,5

1Africa Environmental Sanitation Consult.
2Department of Geography and Resources Development, University of Ghana, Accra.
3Institute of Distance Learning, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.
4Department of Marketing, University of Professional Studies (UPSA), Accra, Ghana
5Zoomlion Ghana Limited, Jospong Group of Companies, Head Office, Ghana.

Abstract
The mobile sorting and composting facility at the Korle Lagoon Ecological Restoration (KLERP) area of Accra is adjacent to Korlebu Mortuary. Upon completion the facility has the capacity of processing 200 tons of waste every 8 hours. The plant is intended to have two production lines each processing 200 tons /per 8 hours shift, thus processing 800 tons of waste daily per 2 shifts. The estimated population within 5000 meters radius of the facility is 1,094,994. Total estimated waste generated by this population is approximately 809.4 tons a day. This will enable the facility to run its planned two production lines daily at maximum capacity. It was observed that, motorized tricycles users prioritize quicker discharge turnaround time over the long distance traveled to discharge waste. Since the facility is located at the heart of town, it will increase its patronage by waste collectors within the 5000 meters radius of the facility. It is expected that they will take advantage of the shorter distance and travel time as well as quick turnaround time. Since Ghana like most African countries are faced with regular power outages, the various compartments of the mobile compositing plant have separate power generating units that will facilitate continues operations without reliance on the erratic power supply from the national grid.

Keywords: Material Recovery; Composting, ArcGIS, Solid Waste; Buffer Zone; Turnaround Time.

Introduction
The mobile sorting and composting facility at the Korle Lagoon Ecological Restoration area of Accra is adjacent to Korlebu Mortuary. The physical structure is under construction and components of the mobile composting plant have been delivered to the site. One operating line of the mobile composting plant has the capacity to process 200 tons of waste daily within 8 hours of operations. Since the location of the plant is pre-determined based on availability of land, the study seeks is to assess communities whose waste can be discharged daily at the plant and the effectiveness and efficiency of the plant. The plant is intended to have two production lines, each processing 200 tons /per 8 hours, thus processing 800 tons of waste daily on 2 shifts. Various compartments of the mobile composting plant have separate power generating systems to facilitate continued operation without reliance on the erratic power supply from the national grid.
**Method**

The ArcGIS software was applied in the area up to 5 kilometers radius to capture communities that may have their waste sent there and the transit population that will also be received on daily base. This was followed by a key informant interview conducted with an official from the Accra Metropolitan Assembly (AMA) waste management department, within which’s jurisdiction the facility is to sited. The population data for all the communities with the buffer zone was also obtained from the AMA to enable the estimation of the daily waste generation from them.

**Conclusion**

From this study, it was clear that the facility will be able to handle the waste generated from the buffer zone on daily basis. This will reduce the turnaround time for waste collected and reduce their daily cost of operations, since much of the cost is associated with transportation and collection. Since, the facility will also recover most fractions of the waste, such as plastics, metals, textile, leather, organics, and paper among others, it is an ideal way of secondary material recovery from solid waste. Furthermore, the recovery and utilization of the organics for compost will reduce the negative impact of the waste on the environment through the reduction in greenhouse gases such as methane and carbon dioxide among others. Not all, the compost will serve as a source of important plant nutrients and soil amendment material.
ABSTRACT
The Integrated Recycling and Compost Plant (IReCoP) is a mobile sorting and composting facility located at the Korle Lagoon Ecological Restoration Project (KLERP) area of Accra, Ghana. Upon completion, the facility is expected to have a processing capacity of 200 tons of municipal solid waste (MSW) per each line installed for each 8 hours shift. The plant is intended to have two production lines with each processing 200 tons /per 8 hours shift, thus processing 800 tons of waste daily per 2 shifts. The estimated population within 5,000 meters radius of the facility is 1,094,994. Total estimated waste generated by this population is approximately 809.4 tons a day. This means that it can handle all this generated waste, the facility has to run its planned two production lines daily at maximum capacity. It was observed that, motorized tricycle users prioritize quicker discharge turnaround time over the long distance travelled to discharge waste. Since the facility is located at the heart of town, its patronage by waste collectors within the 5,000 meters radius will be high. It is expected that MSW management operators will take advantage of the shorter distance and travel time as well as quick turnaround time. Since Ghana like most African countries is faced with regular power outages, the various compartments of the mobile composting plant have separate power generating units that will facilitate continued operations without reliance on the erratic power supply from the national grid.

Keywords: Municipal Solid Waste; Material Recovery; Composting; ArcGIS.

INTRODUCTION
Many cities around the world are experiencing competing demands for land space for landfill sites. Accra, the capital city of Ghana has over the years faced either resistance for the establishment of landfill sites or is unable to obtain land for the same reason. Existing landfills are also overflowing or completely inaccessible due fire outbreaks. These have prompted many calls for disposal of waste from landfills by recovering useful material for reuse and recycling.

Zoomlion Ghana Limited - the largest waste management company in Ghana, in 2018 responded to these calls by establishment an additionally material recovery and composting facility in the country, located in the capital city - Accra. The company hopes it will among others contribute to efforts at achieving the circular economy goals in Ghana and beyond.

The Integrated Recycling and Compost Plant (IReCoP) is located at the Korle Lagoon Ecological Restoration area of Accra in Ghana. The physical structure is under construction and components of the mobile composting plant have been delivered to the site.

One operating line of the mobile composting plant has the capacity to process 200 tons of waste daily within 8 hours of operations. Since the location of the plant is pre-determined based on availability of land, the study seeks to assess communities whose waste can be discharged daily at the plant and the effectiveness and efficiency of the plant. The plant is intended to have two production lines, each processing 200 tons /per 8 hours, thus processing 800 tons of waste daily on 2 shifts. Various compartments of the mobile composting plant have separate power generating systems to facilitate continued operation without reliance on the unpredictable power supply from the national grid.

METHOD
The ArcGIS software was applied in the area up to 5 kilometers radius to capture communities that may have their waste sent there and that of the transit population that will also be received on daily basis. This was followed by a key informant interview conducted with an official from the Accra Metropolitan Assembly (AMA) waste management department, within which jurisdiction the facility is sited. The population data for all the communities within the buffer zone was also obtained from the AMA to enable the estimation of the daily waste generation from the anticipated coverage area.

CONCLUSION
From this study, it was clear that the facility will be able to handle the waste generated from an estimated radius of 5 kilometers on daily basis. This will reduce the turnaround time for waste collected and reduce the daily cost of operations, since much of the cost is associated with transportation and collection. Furthermore, the facility will also recover most fractions of the waste, such as plastics, metals, textile, leather, organics, and paper among others. This will serve as an ideal way of secondary material recovery from solid waste. Additionally, the recovery and utilization of the organics for compost will reduce the negative impact of the waste on the environment through the reduction in greenhouse gases such as methane and carbon dioxide among others. Not all, the compost will serve as a source of important plant nutrients and soil amendment material.
INVESTIGATION ON CHARACTERISTICS OF SLUDGE GENERATED IN THE PRIMARY TREATMENT OF LANDFILL LEACHATE


1: UFRJ, Federal University of Rio de Janeiro, Technology Center, School of Chemistry. 149 Av. Athos da Silveira Ramos, E206, 21941-909, Rio de Janeiro, Brazil.
3: UERJ, University of Rio de Janeiro State, 524 São Francisco Xavier Street, room 5029-F. 20550-900, Rio de Janeiro, Brazil

Abstract: This work aimed to evaluate the production of sludge in primary treatments of landfill leachate. Coagulation-flocculation assays were performed using the coagulants calcium oxide (lime), ferric chloride and aluminum sulphate in leachates from the landfills Seropédica and Gericinó, both located in Rio de Janeiro state. To evaluate the treatments efficiency, Chemical Oxygen Demand (COD), Total Oxygen Carbon (TOC), true color, absorbance at 254 nm (ABS) and conductivity were monitored in leachates. The volume, moisture and volatile material present in sludge were measured after each treatment. The resulting sludge, in all cases, was classified as non-hazardous waste. All the evaluated coagulants presented advantages and disadvantages in the leachate treatment of the landfills studied. However, the use of lime presented the best removal of the pollutant per volume of sludge produced ratio, since it was the coagulant that generated the lower volume of sludge for the same range of removal observed.

Key words: Aluminum sulphate, Coagulation-flocculation, Ferric chloride, Landfill leachate, Lime, Sludge.

1. Introduction

Treatment of landfill leachate generally requires chemical-physical pre-treatments in order to reach better biological treatability [1]. Coagulation-flocculation may be used successfully in treating stabilized and old landfill leachates. It is widely used as a pre-treatment, prior to biological or membrane step, or as a final polishing treatment step in order to remove non-biodegradable organic matter [2].

Several studies have been reported on the examination of coagulation-flocculation for the treatment of landfill leachates, aiming at process optimization, selection of the most appropriate coagulant, identification of optimum experimental conditions and assessment of pH effect. However, this treatment presents some disadvantages, such as consistent sludge volume is produced.

Sludges are residue from leachate treatment processes. Hence, all insoluble or absorbed impurities in leachates will be accumulated in sludge as contaminants. The coagulation-flocculation process in leachate treatment produces alum, ferrous or lime sludge that is principally inorganic matrix with sand particles and coagulants [3]. However, the research regarding the sludge generated and its destination is still very scarce. Thus, this work aims to contribute to the lack of research in the evaluation of sludge generated by coagulation-flocculation using the most common inorganic coagulants in the treatment of landfill leachate.

In this context, the objective of the present study is, therefore, to evaluate the production of sludge in primary treatments of landfill leachate. Coagulation-flocculation assays were performed using the coagulants calcium oxide (lime), ferric chloride and aluminum sulphate in leachates from Seropédica and Gericinó landfills, both located in the state of Rio de Janeiro.

2. Methodology

Jar tests were conducted to determine the optimum operating conditions of treatment. Coagulation-flocculation assays were performed using the coagulants calcium oxide (lime), ferric chloride and aluminum sulphate. After the coagulant had been added, coagulation was achieved by rapid mixing (150 rpm) for 1 min followed by slow mixing (30 rpm) for 20 min. The suspension was then allowed to settle for 120 min.

At the end of the sedimentation step, the volume of the sludge was measured and the clarified was collected to analyze the parameters COD (Chemical Oxygen Demand), Conductivity, Absorbance at 254 nm, True Color and TOC (Total Organic Carbon). Exception for conductivity, which was only monitored in the calcium oxide tests. The sedimentation time was high to guarantee an efficient sedimentation and to avoid possible turbidity interferences in the analysis of the parameters analyzed.
3. Results and Discussion

Table 1 summarizes the results obtained in coagulation/flocculation experiments.

Table 1. Results obtained in the operating conditions chosen for the sludge classification tests.

<table>
<thead>
<tr>
<th>Leachate</th>
<th>Coagulants</th>
<th>Vol. Sludge per Leachate (mL L⁻¹)</th>
<th>Sludge Vol. Rem. COD (%)</th>
<th>Removal Color (%)</th>
<th>Removal TOC (%)</th>
<th>Sludge moisture (%)</th>
<th>Sludge volatile (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seropédica</td>
<td>Lime (16 g L⁻¹)</td>
<td>163</td>
<td>41</td>
<td>72</td>
<td>36</td>
<td>77</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Aluminum sulphate (3.0 g L⁻¹; pH = 6)</td>
<td>382</td>
<td>46</td>
<td>88</td>
<td>19</td>
<td>97</td>
<td>52</td>
</tr>
<tr>
<td></td>
<td>Ferric chloride (3.0 g L⁻¹; pH = 6)</td>
<td>502</td>
<td>64</td>
<td>76</td>
<td>45</td>
<td>97</td>
<td>39</td>
</tr>
<tr>
<td>Gericinó</td>
<td>Lime (12 g L⁻¹)</td>
<td>105</td>
<td>53</td>
<td>92</td>
<td>56</td>
<td>79</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Aluminum sulphate (3.0 g L⁻¹; pH = 6)</td>
<td>300</td>
<td>44</td>
<td>88</td>
<td>58</td>
<td>98</td>
<td>54</td>
</tr>
<tr>
<td></td>
<td>Ferric chloride (3.0 g L⁻¹; pH = 6)</td>
<td>360</td>
<td>49</td>
<td>90</td>
<td>70</td>
<td>98</td>
<td>48</td>
</tr>
</tbody>
</table>

It was observed a greater removal of COD when ferric chloride is used in both leachates. However, it was also the coagulant that presented the largest generation of sludge, mainly in the leachate of Seropédica. In the Gericinó leachate, the formation of sludge using FeCl₃ was close to that of the Al₂(SO₄)₃ experiments. For removals in the range of 40 to 60% COD, lime was efficient and with less sludge generation among the three coagulants. Only experiments using ferric chloride achieved removals above 60%. The highest COD removal in the Gericinó leachate was 75%, with formation of 270 mL of sludge per L treated leachate to the concentration of 5.0 g FeCl₃ L⁻¹. For the leachate of Seropédica, the highest removal was 68% for the concentration of 5.5 g FeCl₃ L⁻¹ and formation of 392 mL of sludge L⁻¹ of treated leachate.

After lixiviation experiments and assuming that the samples did not present flammability, corrosivity, reactivity and pathogenicity characteristics, the sludge generated was classified as non-hazardous waste.

4. Conclusions

The use of ferric chloride promoted the greater removal of organic matter (COD and TOC) in both leachates. However, FeCl₃ was the coagulant that generated the largest volume of sludge, reaching 360 mL sludge per L of treated Gericinó leachate and 502 mL sludge per L of treated Seropédica leachate. Lime was the coagulant that generated less amount of sludge in both leachates. In the leachate of Gericinó generated 136 mL sludge per L of treated leachate and for Seropédica leachate, 186 mL of sludge per L of treated leachate.

The generated sludge was classified as non-hazardous waste (class II) for sludge generated in FeCl₃ and lime treatments. Hence, they can be disposed directly on the site of the municipal solid waste landfill.

References

1. INTRODUCTION

Treatement of landfill leachates generally requires chemical-physical pre-treatments. Coagulation-flocculation (C-F) may be used successfully in treating stabilized and old landfill leachates. It is widely used as a pre-treatment; prior to biological or membrane steps, or as a final polishing treatment step in order to remove non-biodegradable organic matter. However, this treatment presents some drawbacks, such as consistent sludge volume produced.

This work aimed to evaluate the production of sludge in primary treatments of landfill leachates. C-F assays were performed using the coagulants calcium oxide (lime), ferric chloride and aluminum sulphate in leachates from the landfills Seropédica and Gericinó, both located in Rio de Janeiro State.

2. MATERIALS AND METHODS

2.1 Leachate Characterization

The characterization of the leachate was based on the following parameters and methods recommended by American Public Health Association: potential of hydrogen (pH), Total Organic Carbon - TOC (5310-C), Chemical Oxygen Demand - COD (5220-D), conductivity, true color and absorbance at 254 nm (5810-B), it provides an indication of the content of aromatic organic matter and humic substances (APHA, 2012).

2.2 Coagulation-Flocculation

Jar tests were conducted to determine the optimum operating conditions of treatment. The sludge was collected and were placed in the oven at 105 °C until constant weight to determine the moisture content. Afterwards, they were placed in the muffle at 550 °C to determine the volatile solids content (APHA, 2012).

2.3 Sludge

According to Brazilian legislation (ABNT-NBR 10004, 2004) is defined as solid waste, residues in solid and semi-solid states, which due to its danger can be classified into two main classes:

- Class I Waste - Hazardous;
- Waste Class II - Non-Hazardous, this subdivided into two classes: Class IIa- Inert Waste and Class IIb - Non-Inert Waste.

The toxicity potential was verified by analyzing the leached extract of the solid residue obtained according to the procedure established by ABNT NBR 10005:2004. The inorganic parameters (arsenic, barium, cadmium, lead, chromium, mercury, silver and selenium) were analyzed according to Annex F of the ABNT NBR 10004:2004. The sludge generated under the optimized treatment conditions for two coagulants that presented best performances was analyzed.

3. RESULTS AND DISCUSSION

3.1 Leachate characterization

Characterization of the leachate from the Seropédica and Gericinó landfills.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Seropédica leachate</th>
<th>Gericinó leachate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample</td>
<td>Sample</td>
<td>Sample</td>
</tr>
<tr>
<td>pH</td>
<td>7.0425</td>
<td>7.5325</td>
</tr>
<tr>
<td>TOC (mg L⁻¹)</td>
<td>5.7536</td>
<td>5.7536</td>
</tr>
<tr>
<td>COD (mg L⁻¹)</td>
<td>0.8278</td>
<td>0.8278</td>
</tr>
<tr>
<td>Conductivity (μs/cm)</td>
<td>15.31</td>
<td>15.31</td>
</tr>
<tr>
<td>True color (mg P2O5/ L⁻¹)</td>
<td>7.86</td>
<td>7.86</td>
</tr>
<tr>
<td>Abs 254 nm</td>
<td>0.3880</td>
<td>0.3880</td>
</tr>
</tbody>
</table>

- The leachate samples were slightly alkaline pH (7+) with a dark color;
- High concentration of organic matter present in both the raw leachate.

3.2 Coagulation-Flocculation

In view of the established criteria, the conditions chosen for each coagulant were:

- Aluminum Sulphate: pH 6.0 and 3.0 g Al₂(SO₄)₃ L⁻¹, for both leachates.
- Ferric Chloride: pH 6.0 and 3.5 g FeCl₃ L⁻¹, for both leachates.
- Calcium Oxide: 12 g CaO L⁻¹ in Seropédica leachate and 16 g CaO L⁻¹ in Gericinó leachate.

<table>
<thead>
<tr>
<th>Coagulant</th>
<th>pH</th>
<th>FeCl₃ (g L⁻¹)</th>
<th>Al₂(SO₄)₃ (g L⁻¹)</th>
<th>Lime (g L⁻¹)</th>
<th>Sedimentation (%)</th>
<th>Sludge volume (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gericinó leachate</td>
<td>6.0</td>
<td>3.0</td>
<td>12</td>
<td>12</td>
<td>99</td>
<td>99</td>
</tr>
<tr>
<td>Seropédica leachate</td>
<td>6.0</td>
<td>3.0</td>
<td>10</td>
<td>10</td>
<td>99</td>
<td>99</td>
</tr>
</tbody>
</table>

3.3 Sludge

The use of ferric chloride promoted the greater removal of organic matter (COD and TOC) in both leachates. However, FeCl₃ was the coagulant that generated the largest volume of sludge;
- Lime was the coagulant that generated less amount of sludge in both leachates;
- The generated sludge was classified as non-hazardous waste (class II) for sludge generated in FeCl₃ and lime treatments.

4. CONCLUSIONS

- The use of ferric chloride promoted the greater removal of organic matter (COD and TOC) in both leachates. However, FeCl₃ was the coagulant that generated the largest volume of sludge;
- Lime was the coagulant that generated less amount of sludge in both leachates;
- The generated sludge was classified as non-hazardous waste (class II) for sludge generated in FeCl₃ and lime treatments.

REFERENCES


ACKNOWLEDGEMENTS

This work was supported by the Brazilian National Council for Scientific and Technological Development (CNPq) and Foundation for Research Support of the State of Rio de Janeiro (FAPERJ) (#202/203/2018). The authors would like to thank Municipal Urban Cleaning Company (COMLURB) - Rio de Janeiro city, for sending samples of leachates.
INFLUENCE OF INPUT STREAMS ON THE CDW RECYCLING PERFORMANCE OF ADVANCED TREATMENT PLANTS

B. Galán, J. Viguri, E. Dosal, E. Cifrian, A. Andres

Chemical and Resource and Process Engineering Department, Cantabria University, Avda. Los Castros s/n. Santander.

Abstract: Several complicated issues need to be analysed using technological, management, environmental and social criteria in order to avoid to throw away still usable resources such as construction and demolition waste (CDW). Four different scenarios with the combination of two different segregation levels and two homogeneity grade of CDW were analysed in this work and an advanced recycling plant was used to recover the valuable materials from different type of inlet CDW streams. Mass flow analysis was carried out to obtain the quantity and composition of the product streams from the recycling facilities and 19 criteria were selected to classify the results.

Key words: segregation, heterogeneity, recycling, treatment plants, performance criteria.

1. Introduction

The construction industry is one of the greatest and most active sectors in Europe, but consumes more raw materials (40%) and energy than any other economic activity and generates the greatest waste fraction within 35% of the world’s waste [1].

The approach for demolishing a building structure may be either conventional or selective. A detailed economic analysis of conventional versus selective demolition found that although the economic viability of selective demolition depends largely on local conditions it may ultimately be more profitable than the conventional demolition approach [2]. From an environmental point of view, there are clear benefits from using selective demolition mainly arising from a direct reduction in the material sent to landfill. The first variable considered in this work is the percentage of source segregation being associated to grade of selective demolition. It is necessary to point out that demolition practices more importantly rely on clients and prime contractors and if the latter does not ensure that CDW routed to the right outlet, heterogeneity due to mixing can appear.

2. Case-study

Within a circular economy context, several measures to encourage CDW prevention, reuse and recycling, over backfilling and landfilling are being adopted including ambitious recycling targets for CDW. Any target and recommendations going forward in relation to CDW management need to be applied at national, regional and local level despite the differences from one to another. The case-study considers a central county of Cantabria (North of the Iberian Peninsula) with a population of 261,635 inhabitants (2017) with around 1,000 inhabitants/km².

The advanced recycling facility consists of two previous steps for sorting large contraries, to finally crush the waste stream before subsequent treatment. Once the stream is crushed, more specific classification is used to separate metals, to finally separate this stream in two fractions: fines and all-in-one in one side and coarse fraction in the other. In one hand, fines and all-in-one fraction is cleaned in spirals in a wet classification in order to produce a high quality product, but generating a sludge output that should be properly treated. In the other hand, coarse fraction is treated with wind sifting and two steps of wet classification, in order to remove contraries from recycled aggregates.

2.1. Scenarios of CDW

Different scenarios of segregation and waste mixing percentages are considered and can be useful to explore actual and future situations of the CDW management in different countries and regions. The combination of source segregation grade and heterogeneity grade comes out as four possible scenarios. Scenarios 1 represent source low level segregation and scenarios 2 represent source high level segregation. In each one of these situations, two additional versions are defined according to heterogeneity levels or waste stream mixing grade; version A is mixed mostly with similar waste, and version B is mixed mostly with different waste.

2.2. Evaluation criteria

Based on literature, taking into account specific characteristics of this waste treatment, nineteen criteria were defined and classified by economic, environmental, technical and social aspects, summarized in Table 1 [3].
Table 1. Criteria used to evaluate alternatives by aspects.

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Criteria</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic</td>
<td>Revenues from input of waste</td>
<td>€</td>
</tr>
<tr>
<td></td>
<td>Fixed costs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Operational and labour costs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Revenues from selling recovered resources</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Landfill costs of rejected material</td>
<td></td>
</tr>
<tr>
<td>Environmental</td>
<td>Global Warming Potential (GWP)</td>
<td>Teq CO₂</td>
</tr>
<tr>
<td></td>
<td>Acidification Potential (AP)</td>
<td>Teq SO₂</td>
</tr>
<tr>
<td></td>
<td>Water consumption</td>
<td>m³</td>
</tr>
<tr>
<td></td>
<td>Land requirement</td>
<td>m²</td>
</tr>
<tr>
<td></td>
<td>Resources recovery</td>
<td>%</td>
</tr>
<tr>
<td>Social</td>
<td>Noise</td>
<td>Value</td>
</tr>
<tr>
<td></td>
<td>Neighbourhood annoyance</td>
<td>Kg Pm10/ Year</td>
</tr>
<tr>
<td></td>
<td>Potential impact of atmospheric emissions to human health</td>
<td>DALY</td>
</tr>
<tr>
<td></td>
<td>Number of employees</td>
<td>Persons</td>
</tr>
<tr>
<td>Technical</td>
<td>Quality of recycled aggregates</td>
<td>Value</td>
</tr>
<tr>
<td></td>
<td>Potential resources efficiency</td>
<td>Euros/Ton</td>
</tr>
<tr>
<td></td>
<td>Maintenance requirements</td>
<td>Euros/hour</td>
</tr>
<tr>
<td></td>
<td>Average lifetime</td>
<td>Years</td>
</tr>
<tr>
<td></td>
<td>Technical maturity</td>
<td>Value</td>
</tr>
</tbody>
</table>

3. Results and discussion

Ceramic aggregates and concrete aggregates are differentiated in advanced plants; furthermore, differ in particle size distribution and three grade are considered. The grade of aggregates is due to the fact that the segregated, petrous and CDW streams are treated separately; therefore, high grade comes from segregated streams, medium grade comes from petrous streams and low grade comes from mixed streams. From the results is observed that some criteria are not influenced by scenarios, such as: C2-Fixed equipment costs, C15- Quality of recycled aggregates and C19-Technical maturity [4]. Using the rest of the criteria a classification of the scenarios is obtained. The best option is the scenario with high segregation and low heterogeneity and the second best option is the scenario with a high segregated and the waste is mixed mainly in mixed CDW. The other two scenarios with low segregation presents worse behaviour. Furthermore, the results obtained indicates that for the present situation in Cantabria using the advanced plant even at low segregation levels it is possible to achieve high percentage of recycling (78%), even if backfilling is not considered, if efforts are made to avoid the mix of petrous waste (scenario 2A).

4. Conclusions

Though the high number of published research papers concerning to different aspects of recycling of CDW, there are some gaps in relation to the real performance of CDW waste management. The results obtained in this work indicates that for the present situation in Cantabria using the advanced plant the best option is the scenario with high segregation and low heterogeneity.

Acknowledgements

This work has been supported by the Cantabrian government R&D project 2018-2020 entitled “Obtaining, processing and dissemination of data on production and waste management”.

References

1. INTRODUCTION

CDW recycling covers complicated issues from technological, environmental and management perspectives that need to be studied in order to replace natural aggregates by recycled aggregates in various applications.

2. OBJECTIVE

Evaluation of the influence of the segregation of the materials contained in CDW into the performance of an advanced recycling facility considering economic, environmental and technical criteria.

3. CASE STUDY

INPUT STREAMS IN CANTABRIA (SPAIN)

4. RESULTS

SANKEY DIAGRAM FOR SCENARIO 2-A

5. CONCLUSIONS

High percentage of recycling can be achieved even if downcycling is excluded if efforts are made to avoid the contamination of petrous waste with other CDW.

6. BIBLIOGRAPHY


If backfilling is permitted Cantabria fulfill the European Union target (70%) before the end of 2020 in all scenarios

Furthermore, high segregation level involve better environmental, social and technical critical.
Abstract: This work experimentally determined the optimization of cobalt ([Co]) and iron ([Fe]) doses on biogas productivity from food waste (FW) in mesophilic (MD) and thermophilic (TD) anaerobic digesters. Within the design boundaries, maximum cumulative methane production was attained at $0.05 \leq [Co] \leq 0.35$ mg/L and $2.2 \leq [Fe] \leq 9.5$ mg/L in MD (1,650 mL), and $[Co] \leq 0.8$ mg/L and $100 \leq [Fe] \leq 170$ mg/L in TD (1,800 mL). The results show that combination of Co and Fe is effective in biogas production from FW in MD and TD due to advantages of effective processing.

Key words: Anaerobic digestion, Mesophilic, Response surface methodology, Thermophilic, Trace metals.

1. Introduction

The amount of food waste (FW) has been gradually increased. The stacking of FW has become a huge problem as global issue. Direct landfill disposal and ocean dumping of organic wastes are prohibited. Therefore, anaerobic digestion (AD) has regarded as promising treatment technology. FW is highly desirable substrate for AD because it has major nutrient and biodegradability. However, it could lead to the failure of the AD because FW generally has insufficient concentration of trace metals. Supplementation of trace metal is considered as essential strategy for enhancing process of AD of FW. In this study, therefore, Co and Fe were supplemented in the mesophilic (MD) and thermophilic (TD) digesters to evaluate the effects of multi trace metals on AD of FW.

2. Material and methods

The FW used as substrate in this study were obtained from Hongcheon Eco-friendly Energy Town in South Korea. The inoculum was collected at Chuncheon municipal wastewater treatment plant. The effect of trace metals addition on methane production was studied using biochemical methane potential trials. The substrate to inoculum ratio was maintained at levels of approximately 1 (based on volatile solid). On the basis of preliminary experiments, the ranges of independent variables for optimization in this study were $0 \leq [Co] \leq 0.5$ mg/L and $0 \leq [Fe] \leq 10$ mg/L in MD, and $0 \leq [Co] \leq 5$ mg/L and $0 \leq [Fe] \leq 200$ mg/L in TD (Table 1). The reactors were operated until the pressure in them stopped increasing: MD (35°C) for 33 d and TD (55°C) for 54 d.

3. Results and discussion

Nine trials including the center point (Table 1, Trials 1–5) were run first to test the adequacy of a first-order model to describe the response surface of cumulative methane production (CMP). The first-order regression was not statistically significant ($p = 0.665$) with $r^2$ of 0.19, indicating that this model is not adequate to approximate the CMP, and that a higher-order model is needed. To test higher-order models, four augmentation points (Table 1, Trials 6–9) were run and the results were included in the analysis. Increasingly complex polynomials from linear to quadratic were tested to model the augmented data set. The adequacy of each model was assessed based on the $r^2$ and lack-of fit (LOF), and the simplest model of best fit (Eq. (1); $r^2 = 0.70$) was used to describe the response surface of the CMP (mL) in MD:

$$\text{CMP}_{\text{MD}} = 1574.4 + 324.4 \times [Co] + 23.4 \times [Fe] - 990.7 \times [Co]^2 - 2.18 \times [Fe]^2 + 13.8 \times ([Co] \times [Fe])$$

This equation’s LOF was not significant ($p > 0.05$). Plots of residuals showed small variance with no pattern or trend; these variances were random and homogeneous. Therefore, this equation was used to determine the conditions that would maximize the CMP by setting the partial derivatives of the equation to zero with respect to the independent variables. The maximum CMP was at $0.05$ mg/L $\leq [Co] \leq 0.35$ mg/L and $2.2$ mg/L $\leq [Fe] \leq 9.5$ mg/L in MD.

Nine trials including the center point (Table 1, Trials 1–5) were also run first to test the adequacy of a first-order model describing the response surface for The CMP. The first-order model regression had a poor $r^2$, indicating
that this model is not adequate to approximate the CMP, and that a higher-order model is needed. Likewise, to test higher-order models, four augmentation points (Table 1, Trials 6–9) were run and the results were included in the analysis. The simplest model of best fit (Eq. (2); \( r^2 = 0.93 \)) was used to describe the response surface of the CMP (mL) in TD:

\[
\text{CMP}_{\text{TD}} = 1454.4 + 72.7 \times [\text{Co}] + 4.46 \times [\text{Fe}] - 24.6 \times [\text{Co}]^2 - 0.02 \times [\text{Fe}]^2 + 0.21 \times ([\text{Co}] \times [\text{Fe}])
\]  

(2)

Table 1. Experimental design, observed cumulative methane production and methane yields of anaerobic digestion of food wastes with the Co and Fe supplementation of varying concentration of trace metals.

<table>
<thead>
<tr>
<th>Trial</th>
<th>Supplementation of trace metals</th>
<th>Cumulative methane production (mL)</th>
<th>Methane yield (Nm³/kg COD removed)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MD (Co, Fe)</td>
<td>TD (Co, Fe)</td>
<td>MD</td>
</tr>
<tr>
<td>1</td>
<td>(0, 0)</td>
<td>(0, 0)</td>
<td>1,625</td>
</tr>
<tr>
<td>2</td>
<td>(0, 10)</td>
<td>(0, 200)</td>
<td>1,588</td>
</tr>
<tr>
<td>3</td>
<td>(0.5, 0)</td>
<td>(5, 0)</td>
<td>1,513</td>
</tr>
<tr>
<td>4</td>
<td>(0.5, 10)</td>
<td>(5, 200)</td>
<td>1,545</td>
</tr>
<tr>
<td>5a</td>
<td>(0.25, 5)</td>
<td>(2.5, 100)</td>
<td>1,688 ± 15</td>
</tr>
<tr>
<td>6</td>
<td>(0.25, 0)</td>
<td>(2.5, 0)</td>
<td>1,519</td>
</tr>
<tr>
<td>7</td>
<td>(0.25, 10)</td>
<td>(2.5, 200)</td>
<td>1,676</td>
</tr>
<tr>
<td>8</td>
<td>(0, 5)</td>
<td>(0, 100)</td>
<td>1,589</td>
</tr>
<tr>
<td>9</td>
<td>(0.5, 5)</td>
<td>(5, 100)</td>
<td>1,591</td>
</tr>
</tbody>
</table>

* center point was replicated three times (average ± standard deviation).

This equation’s LOF was not significant (\( p > 0.05 \)). The value of [Fe] significantly affected the CMP in TD (\( p = 0.006 \)) but [Co] did not (\( p = 0.116 \)). The maximum CMP was at \([\text{Co}] \leq 0.8 \text{ mg/L} \) and \(100 \text{ mg/L} \leq [\text{Fe}] \leq 170 \text{ mg/L} \) in TD.

![Fig. 1: Two dimensional contour plots of cumulative methane production with respect to Co and Fe concentration in mesophilic (a) and thermophilic (b) digesters within the design boundaries.](image)

4. Conclusions

Optimization was successfully applied to examine the effects of [Co] and [Fe] on the methane production from FW in MD and TD. Within the design boundaries, maximum CMP was attained at \(0.05 \leq [\text{Co}] \leq 0.35 \text{ mg/L} \) and \(2.2 \leq [\text{Fe}] \leq 9.5 \text{ mg/L} \) in MD, and \([\text{Co}] \leq 0.8 \text{ mg/L} \) and \(100 \leq [\text{Fe}] \leq 170 \text{ mg/L} \) in TD. The results demonstrate that multi-trace metals supplement with Co and Fe in MD and TD of FW is an effective technique to enhance the biogas productivity.

Acknowledgements

This work has been supported by Basic Science Research Foundation of Korea (NRF) funded by the Ministry of Education (NRF-2018R1D1A1B07041451).
**INTRODUCTION**

Food wastes contain low concentrations of trace elements.

It could limit the anaerobic digestion process.

Some specific trace elements are essential as enzyme cofactors such as cobalt and iron.

**METHOD**

**ACKNOWLEDGEMENT**

This work has been supported by Basic Science Research Foundation of Korea (NRF) funded by the Ministry of Education (NRF-2018R1D1A1B07041415).
DEVELOPMENT OF SOLID WASTE MANAGEMENT AND ITS NATIONAL STRATEGY IN PALESTINE

M. Yoshida (1) and S. A. Muferreh (2)

1: Environmental Research Laboratory, International Network for Environmental and Humanitarian Cooperation (iNehc), Nonprofit Inc., Tokyo, Japan
2: Directorate of Joint Service Councils, Ministry of Local Government (MoLG), Ramallah, West Bank, Palestine

Abstract: Although there are politically unresolved issues such as Israeli occupation and settlement problems in Palestine, the solid waste problem is inevitable in daily lives and is necessary to manage under given conditions. Palestinian Authority has been working for improving the solid waste management with various supports by donor agencies. In this regards, the "National Waste Management Strategy (2017-2022)" has been formulated. Presently, the top priority issue is the minimization of waste amount through introducing the 3Rs (Reduce, Reuse, Recycle) practice.

Key words: Palestine, Joint Service Council, National Strategy, Waste Minimization, 3Rs

1. Introduction

Palestine consists of the West Bank (5,655 km²) and the Gaza Strip (365 km²), with 3.0 million people in the West Bank and 1.9 million people in the Gaza Strip. However, about 59% (3,336 km²) of the West Bank, called as Area C, is occupied by Israel who has a virtual power in administrative and security controls. Moreover, there are 1.0 million Palestinian refugees in the West Bank refugee camps and 1.4 million in the Gaza refugee camps, who have been driven out by the founding of the State of Israel. Under such given conditions, it is necessary to collect, transport, and properly dispose the solid waste generated by more than 7.3 million inhabitants living in those limited areas, which is the current mission of SWM in Palestine. How has this mission accomplished, so far? And what are the future challenges?

2. Development of Solid Waste Management and Waste Crisis in Palestine

Ministry of Local Government (MoLG) of Palestinian Authority (PA) has attempted to establish a sound solid waste management (SWM) system over Palestine with the support of various international donors since early 2000s, and has promoted waste collection services for securing public health, closed random open dumpsites, and built sanitary landfills for environmental protection.

As of 2016, regional SWM implementing agency (Joint Service Council; JSC) has been established in all governorates of Palestine. In the West Bank, municipal solid waste generation is estimated at 2,190 ton/day, and the per capita generation rate is averaged 0.73 kg/capita/day in JSC service covered area. Around 48.5% of the generated municipal waste (1,062 ton/day) is collected and transferred by the JSCs, and the collection of the remaining quantities is under the responsibility of Local Governmental Units (LGUs) [1]. Overall waste collection service coverage reaches 91.5% to total population and 92.2% to total generation [2], which is better service level in comparing with the international average at comparable economy [3]. Moreover, 1,935 ton/day of waste is successfully disposed to the sanitary landfills, and more than 48 random open dumpsites in north and south West Bank have been closed since 2013 (Fig.1). However, due to unachieved consensus building on siting in Area C with Israel, the construction plan of a sanitary landfill in central part of the West Bank has not yet realized which causes delays in the closure of remaining 84 open dumpsites (Jerusalem, Ramallah, Nablus, and Salfit Governorates). The average operation cost of SWM in the 12 JSCs, West Bank is 144 NIS/ton (maximum 248 NIS/ton, minimum 60 NIS/ton). The SWM service tariff has been adopted by most JSCs, and the operational-cost recovery in majority of the JSCs has been achieved. However, there are still many problems in SWM in Gaza Strip under current situation.

Even now, the municipal waste generation rate is obviously high in comparing with the international average at comparable economy [3], the amount of municipal waste generated will further increase due to population growth and urbanization. Existing sanitary landfills are overloaded, dumpsite collapse is eventually starting, but the remaining capacity of the sanitary landfills is very limited. Nevertheless, it is extremely difficult to construct a new sanitary landfill in the Area C. Systematic recycling practice is in beginning stage in Palestine; where about 1.5% of generated waste is recycled [4]. Under these critical circumstances, a Waste Crisis, the National SWM Strategy (2017-2022) was formulated by PA (MoLG) [4].
3. National Solid Waste Management Strategy and Policy for Waste Minimization

The National SWM Strategy (2017-2022) is composed of 8 strategic objectives; organizational development, institutional development, effective SWM service, sustainable financing, proper treatment of hazardous wastes, public-private partnership, raising public awareness, and information sharing [4]. Under the strategic objectives, 19 sectoral policies, and 95 policy interventions were planned. The main points of the National Strategy are: (i) improvement of public awareness concerning waste problem, (ii) strengthening JSCs for implementing environmentally sound sustainable SWM service, (iii) improvement of legal and institutional system related to solid waste management, (iv) promoting public-private partnership in SWM sector, and (v) construction of regional sanitary landfills and closure of remaining random open dump sites. Palestinian Authority (MoLG) designated 2019 as a waste minimization year [6] and decided to work on the following three issues: (1) reducing waste amount at source such as source separation and/or home recycling, (2) diverting the waste stream such as waste sorting, material recycling, centralized composting, and/or waste-to-energy before landfilling, and (3) mitigation of dumped waste and resource/energy recovery from dumpsites. In other word, the practice of waste minimization will be endeavored through introducing the 3Rs (Reduce, Reuse, Recycle) practice over Palestine.

4. Concluding Remarks

Under current situation there are only two ways for achieving the waste minimization in Palestine; (1) prevention of waste generation at source, and (2) waste diversion before landfilling. The key challenge is prompt actions of 3Rs (Reduce, Reuse, Recycle) by all stakeholders. In order to execute 3Rs, it is necessary to continue the institutional building for sustainable SWM, to enhance the public awareness, to promote investments for equipment and facilities, and to build a partnership with local people, academic, and private sector.

Acknowledgements

This work is based on results of the Project for Technical Assistance in SWM in Palestine, a technical cooperation between MoLG and JICA (Japan International Cooperation Agency). The view expressed in present paper does not necessarily reflect the official position of MoLG or JICA.

References

Development and Crisis of Waste Management: Ministry of Local Government (MoLG) of Palestinian Authority (PA) has attempted to establish a sound SWM system over Palestine with the support of various international donors since early 2000s and has promoted waste collection services, closed random open dumpsites, and constructed sanitary landfills. In the West Bank, municipal solid waste generation is estimated at 2.190 ton/day, and the per capita generation rate is averaged 0.73 kg/capita/day in JSC service covered area. Around 48.5% of the generated municipal waste (1,062 ton/day) is collected and transferred by the Joint Service Council (JSC) for SWM that has been established in all governorates, and the remaining quantities are collected by Local Governmental Units (LGUs). Overall waste collection service coverage reaches 91.5% to total population (Fig. 1). Moreover, 1,935 ton/day of waste is successfully disposed to the sanitary landfills, and more than 48 random open dumpsites in north and south West Bank have been closed since 2013. However, the construction plan of a sanitary landfill in central part of the West Bank has not yet realized which causes delays in the closure of remaining 84 open dumpsites (Fig. 2). Existing sanitary landfills are overloaded, but the remaining capacity of the sanitary landfills is very limited. Nevertheless, it is extremely difficult to construct a new sanitary landfill in the Area C. Nevertheless, it is extremely difficult to construct a new sanitary landfill in the Area C.

Figure 1: Waste collection service coverage by JSCs in terms of population and number of LGUs. Total coverage is more than 80% in terms of population, and overall coverage including the service given by LGUs is 91.5% (Data source: SWM Databook version 2).

Figure 2: Decrease of the number of random open dumpsites in West Bank, and a map showing the distribution of dumpsites. (Data source: MoLG database).

National Solid Waste Management Strategy and Policy for Waste Minimization: The National SWM Strategy (2017~2022) is composed of 8 strategic objectives; organizational development, institutional development, effective SWM service, sustainable financing, proper treatment of hazardous wastes, public-private partnership, raising public awareness, and information sharing. Under the strategic objectives, 19 sectoral policies, and 95 policy interventions were planned. Palestinian Authority (MoLG) decided to work on the following three issues: (1) reducing waste amount at source such as source separation and/or home recycling, (2) diverting the waste stream such as waste sorting, material recycling, centralized composting, and/or waste-to-energy before landfilling, and (3) mitigation of dumped waste and resource/energy recovery from dumpsites. In other word, the practice of waste minimization will be endeavored through introducing the 3Rs (Reduce, Reuse, Recycle) practice over Palestine.

CONCLUSIONS: Under current situation there are only two ways for achieving the waste minimization in Palestine: (1) prevention of waste generation at source, and (2) waste diversion before landfilling (Fig. 3). The key challenge is prompt actions of 3Rs (Reduce, Reuse, Recycle) by all stakeholders. In order to execute 3Rs, it is necessary to continue the institutional building for sustainable SWM, to enhance the public awareness, to promote investments for equipment and facilities, and to build a partnership with local people, academic, and private sector.

Acknowledgements: This work is based on results of the Project for Technical Assistance in SWM in Palestine, a technical cooperation between MoLG and JICA (Japan International Cooperation Agency). The view expressed in this presentation does not necessarily reflect the official position of MoLG or JICA.
COMPARATIVE ANALYSIS OF THE RECOVERING WASTE PRACTICES IMPLEMENTED IN BRAZILIAN CITIES

C. Coutinho-Nóbrega(1), V. Ibáñez-Forés(2), L. de Figueiredo-Lopes-Lucena(3), M.D. Bovea(2)

1: Department of Civil and Environmental Engineering, Universidade Federal da Paraíba, Campus Universitário I, 58051-900 João Pessoa, Brazil
2: Department of Mechanical Engineering and Construction, Universitat Jaume I, Avda. Vicent Sos Baynat s/n 12071 Castellón de la Plana, Spain
3: School of Sciences and Technology, Federal University of Rio Grande do Norte, Campus Universitário Lagoa Nova, 59078-970 Natal, Brazil

Abstract: João Pessoa was one of the pioneering municipalities in implementing strategies to promote selective waste collection in Brazil, and to improve its recyclable waste classification facilities to increase waste recovery rates. This paper aims to analyse the way in which programmes to improve waste recovery rates have been implemented in other Brazilian cities to compare the selective collection to recovered waste ratios obtained in other Brazilian municipalities and to identify improvement aspects. It was observed that only Brasília, João Pessoa, Goiânia, Porto Alegre and Florianópolis recovered more than 5% of their recyclable waste. Of these, JoãoPessoa had the lowest ratios, mainly due to a manual selective collection system being implemented in JoãoPessoa, while automotive systems were adopted in the other four cities.

Key words: Waste Management, Selective waste collection, Brazilian National Policy on Solid Waste

1. Introduction

According to Brazilian Law no. 12.305/2010 [1], which establishes the National Policy on Solid Waste (PNRS), “the waste selective collection, the reverse logistics and other tools related to the implementation of shared responsibility over products’ life cycle” are mandatory for all Brazilian cities.

The Business Commitment for Recycling stated that in 2018, 1,227 Brazilian cities had adopted some kind of selective waste collection initiative. Notwithstanding, in the majority of these cities no full coverage of the urban area exists, and only 17% of the Brazilian population is served for selective collection.

The Selective Collection Programme of João Pessoa was launched in September 2000, 10 years before the PNRS [2]. By 2014, the João Pessoa’s Municipal Plan for Integrated Waste Management (PMGIRS) had been established, which states the waste recovery rates for 2020 (10%), 2025 (16%) and 2034 (25%), the last planning horizon year. In 2018, 7.4% of the recyclable waste in João Pessoa was recovered and marketed by cooperatives and associations in the waste management municipal programme, but around 20.66% potential recyclable materials was generated [3].

This paper examines the applied waste management systems in different Brazilian municipalities to identify the best practices that can improve the current waste recovery rates in João Pessoa and to fulfil the PMGIRS goals.

2. Methodology

To carry out this research, the municipal solid waste management systems implemented in all Brazilian capitals were analysed. These data were acquired from both the National Sanitation Information System (SNIS) and companies in charge of urban cleaning, such as the Special Municipality of Urban Cleaning of João Pessoa (EMLUR). Based on these data, the cities whose percentage of recovered waste exceeded 5% were identified. Then information about how the waste selective collection programme had been implemented in these selected cities was analysed to identify the strengths and weaknesses of each one. Finally according to the obtained results, some changes in the programme of João Pessoa were suggested to improve its selective collection programme and waste recovery rates.
3. Results

Figure 2 compares not only the global waste recovery ratio obtained in all the capitals of Brazil, but also the recovered waste composition in each one. The main characteristics of the analysed waste management systems are indicated below.

From analysing the results, it can be stated that only Brasília (Federal District Capital) and four state capitals had selective collection rates over 5% (see Fig. 1), specifically: Brasília (26.4%), Goiânia (21.88%), Florianópolis (12.5%), Porto Alegre (10.8%) and João Pessoa (7.8%). In recovered waste composition terms, in Fig. 1 we observe that plastic is the main waste recovered fraction in Brasília, but not in the other cities, where the paper/cardboard fraction represents a better recovered ratio.

![Figure 1: Distribution of the waste recovery ratios in state capitals of Brazil](image)

By analysing the systems features, we identified that the main weakness detected in João Pessoa’s system were lack of efficient public communication and, consequently, lack of public interest, besides the manual collection of recyclable fractions. The programmes adopted in Brasília, Goiânia, Florianópolis and Porto Alegre, besides been encouraged by both public and private sectors, were completely vehicle-based, with a weekly scheduled collection, similarly to conventional mixed collections. In addition, recyclable materials are forwarded directly to the associations in charge of the recycling process, with no intermediaries as in João Pessoa.

4. Conclusions

Although João Pessoa’s Selective Collection Programme was established 10 years before the PNRS statement, we observed that the percentage of collected materials was far behind the PMGIRS forecasted goals (from 7.4% of the waste recovered in João Pessoa to 10% for 2020 in PMGIRS).

By comparing the PMGRIS with the existent programmes of Brasília, Goiânia, Florianópolis and Porto Alegre, we observed a huge difference between them as regards diffusion to their inhabitants and the offer of scheduled collections by vehicles. Recyclable materials are delivered to the waste picker cooperatives and associations, which does not occur in João Pessoa, where the main selective collection is performed by cooperative waste pickers and manual door-to-door collection under poor precarious work conditions. We conclude that in order to improve João Pessoa’s collection programme, the adoption of vehicle-based selective collection, along with scheduled plans and well diffusing such activity to society would guarantee broader participation, without which it is impossible to maintain selective collection. Collection lorries would deliver recyclable materials directly to associations, as stated in the PNRS.

Acknowledgement

The authors are grateful to the Universitat Jaume I (Project UJI-A2018-11) for funding for this study.

References


COMPARATIVE ANALYSIS OF RECOVERY WASTE PRACTICES IMPLEMENTED IN BRAZILIAN CITIES

C. Coutinho-Nóbrega1, V. Ibañez-Forés2, M. Guinot-Meneu3, M.D. Bovea2, L. de Figueiredo-Lopes-Lucena2

1. Department of Civil and Environmental Engineering, Universidade Federal de Pará, Campus Universitário I, 68011-000 João Pessoa, Brazil
2. Department of Mechanical Engineering and Construction, Universitat Jaume I, Avda. Vicent Sos Baynat s/n 12071 Castelló de la Plana, Spain
3. School of Sciences and Technology, Federal University of Rio Grande do Norte, Campus Universitário Lagoa Nova, 59078-970 Natal, Brazil

Introduction

According to the Brazilian Law no. 12.305/2010, which establishes the National Policy on Solid Waste (NPSW), the selective waste collection, the reverse logistics and other tools related to the implementation of the extended producer responsibility are mandatory for all Brazilian cities.

The Business Commitment for Recycling states that in 2018, 1,227 Brazilian cities had adopted some kind of selective waste collection initiative. However, in the majority of these cities, no full coverage of the urban area exists, and only 17% of the Brazilian population is served for selective waste collection.

This study examines the municipal solid waste (MSW) management system implemented in the Brazilian city of João Pessoa, which is compared with the implemented in other Brazilian cities of reference in the field of waste management. From this comparison, different improvement options are identified, in order to ensure that the selective waste collection ratio of João Pessoa is close to the targets indicated by the national policy.

Methodology

The selective waste collection programme implemented in João Pessoa was launched in September 2000, 10 years before the NPSW. In 2014, the João Pessoa’s Municipal Plan for Integrated Waste Management stated the recyclable waste recovery ratio (RWRR): 10% for 2020, 16% for 2030 and 25% for 2034. Nonetheless, in 2018, only 7.4% of the recyclable waste in João Pessoa was recovered.

The methodology showed in Fig. 1 was applied in order to identify waste management improvement strategies to bring the RWRR ratio of João Pessoa closer to what is required by legislation.

First, the MSW management system implemented in the Brazilian capitals was analyzed. These data were acquired from the National Sanitation Information System (SISNAC), companies in charge of the urban cleaning, such as the Special Municipality of Urban Cleaning of João Pessoa, and the respective MSW management plans. Based on these data, the capitals whose RWRR was greater than 5% were selected. Then, information about how the selective waste collection programme had been implemented in each selected city was analysed to identify the strengths and weaknesses of each one. Finally, some changes in the MSW management system of João Pessoa were suggested to improve the RWRR ratio.

Results

Fig. 2 compares the RWRR obtained for each Brazilian capital (a), and the composition of the recovered fraction (b).

From the analysis of the main characteristics of each MSW management system and each selective waste collection programme, it can be stated that:

- Only Brasília (26.4%), Goiânia (21.8%), Florianópolis (12.5%), Porto Alegre (10.8%) and João Pessoa (7.8%) have RWRR higher than 5%.
- Although São Paulo has the highest GDP and the largest Brazilian population [3], its RWRR is lower than 5%.
- Plastic is the most recovered recyclable fraction in Brasília, while paper/cardboard fraction is more frequently recovered in the remaining capitals.

Conclusions

The analysis of the MSW management system of Brazilian capitals with RWRR higher than 5%, has allowed to identify weaknesses and improvement options in the MSW management system and selective waste collection programme currently implemented in João Pessoa.

The main weakness detected is the manual collection of recyclable fractions against the vehicle-based one, and the lack of efficient public awareness campaigns.

The main improvement strategies to improve the RWRR ratio are:
- Adoption of vehicle-based selective collection.
- Delivery of the recyclable materials recovered directly to associations, avoiding intermediaries, as stated in the NPSW, and
- Scheduled waste awareness campaigns for the promotion of selective collection of recyclable fractions of MSW.

Acknowledgement

Authors are grateful to the Universitat Jaume I (Project UJI-A2018-11) for funding this study.

References

[2] Instituto Brasileiro de Geografia e Estatística (IBGE). 2018
Abstract: This paper presents the results of the most recent work on the physical composition of household solid waste - HSW generated in the City of Rio de Janeiro, in the year of 2018. It helps to verify behavioral changes and consumption trends of households. The results showed that organic waste is the largest component of the waste stream (50.51%), followed by recyclables (34.94%). As an urbanized city in which the waste is formally managed on a municipal scale, the city exhibited a waste composition comparable to that of underdeveloped cities of the world. Information on the physical composition of solid waste may significantly contribute to the efficiency of the solid waste management system adopted in Rio de Janeiro City.

Key words: household solid waste; Rio de Janeiro; Brazil; composition.

1. Introduction

In Brazil, landfill is the most common form of waste disposal. One of the goals of the National Policy for Solid Waste [1] is to reduce the amount of waste landfilled by encouraging the development and utilization of material and energy recovery technologies.

As the composition of HSW changes and is closely correlated with population growth, socio-economic standards and technological developments [2], knowledge of the waste composition is of vital importance for its integrated management in modern cities. This work is part of a 24 years survey of the physical composition of the HSW generated in Rio de Janeiro city, which helps to identify the best management practices and technological routes for the recovery of materials and energy, according to local waste characteristics.

2. Materials and methods

For a most reliable representation, sampling size and dispersion was calculated proportionally to the resident population in the different districts of the city, based on data from the latest Brazilian Population Census [3]. Sample size was established considering the average quantities of waste produced in the previous year. Waste samples were sent to the Solid Waste Laboratory of COMLURB for sorting, weighting and data recording. Therefore, identifying the physical composition consisted of determining the components of waste obtained by sampling the waste arising from the households and differentiating them into 7 components and into 24 sub-components as show in Table 1.

<table>
<thead>
<tr>
<th>Component</th>
<th>Subcomponent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper/Cardboard</td>
<td>Paper, Cardboard, Tetrapak</td>
</tr>
<tr>
<td>Plastic</td>
<td>Hard Plastic, Plastic Film, PET</td>
</tr>
<tr>
<td>Glass</td>
<td>Incolor Glass, Colored Glass</td>
</tr>
<tr>
<td>Organic</td>
<td>Putrescible Organic Matter, Organic Fine</td>
</tr>
<tr>
<td>Metal</td>
<td>Ferrous Metal, Non Ferrous Metal</td>
</tr>
<tr>
<td>Inert</td>
<td>Rock/Dirty/Sand, Ceramic</td>
</tr>
<tr>
<td>Others</td>
<td>Leaf/Flower, Wood, Rubbe, Textile, Electronic, Disposable Diaper</td>
</tr>
</tbody>
</table>

3. Results and Discussion

In Figure 3 is presented the HSW generated in Rio de Janeiro city over the past fourteen years and show that the total HSW collected has oscillated in recent years, despite a growth of 20.5% since 2009.
Results showed that HSW in the Rio de Janeiro City (Figure 2 a) correspond, basically, to three elements: organic waste (average of 50.51% of total weight in the studied years), followed by recyclables (34.94%) and others components (14.55%). These results suggest that HSW produced in Rio de Janeiro possesses similarities to waste from other cities in low income countries [2].

Recyclables wise, plastic products represent the largest portion of the recyclable fraction of the HSW averaging 43.88%, followed by paper 40.98%, glass 9.95%; and metal 5.19% (Figure 2 b).

4. Conclusions

Organic waste accounted for the highest component of HSW in the city. Approximately 54.5% of all household waste is organic waste and it is directly landfilled, increasing the production of biogas and leachate. In 2018, HSW collected in the Rio de Janeiro City presented predominance of three elements: organic waste, plastic and paper. As an urbanized city, where the wastes are managed formally at a municipal scale, Rio de Janeiro presented a waste composition compared to cities in low income countries. This detailed investigation of the composition of household waste in Rio de Janeiro city may be used as a useful tool for the improvement of waste management solutions.

References


PHYSICAL COMPOSITION OF THE HOUSEHOLD SOLID WASTE OF RIO DE JANEIRO CITY – 2018 - BRAZIL

M. A. G. HINOJOSA*; B. R. QUINTAES*; A. L. F. M. CONDE*; A. F. LOURENÇO*; J. TONNERA JUNIOR*; J. C. CAMPOS*

*COMLURB (Municipal Waste Management Company), Research Center, Rua Americo de Souza Braga 647, 22783-385 Rio de Janeiro, Brazil
*UFRJ (Universidade Federal do Rio de Janeiro), School of Chemistry, Av. Athos da Silveira, 149, 21941-909 Rio de Janeiro, Brazil
*brq uintaes@gmail.com

INTRODUCTION

One of the most important Brazilian cities, Rio de Janeiro produces approximately 8,978 tons of municipal solid wastes per day and 1,766,348 tons per year of household solid wastes (Fig. 1). Public cleaning and waste management services in the City of Rio de Janeiro are provided by the Municipal Waste Management Company (COMLURB). The collection services covers approximately 96% of the commercial and residential units in Rio de Janeiro. The household wastes are manually collected from garbage cans, buckets, containers and bags for waste collection, which are disposed of on the curb by citizens and then placed into a refuse collection truck. This service covers all districts twice a week. At the end of the itineraries, the waste is transported to the sanitary landfill of Seropédica, which is the principal final destination of solid wastes in Rio de Janeiro. This work was conducted to determine the composition of household solid waste produced in Rio de Janeiro City, in 2018.

METHODOLOGY

With the population of approximately 6,409,910 inhabitants in an area of 1,260 km², the Rio de Janeiro City is commonly divided into four zones according to geographical and socioeconomic distinctions: the historic center (Central Zone), the wealthiest, tourist friendly Southern Zone, the less wealthy, residential Northern Zone, and the biggest and socioeconomically ending Western Zone. The samples were randomly collected in predetermined itineraries of the regular collection schedule (Fig. 2) and sent to the Solid Waste Laboratory for sorting and weighing (Fig. 3). Therefore, identifying the composition consisted of determining the components of waste obtained by sampling the waste arising from the households in each area and differentiating them into 11 components (i.e., paper, cardboard, plastics, glass, metal, textile, wood, electronic/electroincorganic waste, inert materials and others) and into more than 45 sub-components. Overall, 24 tons of household solid waste were processed in this study.

RESULTS & DISCUSSION

Household solid waste from Rio de Janeiro City in the year of 2018 consists, notably, of organics wastes as the largest portion of the waste stream (50.41%), followed by recyclables (34.93%) and others components (14.66%, inert waste included) (Fig. 4.a). Of the recyclable materials, plastic products represent the largest fraction with 43.88%; papers and cardboard, 40.22%; glass, 9.95%; and metal, 5.19% (Fig 4.b). These results suggest that the recycling potential of Rio de Janeiro tends to be lower than that of other cities in high-income economy countries.

METHODOLOGY

With the population of approximately 6,409,910 inhabitants in an area of 1,260 km², the Rio de Janeiro City is commonly divided into four zones according to geographical and socioeconomic distinctions: the historic center (Central Zone), the wealthiest, tourist friendly Southern Zone, the less wealthy, residential Northern Zone, and the biggest and socioeconomically ending Western Zone. The samples were randomly collected in predetermined itineraries of the regular collection schedule (Fig. 2) and sent to the Solid Waste Laboratory for sorting and weighing (Fig. 3). Therefore, identifying the composition consisted of determining the components of waste obtained by sampling the waste arising from the households in each area and differentiating them into 11 components (i.e., paper, cardboard, plastics, glass, metal, textile, wood, electronic/electroincorganic waste, inert materials and others) and into more than 45 sub-components. Overall, 24 tons of household solid waste were processed in this study.

ACKNOWLEDGMENTS

The authors would like to acknowledge the Technical and Engineering Directors from The Waste Management Company of the City of Rio de Janeiro (COMLURB) for their support. We are also grateful to the team of workers responsible for the collection and separation of the waste.
PERCAL PROJECT: CHEMICAL BUILDING BLOCKS FROM VERSATILE MSW BIOREFINERY


1: Industrias Mecánicas Alcudia S.A. (IMECAL SA), Avenida de Carlet 74, 46250 L´Alcúdia, Spain
2: AIMPLAS, Calle Gustave Eiffel 4, 46980 Paterna, Spain
3: Leibniz Institute for Agricultural Engineering and Bioeconomy, Max Eyth Allee 100, 14469 Potsdam, Germany
4: Agricultural University of Athens, Iera Odos 75, 11855 Athens, Greece
5: Ghent University, Sint Pietersnieuwstraat 25, 9000 Gent, Belgium
6: Centro Nacional de Energías Renovables (CENER), Ciudad de la Innovación 7, 31621 Sarriguren, Spain
7: TBW Research GesmbH, Schönbrunnerstrasse 297, 1120 Vienna, Austria
8: VISUM Ltd, University College Dublin, Blocks 9 & 10, Belfield Office Park, Belfield – Dublin 4, Ireland
9: Hayat Kimya San. A.S., Mahir Ir 25, 34662 Istanbul, Turkey
10: COVESTRO DEUTSCHLAND AG, Kaiser Wilhelm Allee 60, 51373 Leverkusen, Germany
11: EXERGY Ltd, Puma Way the Technocentre Coventry, CV1 2TT Coventry, UK
12: YPAREX, Urmonderbaan 22, 6167 RD Geleen, The Netherlands

Abstract: PERCAL project will exploit the organic fraction of municipal solid waste (OFMSW) as feedstock to develop intermediate chemical products at high yield and low impurity level with huge industrial interest. These will be complementary to the bioethanol (current PERSEO Bioethanol® technology) to achieve a cascade valorisation of the MSW components, i.e.: a) Lactic acid (LA) to produce: 1) Eco-friendly ethyl lactate solvents by reactive distillation from lactic acid & bioethanol to be used in cleaning products and inks and 2) hot-melt adhesives for cardboard and other non-food applications in combination with maleic anhydride by reactive extrusion. b) Succinic acid (SA) as an intermediate building block to production of polyols for the polyurethane industry and c) Biosurfactants by chemical or microbiological modification of protein and lipid fraction from remaining fraction of MSW fermentations.

Key words: Organic fraction of MSW, Versatile biorefinery, Circular economy, Chemical building blocks, Bio-based products.

1. Introduction

PERCAL project (http://www.percal-project.eu/) addresses the environmental and economic problem of sending municipal solid waste (MSW) flows to landfill and incineration, by changing the current treatment model and producing added-value bioproducts from this heterogeneous and complex waste. PERCAL will exploit the OFMSW as feedstock, which represents around 100 million tonnes every year in Europe, to develop intermediate chemical products with huge industrial interest. The valorization of OFMSW aims to reduce pressure on virgin resources and extract more value from the biowaste generated by our society, increasing the competitiveness of European industry as well as reducing the amount of MSW landfilled or incinerated.

PERCAL is using previous knowledge/background developed by IMECAL in PERSEO technology (second generation bioethanol plant with capacity to process 25 t/day of OFMSW (PERSEO Bioethanol®), as a starting point to produce new high added value products from MSW.

2. Main achievements so far

2.1. Characterization, handling and pre-processing of MSW from different localizations and seasons

Specific requirements and standards for PERCAL’s intermediate and final products based on a review of current petrol or renewable products available in the market were defined. The factors that affect the variability of the OFMSW and their influence on its physicochemical composition were studied and evaluated. Several OFMSW samples from the EU were fully characterized showing that despite the heterogeneity and variation in composition, the chemical components of biowaste are usually within a relatively short range of values. Pretreatment and enzymatic hydrolysis of biowaste were also optimized. Fermentation tests with different strains indicate that ethanol yeasts, LA and SA bacteria are not inhibited and can effectively use the sugars from OFMSW hydrolysate.
2.2. Microbial conversions to lactic acid

The OFMSW hydrolysate has shown good properties as a fermentation substrate for LA production. Fermentations have shown promising results with conversion yields for some strains higher than 0.9 gLA/g sugars. Additionally, work has been carried out to evaluate a pre-treatment before the fermentation in order to remove indigenous undesired D-lactic acid from the hydrolysate.

2.3. Microbial conversions to succinic acid

SA was successfully produced from MSW hydrolysate at relevant rates and yields. Optimization of the minerals and nitrogen source in the medium for \textit{B. succiniciproducens} fermentations was carried out. The in-line extraction of produced SA has been done with a membrane electrolysis cell. The SA becomes concentrated and enriched over LA, in the final extract, which shows the potential of membrane electrolysis to improve the economics of the extraction and purification of SA.

2.4. Valorization of fermentation by-products as surfactants

A complete characterization of by-products generated from the ethanol, LA and SA fermentation processes was made. Regarding biosurfactant from fermentation by-products the targeted fractions are protein and lipids (fatty acids), which accounted over 21% by weight. The development of biosurfactant production is under development at this moment.

2.5. Green chemical routes to produce solvents, hot melt adhesives and polyols and their further industrial validation

The work for the production of ethyl lactate solvent via reactive distillation of ethanol and LA started with a good initial progress. The synthesis of lactide from LA was carried out successfully but the reaction conditions and process set-up have to be improved. PLA and PLA copolymers were successfully obtained by ring opening polymerization (ROP) of lactide in presence of alcohols and polycaprolactone polyols as initiators and stannous octoate as catalyst. The stabilization of PLA is a must and was successfully carried out. First tests with SA for the production of polyols were performed.

2.6. Study of adaptation and monitoring of PERSEO plant for the production of bioethanol, LA & SA.

The study for adapting PERSEO Bioethanol® semi-industrial plant for the versatile production of lactic and succinic acid and determination of the main process parameters to be monitored has started, with a detailed analysis of the processes and the main parameters involved.

2.7. Environmental, regulatory & economic analyses

CORDIS database has been used to identify more than 60 companies and 500 MSW valorization projects that could be possible stakeholders for the project. Gabi software will be used for LCA for all the processes involved in PERCAL project, while safety and regulation risks were gathered from all partners.

3. Conclusions

With the development of PERCAL project it is expected to progress beyond of the state of the art in several technical fields. In the field of enzymatic hydrolysis of carbohydrates contained in OFMSW PERCAL will focus on the improvement of the hydrolysis process by the synergic combination of the most effective commercial enzyme cocktails. Chemical intermediates LA and SA will be produced from OFMSW by using novel electrodialysis and membrane electrolysis purification processes. PERCAL will also focus on the valorisation of the protein and lipid content coming from the by-products of the fermentation processes to produce new biosurfactants. Moreover, the production of renewable hot melt adhesives by reactive extrusion of LA and other co-monomers using suitable catalysts and peroxides will be carried out. PERCAL will also use a prototype reactive distillation to upscale the production of ethyl lactate from produced ethanol and LA to a continuous process. PERCAL will lay the foundation for a truly biobased industry to produce a new range of bio based building blocks for polyols, resins and polyurethane dispersions, maximizing the valorization of the OFMSW as feedstock.

Acknowledgements

This Project has received funding from the Bio-Based Industries Joint Undertaking under the European Union’s Horizon 2020 research and innovation programme under grant agreement N° 745828.
Chemical building blocks from versatile MSW biorefinery

PERCAL will exploit Municipal Solid Waste (MSW) as feedstock to develop intermediate chemical products at high yield and low impurity level with huge industrial interest. These will be complementary to the bioethanol (current PERSEO Bioethanol® technology), to achieve a valorisation into:

1. Lactic acid (LA) to produce:
   - Eco-friendly ethyl lactate solvents by reactive distillation from lactic acid & bioethanol.
   - Hot-melt adhesives in combination with maleic anhydride by reactive extrusion.

2. Succinic acid (SA) as an intermediate building block to produce polyols for the polyurethane industry.

3. Biosurfactants by chemical and/or microbiological modification of protein and lipid fraction from remaining fraction of MSW fermentation.

---

**Impact**

1. Improved yield of intermediate extraction/recovery from the organic content of MSW by 20% with respect to state-of-the-art or exceed 80% yield of intermediates.

2. Validated process by comparison of the resulting product yield with the one obtained from lignocellulosic biomass. The difference in yield should not exceed 10%.

3. Validated removal of inhibitors to such an extent that it allows cost-effective downstream processing.

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**Budget**: 3,394,181,25 €

**Grant**: 2,518,517,64 €

12 partners

3 years (2017-2020)
DEPOLYMERIZATION OF SULFATE POLYSACCHARIDES OBTAINED FROM GREEN ALGAE TO STUDY THE EXTRACTION OF THE ULVAN BIOPRODUCT

C. Macías (1), C. Arce (1), A. Coz (1), J. Robles (2), N.L. Arroyo (2), T. Llano (1)

1: Green Engineering and Resources (www.geruc.es) research group, Department of Chemistry and Process & Resources Engineering. University of Cantabria. Av. Los Castros s/n 39005 Santander (Spain).

2: INVESTALGA AHTI S.L. (www.investalga.com) Technological Development Center of the University of Cantabria (CDTUC) Av. Los Castros 46, 39005 Santander (Spain).

Abstract: The aim of this research was to analyze the depolymerization of the monosaccharides and uronic acids contained in autohydrolyzed extracts of Ulva rigida, as a required step for their HPLC characterization. Different acidic agents (2M HCl dissolved in methanol, 2M HCl in water, 72% H2SO4 and 3% H2SO4) were used to carry out the depolymerization reaction, and its kinetics analyzed. The best results were obtained by acid hydrolysis which yielded extracts with 17% rhamnose, 10% glucose, 8% glucuronic acid and 6% xylose.

Key words: acid hydrolysis, HPLC, methanolysis, Ulvan.

1. Introduction

The use of massive accumulations of nuisance macroalgae could represent a potentially advantageous source of biomass to be explored within the circular and blue economies given their uncontrolled proliferation worldwide and their often detrimental consequences for marine and aquatic ecosystems [1]. In this sense, the production of Ulvan from massive accumulations of green algae could be explored, considering its versatility and potentiality in the food, cosmetic, biomedicine and tissue engineering sectors [2]. Ulvan is composed mostly by rhamnose, glucuronic acid and iduronic acid although other monomers such as glucose, xylose and galactose are also present in the polysaccharide matrix. To analyze the yield and purity of the Ulvan production, different characterization methods should be used, including the quantitative analysis of monosaccharides and uronic acids. Specifically, to characterize the sugar by liquid chromatography, a previous methanolysis to depolymerize the sulphated Ulvan is needed [3]. By means of this process, the β-1,4 glycosidic bonds of the polysaccharide are broken and the monosaccharides and uronic acids are dissolved.

In this study the green macroalga Ulva rigida was used as feedstock for producing Ulvan through autohydrolysis extraction. Sugar and uronic acid depolymerization of the Ulvan sulfated polysaccharide were studied by using different methanolysis and hydrolysis reagents.

2. Methodology

2.1. Ulvan extraction by autohydrolysis

The Ulvan extracts were obtained via autohydrolysis following the protocol provided by INVESTALGA AHTI SL (confidential information). Ulva biomass (Ulva rigida strains and Ulva compressa) harvested from the Cantabrian Coast (SPAIN) and cultivated outdoors in seawater tanks was provided by INVESTALGA AHTI SL.

2.2. Methanolysis and acid hydrolysis

In order to characterize the obtained Ulvan, a polysaccharide depolymerization was carried out with different types of hydrolysis: methanolysis with 2 M HCl diluted in methanol and acid hydrolysis with 2 M HCl, diluted acid hydrolysis at 3% H2SO4 (w/w) and concentrated acid hydrolysis at 72% H2SO4 (w/w).

In the case of the methanolysis and the acid hydrolysis with 2M HCl, the procedure consisted in weighing 10 mg of the dry extract and adding 2 mL of 2M HCl-MeO. The mixture was placed in an oven at 100 °C and left to react for several hours until the sugars degraded, when 200 µL of piridine were added to stop the reaction. Then, the mixture was evaporated in an incubator at 50 °C and the resulting solid was redissolved in the mobile phase used in the HPLC.

The diluted and concentrated acid hydrolyses with 3 % w/w and 72 % w/w H2SO4 were conducted by weighing 35 mg of dry extract and placing them in an oven at 120 °C and 30 °C for 1 hour, respectively.

2.3. Sugars and glucuronic acid quantification by HPLC-RID

The HPLC system used was a Shimadzu Prominence LGE-UV (low pressure gradient system) equipped with a CMB-20A control system, a DGU-20-A5 inline degasser channel, an LC20AD isocratic pump, and a SIL-20AHT
auto sampler with thermostatic cooling (samples held at 4 °C), a CTO-20ASVP column oven and a RID-10A refractive index detector. A Shodex SH-1011 (300 mm× 8 mm, 6-μm particle size) hydrogen H\(^+\) cationic exchange column was used as…/to… The mobile phase was fixed in 0.005 M H\(_2\)SO\(_4\) with a flow rate of 0.5 mL/min. An injection volume of 20 µl was used and the column was thermostatted at 60 °C.

3. Results

The Kinetics of the methanolysis and acid hydrolysis with HCl are displayed in Figure 1. Results of the acid hydrolysis with H\(_2\)SO\(_4\) showed a low depolymerization, with sugar concentrations ranging between 0.08-2 % (rhamnose); 1.4-0.12 % (xylose); 1.3-0.1 % (glucose); 1.3-0.02 % (arabinose); and 1.1-0.1 % glucuronic.

Fig. 1: Reaction kinetics of the monosaccharide and glucuronic acid depolymerization of the Ulvan extracts.

4. Conclusions

Ulvan extracts were depolymerized to quantify their monosaccharide and uronic acid composition through HPLC-RID. The best results were obtained after a 10 hour using HCl 2M in water at 100 °C. Under these conditions an extract containing 30 % of rhamnose and 10 % of glucuronic acid was obtained from the Ulva rigida biomass.

Acknowledgements

This study was carried out in the frame of the POLIEXTRALGA project (“Feasibility study of sulfated polysaccharide extraction and characterization from marine macroalgae biomass”), financed by INVESTALGA AHTI S.L.

References


DEPOLYMERIZATION OF SULFATED POLYSACCHARIDES OBTAINED FROM GREEN ALGAE TO STUDY THE EXTRACTION OF THE ULVAN BIOPRODUCT

C. Macías (1), C. Arce (1), A. Coz (1), J. Robles (2), N.L. Arroyo (2), T. Llanos (1)

1. INTRODUCTION

Green seaweeds → Autohydrolysis → ULVAN

The aim of this research is to study the depolymerization of sulfated polysaccharides extracted from macroalgae Ulva rigida.

2. METHODOLOGY

<table>
<thead>
<tr>
<th>Method Conditions</th>
<th>HPLC-RID sugars and uronic acids quantification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample concentration</td>
<td>H₂SO₄, 5 mM</td>
</tr>
<tr>
<td>Temperature</td>
<td>60 °C</td>
</tr>
<tr>
<td>Concentration (M)</td>
<td>0.5 mL/min</td>
</tr>
<tr>
<td>Time (min)</td>
<td>20 µL</td>
</tr>
</tbody>
</table>

Depolymerization of the sample: 2 mg/mL

Three methods

Two methods: Acid hydrolysis with HCl and methanolation

Three temperatures: 80, 100 and 120 °C

Three acid concentrations (M): 0.5, 1 and 2 M

3. RESULTS

Methanolation is discarded, since a very low depolymerization of the ulvan was obtained.

The best results were obtained using 2 M HCl at 100 °C temperature. Concentration profile obtained at 6 hours is as follows:

- 26.7±2.4 % rhamnose
- 5.1±0.9 % xylose
- 15.6±2.0 % glucose
- 9.7±1.5 % glucuronic acid

Ulvan was extracted, since the major components of the extract are rhamnose and glucuronic acid.

4. MAIN CONCLUSIONS

- Neutral and acid sugars formation and degradation from 1 min to 24 h was determined to find the maximum conversion of the cell-wall polysaccharides extracted from the Ulva rigida.
- The highest sugars concentration (57.2 %) was observed after 6 h of acid hydrolysis with 2 M HCl at 100 °C.
- Extraction yield and ulvan extraction efficiency were 54.0 % and 96.9 %, respectively.

ACKNOWLEDGEMENTS

This study was carried out in the frame of the POLIXTRALGA project ("Feasibility study of sulfated polysaccharide extraction and characterization from marine macroalgae biomass"), financed by INVESTALGA AHTI S.L.
LIPOR’S COMPOST LIFE CYCLE ASSESSMENT

F. F. Martins (1), C. Almeida (2), C. Fernandes (2), J. Oliveira (2), F. Carneiro (2)

1: REQUIMTE/LAQV/ISEP (School of Engineering, P. Porto, Portugal); Rua Dr. António Bernardino de Almeida, 431, 4249-015
2: LIPOR, Serviço Intermunicipalizado de Gestão de Resíduos do Grande Porto, Rua da Morena, 805 | 4435-746 Baguim do Monte, Portugal

Abstract:
Waste management organizations are crucial players in the Circular Economy strategy and want to find solutions that allow keeping products and materials in use. Biodegradable waste according to European Union Landfill Directive (1999/31/EC) must be diverted from landfill and composting is a sustainably favorable option. It is important to quantify the environmental impacts associated with each solution, identifying critical spots and opportunities for improvement. Life cycle assessment (LCA) can be a powerful tool to increase information to the decision-making process and to increase awareness of stakeholders. This work applied LCA methodology to determine environment impacts of LIPOR’s compost. It was possible to conclude, as expected, that composting has several benefits: avoids greenhouse gas emissions, allows the production of good quality compost that can increase soil quality and resource efficiency. In addition it was possible to verify that the compost is a product with a positive impact on environment.

Key words: Biodegradable waste, Circular economy, Life Cycle Assessment, Sustainable Development, Resource Efficiency

1. Introduction
Circular Economy (EC) is a global strategy to implement Sustainable Development [1]. In this context waste management activities are crucial to maximize the potential of wastes. One of the most important principles is to keep materials in use as long as possible [2]. Waste management organizations are at the front of this shift to EC and they want to find sustainable solutions. Waste management hierarchy should be considered in the decision making-process [3]. Biodegradable municipal waste according to European Union Landfill Directive [4] must be diverted from landfill and there are several options that can be implemented. Composting is one of them and is considered an environmentally positive option. Nevertheless it is important to quantify the environmental impacts associated with each solution, identifying critical spots and opportunities for improvement. Life cycle assessment (LCA) can be a powerful tool to increase information to the decision making process and to increase awareness of stakeholders [5]. This work applied LCA methodology to determine environment impacts of LIPOR’s compost.

2. Life cycle assessment
LCA was performed in four steps, namely goal and scope definition, inventory, impact assessment and interpretation (ISO, 2006). The goal of this work was to perform a life cycle assessment of the LIPOR’s compost. The LCA was performed with a “gate to grave” approach: thus, the system boundary begins at the collection of biodegradable waste. The life cycle of biodegradable waste is presented in figure 1 and the stages considered for the existing process are inside the red line, which establishes the system boundary. This study was based on real data and secondary data given by proper LCI data sets available on SimaPro. The methodology of impact assessment used was the “IMPACT 2002+”. The methodology proposes a feasible implementation of a midpoint in a combined approach to damage. It considers four categories of damage: human health, ecosystem quality, climate change, resources. This type of methodology was chosen for the analysis of environmental impacts for LCA of compost production since it has the advantage of being express in points which facilitates the calculations. The LCA included all raw materials and compost production and transport (did not include any agriculture and production activities associated with food products, food consumption and facilities’ construction). The system expansion or substitution option is the preferred option in LCA concerning waste management systems. To this method to be applied the system should also deliver co-products besides doing the waste treatment. The fertilizer ammonium nitrate was chosen as the avoided process for the compost produced (ratio considered 1/3 kg of compost equivalent to 1 kg chemical fertilizer) in composting. The same procedure was adopted to other materials such as metals, paper and plastics. The functional unit considered was 1 kg of compost.
3. Results

Table 1 presents the results obtained with the LCA methodology. It was also possible to conclude that the compost is a product with a positive impact on the environment, since it presents a negative value. In addition, it avoids the emission of 1652 kg CO$_2$eq per ton of compost. The environmental impacts associated with compost application were calculated, however, information available concerning the way the application is done (by hand or using machinery) and dose is not very accurate. In the worst scenario, the contribution is of 0.003 Pt/ton compost, which does not significantly change the overall environmental impact value presented in table 1. The same can be said to greenhouse emissions.

<table>
<thead>
<tr>
<th>Table 1- Results obtained with the LCA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pt/ton compost</td>
</tr>
<tr>
<td>kg CO$_2$ eq avoided /ton compost</td>
</tr>
</tbody>
</table>

4. Conclusions

It was possible to conclude, as expected, that composting has several benefits: avoids greenhouse gas emissions, allows the production of good quality compost that can increase soil quality and resource efficiency. It was also possible to verify that the compost is a product with a positive impact on the environment.

References
EVALUATION OF MASS REDUCTION TREATMENT TECHNOLOGIES WITH THE PURPOSE OF THE LIFE EXTENSION OF SÃO PAULO'S MUNICIPAL SANITARY LANDFILL

E.R. Silva (1), G. Mondelli (3)

1: Center of Engineering, Modelling and Social Applied Sciences, Federal University of ABC – Avenida dos Estados, 5001, Santo André-SP, Brazil

Abstract: The environmental concern with the treatment and final disposal of municipal solid waste generated in cities has increased worldwide. In São Paulo, the use of sanitary landfills is preponderant, so it is necessary to evaluate the treatment technologies currently used in other countries and propose the better treatment scenario that incorporates the segregation of the recoverable fraction or for use in processes as a source of energy, for São Paulo city. The characteristics of the waste generated, which are the main factor for the choice of the treatment technology and consequent recovery efficiency, and the Technique for Order of Preference by Similarity to Ideal Solution, considering factors such as environmental, financial, technical and social, were used over four Scenarios that apply treatment technologies for disposal mass reduction. After the method application, the better Scenario applies the thermal and the mechanical biological treatment, over the application of these methods separately.

Key words: Municipal Solid Waste (MSW), Integrated solid waste management, Mechanical Biological Treatment, Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS).

1. Integrated Solid Waste Management
In the world, the theme of MSW treatment has evolved a lot in recent decades, in several countries there had been an increase of the legal requirement to reduce landfilled waste or increased recycling.

2. Study Site
Located in the Southeast region of the State of São Paulo, the city holds 1.5 million km². The municipality has divided into two large areas, in this way, the search is limited to raise the data pertaining to the divisible services in Southeast Region of São Paulo, which corresponds to about 6.7 million inhabitants in an area of 989.86 km² and representing 54% of the volume generated by the municipality (on average 6,500 t/day) [1].

3. Methods
3.1. Multi Criteria Decision Making and Technique for Order of Preference by Similarity to Ideal Solution
For choosing the best scenario to be applied, TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method will be used, since beyond the advantages cited by Pires et al. (2011) [2] and Roszkowska (2011) [3], which are: Simple; intuitive and clear logic that represent the rationale of human choice; a scalar value that accounts for both the best and worst alternatives ability to measure the relative performance for each alternative in a sample mathematical form.

3.2. Solid Waste Treatment Scenarios
The scenarios proposed, always took into consideration the current total generation of the study area (6,500t/day). The Scenario “1” presents 98% of solid waste collected are forwarded directly to landfill and the remaining 2% are from dry fraction selective collection. The Scenario “2” maintains the selective waste collection and adds 2 mechanical biological treatment units, where the materials are separated (organic fraction / dry fraction). The Scenario “3” adds to the selective collection only 2 thermal treatment plants, each one of 2,400 t/day, with energy recovery. The Scenario “4” considers the sum of scenarios 2 and 3, but with smaller energy recovery units, 1,600 t/day

3.3. TOPSIS
To determine the performance of each scenario, according to the selected criteria to form a decision matrix to be used in TOPSIS. To this step, a combination of working plants data and relevant literature is used, and a scenario vs criteria is formed in Table 1. A scale of 0-100 is used, where “0” corresponds to the actual situation or has no impact to the criteria, while 100 corresponds where the situation has a relevant impact to the criteria. Next, a standard decision matrix is computed by using the elements of decision matrix, and the weighted standard decision matrix is developed by multiplying the values in the standard decision matrix with the weight value of those criteria [4]. To increase fairness, was used equal weights for each criteria.
4. Results and Discussion
The deviations of each decision point from the ideal and negative ideal solutions are computed via using Euclidian Distance Approach; and the relative proximity of each decision alternative to the ideal solution (Ci*) is computed using the ideal and negative ideal separation measures. Here, Ci* takes a value between 0 and 1; and the closer Ci* value to 1 is, the closer the decision alternative is to the ideal solution; Applying the appropriate formulas, the values of D+, D- and Ci*[5]; and the resulting ranking of the scenarios alternatives are presented in Table 2. Hence, according to the outgoing flow and incoming flow values, it is found that scenario 4 is the best for the chosen criteria.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>(C1)</th>
<th>(C2)</th>
<th>(C3)</th>
<th>(C4)</th>
<th>(C5)</th>
<th>(C6)</th>
<th>(C7)</th>
<th>(C8)</th>
<th>(C9)</th>
<th>(C10)</th>
<th>(C11)</th>
<th>(C12)</th>
<th>(C13)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>2</td>
<td>-</td>
<td>98</td>
<td>2</td>
<td>10</td>
<td>2</td>
<td>10</td>
<td>2</td>
<td>11</td>
<td>99</td>
<td>99</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Scenario 2</td>
<td>13</td>
<td>18</td>
<td>76</td>
<td>32</td>
<td>20</td>
<td>15</td>
<td>8</td>
<td>21</td>
<td>22</td>
<td>29</td>
<td>86</td>
<td>84</td>
<td>23</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>2</td>
<td>74</td>
<td>46</td>
<td>76</td>
<td>70</td>
<td>2</td>
<td>62</td>
<td>16</td>
<td>39</td>
<td>26</td>
<td>84</td>
<td>54</td>
<td>62</td>
</tr>
<tr>
<td>Scenario 4</td>
<td>13</td>
<td>67</td>
<td>42</td>
<td>81</td>
<td>59</td>
<td>15</td>
<td>42</td>
<td>30</td>
<td>47</td>
<td>39</td>
<td>76</td>
<td>55</td>
<td>58</td>
</tr>
</tbody>
</table>

Table 1: Scenario vs Criteria using TOPSIS method

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Positive Ideal Separation Measures (D+)</th>
<th>Ideal Separation Measures (D-)</th>
<th>Ci*</th>
<th>Result Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>0.25422</td>
<td>0.01184</td>
<td>0.29977</td>
<td>4</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>0.14604</td>
<td>0.03027</td>
<td>0.54368</td>
<td>2</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>0.16551</td>
<td>0.03753</td>
<td>0.53927</td>
<td>3</td>
</tr>
<tr>
<td>Scenario 4</td>
<td>0.09862</td>
<td>0.06053</td>
<td>0.71385</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 2: Results TOPSIS Ranking

5. Conclusions
Contrary to popular thought in Brazil, in other countries such as European Union, Japan, China and EUA, indicate that the deploying of waste treatment technologies are widely used and, with China's exception, the growth of recycling is directly proportional to the thermal treatment use. Considering the city of São Paulo size, an alternative, which should take into consideration for the minimization of waste being sent to landfills, is a sum of technologies such as mechanical biological treatment and thermal treatment. The best scenario, after application of TOPSIS methodology, contributes to recovery of materials and consequently for circular economy. The thermal treatment, beyond the energy generation, contributes favorably reducing the disposal of organic material in sanitary landfills.

Acknowledgements
This work has been very supported by Ecourbis Ambiental S.A. that became possible several technical visits in municipal waste treatment plants, as also supplied the data from the Gravimetric studies carried out in the years 2017 and 2018 in the Southeast Region. This research is also approved by CNPq (National Council for Scientific and Technological Development), but without financing.

References
WASTE MANAGEMENT INDICATORS THAT CONTRIBUTE TO SUSTAINABLE CITIES: AN ANALYSIS FROM A CIRCULAR PERSPECTIVE

M. Braulio-Gonzalo(1), M.D. Bovea(1)

1: Department of Mechanical Engineering and Construction, Universitat Jaume I, Avda. Vicent Sos Baynat s/n 12071 Castellón de la Plana, Spain

Abstract: In the sustainable cities context, circular economy is recently gaining more attention, where waste management is one of its main topics. Traditionally however, the sustainability of an urban area can be analysed by applying different Urban Sustainability Assessment (USA) tools that combine environmental issues such as transport, energy, water or waste with socio-economic issues. This study aimed to analyse how waste management-related indicators are included in some internationally recognised USA tools, and how they are related to the circular economy perspective.

Key words: Waste management, Waste fraction, Circular economy, Urban sustainability assessment tools.

1. Introduction

As cities are currently considered to form a vital part of the global impact response, their urban sustainability assessment is being increasingly analysed [1]. Some methods called Urban Sustainability Assessment (USA) tools have been developed worldwide for this purpose [2], which address different environmental issues, such as transport, energy, water or waste, among others, and also socio-economic issues. In addition, and specifically in relation to waste management, the European Commission recently adopted an ambitious Circular Economy Package [3], which includes legislative proposals on waste [3] to stimulate Europe's transition towards circular economy. By linking these actions, this study presents a review on how waste management-related indicators are included in some internationally recognised USA tools, and how they are related to the circular economy perspective. The results allowed the critical analysis of the level of contribution of waste management issues to assess urban sustainability, and to also identify if circularity principles are being taken into account.

2. Methodology

The employed methodology is split into two main stages, as seen in Figure 1. Stage I approaches a content review of the indicators included in 13 USA tools ((BREEAM, LEED, CASBEE, ECOCITY, Le Modele INDI-RU, BRIDGE, KITCASP, LB, SIDS, CGYM, SEV, BCN and BIL). Accordingly, 786 indicators were classified into 14 topics [4], which allowed waste-related indicators to be identified, included as topic “WASTE”. In Stage II, the circular economy principles are reviewed and a classification of the previously identified waste indicators is conducted according to the “waste management” and “waste fraction” criteria.

3. Results

The results from Stage I are presented in Figure 2, which depicts the number of indicators that the 13 reviewed tools include in the 14 topics. The “WASTE” topic includes 40 indicators, which account for a weight of 5.09% in relation to the global one. ECOCITY is the tool that includes the most waste indicators (10), while LEED, BREEAM and BIL only include 1, and BRIDGE and KITCASP do not include any.

Fig. 1: Methodology.
The **Stage II** results are in Figure 3, which classifies the waste-related indicators into the considered “waste management” strategy used and the “waste fraction”.

4. Conclusions

As depicted from the results of this study, waste is barely covered by the reference USA tools developed to assess the urban sustainability of neighbourhoods or entire cities. Among the waste management-related indicators, segregation is the most widely promoted, followed by other kinds of valorisation (not reuse or recycling), composting and prevention of waste generation. Reuse and recycling are barely encouraged. Regarding waste fractions, indicators do not generally specify which kind of materials need to be separately treated. Most refer to generic waste, and then suggest segregation in separate containers in a storage space in households or the building to be subsequently collected and transported. CDW and hazardous waste are rarely considered, while WEEE or packaging is not covered by any of the tools.

Acknowledgements

The authors are grateful to the Ministerio de Ciencia, Innovación y Universidades (Spain) for funding for this study (Project DPI2017-89451-R).

References

INTRODUCTION

As cities are currently considered to form a vital part of the global impact response, their urban sustainability assessment is being increasingly analysed [1]. Some tools included in the concept of Urban Sustainability Assessment (USA) have been developed worldwide for this purpose [2], which address different environmental issues, such as transport, energy, water or waste, among others, and also socio-economic issues. In addition, and specifically in relation to waste management, the European Commission recently adopted an ambitious Circular Economy Package [3], which includes legislative proposals on waste [3] to stimulate Europe’s transition towards circular economy. By linking these actions, this study presents a review on how waste management-related indicators are included in some internationally recognised USA tools, and how they are related to the circular economy perspective. The results allowed the critical analysis of the level of contribution of waste management issues in the assessment of urban sustainability, and its relationship with the circular economy principles.

METHODOLOGY

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RESULTS

The results from Stage I are presented in Figure 2, which depicts the number of indicators that the 13 reviewed tools include in the 14 topics. The “WASTE” topic includes 40 indicators, which account for a weight of 5.09% in relation to the global one. ECOCITY is the tool that includes the most waste indicators (10), while LEED, BREEAM and BIL only include 1, and BRIDGE and KITCASp do not include any. The Stage II results are in Figure 3, which classifies the waste-related indicators into the considered “waste management” strategy used and the “waste fraction”.

CONCLUSIONS

As depicted from the results of this study, waste is barely covered by the reference USA tools developed to assess the urban sustainability of neighbourhoods or entire cities. Focusing on waste management indicators related to waste management activities, segregation is the most widely promoted, followed by other kinds of valorisation (not reuse or recycling), composting and prevention of waste generation. Reuse and recycling are rarely encouraged. Regarding waste fractions, indicators do not generally specify which kind of materials need to be separately treated. Most refer to generic waste, and then suggest segregation in separate containers in a storage space in households or the building to be subsequently collected and transported. Construction & demolition and hazardous wastes are rarely considered, while electric and electronic equipment or packaging wastes are not covered by any of the tools.

ACKNOWLEDGMENT

The authors are grateful to the Ministerio de Ciencia, Innovación y Universidades (Spain) for funding this study (Project DPI2017-89451-R).

REFERENCES

A COLLABORATIVE REUSE MODEL FOR SURPLUS FOOD MATERIALS

P. Tavri (1)

1: Faculty of Arts and Architecture, Kingston University, UK

Abstract: In the UK, it is already a matter of concern within the industry that, to most people outside the waste sector ‘reuse’ and ‘recycle’ are essentially synonymous [1]. Furthermore, in the waste hierarchy, the term ‘reuse’ is overshadowed by the umbrella term ‘Preparing for reuse’ [2]. Such problematic conflations highlight a wider issue surrounding the ambiguity regarding the understanding of what constitutes reuse, both within and outside the sector.

This contribution focuses on introducing the new definition needs to be aligned with the Organisation for Economic Co-operation and Development definition [3] and the recent Defra definition [4]. The newly introduced definition is justified in this contribution by presenting one of the collaborative reuse models which is, in this instance, for surplus food materials with the focus on the retail sector [5].

Key words: Reuse, collaboration, organisations, surplus food waste, redistribution.

1. Introduction

My PhD research investigation regarding reuse behaviour at an organisational level in the UK developed collaborative reuse models, presenting the type of materials that are identified as carrying the capacity to reduce waste production, while maintaining economic growth when reused. The research involved employing a mixed method approach, whereby content analysis was carried out on 36 organisations selected from the WRAP case studies between the years 2012 and 2013. Following this, I conducted semi-structured interviews within 11 corporations (five retailers, two construction companies, two waste service provides, and two manufacturers) and 8 Third Sector Organisations (TSOs). The collaborative models that I then developed through the investigation were further validated through my evaluation process, which involved the view proffered by Robson [6] that “...[this form of participative evaluation can empower key stakeholders] to work in more reflective ways and, possibly, to incorporate a general questioning evaluative stance into their way of working,” Taking this approach enabled me to revise the models and thus, enhanced their usability in real-life situations.

This article presents one of these collaborative reuse models, which is, in this instance, for surplus food materials with the focus on the retail sector (Fig. 1). The successful reuse of surplus food materials1 is evident in the report by WRAP [7] on surplus food redistribution in the UK. The report shows that in the UK between 2015 and 2017, the redistribution of surplus food from the retail sector doubled (the equivalent of an additional 15 million meals given to people in need) and redistribution from the manufacturing sector increased by 71%. With the focus on the retail sector, this article presents a model (see Fig. 1) detailing the type of organisations and key collaborative measures that could enable long-term partnerships towards the reuse of surplus food materials, thus elevating the visibility of reuse. Furthermore, the model is intended to augment the viability of reuse at organisational level, thereby allowing other similar organisations to utilize it as a guidance tool for facilitating collaborative reuse practice.

2. Section

Fig. 1 presents the model, whereby, Option 1 and Option 3 in the Figure indicate that retailers’ partnerships with either national level TSOs or local level TSOs respectively carry distinct benefits in terms of accessibility, profitability, and sustaining localism. Therefore the model demonstrates that reuse of surplus food materials can provide a solution to the seemingly irreconcilable differences between retailers - whose main focus is gaining profit and TSOs - who are typically geared towards gaining partnerships with retailers in order to generate social and environmental benefits. Nevertheless, this reconciliation of reuse partnerships only becomes viable when various ‘Requirements’ (See no. 2 in model) are accounted for. This is owing to the fact that, behind what might appear to be a simple partnership, there is a more complex range of qualities, which retailers assess. For instance, space, logistics, economic benefit, corporate thinking, reputation, and credibility are the identified key requirements that retailers consider prior to establish a partnership with national level TSOs. In addition, the research findings indicate that it is as yet unclear whether the reuse partnerships between retailers and TSOs have longevity. For instance, a food retailer said in the interview that “...in terms of forecast, the partnership with TSOs is in

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1 For the purpose of the research surplus food materials are referred to as unsold or surplus food stock.
a bit of a dilemma. Since through our supply chain, we have been trying to reduce the amount of surplus, which will reduce the amount of food going to TSOs. On one hand, we will have an economic benefit, but it will lead to a reduction in social benefit.” The research further reemphasizes the findings presented in the model, which demonstrates the various options taken by food retailers and the differences between redistribution at store level and depot level. The model demonstrates that distribution for reuse via national level TSO (See Option 1 in model) is prioritized when unsold food stock is generated at depot level. However, at store level, recycling, recovery, and anaerobic digestion (See Option 4 in model) is prioritized, this is owing to the fact that most of the food is retained until its expiry date in stores and thus become non-consumable.

The uncertainty of the reuse partnership between retailers and TSOs is reiterated via Option 2 (in-house storage for redistribution to manufacturers) whereby retailers consider this a preferable choice over Option 1 (distribution for reuse via national level TSOs). Concern regarding the quality of unsold food stock is indicated in the research as one of the major reasons towards this shift. The research argues that despite the fact that national level TSOs has the necessary credibility to check the technical standards of surplus food quality. However, from a retailer's perspective, there is an advantage for them in retaining the quality checks in-house, as this allows them to measure possible risks inherent in distributing food that is non-consumable. In addition, retailers perceive that preference of redistribution to manufacturers enable them to achieve the circularity and close-the-loop through reverse logistics.

3. Conclusion

In summary, this model provides a useful analytical measure for managing surplus food materials (potentially via reuse) in practical scenarios and various ‘Options’ deliver an effective guidance tool for relevant stakeholders. Nevertheless, the model also emphasizes the fact that, in real-life situations, partnerships with the TSOs are much more complex than can possibly be represented in a model. This is based on the fact that TSOs are mostly underfunded, suffering from a lack of expertise, logistics, and space; all of these factors make them vulnerable when representing themselves as potential leaders in the area of reuse. Nonetheless, despite these challenges, in a broader context, reuse partnerships show that, unlike the business or corporate market (where smaller organisations/businesses are increasingly crowded out or taken over by large corporations, and their share in the market grows ever smaller [8]) in the reuse TSO market, within this sample of the research, a very different dynamic can be seen. In contrast to the ‘big fish/small fish’ inequality within the corporate sector, the national level TSOs actually require partnerships, and must build links with local level TSOs, charities, communities or social enterprises in order to make reuse the first ‘Option’ for corporations. Essentially, collaboration across different levels and different sectors is the key factor for making reuse work, and the dynamic force in these collaborative partnerships is often the TSOs. The research has identified that TSOs take pride in their achievements in reuse. However, these activities are pre-dominantly presented as ‘recycle’ for the community and not ‘reuse’. Thus, this article presents a model that establishes an appropriate use of the term reuse to make it clear and visible by defining it as “an item or product which is used multiple times (more than once), either in its original form or after washing or minor repairs, for the same or an alternative purpose.”

4. Bibliography

Fig. 1: Collaborative reuse model for surplus food material
Collaborative reuse model for surplus food materials

Option 1: National level TSOs registered with local level TSOs for donations

Option 2: In-house storage for redistribution to manufacturers

Option 3: Local level TSOs registered/not registered with national level TSOs for donations

Option 4: Recycling or recovery (such as Anaerobic Digestion)

Requirements to maintain reuse partnerships among retailers & national level TSOs:
- Space
- Logistics
- Economic benefit
- Corporate thinking
- Reputation
- Credibility

Requirements to maintain reuse partnerships among retailers & local level TSOs:
- Space
- Credibility
- Localism
- Corporate thinking

Notes:
- All links are equally important with no hierarchy
- Breakage of single link can act as a barrier and make the model unsustainable

Reference:
- TSOs: Third Sector Organisations
- Images are captured from: https://thenounproject.com/

Author:
Purva Tavri, Researcher
FROM ELECTRONIC WASTE TO PLASMONIC RESPONSIVE GOLD NANOPARTICLES

V. Oestreicher (1,2), C.S. García (1), M.B Rossi (3), R.M. Pontiggia (3), G. Soler-Illia (1*), P.C. Angelomé (2*)

1: Instituto de Nanosistemas, UNSAM, CONICET, 25 de mayo 1021, San Martín (1650), Buenos Aires, Argentina
2: Gerencia Química, Centro Atómico Constituyentes, Comisión Nacional de Energía Atómica, CONICET, Av. Gral. Paz 1499, San Martín (1650), Buenos Aires, Argentina
3: Investigación, Desarrollo e Innovación, Benito Roggio Ambienta, Buenos Aires, Argentina

Abstract: The possibility of using Waste Electrical and Electronic Equipment (WEEE) as a secondary raw material to synthesize stable and sensitive Au nanoparticles has been demonstrated. By means of physical and hydrometallurgical methods, metallic Au was extracted selectively from microprocessors, giving rise to a metallic solution enriched in Au (III). Afterwards, the obtained solution was used to obtain pure and stable Au nanoparticles, using a reduction method adapted to the high acidity and ionic force of the metallic solution. Finally, the obtained nanoparticles were tested as optical sensors, with promising results. This work demonstrates the feasibility of coupling urban mining with reduction of environmental harm, and recovery and reuse of critical raw materials - such as precious metals - to produce valuable nanomaterials, with potential applications for end-users.

Key words: Urban mining, WEEE, Critical raw materials, Hydrometallurgy, Gold nanoparticles, Green Chemistry.

1. Introduction

Production of EEE is highly resource intensive, making use of several elements already classified as critical raw materials (rare earth elements and precious metals), according to the European Commission. Currently, EEE are massively consumed and are disposed of prior to their end-of-life, resulting in accumulation and eventually inappropriate final disposal, with subsequent loss of valuable metals. Gold is one of the most valuable metals contained in WEEE, and more than 300 tons of this metal are used in electronics each year. Au concentrations range 300-350 g/ton for mobile phones, and 200-250 g/t for printed circuit boards, representing a 10:1 rate compared to primary metal sources. Therefore, the recovery of gold from this secondary raw material would reduce the environmental and social impact of conventional mining, and would mean a potential saving of 17,000 tons of carbon dioxide emissions. [1] On the other hand, nanomaterials exhibit physical and chemical properties that are very different from those of bulk materials. This behavior is due to the fact that they have at least one dimension in the 1-100 nm range. Properties such as the melting point, conductivity or color show a strong dependence on the material’s size. These differential properties make nanotechnology one of the most developed areas of the 21st century. In particular, Au nanoparticles (Au NPs) have aroused much interest in recent years, due to their optical and catalytic properties and their high chemical stability. As a consequence, Au NPs have been tested in a wide variety of applications, including: optical sensors, solar cells, catalysts, biotargeting and drug delivery. [2]

2. Results and discussion

Figure 1 shows an illustrative scheme of the experimental design performed in this work.

Fig. 1: Sequence of physical and chemical steps involved in the transformation of WEEE in Au (III) solution and finally in a stable suspension of Au NPs.

First stage is about selective extraction of Au contained in microprocessors. A WEEE collection campaign was performed and microprocessors were obtained by means of dismantling and sorting of discarded personal computers. After mechanical treatments (i.e. shredding and magnetic separation), a metallic fraction was obtained, mainly composed of metallic pins. Chemical composition analysis demonstrated Au content is concentrated in this fraction. Subsequently, this Au enriched fraction (Au-E) was subjected to a hydrometallurgical extraction, by means of a two-step oxidation process. The first step involved the dissolution of the pins cores, mainly composed of either platinite (Ni, Fe, Cu) or kovar (Ni, Co, Fe), whereas Au layers remained solid. After filtration, a second oxidation step was performed, allowing the dissolution of the metallic Au into Au (III).
The obtained Au (III) solution presented a high acidity and a high ionic force that are, in principle, incompatible with the most commonly used Au NPs synthesis. Thus, a new methodology was developed to overcome those limitations: sodium citrate was used both as a reductive and neutralizing agent. Ascorbic acid was added as second reductive agent and polyvinylpyrrolidone was used as stabilizing agent. By carefully controlling the proportion of all the reagents, stable and pure Au NPs could be obtained, as can be seen in Figure 2. The obtained particles are a mixture of both spheroids and triangles of 10 nm and 15 nm of characteristic length respectively. The particles are crystalline and composed exclusively by Au.

![Image](image.png)

Fig. 2: Characterization of the obtained Au NPs: UV-Vis and digital photography of Au NPs suspension (left), TEM inspection (top right) and sensing behavior of Au NP covered substrates (low right).

To test the potentialities of the obtained Au NPs, a proof of concept experiment was designed accordingly. For that purpose, Au NPs covered substrates were prepared in a simple two step method. First, glass slides were functionalized with a positively charged polymer. Afterwards, the substrates were immersed in the Au NPs solution. The obtained sample present a violet color, whose intensity can be controlled through reaction time. Interestingly, once attached, the Au NPs remain stable for months: no significant variations in the UV-vis spectra were observed. Sensitivity towards medium’s refractive index changes was tested by measuring the spectra of Au NPs covered glass slides immersed in different solvents (see Figure 2). The results indicate that the particles are sensitivity towards medium’s refractive index changes and thus, could find applications as components of optical sensors.

3. Conclusions

The use of WEEE as Au source to prepare stable and sensitive Au nanoparticles was demonstrated in this work. Through a series of mechanical and hydrometallurgical steps, we have been able to selectively extract metallic Au from microprocessors, giving rise to a Au (III) solution. Such solution was employed as a secondary raw material to obtain metallic Au NPs. Moreover, we have demonstrated that the obtained nanoparticles are stable and can be used as optical sensors. The obtained results pave the way towards utilizing urban mining to obtain highly valuable nanomaterials.

Acknowledgements

This work was performed under a collaboration established between CONICET and TECSAN S.A., in the framework of a PDTS (Res. 3011/2016). VO and CG acknowledge CONICET for their postdoctoral fellowships.

References


The use of WEEE as gold source to prepare stable and sensitive Au NPs was demonstrated in this work. Through a series of simple steps, we have been able to extract metallic gold from microprocessors, dissolve it to obtain a Au (111) solution and use such solution as a source to obtain metallic Au NPs. Moreover, we have demonstrated that the obtained nanoparticles are stable and can be used as optical sensors. The obtained results pave the way towards utilizing urban mining to obtain highly valuable nanomaterials.

References
PILOT PROJECT ON CIRCULAR BIO-ECONOMY OF ORGANIC WASTES AT LOCAL SCALE WITH SOCIAL AND TRAINING DIMENSION

I. Irigoien (1,2), J. S. Arizmendiarieta (1,2,3), J. Muro (2), A. Oreja (2), E. Ayape (4), J. Cia (4), R. Plana (1,5)

1: FertileAuro (FeA). Professionals association. Spain. fearesiduos@gmail.com
2: Agonomía, Biotecnología y Alimentación, Universidad Pública Navarra. Campus arrosadia s/n. 31006 Pamplona, Navarra, Spain. natxo.irigoien@unavarra.es
3: Luar Ingurumena. Environmental Consultancy, Leitzar, Spain. josebasanchez.luar@gmail.com
4: Josenea. Medicinal plants, production. Lumbier, Spain. Biojesus.cia@josenea.com
5: Maestro Compostador Environmental Consultancy, Barcelona, Spain. plana.compost@gmail.com

Abstract: The local system of biological waste management in small and decentralized facilities provides agile and effective tools to achieve the objectives of recovery of materials marked by the circular economy legislation. They can present technical, economic, social and environmental advantages compared to centralized systems, especially in rural regions. In the Sangüesa region, in the Navarre Pyrenees, a pilot project is being carried out to develop, investigate, teach and broadcast this decentralized model in the region. This project is being carried out in Josenea, a social integration and training center for people in a situation of social exclusion that grows and produces organic medicinal plants. The project is currently being executed and this paper presents some of the main results achieved.

Keywords: Social economy, decentralized composting, fractal, bio-waste management, agroecology.

1. Introduction

Linear economy, based on “use and throw”, have led to degeneration of human capital at local and global [1]. Our rural environment is depopulating, our soils are being worse and eroding and the climate is changing. To face this situation, the European Union passed the first package about Circular Economy who tries to develop a regenerative economic model instead of degenerative one. For this, among other measures, it states the source-separate collection obligations and/or local treatment of bio-waste, to recycling the 65% of municipal waste by 2035 [2].

In Spain, the bio-wastes treatment is usually performed mainly in waste disposal sites and in large size centralized facilities. This entails that bio-wastes must be transported long distances. Therefore there is a lack of connection among waste materials, their generators, and the place where they are generated. When this kind of system is applied, the percentage of participation by population in the waste collection is usually insufficient to achieve the targets of the Circular Economy. However, it has been proved that decentralized management of bio-wastes is a powerful strategy for the bio-wastes recycling. It has good technical, social, economic and environmental results, especially in rural and suburban zones [3].

Decentralized management is based on simple but strong and reliable technologies like in situ composting (household, communal, municipal, regional) with or without collection systems (drop off systems) and that can be developed by growers (Austrian model), by social-labour centres (social composting) or by other municipal agents (municipal workers, master composter), etc. In this way, it can be a great tool in order to develop of social and environmental territorial policies, and it can generate important and amazing synergies between them.

The objective of this project is to develop, research and broadcasting this decentralized system integrating a social inclusion enterprise. Besides this, the project also aims to capacitate people to replicate or adapt the model to other areas.


The PDR project 2014-2020 "CIRCULAR LOCAL BIO-ECONOMY WITH SOCIAL DIMENSION AND LOCAL TRAINING" started in the summer of 2018. The project is funded by the FEADER funds in the announcement of grants “Support for pilot projects, new products, practices, processes and technological development”. This project was carried out in Josenea because it is a socio-labor integration company that works with people at risk of social exclusion. This company is located in Lumbier (northern Spain), has more than 45 workers and is mainly engaged in the production, processing and marketing of medicinal plants.

Lumbier belongs to the Waste Association of the Sangüesa region. This is a rural community of pre-Pyrenees with 10,000 residents distributed in 18 cities and has a density of 10 inhabitants / km². It has a high rate of depopulation and its population is aging gradually. There is not a specific bio-waste management system in this region and more than 69% of the waste generated is deposited directly in a sanitary landfill located 40 km away [4]. This is clearly a linear model in a typically rural area. The climate of the region is Mediterranean, with strong periods of summer drought and its soils have significant erosion problems that increase year after year.

3. Results

The project has a budget of 199,000 € and is organized into 5 main interrelated points: i) organic waste collection, ii) treatment, iii) research, iv) training and v) dissemination.
3.1. Biowaste Collection

The waste produced by the large generators of this area is collected through a system of individual containers of less than 100 litres. More than 500 kg of bio-waste and pruning waste are collected per week and transported by a truck to the Josenea’s facilities located in Lumbier.

3.2. Treatment

Bio-waste collected separately is mixed weekly with waste pruning in dynamic composting windrows located over a concrete floor with leachate collection. This compost suffers strong thermophilic phases and reaches maturity (Rottegrade III) in a few weeks. There have been no problems with significant leachates or odours. The compost piles need to be watered several times throughout the process with their own leachates, as well as water obtained from a water well.

3.3. Investigation

The composting process and its effect on long and short-term crops are being studied. The results of the research have led to optimize the composting process, allowing the adjustment of the initial mixtures, as well as the technical instructions for the operators of the installation. In relation to the use of compost, it is worth noting its low content of heavy metals and high content of N. Therefore, this compost is suitable for organic farming. In addition to compost, vermicompost and various liquid fertilizers have been developed within this project.

3.4. Training

This model is being used as a living laboratory of the decentralized model for waste management. Therefore, during the project four training activities have been carried out, in which more than 100 people from different regions have been trained in site composting. Some training activities have been developed with the Public University of Navarra (UPNA) and other with organizations such as Udako Euskal Unibertsitatea.

3.5. Broadcasting

The diffusion of the project has been carried out at different levels. At the local level, the project has been reported in all local print media and in several local and regional radio programs. The project was presented in Lumbier in a summer course organized by UPNA ("Social and economic opportunities for the decentralized management of biological waste: Josenea Project") in August 2018. This course was attended by local and regional authorities and more than 50 people. A training program on composting and circular economy has been developed in the scholar centres of the region. On a global scale, the project has a website and is active in several social networks. In addition, scientific communications related to the project have been presented at several scientific meetings (Spanish Composting Network in Valencia. Finally, the project has been selected as an exemplary practice of rural development by the European Network for Rural Development and, it has also been officially declared as "Investment of regional interest" by the government of Navarra.

4. Conclusions

This pilot project about bio-waste management made by a social company has contributed to regenerate the human and natural capital of this area. Beside this, it also has generated economic capital, which directly affects to the area where bio-wastes are produced. This project has contribute to improve the decentralized bio-waste management model, to broadcast it, and to capacitate people to take this model to other regions adapting it to their circumstances and characteristics.

Acknowledgements

This work has been funded by the European Agricultural fund for Rural Development. Rural Development Program of Gobierno de Navarra 2014-2020. “Pilot Project of circular bio-economy of organic wastes at local scale with social and training dimension.”

References

Decentralized management of the Organic Fraction of Municipal Waste by means of composting in small, simple and safe facilities is an effective way to achieve the objectives of European legislation on circular economy. In order to test, research, train and broadcast this decentralized management system, a pilot project is being developed in Lumbier (Navarre, Spain). This Pilot is being carried out in Josenea, a social integration and training company for people in a situation of social exclusion dedicated to the production of medicinal organic certified products. This project entitled “Pilot Project of circular bioeconomy of organic wastes at local scale with social and training dimensions” has been funded with 199,000€ from the European Agricultural fund for Rural Development. It will finish in February 2020. The project has been selected as an exemplary practice of rural development by the European Network for Rural Development and it has also been officially declared as "Investment of regional interest" by the Government of Navarra.

Facilities to develop and disseminate this pilot project have been built and are already in service. Biowaste is collected and composted on a small-scale facility through outdoors dynamic windrows (4 tons / windrow). At the moment, different researches are being carried out in order to: i) improve the process (amount and type of bulking required, compost maturation alternatives, developing a low-cost turning machine, etc.), ii) testing the compost (long time effect of this fertilizer on soil, short time effect on crops and weed control, etc.). In addition, different trainings are being carried out to train staff for the management of small-scale composting facilities. Finally, in order to broadcast this pilot project, multiple divulgation activities are being developing, such as summer courses, workshops, congress communicações, conferences and visits to show this project.

Preliminary Main Conclusions:

- According to the preliminary results biowaste generated by big producers presents a very low inorganic material content (<0,5%).
- More than 6,000 kg of OFMW/week can be easily managed reaching high thermophilic conditions during weeks.
- No any negative impact (leaching, odors, pests, etc) in the area has been noticed in despite of the large number of visitants.
- Produced compost has an high quality level (A Class). Its use is safe and suitable for organic farming production.
- Josenea staff trained by a Learning by Doing program. More than > 60 people train in several university courses.
- More than 100 people have visited the facilities and a lot of broadcasting activities developed: workshops, conferences, university summer courses, mass media interviews, etc.
ENERGETIC COMPARISON OF TWO SORTING PLANTS

B. S. Lopes (1), T. Henriques (1), T. Faria (1)

1: EFACEC Engenharia e Sistemas, S. A., Porto Salvo, Portugal

Abstract: Waste sorting facilities are a way to recover the material that can be re-used or recycled, avoiding other processes such as deposition in landfill or incineration. The energy consumed in these plants is very important and, as the time passes, efforts should be made in order to reduce it. The paper compares the energetic performance of two sorting plants: an automatic and a semi-automatic.

Key words: Sorting plant, energy consumption, material recovery.

1. Introduction

Waste sorting is a widely used process that can precede recycling. This process can occur manually or automatically [1]. In automated plants different equipment can be installed according to the material to be sorted: eddy current separator, near infrared sensors (NIR), disc screen, etc. As the main goal of these plants is to sort the recyclables, the design phase is a fundamental step.

The paper briefly describes the two sorting plants on section 2. Section 3 compares the performance of the plants. Finally, section 4 presents the conclusions.

2. Plants description

Plants have different configurations and equipment. Plant A (PA) is an automatic plant that was designed to process 4.2 tons per hour to sort polyethylene terephthalate (PET), high-density polyethylene (HDPE), low-density polyethylene (LDPE), mix plastic (MIX), ferrous (FERR) or non-ferrous (NFERR). Plant B (PB) processes 2.5 tons per hour to sort PET, HDPE, LDPE, MIX, FERR, NFERR, tetra-pack (TP) and paper (PAPER).

Both plants have a bag opener in the input phase, a magnetic separator and a baler in the end. In PA there are: two discs screen (>250 mm and <20 mm), one air separator for LDPE, two NIR for the other plastic fractions and one eddy current separator for non-ferrous. In PB there are: one ballistic separator, one NIR for LDPE, one NIR for MIX and PET and other one for PEA and ECAL.

In PA there is one sorting cabinet, after the bag opener, where large pieces of LDPE and bulky fraction are removed. On the other hand, in PB there are two sorting cabinet: one after the bag opener and another one to improve the final quality of the plastic fraction. Another difference between the plants is the number of operators: five in PA and sixteen in PB.

3. Results

The following results were obtained by analyzing the data of the plants for one month. Part of the data were recorded in a Supervisory Control and Data Acquisition (SCADA) system.

During the considered month, both plants processed per hour the same quantity: 2.3 ton/h. The refuge of PA is almost 53% of the total input mass, while the refuge of PB is 22%.

The predicted value of the refuge in PA was 18%. The high value found during the test means that a huge quantity of recyclables is being sent to the refuge. This fact will affect negatively the plant performance.

The recycling efficiency is defined as

$$\eta_{rec} = \frac{m_{output}}{m_{input}}$$  (1)

where $m_{output}$ is the total input mass without the refuge. The recycling efficiency of PB is 47%, while in PA it is 78%.

The electrical consumption of both plants was recorded. In order to compare the plants, the electrical consumption, during the considered month, was normalized using $m_{output}$ and the values are presented in Tab.1.
Table 1. Electrical consumption per ton of recyclables of PA and PB.

<table>
<thead>
<tr>
<th></th>
<th>Plant A</th>
<th>Plant B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical consumption per ton of recyclables [kWh/ton]</td>
<td>90.5</td>
<td>52.1</td>
</tr>
</tbody>
</table>

As can be seen in Tab.1, the electrical consumption per ton of PA is approximately 1.7 times higher than in PB.

If the designed conditions of PA were verified during the analyzed period, the refuge would be about 18%, what would bring the electrical consumption per ton of recyclables to 51.7 kWh/ton.

Figure 1 presents the percentage of the electrical energy consumed per equipment, which are similar in both plants. The compressed air station (associated to the NIR), the conveyors and the baler are the major fractions of the electrical energy consumed.

4. Conclusions

An energetic comparison of two sorting plants was presented. The previous analysis led us to conclude that in PA with a value of refuge of more than 50%, the electrical consumption per ton of recyclable almost double. On the other hand, if the plants are working with a refuge at about 20% (as predicted), the electrical consumption per ton of recyclables will be similar for both (about 50 kWh/ton).

Globally the different strategies used to sort LDPE, in terms of energy consumption, seems to have no impact on the total energy consumption.

It is also important to remember that PA is an automatic sorting plant while PB is a semi-automated one (with sixteen operators). The high number of operators will have an impact in the operational cost of the plant.

References

INTRODUCTION

Waste sorting is a widely used process that can precede recycling [1]. The energy consumption in these plants is very important and, as the time passes, efforts should be made in order to reduce it. A comparison of the energetic performance of two sorting plants: plant A and B is presented.

PLANTS DESCRIPTION

<table>
<thead>
<tr>
<th>PLANT</th>
<th>DESIGN CONDITIONS</th>
<th>TARGET MATERIALS</th>
<th>EQUIPMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>PLANTA</td>
<td>4.2 ton/h</td>
<td>PET, LDPE, FERR</td>
<td>Baler, Disc screen</td>
</tr>
<tr>
<td>PLANT B</td>
<td>2.5 ton/h</td>
<td>PET, LDPE, FERR</td>
<td>Baler, Disc screen</td>
</tr>
</tbody>
</table>

Legend: PET - polyethylene terephthalate; LDPE - low-density polyethylene; FERR - ferrous; NFER - non-ferrous; TP - tetra-packs; DAD - paper.

RESULTS

The electrical consumption of each plant was recorded, during one month, using the supervisory control and data acquisition system. Figures 1 and 2 present the electrical equipment consumption distribution for plants A and B. As can be seen, it is similar for both plants.

As showed in Fig. 3, the compressed air station, part of the optical sorters, consumes almost 1% of the total electrical consumption. In Plant B, this represents 6% of the optical sorters consumption, while in plant A it represents 87%. It is important to mention that in plant B the optical sorters consumption includes the conveyors while in plant A this was not taken in account.

Plants A and B have different strategies for LDPE sorting: a windshifter in plant A and a dedicated optical sorter in plant B. An electrical consumption comparison of these strategies is presented in Fig. 4. The chosen strategy seems to have a similar electrical consumption:

Plant A: 30% + 14%  
Plant B: 44%

In order to compare the plants, the electrical consumption of each one was normalized by the output recyclables, ξ:

$$\xi = \frac{E_{\text{consump}}}{m_{\text{output}}}$$

$$\xi_A = 90.5 \text{ kWh/ton}$$

$$\xi_B = 52.1 \text{ kWh/ton}$$

$$\xi_A / \xi_B = 1.7$$

This is due to the high refuge in plant A: almost 53%. This value is higher than the design value (18%). If the design value was verified ξ_A = 51.7 kWh/ton.

CONCLUSION

The previous analysis led us to conclude that both plants have a similar electrical consumption distribution. In plant A with a value of refuge of more than 50%, the electrical consumption per ton of recyclables almost doubled. On the other hand, if the plants are working with a refuge at about 20% (as predicted), the electrical consumption per ton of recyclables will be similar for both (about 50 kWh/ton).

REFERENCES

CHARACTERIZATION OF THE SOLID URBAN WASTE OF THE CITY OF USHUAIA, PCIA DE TIERRA DEL FUEGO, ARGENTINA

Lic. Pecotche, Santiago (1); Dr. Barcia, Lucia (2)

1: Technical Area, Consultora Impactos Ambientales SA, Buenos Aires, Argentina
2: Executive Director, Consultora Impactos Ambientales SA, Buenos Aires, Argentina.

Abstract: The generation of waste is currently one of the most important environmental problems in urban areas, mainly due to the volume of waste generated and the limitations of physical space for its final disposal. The city of Ushuaia is located in a geographical site limited by the Andes Mountains, which limits the availability of physical space for the construction of new landfills. That is why the planning of integrated urban solid waste management systems in the city should be framed in the study and characterization of each of its stages in order to make public resources more efficient.

The purpose of this paper is to provide up-to-date information on the generation and composition characteristics of the waste generated in the city of Ushuaia for the subsequent design of public policies for the integral management of more sustainable MSW.

Keywords: Urban Solid Waste (RSU), characterization, planning.

1. Introduction:

In the framework of compliance with the SDGs (Sustainable Development Goals) established from the Paris Protocol (2015) and whose mission is to guide global efforts to respond to the threat of climate change, within a context of sustainable development and eradication of poverty. To this end, a series of Objectives related to different topics was developed that obliges the parties to reach the goals of the global agreement. In the set of the 17 established SDGs, the present project fits within what is mentioned in number 11.6 "By 2030, reduce the per capita negative environmental impact of cities, including paying special attention to air quality and management of municipal and other types of waste ".

The generation of waste is currently one of the most relevant environmental issues in urban areas, mainly due to the volume of waste generated and the limitations of physical space for its final disposal. The effects related to inadequate management of urban solid waste (MSW) can be: risk of contamination of soils, aquifers and fluvial courses, emanation of polluting gases, proliferation of diseases, impact of ecosystems, among others. That is why the planning of integrated urban solid waste management systems in the city should be framed in the study and characterization of each of its stages in order to make public resources more efficient.

This work is carried out by the Consultant Impactos Ambientales SA in conjunction with the Agrotechnical Company Fueguina SACIF through an agreement with the National University of Tierra del Fuego and the Municipality of the city of Ushuaia in the months of April and May 2019

The purpose of this study is to provide up-to-date information on the generation and composition characteristics of the waste generated in the city of Ushuaia for the subsequent design of public policies for the integral management of more sustainable MSW. To achieve this general objective, it will be necessary to: 1) Identify the relationship between the generation of waste and the socioeconomic level of the population according to its strata; 2) Determine the composition and average quality of the RSU of the city of Ushuaia; 3) determine the composition and quality of the waste generated in the different geographical areas (neighborhoods) and the areas of provision of Urban Hygiene services; 4) know the seasonal variations of the city's RSU; 5) determine those fractions of potentially recyclable and compostable waste by zones or neighborhoods; and 6) determine quantities and materials that are currently segregated by the waste separation system currently implemented in the city.
2. Development:

The lack of data on the quantitative and qualitative characteristics of the RSU generated in a community, the scarcity of comprehensive studies that evaluate the management of solid waste in terms of environmental sustainability, the lack of a comprehensive vision of the problem, citizen habits unfriendly to the environment, lack of commitment of those responsible for the management of the RSU, further complicate the possibilities of recovery, use and comprehensive management of waste. We can only mention an antecedent of 2009 made by the Inter-American Development Bank (IDB) which determined the characteristics of the city's waste for a population of approximately 50,000 inhabitants. Currently the city owns about 75,000 which implies a change in the socioeconomic conditions that invite to the update of the studies of characterization of RSU of the city.

This new study was based on the methodology developed by the IRAM according to Standard 29523: 2018, which establishes that each of the selected trucks, Primary Sample Units, will discharge approximately 500kg of waste which, after being homogenized and quartered, make up the Secondary Sample Unit (300kg). After successive quarters, around 90 to 150 kg are separated, which constitute the Tertiary Sample Unit, to determine their physical characteristics and the volumetric weight (40 to 70 kg).

We proceeded to the collection and analysis of: the amount of waste collected daily according to the collection areas; the delimitation of the 10 collection routes in which the city is subdivided; determination of sociodemographic information. The determination of the number of samples to be collected will depend on the number of samples required to reach a desired level of precision based on the components of the waste under consideration and the desired level of confidence. For this study, the number of samples was determined taking with reference parameters the statistical values of the average and the main components or categories established: Paper and Cardboard, Plastics, Glass and Organic Waste, being these the most representative established in the background of the year 2009.

Depending on the Iram Standard selected for the work methodology, the components to be determined will be classified into the following categories: Paper and Cardboard, Plastics, Glass, Ferrous Metals, Non-Ferrous Metals, Textile Materials, Wood, Rubber - Leather - Rubber, Pathological waste, Pruning Waste, Construction Materials and Hazardous Waste.

Currently the project is in execution and the results are expected by the end of May 2019. From the obtaining of the same, the statistical evaluation of the Physical Composition, Volumetric Weight, Weight per capita, total and according to the established categories.

3. Conclusion:

According to the values to be obtained from the sampling, the generation data per capita and according to category or composition will be established. In this way, we will have an approximate fact to the reality that will allow us to evaluate the management of the city's RSUs. It is worth highlighting the collaboration of the staff of the company that is proposing the current project together with the municipal staff and the University of Tierra del Fuego.

Finally, we must clarify that this study should be executed at different times of the year because the generation of waste from the city of Ushuaia, has a marked seasonality because of its geographical location and the possibility that its population has for "Leave" the island in summer and winter periods. This will deepen the knowledge regarding the generation and composition of the RSU offering the municipal authorities, more and more accurate information on the reality of the city.
INTRODUCTION

Waste generation is one of the environmental biggest issues in urban areas nowadays, mainly because of the amount of waste produce and the lack of space for its final destination. Ushuaia city is placed at the south of Argentina, being the only city in this country that encounters with Andes mountains. The geographical conditions limits the possibility of new landfills.

OBJECTIVES

The objective of this Project is to provide updated information about waste's composition in the city of Ushuaia and the amount generated per person, provided by its population, in order to design proper public policies about urban solid waste sustainable's management.

RESEARCH AND METHODS

The used methodology consists in what have been established by CEPIS (2005), developed by Dr. Kunioshi Sakurai in 1982. He proposes a stratified sample by social and economics values, to determined the representative number of homes to be evaluated. However, it hasn't been found studies which show social and economics characteristics in the population of Ushuaia. This is why it's been determined to modified the methodology to available data. It's been used the number of gather rounds of the Company in charge of this service, with a total amount of 10 rounds per day. It is also available the total amount of tons reccollected, being of 86 Tn per day.

RESULTS

After adapting CEPIS methodology, it is expected the possibility to determined waste characterization values, in the more accurate way. This will allow to know city's reality when it comes to quantity and type of generated waste.

CONCLUSIONS

Understanding that the preview research is still in development and data processing stage, it is expected to obtain of it, approximated values about waste generation levels per person in the city and their different categories. This data could be compared with the one obtained in 2009, which shows that waste's generation per person was of 1.7 kg/per/day. According to samples values obtained, it will be determined the amount generated per person and its proper category or composition. This way, we will face more close to reality data, which will allow evaluate urban solid waste management in the city. It is proper to clear out that this study must be executed in different times of the year, due to the fact that waste generation in the city of Ushuaia is intimately related to seasonal changes, because of its geographical location and the possibility for its population to leave the island during summer and Winter time. This way, the knowledge about generation and composition of urban solid waste would be improved, offering more accurate information to local authorities.
be’ah’s Circular Economy Initiatives

1. Abstract

be’ah strives to execute sustainable waste management practices in line with international standards by creating the essential infrastructure, reforming the waste management services, and improving public awareness of waste management. Sustainability and safety are some of be’ah’s core values and this is demonstrated through the closure of open dumpsites. Two subsidiaries were proposed by be’ah to facilitate improved waste management; Municipal Solid Waste and Industrial Waste. The Municipal Solid Waste Subsidiary (MSWS) is tasked with ensuring efficient collection, transportation, treatment and final disposal of municipal solid waste. This is accomplished by the installation of state-of-the-art landfills, transfer stations, reuse center, and waste management services in different governorates around the Sultanate. The Industrial Waste Subsidiary (IWS) ensures that disposal of hazardous waste is conducted in a safe way. Numerous projects are being planned to improve the recycling capability of the Sultanate, these include a reuse center and waste to energy facilities.

2. Introduction

be’ah has been granted the mandate and the legal status as the entity responsible for waste management in Sultanate of Oman. Within this umbrella, be’ah works on moving towards sustainable waste management practices as per international standards by establishing the required infrastructure, restructuring the waste management services, and improving public awareness of waste management.

The waste management hierarchy, which emphasizes minimal waste production with disposal as the least favored option, is the foundation of the integrated sustainability approach which covers three main aspects of waste management: (1) stakeholders, (2) sustainability aspects and (3) waste system elements. This approach aims to adopt practices which diverge an economy from a linear approach where resources are utilized overwhelmingly with minimal reutilization towards a circular economy. The circular economy necessitates a recuperative and regenerative system designed to close the loop of industrial production to ensure minimal waste disposal at landfills. Consumed biological products are distinguishable and processed to extract chemical feedstock, biogas and digestives abundant in nutrients to be reintroduced into the biosphere. The technical cycle handles products with a low tendency to decompose and examines methods to maximize their lifetime in the market prior to distribution into upcycling processes.

3. Projects/Initiatives

3.1. Diversion Strategy Projects

The waste reaching our landfills throughout the sultanate comes from a variety of different sources, be’ah’s first aim is to recover the lost value of this waste. However, as the waste becomes more mixed, the less recoverable value that waste has. Therefore, be’ah is working on a solution to recover the energy from the MSW waste by incinerating it as a fuel source to power various activities.

3.1.1 Barka Waste to Energy Project

The project will be in collaboration with Oman Power and Water Procurement Company (OPWP). And the plant will be located at be’ah’s Barka Landfill with a capacity of 3,400 tons per day of MSW waste. The projects technical and financial feasibility study was done in 2018 and OPWP is expecting to float a tender for the implementation of the project by the end of 2019.
3.2. The Reuse Center
be’ah focuses on promoting the concept of 3Rs ‘Reduce, Reuse & Recycle’ through the establishment of ‘Reuse Center’ in collaboration with SQU, which is currently exploring opportunities to promote its sustainable development culture and practices within the campus community. The Reuse Center will provide environmental, economic and social benefits for all stakeholders involved and will become a centralized hub promoting sound environmental practices across the country. Accepted items for the re-use center will be clothes and textile, books, electrical appliances and furniture.

3.3. ECE
be’ah actively seeks out dialogue and collaboration with industrial and governmental entities in Oman. We engage broadly, and at every level, with all the environmental entitled stakeholders to discuss the issues affecting the environment and the methods in which sustainability can be achieved. The Environmental Center of Excellence (ECE) intends to become the primary independent non-profit organization responsible for the provision of marketable products and services in the Sultanate of Oman in a designated domain on the environmental field of research, innovation, technologies, product development, training, consultancy and advisory services, education and awareness support. The ECE promotes open innovation and regulates education, collaborative-research and training in the environmental field. It transforms industry research into ideal practices, acts as a broker of information and provides governmental entities with valuable data and insights.
TRANSFORMING THE FUTURE OF WM PRACTICES BY RECONCILING WITH THE PAST IN SULATANTE OF OMAN

- Daily Covering of Waste
- Controlling GHG Emissions through Engineered Landfills
- Waste to Energy

- Education Program for Schools
- Awareness & Cleanup Campaigns
- Sustainability within be‘ah

- Environmental Excellence Apprenticeship Program
- Capacity Building through be‘ah Academy
- Internship Programs

- Replacing Plastic Bottles with Reusable Glass Bottles for all Employees
- Future Projects: Biogas & Biodiesel from Waste

Rahma Al Riyami, MS-Engineering Sustainable Development. Executive Oman Environmental Service Holding Company, be‘ah
GUIDELINES ON PRE- AND CO-PROCESSING OF WASTE IN CEMENT PRODUCTION

M. Hinkel\(^{(1)}\), S. Blume\(^{(2)}\), D. Hinchliffe\(^{(2)}\), A. Lindau\(^{(1)}\), D. Mutz\(^{(3)}\), D. Hengevoss\(^{(3)}\)

1: Holcim Technology Ltd, Im Schachen, CH-5113 Holderbank
2: GIZ GmbH, Dag-Hammarskjöld Weg 1-5, D-65760 Eschborn
3: University of Applied Sciences and Arts Northwestern Switzerland, School of Life Sciences, Institute for Ecopreneurship

Abstract: In 2019 GIZ and LafargeHolcim published their new Guidelines on Pre- and Co-Processing of Waste in Cement Production. The main objective of these Guidelines is to improve waste management by offering updated and objective information about pre- and co-processing of waste in the cement industry. They contain knowhow and practical experiences gained in implementing pre- and co-processing since the first edition that served as a reference document in international agreements and adaptation of various national guidelines. These Guidelines are thus an update of the former GTZ-Holcim Guidelines on Co-processing Waste Materials in Cement Production (GTZ-Holcim, 2006)\(^{(1)}\).

Key words: Co-processing, pre-processing, waste, cement, alternative fuels, alternative raw materials

1. Scope

The Guidelines address stakeholders and decision makers from the private and public sectors engaged in waste management and cement production. They provide guiding principles and general orientation concerning for pre- and co-processing, but cannot and should not be used as a template.

They promote an approach that aims to reduce existing waste problems and at the same time to encourage the use of waste as an alternative source for primary energy and virgin raw materials in cement production. They follow common understanding that avoiding and reducing waste is the best way of dealing with current waste problems all over the world. Wherever possible, the concepts of resource efficiency, circular economy, recycling and reuse must be given first priority. Pre- and co-processing respects the waste hierarchy and does not contradict it, when the Guidelines are followed. In this context, co-processing is classified as a technology for energy recovery and mineral recycling.

The key for implementation of these Guidelines and to achieve the maximum benefit from pre- and co-processing of waste in cement production continues to be close collaboration and co-operation between the public and the private sectors. Innovative techniques and technical knowhow are available and will be further developed by the private sector, whereas the public sector should ensure that environmental standards are maintained and health and safety regulations are applied and enforced. In addition ethical business conduct, good governance and social responsibility remain prerequisites for successfully implementing the Guidelines.

1.1. Definition of pre- and co-processing

Pre-processing refers to preparing of waste to make it suitable for co-processing in cement kilns. Waste is converted from an unwanted discarded material to a useful resource, so-called Alternative Fuel and Raw Materials (AFR).

Co-processing refers to using AFR in the cement production process at suitable feed-in points in a controlled manner, where it burns as fuel and provides raw material. This enables substitution of primary fuels (coal, petroleum coke, natural gas) and raw materials, recovering energy from the waste and recycling its mineral content. Only qualified waste materials may be used for this process.

2. Guidelines overview

Different types of wastes have been successfully co-processed as AFR in cement kilns in Europe, Japan, USA, Canada and Australia since the beginning of the 1980s. In 2006 the first edition of the GTZ-Holcim Guidelines on Co-processing Waste Materials in Cement Production was published (GIZ-Holcim, 2006)\(^{(1)}\), aiming to gather the lessons of these experiences and offer it particularly to low and middle income countries as an option to improve approaches to waste management.

Since then, waste management has earned a much more prominent place on the political agenda. Legal and institutional frameworks for waste management look more and more at the importance of increasing resource efficiency, improving public health, mitigating climate change and avoiding marine litter. These positive developments, as well as the experience gained with pre- and co-processing since the first guidelines were published, contribute to the motivation to publish a revised edition of the guidelines to update technical, institutional and
While the first edition of the guidelines focused mainly on co-processing of industrial and commercial waste, these updated guidelines now put a stronger emphasis on pre-processing of wastes into AFR, pre- and co-processing of municipal waste and integrating pre- and co-processing into local waste management value chains. More information is given on how pre- and co-processing contributes to the sustainable development goals, its climate relevance, financing and ways to work with the informal waste sector. The original principles have been expanded and grouped with corresponding requirements for implementation. They continue to be based on findings and recommendations from experiences in industrialized and developing countries, as well as from the public and private sector to improve waste management at national and local levels, including attempts by the cement industry to improve environmental performance of cement production.

Pre- and co-processing is not a standalone solution to all waste management needs, but when following the principles and requirements for sound operation as set out in this document, it has its role in an integrated waste management system. AFR use in cement kilns shall respect the waste hierarchy and not interfere with waste reduction efforts. It is beneficial and desirable when it diverts wastes from disposal which cannot be recycled or reused. In this way, pre- and co-processing can make an important and structural contribution to the improvement of waste management in low and middle-income countries, while at the same time reducing the incidence of open burning, marine littering and disposal in uncontrolled dumpsites.

Pre-processing is a key enabler for co-processing by producing qualified homogeneous AFR thereby avoiding operational issues during co-processing. Changes to the waste system related to the introduction of pre- and co-processing should aim to create mutual benefits to local communities, stakeholders in the waste system and the cement producer. To achieve this, pre- and co-processing must be adapted to local conditions (with input of stakeholders) and regularly evaluated for their benefits to the overall situation. Mutual benefits should be clear to all stakeholders and it helps if the changes are measured, documented and monitored.

The use of pre- and co-processing can support waste management, substitute fossil fuels and primary raw materials in cement production, and eliminate harmful substances from the circular economy. This improves resource efficiency and reduces GHG emissions, thereby supporting the 2015 Paris Climate Agreement and the Sustainable Development Goals. Compared with other waste-to-energy technologies such as waste incineration, co-processing has the advantage that it can be incorporated into existing local cement production facilities and does not require major investments in new waste management infrastructure. The high temperature condition in the cement kiln have inherent advantages that prevent the formation of dangerous compounds or destroy these, whilst at the same time binding minerals into the cement product, avoiding problems of residual hazardous wastes.

However, pre- and co-processing can represent relatively complex processes involving a range of stakeholders. It is of paramount importance that these activities are implemented in a safe and environmentally sound way. There are some basic rules and principles that should be observed, which are summarized by the following guiding principles, laid out in detail in the Guideline document.

- Waste hierarchy & circular economy
- Legal & institutional framework
- Environment
- Operation & quality control
- Health & safety
- Inclusivity and engagement
- Economic & financial
- Implementation

Acknowledgements

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References

Guidelines on Pre- and Co-processing of Waste in Cement Production: Use of waste as alternative fuel and raw material

GIZ, FHNW, LH and Geocycle have updated the 2006 Guidelines on Co-processing Waste Materials in Cement Production to support further development of environmentally sound and safe pre- and co-processing in developing countries.

Objective of the new guidelines:
- Improve waste management by offering updated and objective information about pre- and co-processing of waste in the cement industry
- Promote Pre- and Co-processing as a competitive and sustainable waste management solution
- Facilitate close collaboration between the public and private sectors on the topic
- Set ambitious global standards for companies active in Pre- and Co-processing
- Share good practices and propose means for capacity building to ensure sound application of the technology

What’s new?

| Stronger focus on Pre-Processing and Inclusivity | Pre- and Co-processing as part of Integrated Waste Management Plans | The role of Pre- and Co-processing for
| | | the Circular Economy
| | | Improving Resource Efficiency
| | | mitigating Climate Change
| | | mitigating Marine Litter | New Case Studies e.g. Austria, Philippines, China, Egypt, Argentina, Colombia and Ukraine

Principles & Requirements

- Waste Hierarchy & Circular Economy
  - Pre- and co-processing shall respect the waste hierarchy and can be regarded as a contribution to the circular economy
- Legal & Institutional Framework
  - An appropriate legal framework needs to be established
  - All relevant stakeholders shall be involved during the permitting process
- Environment
  - Pre- and co-processing shall not have negative impacts on emissions
  - Emission monitoring is obligatory
  - The environmental performance of the cement products (concrete, mortar) shall not deteriorate
- Operation & Quality Control
  - Suitability of waste (HW) shall be ensured so that it can be accepted for Pre- and Co-processing
  - Transport, storage, treatment and handling shall be regulated and monitored
  - Standard operating procedures shall be clearly defined and known by operators
  - A quality control system shall be implemented
- Health & Safety
  - A Health & Safety management system shall be implemented at all sites
  - Emergency response plans shall be implemented for each site
- Inclusivity & Engagement
  - Mutual benefit of involved stakeholders shall be achieved
  - Openness and transparency are the guiding principles in communication and engagement with all stakeholders
- Economic & Financial
  - Pre- and Co-processing projects should be based on a financially sustainable business model
- Implementation
  - Monitoring and auditing systems need to be in place to enable successful implementation
  - Capacity building and training at all levels is essential

Waste Volume

Reduce
Avoid or reduce the production of potential waste
Reuse
Use materials more than once for the same purpose
Recycle
Leak
Disperse
Recover
Pre-processing
Co-processing

Authors

M. Hinkel 1  S. Blume 2  A. Lindau 1
1 Holcim Technology Ltd, Im Schachen, CH-5113 Holderbank
2 GIZ GmbH, Daag-Hammarskjöld Weg 1-5, D-65760 Eschborn

Conclusion

Pre- and Co-processing cannot solve the global waste challenge alone, but can provide an environmentally sound solution as part of an integrated waste management plan.

Pre- and Co-processing requires robust and adopted legal and institutional framework - Guidelines can help to adopt.

The Guidelines should be implemented on the basis of a spirit of cooperation between the public and private sector.

Contact details
Steffen Blume
email: steffen.blume@giz.de
Michael Hinkel
email: michael.hinkel@geocycle.com
CONTINUOUS MERCURY EMISSION AND PROCESS MONITORING

M. Boness(1),
1: SICK AG, Rengoldshauser Str. 17a, D-88662 Überlingen, Germany

Abstract: As a well-known toxic heavy metal, mercury has become a major issue for the emission-monitoring scheme of the incineration industries such as waste, chemical, cement and power. This presentation will introduce a reliable measuring technique based on the so-called Zeeman [1] effect, which allows a direct and continuous Hg analysis in a high temperature cell of 1.000 °C. This measuring technique fulfills the necessary performance for the upcoming WI BREF [2] and shows high reliable results due to its resistance for any cross contamination by high concentrated pollutants like sulfur. We like to show that this new technology is applicable for different types of incineration processes in order to provide reliable measurements without complicated preparation steps. The operation and the necessary maintenance by the plant operator is reduced to a minimum.

Key words: Mercury, Zeeman effect, High temperature cell, Continuous process monitoring, Continuous emission monitoring, WI BREF, Emission limit level, BAT-AELs, Waste-to-Energy.

1. Introduction

The main problem for existing analyzers is still to find a reliable transfer of the oxidized mercury (e.g. HgCl₂) into the elemental form (Hg°) by wet or dry methods. Experiences from the past have shown that the used conversion materials are losing its transfer efficiency by acidic poisoning through higher HCl and or SO₂ concentrations in the flue gas. In this presentation, we like to introduce a reliable measuring technique based on the so-called Zeeman effect, which allows a direct and continuous Hg analysis in a high temperature cell of 1.000 °C. Under this measuring condition, all Hg-species are reduced to the elemental form without showing any recombinantio of oxidized mercury species again [3].

2. Continuous Mercury Monitoring

The abatement system of incinerators must secure that no pollutants in the flue gases will exceed the allowed ELV (emission limit levels), e.g. according to European Industry Emission Directive (IED 2010/75/EU) [4] [5]. With this Directive the new WI BREF became a higher importance in terms of components to be monitored continuously and new given lower level ranges. As in example, the final draft of the WI BREF document the mercury ELV range was set from 50 µg/m³ to a range of 5-20 µg/m³. In Germany an ELV of 30 µg/m³ (24 h ELV at waste-to-energy plants) was already valid in the German 17.BImSchV. [6]. For coal-fired power plants, the BREF requires even lower ELV of down to 2 µg/m³ [7]. This development, caused by legislation, made it necessary to develop new technology for continuous mercury monitoring.

2.1. Zeeman AAS Measuring Principle

The Zeeman technology was developed together with the capability to measure mercury directly in a heated cell of 1.000 °C. With this combination a reliable conversion of oxidized mercury (HgCl₂) into the elemental Hg° was reached. In addition the used Zeeman effect showed no cross contamination to other components like sulfur. This is very important, due to applications for Hg-measurements in the process gas, upstream of the abatement system.

2.2. Application for Process and Emission Monitoring

According to the outstanding performance of this measuring method the benefit for the plant operator is to use the same instrument for sudden Hg peak detection in the raw gas (up to 3.000 µg/m³) [8], as well as for continuous emission monitoring of low Hg concentrations, e.g. below 10 µg/m³ [9]. The approval data of this measuring technique in the laboratory and in the 12 months field test gave following results:

- Detection limit: 0.05 µg/m³
- Total uncertainty incl. sampling: 2.3 % related to ELV 30 µg/m³ (0.7 Hg µg absolute value)

Test installations in the raw gas for high Hg concentration detection showed fast and reliable results, which can be used by the plant operator to react in the abatement system before plant contamination with Hg is evident.
4. Conclusions

With the introduction of new BAT-AEL’s in the final draft of the WI BREF new challenges for the continuous measurement of mercury went up. In some European member states, like Germany, experiences for the continuous measurement already exist since more than 20 years. Meanwhile a second generation of mercury monitoring systems was developed. So it’s not surprising that most of the providers of such mercury measuring systems are based in Germany. Different technologies are used and seem to be ready for these new performance challenges. However, there are some differences in the capability regarding operation, maintenance and service efforts. With the direct mercury measurement in a 1.000 °C heated measuring cell the problem of loosing effects for total mercury measurement is solved. The Zeeman effect is meanwhile a proven technology and suppresses by its physical measuring principle especially the cross contamination caused by sulfur and other components in the flue gas. In addition this makes the instrument capable to measure not only for lowest concentrations according to new BAT-AEL’s the emissions but also to provide a proven and reliable measurement to control sudden Hg peaks caused by unknown waste composition during the incineration process.

References

Introduction
- Mercury, a toxic heavy metal
- Key environmental issue for the emission-monitoring
- Concerned industries: Waste-to-energy plants, chemical, cement and power

Measuring method
- Reliable measuring technique based on Zeeman effect
- Direct and continuous Hg analysis in a high temperature cell of 1,000 °C
- Elimination of all cross contaminations, like sulfur
- Reliable measurements without complicated preparation steps

Advantages
- Fulfills the necessary performance for the revised WI BREF
- Applicable for different types of incineration processes incl. high concentrated raw gases
- Reduced efforts for operation and maintenance

Patented direct measurement
- Measurement within heated cell of about 1,000 °C

Advantages
- Continuous monitoring of total Hg
- No moving parts
- No Hg - recombination
- No memory effects
- Best possible cross sensitivity correction

Benefits
- Reliable monitoring of total Hg in waste incinerators, power plants as well as cement plants
- Lowest range 0 – 10 µg/m³ according to new WI BREF
- Measuring uncertainty close to current standard reference method
- One system set up for emission and raw gas applications

Hg²⁺-Conversion + Hg-Analysis in patented high-temperatured measuring gas cell (1000°C)

Zeeman AAS measuring principle without moving optical filter parts

Current and future emission limit values

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Current ELVs</th>
<th>WI BREF DL 2018</th>
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<tr>
<td>(mg/m³ unless marked)</td>
<td>(µg/m³)</td>
<td>(µg/m³)</td>
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<tr>
<td>Daily (Germany)</td>
<td>Yearly (Germany)</td>
<td>Existing plant</td>
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<tr>
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Comparison between standard reference methods and automated measuring systems at a coal fired power plant for three different coal types
EDUCATION BY ART - PROPOSAL FOR THE CONCRETIZATION OF AN ART BIENNIAL WITH RECYCLED MATERIALS

Rui Rodrigues International Business Unit, LIPOR, Baguim do Monte, Portugal (Senior Technician)

«The work of Art does not cover up what exists - reveal it» Herberi Marcuse

Key words: Art, environmental education, sensitization, climate change, awakening consciousness, emotions, planet, culture.

Abstract: In view of the climate change that the planet is witnessing, it is necessary to implement more favorable adaptation measures in the medium term, complemented with those of combat, in order to minimize its impact.

It is crucial for citizens to be aware of the challenges and to support public policies in responding to climate change.

It is therefore essential to involve society in responding to its challenges by helping to increase individual and collective action by recognizing the dimension of environmental awareness through culture as a key element of climate policy.

1. Introduction

It is crucial to put the profound decarbonisation of our society on the agenda. However, behavior change is at the heart of the paradigm shift on which the transition to this competitive, resilient, low-carbon economy is based. Likewise, adapting to the unfortunately inevitable impacts of climate change must be a priority of urban and rural communities, so also in this dimension, Environmental Awareness is fundamental to the success of responses that, as a society, we chose for our territory.

To achieve this goal, the idea of promoting the Biennial of Art with Recycling, a major event that, through art and the awakening of emotions, has been raised to sensitize local communities, schools, government, public and private institutions for a change of mentality that places the environment at the center of our concerns, encouraging increased separation, reuse, recycling and waste reduction and decarbonization.

The purpose of this event is to sensitize local communities, schools, government, public and private institutions for a change in: mentality that places the environment at the center of our concerns, encouraging increased separation, reuse, recycling and waste reduction and decarbonization through art.

The idea is for people to start rethinking their behavior and being responsible when it comes to the ecological side. And therefore, try to avoid to the maximum the production of residues and the emission of greenhouse gases.

The event also aims to promote an efficient and productive economy in the use of resources, water and soil, regional and local basis, reducing the pressure on these resources through the reduction of contamination. Abandon the model of Linear Economy and move to the Circular Economy.

2. Plan of means

This cultural event of great impact will be itinerant and will have a maximum stay of 3 months in each host city. Renowned artists and emerging artists will be invited to address the theme of the environment in their artistic creations or use waste as their main raw material.

There will be a multidisciplinary opening show, launch of the website, presentation of the event and its graphic image, exhibitions, international conferences, concerts with renowned artists and environmental defenders, theater, visual arts, dance, launches, art public, auctions, Zero Waste restoration and crowdfunding.
With the event taking place in each of the cities, there are preferential moments to establish contact between the different stakeholders: social media, sponsors, patrons, partners, critics, cultural producers, opinion makers, and specialized audience, participants and the public. Our main objective is never to let the subject be stopped during the year in the Social Communication and particularly in prime time news.

3. Social Responsibility

All the revenues raised during the event will be allocated to the financing of Environmental Education in developing countries.

Saving the planet is a complex attitude and depends on cooperation between all individuals, companies and government institutions. However, some simple attitudes can bring significant changes in this struggle. Actions that begin in each of us as long as we are properly sensitized and motivated to do so.

We intend with this project to transform a cultural event into a global campaign to save the planet and involve all stakeholders and train the next generation through Environmental Education.

4. Conclusion

Without measures to reduce emissions, the temperature will rise by more than 0.8°C by 2050, triggering a series of serious and irreversible consequences in our ecosystem, such as the widespread spread of tropical diseases and the extinction of more than 20% of the current species of fauna and flora.

Saving the planet is a complex attitude and depends on cooperation between all individuals, companies and government institutions. However, some simple attitudes can bring significant changes in this struggle. Actions that begin in each of us as long as we are properly sensitized and motivated to do so.

We intend with this project to transform a cultural event into a global campaign to save the planet and engage all stakeholders and train the next generation through Environmental Education.

References


SUSANNE, Langer “Sentimento e Forma” (Edições Perspectiva, 1980).


HERBERI, Marcuse “A dimensão estética” (Edições 70,1999).


https://www.labiennale.org/en

http://montanhamagica.ubi.pt/


http://repositorio.roca.utfpr.edu.br/jspui/bitstream/1/4801/1/MD_ENSCIE_IV_2014_47.pdf


http://sociedadedospoetasamigos.blogspot.com/2013/10/jane-perkins-artista-plastica-britanica.html

https://www.unenvironment.org/

https://wedocs.unep.org/bitstream/handle/20.500.11822/9851/UNEP_2030_agenda_PT.pdf?sequence=4&isAllowed=y

https://www.widewalls.ch/environmental-artists/red-earth-environmental-art-group/
ABSTRACT

In view of the face to climate change that the planet is witnessing, it is necessary to implement more favourable medium term adaptation measures, complemented with combat measures, in order to minimize its impact.

It is crucial for citizens to be aware of the challenges and to support public policies responding to climate change.

It is therefore essential to involve society in responding to its challenges by helping to increase individual and collective action by recognizing the dimension of environmental awareness through culture as a key element of climate policy.

SOCIAL RESPONSIBILITY

All the revenues raised during the event will be allocated to the financing of Environmental Education in developing countries.

This cultural event will be a source of inspiration to thousands of people around the world and will contribute to change our behaviours and to help protect our planet.

REFERENCES


SUSANNE, Lang “sensibility to a future” (Edições Perspectiva, 1988).

JANA, Bartos “A imagem no Enfato da Arte, ano 1906 à no sec tempo” (Edições Perspectiva, 1998).

HERBER, Marcus “A dimensão assistiva” (Edições J.1.999)


http://www.worldatwork.com/magazine/interviews_features/turning_in_0r_extracting_artist_changing_the-way_we_think_about_the_environment

http://www.1ebulinho.org/lan

http://mostranorteacagoa.com.pt/


http://reposi.eion.br/1108571/h90n=en&LANGUAGE=PT


http://sociedadeclassearticulo.blogspot.com/2013/10/gretn-perkins-artist-la-britannia.html

http://www.enviromnt.org/

http://www.red-turtle.com.br/red-turtle-environmental-art-group/

CONCLUSIONS

Without measures to reduce emissions, the temperature will rise more than 1°C by 2050. Assuming extreme increases in emissions and irreversible consequences in our ecosystem, such as the spread of tropical diseases and the extinction of more than 20% of the current species of land and freshwater species.

Saving the planet is a complex challenge and depends on cooperation between all stakeholders, companies and government institutions. However, some simple actions can bring significant changes in this struggle.

Actions that begin in each one of us and we are properly sensitized and motivated.

We will work on this project to transform a cultural event into a global call that can save the planet and engage all stakeholders and the next generation through Environmental Education.
ECOTOXICITY OF ALTERNATIVE POTENTIAL PRECURSORS IN ALKALINE ACTIVATION PROCESSES

J. Santos (1), A. Rodriguez-Romero (1), E. Cifrian (1), A. Maldonado-Alameda (2), J.M. Chimenos (2), A. Andrés (1),

1: GER Green Engineering and Resources Group, Department of Chemistry and Process & Resource Engineering, ETSII, University of Cantabria, Cantabria, Spain
2: DIOPMA Design and Optimization of Processes and Materials, Department of Materials Science and Physical Chemistry, University of Barcelona, Barcelona, Spain

Abstract: Ecotoxicity tests can be a valuable tool to indicate whether environmental impact has to be expected from a certain construction product. Bioassays allow integration of effects of all contaminants, including additive, synergistic and antagonistic effects. The aim of this study is to know the potential environmental effects derived during the life cycle of alternative materials precursors in alkaline activation processes on marine ecosystem using sea urchin liquid phase bioassays.

Key words: Construction products; Alkali activated cements (AACs), Geopolymers; Ecotoxicological evaluation; Seaurchin embryogenesis; Metakaolin; CSP; PAVAL®; Weathered Bottom Ash.

1. Introduction

Ecotoxicological assessment of construction products is especially relevant for the building and for the demolition phase in their life cycle, taking into account that geopolymers are new construction materials based in alumina and silica by alkali activation process, using alternative raw materials. In order to know the potential environmental effects derived during the life cycle of the new products on aquatic/marine environment, the leaching tests and acute toxicity tests should be carried out on alkaline activated materials (AAM) and alternative raw materials. Taking into account that the two main factors in the alkaline activation process are the precursor and the dissolution alkalinity (alkaline activators), in this work the objective is to investigate the potential of residual materials as precursors in the formulation of AAM. In the first phase, the environmental characterization of residual precursor materials was carried out, as well as a reference precursor. Leachates from different materials were obtained by mobility leaching test (UNE-EN 12457-4) and used as test samples in ecotoxicity test with the marine sea urchin Paracentrotus lividus.

2. Materials and Methods

Several materials precursors have been used to formulate Alkali-Activated Materials (AAM). A commercial Metakaolin (MK) powder, CSP sample was collected from a glass treatment plant; PAVAL®, which is an industrial by-product obtained during melting process of secondary aluminum and; Weathered Bottom Ash (WBA), > 8 mm, collected from WtE plant.

Leaching test in seawater for 24 h was conducted according European standard UNE-EN 12457-4: 2003 to evaluate the hazardousness of the different alternative materials. A bioassay of larval development (embryogenesis) using ovules, sperm and embryos of the marine sea urchin Paracentrotus lividus was carried out through exposure to different percentages of volume (10%, 25%, 50%, 75%, 100%) of leachate of the alternative materials. Previously to embryogenesis test, pH leachate was adjusted. The assay was performed according to the procedure described by Garmendia et al. 2009 [1]. Briefly, vials (20 mL) were filled with the different dilutions (5 replicates per dilution). Approximately 500 fertilized eggs were placed in each vial. The vials were incubated for 72 h at 20 °C under dark conditions. After the incubation period, the larvae were fixed by adding 1 mL of 40% formalin, and were then observed in an inverted microscope. One hundred larvae were counted in each vial and developmental abnormalities recorded. Toxicity was quantified by counting the frequency of malformations detected. Developmental abnormalities were classified by applying the following toxicity criteria, modified from Carballeira et al.,2012 [2]: a) Level 0: no toxicity, normal development (larvae having 4 well-development arms and skeleton); b) Level 1: moderate/high toxicity (larvae without skeleton, prepluteus stage) and c) Level 2, high toxicity, development blocked (undeveloped stages). A control treatment (only seawater) was used to ensure the acceptability of the tests (> 85% normal larval development).

3. Results

3.1 Characterization of the leaching behavior.

Table 1 shows the results of the chemical analysis of the leachates obtained according to the leaching test EN 12457-4 proposed by European regulations, and carried out with seawater as extraction agent.
The hazard of residual raw materials is clear when the mobility results are compared with the chemical analysis of the seawater used as a leaching fluid in the test. The Bottom Ash (WBA) characterize by an increase of the concentration with respect to the reference of Zn, Cu, Ba, Mo and Sb, while the rest of elements, are maintained in the same order as the seawater. The aluminum rich residues (PAVAL®) show a significant leaching of Mo, while Cr and Sb, are mobilized slightly. While the MK sample that corresponds to calcined clay, metakaolin, virgin raw material, shows high values of Zn, Ni, Ba, with respect to those of seawater, which can be due to the variation of the pH values, as well as to the presence of other elements such as Fe that act as complexers. It is important to remark that it is demonstrated these materials can be classified as a non-hazardous material because of all values are below non-hazardous limits (DOCE 2003/33).

<table>
<thead>
<tr>
<th>Sample</th>
<th>Zn</th>
<th>Pb</th>
<th>Ni</th>
<th>Cr</th>
<th>Cu</th>
<th>As</th>
<th>Ba</th>
<th>Mo</th>
<th>Cd</th>
<th>Sb</th>
<th>Hg</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control treatment</td>
<td>0.04</td>
<td>&lt;0.005</td>
<td>&lt;0.01</td>
<td>&lt;0.025</td>
<td>&lt;0.1</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.005</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>&lt;0.01</td>
<td>7.60</td>
</tr>
<tr>
<td>MK</td>
<td>1.35</td>
<td>0.05</td>
<td>4.56</td>
<td>&lt;0.25</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>2.5</td>
<td>&lt;0.25</td>
<td>&lt;0.05</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>6.90</td>
</tr>
<tr>
<td>CSP</td>
<td>1.66</td>
<td>&lt;0.05</td>
<td>&lt;0.1</td>
<td>&lt;0.25</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>0.07</td>
<td>&lt;0.25</td>
<td>&lt;0.05</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
<td>7.72</td>
</tr>
<tr>
<td>WBA</td>
<td>0.5</td>
<td>&lt;0.05</td>
<td>&lt;0.1</td>
<td>&lt;0.25</td>
<td>0.24</td>
<td>&lt;0.1</td>
<td>0.76</td>
<td>0.03</td>
<td>&lt;0.05</td>
<td>&lt;0.23</td>
<td>&lt;0.1</td>
<td>8.78</td>
</tr>
<tr>
<td>PAVAL®</td>
<td>&lt;0.25</td>
<td>&lt;0.05</td>
<td>&lt;0.1</td>
<td>0.18</td>
<td>0.04</td>
<td>&lt;0.1</td>
<td>1.06</td>
<td>8.54</td>
<td>&lt;0.05</td>
<td>0.22</td>
<td>&lt;0.1</td>
<td>8.71</td>
</tr>
<tr>
<td>Non-hazardous Limit</td>
<td>50</td>
<td>10</td>
<td>10</td>
<td>50</td>
<td>2</td>
<td>100</td>
<td>1</td>
<td>1</td>
<td>0.7</td>
<td>0.2</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

3.2. Ecotoxicity test: Sea urchin embryogenesis

The good quality of gametes and exposure solutions was tested, with percentages of normal embryos in control treatments > 90% which fell within the acceptability range. The embryogenesis (larval development) results are shown in Figure 1. Each row represents the three toxicity levels for each leachate solution and the control treatment. It is observed that for all the leachates the toxic impact increase with the solution concentration, except for the WBA case which seems to show a low toxic impact. On the other hand, PAVAL® develops the earliest toxic effects, affecting the 82% of the larval population at the 50% leachate solution. The CSP and the MK (reference precursor) show as well high toxic impact, reaching, in the case of MK the total larvae destruction.

![Figure 1. Ecotoxicity bioassay Sea urchin Paracentrotus lividus: Embryogenesis results](image)

4. Conclusions

No correlations could be made to link mobility of contaminants and values at the different levels of toxicity in the bioassays. Even if the characterization using leaching test demonstrates that these materials can be classified as non-hazardous materials; the ecotoxicity test demonstrates that the MK as reference precursor, being virgin raw material, the CSP and the PAVAL® as alternative precursors show similar toxic impacts results. Results left in evident the importance of including bioassays in the analysis of the cycle of life of construction products in order to assess more accurately their potential impacts in the marine environment.

Acknowledgements

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References


ECOTOXICITY OF ALTERNATIVE POTENTIAL PRECURSORS IN ALKALINE ACTIVATION PROCESSES

J. Santos (1), A. Rodríguez-Romero (1), E. Cifrian (1), A. Maldonado (2), J.M. Chimeno (2), A. Andrés (1)

1. GER Green Engineering and Resources Group, Department of Chemistry and Process & Resource Engineering, ETSET, University of Cantabria, Santander, Spain
2. Department of Chemistry and Materials Engineering, University of Barcelona, Martí i Franqués, 1-4, 08028, Barcelona (Spain)

Introduction
Ecotoxicological assessment of construction products is especially relevant for the building and for the demolition phases in their life cycle, taking into account that geopolymers are new construction materials based in alumina and silica by alkali activation process, using alternative raw materials [1]. In order to know the potential environmental effects derived during the life cycle of the new products on aquatic marine environment, the leaching tests and acute toxicity tests should be carried out on alkaline activated materials (AAM) and alternative raw materials. Taking into account that the two main factors in the alkaline activation process are the precursor and the dissolution alkalinity (alkaline activators), in this work the objective is to investigate the potential of residual materials as precursors in the formulation of AAM.

Materials and methods
The environmental characterization of residual precursor materials was carried out, as well as a reference precursor. Leachates from different materials were obtained by mobility leaching test (UNE-EN 12457-4) and used as test samples in ecotoxicity tests with the marine sea urchin Paracentrotus lividus (Fig. 1). The bioassay was performed according to the procedure reported by Garmendia et al. (2009). The results were expressed percentage of embryogenesis reduction (PER, abnormally developed larvae those not having four well-developed arms) (see, Fig. 2), respectively.

Results
Environmental characterization
Table 1 shows the heavy metals content found in the eluates after leaching tests for the different materials. The Chemical analysis was carried out on using deionized water (WBA and PAVAL®) and sea water (PAVAL®, WBA, CSP and MK) reaching in both cases similar results. It is demonstrated these materials can be classified as a non-hazardous material because of all values are below non-hazardous limits.

Embryogenesis
The good quality of gametes and exposure solutions was tested as reported in the Materials and Methods section, with percentages of normal embryos in control treatments >90% and positive controls which fell within the acceptability range.

The embryogenesis results are shown in the figure 3. Each row represents the three toxicity levels for each leachate solution results and the reference. It is observed that for all the leachates the toxic impact increase with the solution concentration, except for the WBA case which seems to develop a low toxic impact. In the other hand PAVAL® develops the earliest toxic impact, affecting the 82% of the larva population in the 90% leachate solution. The CSP and the MK show as well high toxic impact, reaching, in the case of MK the total larvae destruction.

Conclusions
The results obtained in this research left evident the need of future works focused on the effect of the amount of contaminant charge in the building material formulations. Even if the environmental characterization results demonstrate that these materials can be classified as non-hazardous materials; the ecotoxicological test demonstrate that the MK, the CSP and the PAVAL® can develop serious toxic impacts.

Funding
This work was funded by the University of Cantabria "Proyecto Puente 2017" through two grants (A. Andrés) under SODERCAN and ERDF Operational Programme. A. Rodríguez-Romero is supported by the Spanish grant Juan de la Cierva Formación 2015 (JCI-2015-26873).

References
ASSESSMENT OF ELECTRIC AND ELECTRONIC EQUIPMENT STOCK IN GREEK HOUSEHOLDS

C. Chroni (1), K. Lasaridi (1), E. Terzis (1), A. Lekkas (2), C. Drakooli (2), K. Abeliotis (1), Ch. Angelakopoulos (2)

1: Harokopio University, School of Environment, Geography and Applied Economics, El. Venizelou 70, Athens, Kallithea, 176 71, Greece
2: ECYCLE, Sygrou Av. & Harokopou 2, Athens, Kallithea, 176 71, Greece

Abstract: Statistical models have been employed in order to calculate the amount of Electrical and Electronic Equipment (EEE) put on the market and the corresponding in time generation of Waste Electrical and Electronic Equipment (WEEE). Most available estimates make use of material flow models based on EEE put on the market and the lifespan distribution for the different EEE type groups. The lifespan distribution varies over time and between countries and regions, as differences in purchasing power and consumption habits result in differences in the replacement time of the various EEE items. Currently, there is no reliable estimate of the various groups of EEE in Greece, neither an estimation of their stock and WEEE generation rate.

The estimation of generated WEEE amounts is based on the EEE put on the market and the results of a comprehensive questionnaire-based study. The questionnaire-based survey aimed to evaluate the EEE stock of Greek households (excluding lamps). The questionnaire was distributed to over 250 households, targeting to Greek individuals between the age of 18 and 80. The analysis of the questionnaires showed that the average amount of EEE (lamps are excluded) in Greek households is 48 items.

Key words: Electronic and electrical equipment, service lifetime, Greek households.

1. Introduction

The amount of Electrical and Electronic Equipment (EEE) put on the market and the consequent generation of Waste Electrical and Electronic Equipment (WEEE) is usually calculated through statistical models [1-3]. Most of the available estimates are based on the EEE put on the market and the lifespan distribution of different types of EEE (i.e. the statistical distribution of the time required for EEE items in each category to become waste). However, differences in purchasing power, consumption habits, and age distribution between countries resulting in differences in the replacement time of the various EEE items [4], and consequently, in the lifespan distribution. This study aimed to define the EEE stock in Greek households with a questionnaire-based study. The structured questionnaire was distributed and completed, between October 2017 and March 2018, in Greece. The study estimates the amount of EEE stock in Greek households.

2. Materials and methods

The questionnaire-based survey was targeted to members of Greek households and it was developed in order to collect key information regarding the amount and the types of electrical and electronic equipment (EEE) (excluding lamps) stocked in Greek households. It consisted of 25 questions, regarding the amount and the type of the EEE, in the Greek households, the intention of the interviewees to keep, repair, recycle or discard unused EEE. The questionnaire was filled in by 167 households (distributed to over 250 households).

The groups of interviewees were selected upon the household types in Greece, to investigate whether they influence the number and the lifespan of the EEE useful life. Therefore, the survey is based on the distribution of the different types of household, rather than the geographical distribution of the Greek population.

Lifetime (or lifespan) of commodities is crucial information for material flow analysis and material stock accounting. There are two main approaches to the estimation of commodity lifetime [5]. One is the non-parametric approach, which does not assume any statistical distribution. The other one is the parametric approach, which assumes a statistical distribution function, such as normal distribution, log-normal distribution, or Weibull distribution, and then approximates the observed data to the statistical distribution function. Currently, there is no reliable estimate of lifetime profiles of the various EEE categories in Greece, neither a robust assessment of their stock and the WEEE generation rate [6-8].

The expected WEEE generated from the Greek households in the next 16 years was assessed by using the Weibull distribution, based on residence times established for Italian households [9], which with certain reservations were used to determine the median lifetime of electrical and electronic appliances found in the Greek households.
4. Conclusions

Of the categories [10] of electrical and electronic items identified in Greek households, the large household appliances, with an average of 78.3%, the small household appliances, with an average of 5.8% and consumer equipment, with an average of 6.0%, accounted for the greatest proportions (almost 90%) of the total mass of EEE stocked in the Greek household. In the next 16 years in Greece, similarly, the contribution of these categories to the WEEE generation accounts for the greatest proportion- the three categories totalling a virtually 90%, of the mass of WEEE that will be generated.

The average stock (equipment in use and hibernated at households) of EEE for the households in Greece, amounted to 394.04 kg. Consequently, a Greek household will generate an average 583.3 kg of WEEE in the next sixteen (16) years or on average 36.5 kg of WEEE annually. This corresponds on average to 13.6 kg per inhabitant or an amount of 146,154 metric tonnes of waste electrical and electronic appliances annually.

Acknowledgements

This work is partly co-funded by the European Commission through the LIFE+ Funding programme, LIFE14 ENV/GR/000858: LIFE REWEEE “Development and demonstration of Waste Electrical and Electronic Equipment (WEEE) prevention and reuse paradigm”.

References

ASSESSMENT OF ELECTRIC AND ELECTRONIC EQUIPMENT STOCK IN GREEK HOUSEHOLDS


*Harokopio University, School of Environment, Geography and Applied Economics, El. Venizelou 70, Athens, 176 71, Greece
**ECYCLE, Sygrou Av. & Harokopou 2, Athens, Kallithea, 176 71, Greece

Introduction

The amount of Electrical and Electronic Equipment (EEE) put on the market (POM) and the consequent generation of Waste Electrical and Electronic Equipment (WEEE) is usually calculated through statistical models. Most of the available estimates are based on the EEE put on the market and the lifespan distribution of different types of EEE. However, differences in purchasing power, consumption habits, and age distribution between countries resulting in differences in the replacement time of the various EEE items and consequently, in the lifespan distribution.

This study aimed to define the EEE stock in Greek households with a questionnaire-based study. The structured questionnaire was distributed and completed, between October 2017 and March 2018, in Greece. The study estimates the amount of EEE stock in Greek households. More specifically, this study investigates both the service and storage lifetime of EEE in households.

The groups of interviewees were selected upon the household types in Greece, to investigate whether they influence the number and the lifespan of the EEE useful life. Therefore, the survey is based on the distribution of the different types of household, rather than the geographical distribution of the Greek population.

Results & Discussion

The questionnaire-based survey was targeted to members of Greek households and it was developed in order to collect key information regarding the amount and the types of electrical and electronic equipment (EEE) (excluding lamps) stocked in Greek households. It consisted of 25 questions, regarding the amount and the type of the EEE, in the Greek households, the intention of the interviewees to keep, repair, recycle or discard unused EEE. The questionnaire was filled in by 167 households (distributed to over 250 households).

The statistical treatment of the questionnaires allowed for the estimation of the EEE stock held by the Greek households and for the estimation of the waste electric and electronic equipment (WEEE) that the Greek households (hh) will generate in the following years. These results are presented in Table 1.

<table>
<thead>
<tr>
<th>Category/Description</th>
<th>Items/ hh</th>
<th>Stock (kg)</th>
<th>Weight % of Stock</th>
<th>Renewal in 16 years</th>
<th>Total Weight kg/ hh</th>
<th>Weight % of WEEE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Large household appliances</td>
<td>8.4</td>
<td>308.5</td>
<td>78.3%</td>
<td>11.7</td>
<td>416.10</td>
<td>26.0</td>
</tr>
<tr>
<td>2. Small household appliances</td>
<td>11.8</td>
<td>22.8</td>
<td>5.8%</td>
<td>18.6</td>
<td>60.40</td>
<td>3.8</td>
</tr>
<tr>
<td>3. IT and telecom equipment</td>
<td>8.2</td>
<td>10.4</td>
<td>2.6%</td>
<td>19.4</td>
<td>28.50</td>
<td>1.8</td>
</tr>
<tr>
<td>4. Consumer equipment</td>
<td>7.1</td>
<td>23.7</td>
<td>6.0%</td>
<td>16.2</td>
<td>42.60</td>
<td>2.7</td>
</tr>
<tr>
<td>5. Lighting equipment</td>
<td>3.2</td>
<td>0.3</td>
<td>0.1%</td>
<td>2.29</td>
<td>0.66</td>
<td>0.04</td>
</tr>
<tr>
<td>6. Electrical and electronic tools</td>
<td>1.2</td>
<td>28.3</td>
<td>7.2%</td>
<td>1.23</td>
<td>34.82</td>
<td>2.18</td>
</tr>
<tr>
<td>7. Toys, leisure and sports</td>
<td>0.1</td>
<td>0.04</td>
<td>0.01%</td>
<td>4.00</td>
<td>0.15</td>
<td>0.01</td>
</tr>
<tr>
<td>8. Medical devices</td>
<td>0.6</td>
<td>1.0</td>
<td>0.03%</td>
<td>1.45</td>
<td>0.14</td>
<td>0.01</td>
</tr>
<tr>
<td>Total</td>
<td>394.0</td>
<td>583.3</td>
<td>36.5%</td>
<td>100.0%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1. The stock of EEE and generated waste EEE in Greek households.

Of the categories of electrical and electronic items identified in Greek households, the large household appliances (LHA), with an average of 78.3%, the small household appliances (SHA), with an average of 5.8% and consumer equipment (CE), with an average of 6.0%, accounted for the greatest proportions (almost 90%) of the total mass of EEE stocked in the Greek household.

Conclusions

In Greece, in the next 16 years, the contribution of the large household appliances, the small household appliances and consumer equipment categories to the WEEE generation accounts for the greatest proportion - the three categories totaling a virtually 90% of the mass of WEEE that will be generated. The average stock (equipment in use and hibernated at households) of EEE for the households in Greece, amounted to 394.04 kg. Consequently, a Greek household will generate an average of 583.3 kg of WEEE kg in the next sixteen (16) years or 36.5 kg of WEEE annually. This corresponds on average to 13.6 kg per inhabitant or an amount of 146,154 metric tonnes of waste electrical and electronic appliances annually.

Acknowledgements

This work was partly funded by the European Commission through the LIFE+ Funding programme, LIFE14 ENV/GR/000858: LIFE REWEEE “Development and demonstration of Waste Electrical and Electronic Equipment (WEEE) prevention and reuse paradigm”.

Figure 1. The Weibull probability distribution function for selected EEE products.

Figure 2. Frequency of use

The large household appliances are mainly used on daily basis. The rest EEE are used for 2-3 times a week.
CONSIDERATION OF CIRCULAR ECONOMY CRITERIA IN THE DESIGN OF TECHNICAL SOLUTIONS FOR LANDFILLS. THE EXTENSION OF THE ARTIGAS LANDFILL IN THE MUNICIPALITY OF BILBAO

J.M. Baraibar (1), N. Escallada (2), G. Bernal (3)

1: Viuda de Sainz, S.A, Pol. El Campillo nº19, 48500 Abanto-Zierbena (Bizkaia)
2: Diputación Foral de Bizkaia, Departamento de Medio Natural, Alameda Recalde nº30, 48009 Bilbao (Bizkaia)
3: Lurgintza Ingeniería Geológica, S.L., c/ Euskalduna, nº5, 48008 Bilbao (Bizkaia)

Abstract: This article reviews the project of the “First phase of waterproofing in the right trough of the Artigas landfill, in the municipality of Bilbao”, promoted by the Department of Natural Environment and Sustainability of the provincial council of Biscay. This intervention represents a success in crystallising the strategies about waste management hierarchization and adoption of initiatives towards a more circular economy supported by the Administration, as it encourages the innovative use of valorized waste products in high-value civil works applications, as constitutive materials of the main structural elements that are part of the landfill. In this way, the retaining dike supporting the new waste mass uses recycled aggregates produced from construction and demolition waste (C&DW), and the filter layers are formed with siderurgic aggregates from electric arc furnace slag.

Key words: Sustainability, landfill, eco-design, circular economy, construction and demolition waste (C&DW), siderurgic aggregates

1. Introduction

In contrast to the pattern of traditional linear economy, consisting on buying, using and throwing away, circular economy is intended to increase the proportion of renewable and recyclable resources while reducing the consumption of raw material and energy, limiting at the same time the emissions and the material losses [1]. Although there is increasing evidence of integrating concepts of circular economy in engineering processes, the transition towards a more circular economy requires a profound transformation of the current socio-economic system [2]. The main enablers of a circular economy are business model innovation, eco-design, waste prevention and the possibility of extending the lifetime of products developing reusing and remanufacturing strategies [1].

On the other hand, it should be underlined that waste generation in the Basque Country, particularly in the Historical Territory of Biscay, is highly influenced by its industrial activity and the structure of their more relevant production processes. The main streams, apart from solid urban waste, are the flows produced by the iron and steel industry and the construction industry [3]. The regional plan for waste prevention and management foresees several action programmes providing diverse specific strategies for improving the situation of the main waste streams. This plan includes the finalization of the valorization strategy for both construction and demolition waste and electric arc furnace slag, as well as several initiatives for promoting their use among all the stakeholders [3].

In this article, the project of the “First phase of waterproofing in the right trough of the Artigas landfill, in the municipality of Bilbao”, is described. The main objective of this intervention is guaranteeing in the forthcoming years the storage capacity of the mail landfill in the territory, for that fraction of secondary waste that cannot be recycled or valorized and has to be inevitably eliminated. This project is a specific example of crystallization of the public strategies of waste management hierarchization and adoption of eco-design criteria as a leverage for boosting the transition towards a circular economy. The innovation of this project is the prescription, from the early design stage, of the use of both recycled aggregates produced from CD&W, and siderurgic aggregates from electric arc furnace slag, for conforming two key elements in the design of the landfill extension: the retaining dike and the filter layers.

2. The extension of the Artigas Landfill

2.1. Historical review

Artigas began its operation as a controlled urban solid waste landfill for the municipality of Bilbao in 1976. Since then, it has constantly been improving with several milestones, such as the construction of a landfill gas...
energy plant in 1992, the construction of a packaging recycling plant in 1997, or the adaption to the European normative in 2009. In 2014 the landfill transfers its ownership to the regional Administration, strengthening its supramunicipal character. In 2016 the draft of the first phase of waterproofing in the right trough of the Artigas landfill is elaborated, once the storage capacity of the operating landfill was finished.

2.1. Description of the project

The new landfill section that had to be waterproofed has an area of 2.50 Ha. It will be managed in two separate cells, divided by a rain-flap. In a landfill like Artigas, with a trough configuration, the main element for holding the waste mass is the retaining dike, with a height of 9 m. This dike is conformed with aggregates from the valorization of CD&W. The project defines two bottom liner systems for the landfill body and one final cover system. The main bottom liner system consists on the following sequence, from bottom to top: a regularization/forming layer; a 30-cm-thick secondary filter layer using both valorized aggregates from CD&W and siderurgic aggregates from electric arc furnace slag (40-100 mm), confined between two reinforcing geogrid and geotextile membranes; a 20-cm-thick embankment layer (0-40 mm); a bentonite geotextile, with a hydraulic conductivity less than \(1.5 \times 10^{-11} \text{m/s}\); a 2-mm-thick HDPE smooth geomembrane; a drainage geocomposite (anti-UV on slopes) for assuring the protection of the geomembrane and collaborate in the evacuation of the leachate drainage; a 50-cm-thick primary filter layer using siderurgic aggregates from electric arc furnace slag (40-100 mm) and a separation and filter geotextile, on which the future waste mass will be placed [4].

![Diagram](image)

**Fig. 1:** Bottom liner system sequence. Both primary and secondary filter layers are conformed with aggregates from the valorization of CD&W and siderurgic aggregates from electric arc furnace slag

The installation of all geosynthetic materials has been awarded with the ISO/IEC/17020 certification. Besides, the project includes additional separate networks for collecting the infiltration water and the landfill gas from decomposing waste.

3. Conclusions

The project of the “First phase of waterproofing in the right trough of the Artigas landfill, in the municipality of Bilbao” has been designed integrating eco-design criteria, which is recognised as one of the main enablers for encouraging the transition to a more circular economy. This project presents the technical innovation of prescribing from the early design stage the use of valorized waste for conforming two of the key elements of the landfill extension: the retaining dike and the filter layers. The retaining dike used recycled aggregates produced from CD&W and the filter layers were formed with siderurgic aggregates from electric arc furnace slag. The above-mentioned waste streams are commonly found in Biscay, given the composition of its industrial network.

References

In this article, the project of the "first phase of waterproofing in the right trough of the Artigas landfill in the municipality of Bilbao" is described. The main objective of this intervention is guaranteeing in the forthcoming years the storage capacity of the mail landfill in the territory, for that fraction of secondary waste that cannot be recycled or valorized and has to be inevitably eliminated. This project is a specific example of crystalization of the public strategies of waste management hierarchization and adoption of eco-design criteria as a leverage for boosting the transition towards a circular economy.

The innovation of this project is the prescription, from the early design stage, of the use of both recycled aggregates produced from CDW, and siderurgic aggregates from electric arc furnace slag, for conforming two key elements in the design of the landfill extension: the retaining dike and the filter layers.

The new landfill section that had to be waterproofed has an area of 2,500 m². It will be managed in two separate cells, divided by a rainfall. In a landfill like Artigas, with a trough configuration, the main element for holding the waste mass is the retaining dike, with a height of 9 m. This dike is conformed with aggregates from the valorization of CDW.

The project defines two bottom liner systems for the landfill body and one final cover system. The main bottom liner system consists on the following sequence, from bottom to top: a regularisation/forming layer; a 30-cm-thick secondary filter layer using both valorized aggregates from CDW and siderurgic aggregates from electric arc furnace slag (40-100 mm), confined between two reinforcing geogrid and geotextile membranes; a 20-cm-thick embankment layer (0-40 mm); a bentonite geotextile, with a hydraulic conductivity less than 1.5 x 10⁻¹¹ m/s; a 2-mm-thick HDPE smooth geomembrane; a drainage geomcomposite (anti-UV on slopes) for assuring the protection of the geomembrane and collaborate in the evacuation of the leachate drainage; a 50-cm-thick primary filter layer using siderurgic aggregates from electric arc furnace slag (40-100 mm) and a separation and filter geotextile, on which the future waste mass will be placed.

The implementation of the project is developed in two stages, related to the installation of a new secondary linear system following the emptying of the upper cell and the raising of the dike, with an increase of 3 m. This dike has been offered to the local community, citizens, and businesses which partner with the company.

In the project, there is the opportunity to implement another innovative stage, which consists of the valorization of some landfill materials as a source of energetic material.
1. Introduction

Technological and economic development as well as a multitude of usages for electrical and electronic equipment (EEE) has made these devices an ubiquitous part of citizens lifestyle. As a result, the amount of waste of electrical and electronic equipment (WEEE) has grown rapidly, generating 44.7 million tonnes of WEEE globally in 2016. In the EU countries alone more than 10 million tonnes of EEE was put on market in 2016. As WEEE in Denmark, this development accounts according to Eurostat’s ‘three year average’ calculation for 26 kg per inhabitant annually, equivalent to 143.000 tonnes in total per year [2]. Much research has been done focusing on technical solutions for WEEE resource recovery efficiency [3] [4], but what about social solutions with cases preventing it from becoming e-waste in the first place, by re-using and re-furbing more of what is stored unused in households already? Looking at orders of magnitude, the WEEE collection rate in Denmark is around 47% of all e-waste, which makes approximately 12 kg e-waste per inhabitant that is not collected, and therefore assumingly not resource recovered nor registered in the Danish producer responsibility system. According to the latest WEEE collection counts in the producer responsibility system in Denmark, these figures have remained largely the same in Denmark also for 2017 [5].

Given the on average 12 kg WEEE per inhabitant staying outside the producer responsibility system, it annually adds up to 2.400 tonnes of unregistered e-waste in Odense municipality with its 200.000 inhabitants. This might be stored at home unused, put in the trash, or perhaps re-sold person-to-person. In addition, research [6] has indicated that 40% of the 2.000 tonnes WEEE collected at the waste stations in the city and municipality of Odense is still fully functional, which adds up to 800 tonnes. If this applies also to the unregistered WEEE, there
is potentially 1.760 tonnes (960 + 800 tonnes) of fully functional WEEE in Odense municipality. From a circular economy perspective on this, two important issues will be addressed in the following; 1) The fully functional EEE ending up as waste (WEEE) and 2) The EEE stored and un-used in citizens households.

1.1 WEEE that is still functional

When looking at this locally in the city and municipality of Odense, research at University of Southern Denmark’s LifeCycle Center has shown that approximately 40% of all WEEE collected at the municipality’s waste stations is still fully functional. Even so, nearly all of this is shredded for resource recovery according to the current producer responsibility system, although the existing preprocessing infrastructure causes significant losses of valuable resources in the process [6]. At the same time all EEE that enters Odense Waste Management Ltd.’s waste stations is legally regarded as e-waste or WEEE, whether it is functional or not, and is therefore handled under the Danish producer responsibility system. Consequently, Odense Waste Management Ltd is not allowed to let anyone else than this system sort, handle or re-use WEEE.

1.2 (W)EEE that is stored and unused

An EEE campaign and survey running from October to December 2018 by University of Southern Denmark’s LifeCycle Center, in collaboration with a regional TV station TV2/Fyn and several waste management stations, showed that many households keep EEE in stock at home, including several mobile phones and laptops. Altogether 1.600 items were donated from citizens, brought to the participating waste stations, and out of these 80% were still fully functional [7]. From a circular economy perspective it is great people are willing to bring in and donate their storage of household EEE, but on the other hand much of what was brought in had been unused for years, and especially for mobile phones and laptops, the lack of fast resale once taken out of use by the owner, pose a problem; there is no demand for outdated items of this kind! Indications so far show that one of the explanations for this storage tendency, is the lack of infrastructure in Odense to re-sell or donate EEE while still in demand.

2. Problem framing and the ‘waste-less’ circular economy initiative

Since there is currently no systematic and easily available infrastructure for household EEE in general in Odense, it brings opportunities for new infrastructures and (social) business models to emerge. In the following the case of a start-up, Re-Circle, is illustrating an initiative trying to do something about this.

2.1 Co-creating a pentahelix ‘waste-less’ infrastructure

In early 2019 a diverse group of business consultants, social entrepreneurs, researchers, politicians, advisers and public waste management specialists found common ground to co-create a pentahelix; Re-Circle. Their purpose is to develop a novel infrastructure to leapfrog the current system, where the collected WEEE – functional or not - is mainly shredded. Even though a re-used second-hand EEE item may not replace demand for another new EEE item fully with a 100% replacement rate, it could potentially make a significant contribution to reducing the number of new EEE products sold. Therefore, Re-Circle will, in addition to the infrastructure, do events and repair café training sessions to contribute to an increased awareness and circular economy mindset amongst citizens in Odense. An initiative the authors are going to follow closely over the next years.
References


WEEE PENTA HELIX: CO-CREATING A ‘WASTE LESS’ INFRASTRUCTURE

W. Evers [1], J. Thrane [2]

How might we... re-use more of the fully functional Electronic Waste/WEEE in Public Waste Management, and in households?

40% of all household electronic waste/WEEE is fully functional
80% of all non-active household electronics/EEE is fully functional

New forms of collaboration between different sectors of society - from Triple’ to ‘Penta-helix’
AMINE-MODIFIED SORBENTS FOR CO₂ CAPTURE: SCREENING APPROPRIATE TEMPERATURES FOR INHIBITING O₂-INDUCED DEACTIVATION.

Yuan Meng (1), Jianguo Jiang (1), Tongyao Ju (1)

1: School of Environment, Tsinghua University, Beijing 100084, China.

Abstract: Reducing CO₂ emissions is vital to counteract ongoing climate change. As the requirement of a low-carbon development, the use of technologies such as carbon capture and storage (CCS) is necessary. Amine-modified materials have recently emerged as a promising choice that can effectively capture CO₂ at a low temperature. However, O₂ contained in the flue gas is easily overlooked, which can induce the deactivation of the sorbents. In this study, we explored the effect of temperatures on O₂-induced deactivation, and screening appropriate temperatures for inhibiting O₂-induced deactivation. After 12h air exposure, O₂-induced deactivation was obviously inhibited at below 90℃, and CO₂ capture performance was still stable. In addition, in the 50 cycles of long-term experiments, 75℃ was considered as the optimum temperature for CO₂ capture from O₂ containing flue gas, which ensured the long-term stability of an only 2.1% decrease with a higher adsorption capacity.

Key words: CO₂ capture, amine-modified sorbents, O₂-induced deactivation, temperature.

1. Introduction

The increasing global warming and climate change are believed to be associated with the massive CO₂ emissions from fossil fuel combustion processes. According to the data of The Emissions Database for Global Atmospheric Research (EDGAR), the global fossil CO₂ emission was approximately 35.76 Gt in 2016 [1]. Carbon capture and storage (CCS) is considered to be the method of primary consideration for the CO₂ adsorption so as to reduce CO₂ emission from flue gas [2]. Among the traditional CCS technologies, adsorptive capture of CO₂ using amine-modified porous sorbents is a promising technology and a potential alternative for amine-scrubbing methods to control CO₂ emissions [3]. The porous material introduced functional organic groups will enhance the affinities between CO₂ and sorbents. Many researchers have exploring the amine-modified sorbents performance for improving and stabilizing the adsorption capacity and selectivity for CO₂ capture from flue gas [4].

However, considering the realistic flue gas conditions, the sorbents can be deactivated by several pathways including urea-linkage formation in the hot CO₂ atmosphere, oxidative deactivation, and the irreversible adsorption of SO₂, NO₂ [5]. Among them, flue gas from power plants generally contains 3–10% of oxygen (O₂) [6], so the O₂-induced deactivation need to be properly solved. In the present work, we synthesized a polyethyleneimine-modified silica by impregnation method, which had been proven to be with excellent capture performances [4]. We explored the effect of temperatures on O₂-induced deactivation, and screening appropriate temperatures achieving the meets of an excellent adsorption capacity and stability under O₂-containing flue gas.

2. Methods

2.0g of polyethyleneimine (PEI, 600Da) dissolved in 25mL of methanol was stirred at room temperature for 10 min, then added 2.0g commercial SiO₂ which was degassed in vacuum oven at 105℃ for 3h in advance. After adding 10mL of methanol, the mixture was stirred at 45℃ until the solvent was almost evaporated. Then the sample was dried under vacuum at 50℃ and collected the sample (named as PEI/SiO₂) for test analysis.

The experiments were performed by a thermogravimetric analysis (TGA) setup. The sample was degassed under N₂ at 120℃ for 30 min firstly, and then the temperature was decreased to 75℃ for adsorption under flue gas containing 15%CO₂ and N₂ balance. CO₂ adsorption capacities were calculated from the TG profiles. For exploring the O₂-induced deactivation of PEI/SiO₂ at different temperatures, air aging experiments were performed by synthetic air purging for 12h. In addition, to test the long-term stability of CO₂ capture from O₂-containing flue gas, 50 cycles experiments were carried out under 15%CO₂, 10%O₂, N₂ balance for adsorption and N₂ for regeneration.

3. Results and discussion

3.1. Air aging experiments

To compare the effect of quantitatively at different temperatures, Fig.1(a) showed the CO₂ adsorption capacity of the sorbent after aging, normalized by their adsorption capacity before aging. According to the results, CO₂ cap-
ture performance of PEI/SiO$_2$ seemed stable under air purging when the temperature was below 75°C. But further elevated temperatures would obviously promote O$_2$-induced deactivation, and CO$_2$ adsorption capacities of the sorbent were decreased by 7.2%, 64.7%, 93.9%, 97.4% and 97.8%, respectively, from 90 to 150°C. In addition, the adsorption capacities were not progressively affected after 12h N$_2$ aging at 90–150°C, which indicated the exacerbated deactivation was dominated by oxidation instead of thermal amine evaporation with temperature.

![Graph of normalized adsorption capacities and attenuation rate of adsorption capacity](image)

**Fig. 1:** (a) Normalized adsorption capacities after 12h air/N$_2$ aging at different aging temperatures. (b) Long-term stabilities of the sorbent under O$_2$-containing flue gas at different adsorption temperatures.

### 3.2. Long-term cyclic experiments

It was concluded that the O$_2$-induced deactivation of PEI/SiO$_2$ was not significant at below 75°C. Subsequently, the long-term (50 consecutive cycles) stabilities of the sorbent were investigated for CO$_2$ capture from O$_2$-containing flue gas, and the results were collected in Fig.1(b). PEI/SiO$_2$ showed steady cyclic behavior at 60°C and 75°C, consistent with air aging experiments, and the CO$_2$ adsorption capacity was reduced only 1.1% and 2.1%, respectively. As an obvious contrast, the adsorption capacity decreased gradually with repeated TGA cycles by 88.5% at 105°C. It was therefore concluded that less than 75°C would be appropriate for CO$_2$ capture from O$_2$-containing flue gas, and the O$_2$-induced deactivation was effectively inhibited. However, compared with 60°C, CO$_2$ capture at 75°C could also achieve a higher adsorption capacity of 138.2 mg/g.

### 4. Conclusions

In this work, we have evaluated the effect of temperatures on the O$_2$-induced deactivation of PEI/SiO$_2$ for CO$_2$ capture from more realistic flue gas. The temperature-dominated oxidative deactivation could limit the application of amine-modified sorbents at above 90°C. By air aging and long-term experiments, 75°C was screened as an appropriate temperature and could ensure a long-term stability of a 2.1% decrease with a higher uptake.

### Acknowledgements

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### References


A high temperature would accelerate the significant oxidative deactivation of PEI/SiO$_2$, especially at above 105ºC.

The deactivation was associated with the formation of new species like amide by O$_2$ inducing. A stable and efficient CO$_2$ capture was feasible at below 75 ºC.

**Summary**

- A high temperature would accelerate the significant oxidative deactivation of PEI/SiO$_2$, especially at above 105ºC.
- The deactivation was associated with the formation of new species like amide by O$_2$ inducing.
- A stable and efficient CO$_2$ capture was feasible at below 75 ºC.
PLASTICS AT SEA IN ECOTOURISM SITES IN ZANZIBAR, TANZANIA

C. Maione (1)

1: School for Environment and Sustainability / University of Michigan, 440 Church Street, Ann Arbor, 48104 Michigan

Abstract: Plastic debris are amongst the most documented beach litter worldwide and beach pollution is becoming a growing concern in tourism sites in Zanzibar, Tanzania. Unquantified amounts of plastic materials are discharged into its coastal waters and have detrimental effects on local marine environments. With the expansion of the tourism industry on the island, plastic debris increasingly originate from tourism activities and end up into the ocean due to poor management of solid waste and lack of recycling services. This paper explores source and type of plastic waste by surveying local tourism activities. It was observed that plastic is second largest component of solid waste in the form of food packaging, plastic bags and wrappings, water bottles, and single-use containers.

Key words: Plastic pollution, Zanzibar, Coastal waters, Ecotourism.

1. Introduction

Marine littering is causing serious economic damages by affecting a wide range of natural environments that are considered primary ecotourism attractions, as it is the case in Zanzibar. Especially, coastal-dependent activities such as commercial and sport fishing, snorkeling, diving, and safari blue can see rapid declines if actions are not taken to cope with ocean plastic pollution. Plastic pollution has several implications on local economies by causing a decrease in the number of tourists and lost tourism revenues due to marine debris. It can impoverish local economies by reducing tourism development, damaging economic activities, and threatening private investments in hotels and tourism infrastructures.

While it is known that the tourism industry has seen the detrimental effects of marine pollution, its total contributions to environmental degradation is still an open question, particularly in small islands that heavily rely on ecotourism incomes. This is the first study that investigates the extent to which the expansion of tourism contributes to increasing level of plastic pollution on tourism beaches. It focuses on Zanzibar as a main case study and is based on expeditions that took place over Spring-Summer 2018. The main goals of the study were to explore the provenience of beach accumulations of plastic materials and assess the management of recyclables at the hotel level.

2. Methods

2.1. Study area

Four sites were chosen on Unguja island for this study to understand the interconnections between the expansion of tourism in Zanzibar as a consumption sector and lack of infrastructures to manage solid waste. These locations represent areas that are broadly accepted within definitions of ecotourism and cultural tourism. One site is located in Stone Town which is designated as a UNESCO’s World Heritage Site. Two sites are located in the coastal areas of Nungwi and Uroa, on the Eastern coast of the island, that are well known for tourism expansion. The third site, Fumba, is a fishermen village located in the biggest reef area of the island and famous for snorkeling and diving tours.

2.2. Data collection

To gather data on management of solid waste and emergence of marine plastic pollution in coastal areas, we conducted interviews and focus groups and made direct observations of littering practices. Being exploratory, this study covered a diverse range of topics including perception of the tourism sector and its impacts in addition to waste production.

3. Results

3.1. Tourism as a waste generating sector

This analysis is designed to outline the perception of tourism as a waste generating sector and tourist behaviors. The 57 respondents were employed in the tourism or waste sector at the time of the. Out of the total number of respondents, only 7.0% perceived the lack of waste management infrastructures as a driver of poor waste man-
agagement on the island. Nearly half of the respondents (50.9%) identified tourism as a waste generating sector as they reported greater accumulations of waste during tourist high season. Waste production in the months between June and March “can even double” according to respondents working in the waste sector. However, our results reported unclarity amongst respondents about which waste materials are more likely to increase due to tourism.

When asked about tourist behaviors, the relative majority of respondents (42.1%) said that tourists are respectful of the local environment and only 15.8% had noticed tourists dumping trash into the ocean. Contrarily, Zanzibaris are more likely to adopt a “throw everywhere culture” by making insufficient use of trash cans and other disposal facilities to dispose of waste materials. Overall, approximately 1 out of 3 respondents (31.6%) reported to have seen plastic at sea, but they could not identify the waste source.

3.2. Marine littering behaviors

Observation of littering behaviors in Stone Town reported that proximity to the coast of food markets and other food distribution activities was a major predictor of waste at sea. In particular, the area of Forodhani Gardens, a small park along the coast where the island’s biggest food market takes place on a daily basis, was recorded as a major source of waste pollution that ends up into the sea. Each hour, between 10:00 am and 12:00 pm, street sweepers were observed swiping food wrapping and packaging from the market on the shoreline and into coastal waters. Objects found in waters were: paper plates, plastic straws, plastic cups, plastic cutlery, water bottles, and cigarettes.

Beach and marine littering observations in Fumba reported that boat tours on reef areas greatly contribute to production and disposal of waste into the sea. While tourists seemed to be mindful while traveling by boat, littering behaviors observed on the beaches and in land areas between each boat trip reported uncontrolled dumping. Objects found on the beaches were: plastic plates, plastic cups, plastic cutlery, aluminum cans, water bottles, cigarettes, aluminum food containers, and plastic bags and wrappings.

3.3. Waste accumulations on tourism sites

Visual data on plastic accumulations were supplied through trash tracking. The tracking system used during the expeditions extracted geospatial information from trash photography and merged them to a georeferenced map to build a waste pollution map of the three main sites surveyed. 554 data points were reported, of which 333 in Stone Town, 87 in Nungwi, and 134 in Uroa. These points recorded presence of single waste elements, waste accumulations, and illegal dumping.

Observations of waste materials at sea consisted of readily visible plastic debris classified as macroplastics (20-100 mm) or megaplastics (>100 mm) according to their size.⁴ Results from both expeditions recorded single-use food containers to be the most common type of waste found in superficial waters. The trip that departed from Stone Town recorded: water bottles, plastic plates, plastic cups, plastic straws, plastic cutlery, and styrofoam food containers. Similarly, during the trip from Fumba, single-use plastic items were observed. In addition to food containers, we recorded: one toothpaste tube and one facial tissue wrapping.

4. Conclusions

This study explores the causes of marine littering and type of waste materials found on ecotourism sites in Zanzibar. Plastic pollution results from a combination of inefficient regulations to prevent waste disposal into the ocean and lack of integration between tourist waste collection and municipal solid waste services. The results suggest a correlation between three variables: tourism, income, and waste. As the tourism sector expands, Zanzibari economies record higher income opportunities for local populations on one hand, and increasing waste production on the other. As a result, ecotourism environments will deteriorate and cause a decline in tourism activities by restricting access to tourism incomes.

References

CASE STUDY: UNGUJA, ZANZIBAR
Plastic pollution has been documented in every aquatic habitat with detrimental effects for pelagic biota and, eventually, for human communities that rely on water and marine resources. While the presence of plastic debris has been widely substantiated with scientific evidence, the amounts and contributions of different flows of plastic waste remain an open question. This study investigates how the sectors of local economies (e.g., household, industries, and tourism) contribute to the production of solid waste in urban and coastal environments, exploring each sector’s specific contributions to plastic leakages into the environment. Such inputs are reported by polymer type, state-of-the-art at the moment of the survey, and recyclability potential. For the purpose of this study, data were collected during an expedition in Zanzibar, Tanzania over the Summer 2018, and analyzed using statistical analysis tool, Sankey diagrams, and dynamic flows modeling. Findings suggest that PET and LDPE are by far the most plastic litter types, covering approximately 70% of mismanaged plastics waste. Based on findings, this study suggests that it is urgent to catalyze actions and policy efforts towards end-of-life management of plastics waste through a multi-focal strategy approach.

WASTE-TOURISM SYSTEM

1. PERCEIVED PUSH/PULL FACTORS TOWARDS LITTER ACCUMULATIONS
Structured interviews with 57 respondents from waste and tourism sectors.

2. OBSERVED PUSH/PULL FACTORS TOWARDS LITTER ACCUMULATIONS
Overt and covert observations on littering practices, source, amount, type, and items of waste materials, number, location, type, and conditions of waste facilities.

3. FINDINGS COMBINING PERCEIVED AND OBSERVED PUSH/PULL FACTORS
Multi-criteria decision analysis to reduce marine littering.

WASTE-TOURISM SYSTEM

SOURCE AND TYPE OF LITTER

1a. STONE TOWN: Sector / Product type
1b. STONE TOWN: Sector / Plastic type
2a. NUNGWI: Sector / Product type
2b. NUNGWI: Sector / Plastic type
Abstract: This study has examined the extent to which consumers have recognized food loss resulting from their behaviors, and whether they intend to work on improving those behaviors. It has been confirmed that consumers' awareness has spread not only to direct food disposal associated with consumption, but also to indirect food loss in the food supply chain. On the other hand, there were also several indirect food loss generation with low consumer awareness level. It is therefore necessary to provide information regarding such indirect food loss. It has also been revealed by this survey, however, that awareness of problems, and encouragement of improving activities, are by themselves insufficient to improve such behaviors regarding of behavior to be felt burdensome for consumers.

Key words: Food loss, Food waste, Consumer behaviors, Consumer awareness, Food supply chain.

1. Introduction
Reduction of “food loss”, and effective utilization of food otherwise wasted, is a global challenge. In Goal 12 of the “Sustainable Development Goals” (SDGs) adopted at the United Nations General Assembly in 2015, there is now an international target (12.3) to halve food waste per capita at the retail and consumer levels, and to reduce food losses along the production and supply chain by 2030.

Approximately 28 million tons of food waste are generated annually in Japan. Of this, food loss accounts for approximately 6.5 million tons, which corresponds to about 10% of the food distributed annually in Japan. Of these 6.5 million tons, about 2.9 million tons are generated from households, and 3.6 million tons from food-related businesses operators (food manufactures, food wholesalers, food retailers, restaurant industry).

2. Objectives
This study investigates the extent to which consumers have recognized food loss resulting from their behaviors, and whether they intend to work on improving those behaviors. The items surveyed were as follows:

- Degree of awareness of behaviors that generate direct food loss at the consumption stage
- Degree of awareness of consumer behaviors that induce food loss in the course of the food supply chain
- The feasibility of improvement behaviors.

The survey was conducted via a questionnaire on the internet for respondents aged 20 or older in December 2018. A total of 960 responses were collected.

3. Results

2.1. Awareness of behaviors that generate direct food loss at the consumption stage
Regarding direct food loss at the consumption stage, i.e. “direct disposal”, “leftovers” and “excessive trimming during preparation”, 60 to 70% of consumers responded that they “strongly recognized” or “somewhat recognized” these behaviors. Especially, more than 20% of respondents “strongly recognized” such tendencies as foods being “disposed of just by reason of being past their expiration date, even if the food is still edible,” and that “excessively cooked dishes at home, overbuying ready-made meals at supermarkets and convenience stores are disposed of as leftovers.”

2.2. Awareness of consumer behaviors that induce food loss in the course of food supply chain
Regarding food loss generated in the food supply chain and affected by consumer behaviors, 50 to 70% of consumers responded that they “strongly recognized” or “somewhat recognized” this issue. We had assumed that consumers’ awareness would be low regarding indirect generation of food loss, but the degree of their awareness was higher than expected. In particular, the facts that “vegetables with poor shape or color, or with any damage,
are disposed of at the farm or during the distribution process, even if they are edible, due to many consumers’ preference for those with good shape and color, and without any damage”, and that “dishes and ingredients prepared by restaurants are wastefully disposed of due to cancellation at the last minute” were “strongly recognized” by more than 20% of respondents.

On the other hand, the number of consumers who “strongly recognized” or “somewhat recognized” that “fresh foods that have been put in a shopping basket but then left in the supermarket away from their original place are disposed of, due to freshness management or safety reasons (such as suspicion of contamination)” did not exceed 50% in total.

2.3. Feasibility of improvement behaviors

The top three behaviors leading to food loss reduction, with large numbers of responses as “feasible” and “almost feasible” were behaviors to reduce “leftovers” either directly or indirectly, such as “not cancelling restaurant reservations at the last minute”, “eating all food ordered when eating out” and “storing leftovers at home in a storage container and eating them all later.”

On the other hand, the top three behaviors with large numbers of responses as “infeasible” and “not very feasible” were “making donations to food banks”, “selecting foods placed not at the rear but at the front when purchasing food products”, and “purchasing food products frequently rather than bulk buying.” The reason why “donating to food banks” is thought not to be feasible is that it is believed that such organizations are not located nearby, or people do not know of their existence. “Purchasing of products placed at the front” has been introduced by various media as a way to reduce food loss. Moreover, nearly 70% of consumers recognized that “foods past their expiration date are disposed of due to consumers’ preference for selecting foods at the rear, with longer expiration dates, rather than those placed at the front, with shorter expiration dates” in this survey. Therefore, it has been shown to be a behavior that is understood, but which is difficult for consumers to implement. In other words, it is suggested that recognition of problems and encouragement of improved behaviors alone is insufficient as an information provision program. As for “frequently go shopping”, it has been shown to be burdensome for consumers to increase the frequency of their shopping.

3. Conclusions

This study has examined the extent to which consumers have recognized food loss resulting from their behaviors, and whether they intend to work on improving those behaviors. It has been confirmed that consumers' awareness has spread not only to direct food disposal associated with consumption, but also to indirect food loss in the food supply chain. On the other hand, there were also several indirect food loss generation with low consumer awareness level. It is therefore necessary to provide information regarding such indirect food loss. It has also been revealed by this survey, however, that awareness of problems, and encouragement of improving activities, are by themselves insufficient to improve such behaviors regarding of behavior to be felt burdensome for consumers. From now on, we would like to consider the ideal way to provide information that would lead to improvement of consumers' behaviors, as well as information for other stakeholders involved in food loss.

Acknowledgements

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References


Introduction
Reduction of "food loss" and effective utilization of food otherwise wasted, is a global challenge. In Goal 12 of the "Sustainable Development Goals" (SDGs) adopted at the United Nations in 2015, there is now an international target (12.3) to halve food waste per capita at the retail and consumer levels, and to reduce food losses along the production and supply chain by 2030.
Approximately 6.5 million tons of food losses are generated annually in Japan (Fig. 1). Of these 6.5 million tons, about 2.9 million tons are generated from households, and 3.6 million tons from food-related businesses operators (food manufacturers, food wholesalers, food retailers, restaurant industry). However, food losses that generate from food-related businesses operators are also not unrelated to consumer behaviors.

Objectives
This study investigates the extent to which consumers have recognized food losses resulting from their behaviors, and whether they intend to work on improving those behaviors.

Results
The survey was conducted via a questionnaire on the internet for Japanese respondents aged 20 or older in December 2018. A total of 960 responses were collected.

1. Awareness of behaviors that generate direct food losses at the consumption stage

2. Awareness of consumer behaviors that induce food losses in the course of food supply chain

3. Feasibility of improvement behaviors

Conclusions
This survey revealed the following facts:
1. Consumers’ awareness has spread not only to direct food disposal associated with consumption, but also to indirect food losses in the food supply chain.
2. There were also several indirect food losses generation with low consumer awareness level. It is necessary to provide information regarding such indirect food losses.
3. On the other hand, awareness of problems, and encouragement of improving activities, are by only themselves insufficient to improve such behaviors regarding of behavior to be felt burdensome for consumers.

Survey on Awareness of Food Loss Caused by Consumer Behaviors and Feasibility of Improvement Behaviors
Hhideaki KURISHIMA1, Tatsuo HISHINUMA1,2 and Reiko Omori2
1 Shibaura Institute of Technology, JPN 2 Utsunomiya University, JPN

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Contact adress: Hhideaki KURISHIMA kurikuni@shibaura-it.ac.jp
URBIOFIN PROJECT: DEMONSTRATION OF AN INTEGRATED INNOVATIVE BIOREFINERY FOR THE TRANSFORMATION OF MUNICIPAL SOLID WASTE INTO NEW BIOBASED PRODUCTS


1: Industrias Mecánicas Alcudia S.A. (IMECAL SA), Avenida de Carlet 74, 46250 L’Alcúdia, Spain
2: AINIA, Calle Benjamin Franklin 5-11, 46980 Paterna, Spain
3: URBASER S.A., Camino de las Hormigueras 171, 28031 Madrid, Spain
4: BIOMASA PENINSULAR S.A, calle constancia bajo 38, 28002 Madrid, Spain
5: Universidad de Valladolid, Plaza Santa Cruz 8 Palacio de Santa C, 47002 Valladolid, Spain
6: EXERGY Ltd, Puma Way the Technocentre Coventry, CV1 2TT Coventry, UK
7: NOVOZYMES A/S, Krogshojevej 36, 2880 Bagsvaerd, Denmark
8: WAGENINGEN UNIVERSITY, Droevendaalsesteeg 4, 6708 PB Wageningen, The Netherlands
9: CIEMAT, Avenida Complutense 40, 28040 Madrid, Spain
10: VISUM Ltd, University College Dublin, Blocks 9 & 10, Belfield Office Park, Belfield – Dublin 4, Ireland
11: NATUREPLAST SAS, Rue Francois Arago 11, 14123 Issy, France
12: IRIAF, Ctra. Albacete-Toledo, s/n, 13700 Tomelloso, Spain
13: BCM BioEconomy Cluster Management GmbH, Blücherstraße 26, 06120 Halle, Germany
14: SES, ZI de Courtanne, 43620 Saint Pal de Mons, France
15: NATRIUE, square de meeus 37 4ieme etage, 1000 Brussels, Belgium
16: Sustainable Energy and Chemistry Group, CSIC, c/ Marie Curie 2, Cantoblanco, 28049 Madrid, Spain

Abstract: Each person in Europe generates an average of 487 kg of municipal solid waste (MSW) per year. Around 50 percent of this is organic waste, made up of carbohydrates, proteins and lipids, all of which represent useful raw materials for creating valuable bioproducts. However, until today this potential has not been fully exploited. The URBIOFIN project will demonstrate the techno-economic and environmental viability for the conversion of the organic fraction of MSW (OFMSW) into: chemical building blocks (bioethanol, short and medium volatile fatty acids, biogas), biopolymers (low and medium chain polyhydroxyalkanoates (PHAs), composites combining different PHAs) and additives (bio-ethylene, biochemical products derived from microalgae).

Key words: Organic fraction of MSW, Urban biorefinery, Circular economy, Bio-based products.

1. Introduction

The rapid population growth and its concentration in large cities has caused an important increase of urban waste, which contributes significantly to the total amount of waste generated by our society. Today in Europe, each person generates, on average, 487 kg of urban waste annually. Around 50 % of this correspond to biodegradable waste (biowaste) so that a total biomass of around 100 million tons derived from MSW is yearly produced in the EU. This organic fraction mainly contains carbohydrates, proteins and lipids, which are all useful raw materials for producing valuable products, but this potential has not been fully exploited. By using the biorefinery concept applied to MSW (urban biorefinery), URBIOFIN will exploit the OFMSW as feedstock, taking into account its heterogeneity and variable composition, to produce at semi-industrial scale different valuable marketable products. The processes involved in the development of these bioproducts will be interconnected so that a versatile and efficient biorefinery for OFMSW will be demonstrated. URBIOFIN project will offer a new feasible and more sustainable scenario alternative to the current treatment of the OFMSW.

2. Main achievements so far

2.1. Preliminary actions for the urban biorefinery design

The URBIOFIN feedstock - OFMSW - is a complex stream with variable composition. URBIOFIN was designed based on the variability of the OFMSW composition. The essential biological processes, such as bioethanol fermentation and anaerobic digestion were selected because they are predestined to deal with complex and heterogeneous substrates. The target feedstock for the URBIOFIN processes is OFMSW from selective collection. URBIOFIN aims to convert all components of the OFMSW into a wide range of products. In the circular system of URBIOFIN most of the nutrients present on the OFMSW could be returned to the biosphere by its capturing into solid and liquid fertilizers. Most of the organic content is transformed into biodegradable plastics.
composites, that can be recycled and utilized as new carbon source susceptible to be biologically transformed by any other biorefinery into another bio-based products. Currently, unavoidable biowaste, at best, is used to produce biogas, compost or animal feed and, at worst sent to landfill. With todays technologies, as some of the applied in the URBIOFIN model, it is possible to aim for higher value products other than bioenergy or compost. More importantly, there is a potential market for the URBIOFIN bio-based products. To successfully enter the targeted markets the requirements of the bioproducts were defined. The products must fulfil requirements in terms of technical properties and compliance with existing or upcoming European regulations.

2.2. Conversion of OFMSW to bioethanol as building block for the production of bioethylene

The pre-treatment and enzymatic hydrolysis processes of the OFMSW feedstocks for bioethanol production have been optimized. A number of different yeasts for the sugars fermentation into bioethanol were evaluated and the optimum strain was selected. IMECAL performed an engineering study for the adaptation of the PERSEO Bioethanol® semi-industrial plant and carried out different modifications in the plant units. Preliminary engineering studies for the installation of an ethanol-to-ethylene demonstration module in PERSEO Bioethanol® plant have been performed. The preliminary demonstration planning schedule, defined timing, capacities and logistics for the demonstration stage was set. The continuous demonstration activities of URBIOFIN biorefinery, located in PERSEO Bioethanol® semi-industrial plant, will be carried out during the next months of the project.

2.3. Conversion of OFMSW to VFAs for the production of PHA

The construction and the start-up of the bio-plastic section of the urban biorefinery is being carried out. The first unit corresponds to the optimization of the VFA production. The VFA stream is used for the elongation to MCFA, SCL-PHA and MCL-PHA production. The PHA demo plant is fully constructed and ready to be operated as soon as the VFA stream is produced. The PHA extraction system has also been studied and improved to produce bioplastics and to complete the biorefinery concept.

2.4. Biogas bioconversion to biomethane and added value products

In the coming months the pilot photosynthetic biogas upgrading plant, the pilot anoxic biofilter for biogas desulfurization and the pilot plant for biogas conversion to biopolymers will be built up. It has assessing the analytical interactions of the most common siloxanes and enriching microbial communities able to biodegrade these hydrophobic biogas pollutants.

2.5. Final applications and industrial validation of the biobased products developed

The definition of the specific methodologies for the validation of the bio-based products performances within URBIOFIN has been done. A methodology for carrying out accelerated aging-tests on the different cosmetic packaging formulations and domestic waste bags obtained in URBIOFIN to substitute conventional plastic materials is being carried out. Furthermore, preliminary characterization trials regarding fertilizing and biostimulant properties of liophyllised microalgae have been performed. Moreover, new formulations of PHA-based composites are being designed to be applied for cosmetic packaging, plastic bags and agricultural film applications to improve processing and thermo-mechanical properties of the new bioplastic materials.

2.6. Integration of the urban biorefinery. Economic, environmental and regulatory assessments

This part of the project aims at integrating, modelling and assessing the overall urban biorefinery concept developed in the project, including the processes and the bioproducts. The activities started early in the project and are being prepared for further modelling and simulation; preliminary assessments have been carried out (LCA); and reference framework is established to study the regulatory aspects related to the technology and the products, including contribution and participation in linked events and workshops.

3. Conclusions

URBIOFIN project (www.urbiofin.eu) will demonstrate the viability for the production of added value products from the OFMSW for identified market applications. The valorization of organic MSW not only helps to solve environmental pollution but also contributes to the transition from a linear to a renewable circular economy.

Acknowledgements

This Project has received funding from the Bio-Based Industries Joint Undertaking under the European Union’s Horizon 2020 research and innovation programme under grant agreement N° 745785.
The aim of the URBIOFIN project is to demonstrate the techno-economic and environmental viability of the conversion of 10 tonnes per day of the organic fraction of municipal solid waste (OFMSW) into:

- Chemical building blocks (bioethanol, volatile fatty acids, biogas)
- Bio-polymers (short and medium chain polyhydroxyalkanoates, composites combining different PHAs)
- Additives (bioethylene, microalgae derived biochemicals)

www.urbiofin.eu | imecal@imecal.com | @URBIOFIN | im URBIOFIN Project

FROM URBAN WASTE TO BIOPRODUCTS THROUGH BIOREFINERY

The Project has received funding from the Bio-Based Industries Joint Undertaking under the European Union’s Horizon 2020 research and innovation programme under grant agreement No 743763.
THE CLIMATE BENEFITS OF A PROPOSED ANAEROBIC DIGESTER: A U.S. EPA CASE STUDY FROM NAUCALPAN, MEXICO

Elizabeth Mettetal¹, Benjamin Matek¹, Joseph Donahue¹, Santiago Enriquez¹, Roger Peniche Sala², and Tom Frankiewicz³.

¹: Abt Associates, Rockville, MD, USA.
²: Municipality of Naucalpan, Mexico.
³: Climate Change Division, U.S. Environmental Protection Agency, Washington, DC, USA.

Abstract: With nearly one million residents, Naucalpan, Mexico, generates significant quantities of municipal solid waste. At present, the city lacks the infrastructure needed to divert and treat organic waste, which leads to excess landfilling and methane emissions. To address this, Naucalpan is planning an anaerobic digestion (AD) project to process organic waste. Waste processed by the AD will produce biogas that can be used to generate electricity. This paper presents an analysis of the potential emissions reductions associated with the project, conducted by the U.S. Environmental Protection Agency on behalf of the Climate and Clean Air Coalition Waste Initiative and the Global Methane Initiative. The reductions are driven by lower landfill emissions and lower electric grid emissions, as biogas-generated electricity is fed onto the grid. Using the Solid Waste Emissions Estimation Tool (SWEET), the authors demonstrate that the AD project could mitigate 58,000 to 77,000 tonnes CO₂-equivalent emissions annually.

Key words: Municipal solid waste, anaerobic digestion, organic waste, climate benefits.

1. Introduction

Waste disposal sites are the world’s third-largest source of anthropogenic methane (CH₄) emissions. CH₄, a short-lived climate pollutant, is 25 times more powerful as a greenhouse gas than carbon dioxide (CO₂) over a 100-year time period [1]. In addition, CH₄ is a precursor to tropospheric ozone, which causes respiratory damage and is harmful to crops. Since 2016, Naucalpan has participated in the Climate and Clean Air Coalition (Coalition) Municipal Solid Waste Initiative (Waste Initiative) to help improve the municipality’s waste management practices. The U.S. Environmental Protection Agency (EPA), as a lead partner in the Waste Initiative, supported the city in this analysis, which evaluates emissions benefits of a proposed anaerobic digestion (AD) project.

2. Context

Naucalpan’s waste generation rate has increased substantially over time, given significant industrial and urban population growth as well as changing consumption patterns over time. Currently, Naucalpan collects about 1,348 tonnes of municipal solid waste (MSW) per day, after accounting for informal separation of recyclables and other re-sellable waste [2]. This collected waste is about 40 percent organic waste (primarily compostable paper and food scraps), based on a waste characterization study conducted by EPA for the Waste Initiative.

The AD project will involve diverting organic waste from the landfill to an anaerobic digester constructed as part of a mechanical-biological treatment facility. The anaerobic digestion process catalyzes the natural decomposition of organic waste without oxygen. This process produces biogas (a mixture of primarily CH₄ and CO₂), which can be combusted and used as an electricity source, as well as digestate, which can be applied to land as a fertilizer. Naucalpan plans to use the biogas produced to generate electricity at a combined heat and power (CHP) plant located on site. Some of the electricity will be used to power the AD facility, and the remaining portion will be fed into the national electrical grid.

3. Methodology and Assumptions

Estimating the direct CO₂-equivalent (CO₂e) emissions reductions associated with the AD project proceeded in three main steps. First, the team estimated emissions from a business as usual scenario. Second, the team estimated emissions under the AD project scenario. Finally, the team estimated the net changes in emissions associated with the AD project by subtracting emissions under the AD project scenario from emissions under the business as usual scenario.

Although there are many emissions sources from a waste management system, only some emissions were expected to significantly change due to construction of the AD facility. These included landfill emissions, emissions due to operation of the AD, and net electricity grid emissions. Other emissions sources, including emissions from waste transportation, emergency flares, and digestate application, were omitted from this analysis because the emissions were not expected to change between the baseline and project scenario.
The analysis utilized SWEET Version 2.1, developed by the EPA on behalf of the Waste Initiative [3]. SWEET relies on established methodologies for estimating changes in landfill emissions resulting from the diversion of waste. Methane emissions from disposal sites are estimated as the amount of CH\textsubscript{4} generated, minus the amount either collected and destroyed, or oxidized in cover soils. The calculations are based on the Colombia Landfill Gas Model and depend on the waste amount deposited and landfill characteristics. Similarly, emissions from the digester operations rely on default emissions factors for the treatment of biological waste from the IPCC [4].

Though SWEET calculates emissions from running the AD facility, it does not estimate emissions reductions associated with the AD facility displacing electric grid emissions. Instead, emissions reductions from displaced grid electricity were calculated based on assumptions from the engineering literature and experts. Gross electricity generation was estimated given the amount of the biomass processed, the expected biogas production, and the estimated electrical efficiency of the CHP plant. The total was then adjusted downward based on the expected electricity consumption from the AD, the separation plant, and the CHP plant, as well as potential line losses. This yielded an estimate of the net electricity transmitted to the grid, which displaces marginal grid generation.

Based on guidance from Naucalpan, EPA considered two scenarios that represent the lower bound (300 tonnes/day) and upper bound (400 tonnes/day) amounts of organic waste processed by the digester, with waste being 77% food scraps and 23% compostable paper. EPA assumed a 20-year lifetime, from 2019 to 2038.

4. Results and Discussion

The analysis estimated emissions reductions for three sources: organic waste diversion from the landfill, operation of the AD facility, and displaced electricity production. The results of the analysis demonstrated that the AD facility will reduce emissions considerably: on the order of 58,000 to 77,000 tonnes of CO\textsubscript{2}e per year, or 1.16 to 1.54 million tonnes of CO\textsubscript{2}e over the project life. This effect is driven largely by reductions in landfill emissions, which constitute 93% of total reductions. The total change in emissions reductions by is shown in Figure 1.

![Figure 1](https://example.com/figure1.png)

*Figure 1. The figure reflects the change in emissions that occurs due to the AD project. The lower bound corresponds to sending 300 tonnes/day to the AD, and the upper bound reflects sending 400 tonnes/day.*

4. Conclusions

Naucalpan has the opportunity to curtail harmful CH\textsubscript{4} emissions through the construction of an AD. This project is on track to generate significant climate benefits for Naucalpan, including reductions of over a million tonnes of CO\textsubscript{2}e emissions. Given these important reductions, this project may serve as an example to cities throughout Mexico and around the globe as they seek to reduce emissions and curb the effects of climate change.

Acknowledgements

This work was built on technical assistance provided by the U.S. Environmental Protection Agency on behalf of the Climate and Clean Air Coalition Waste Initiative.

References


BACKGROUND
- Naucalpan is a city of nearly 1 million people outside Mexico City.
- Naucalpan is planning an anaerobic digestion (AD) project to treat organic waste, which accounts for 40% of the waste stream.
- The project will produce biogas to generate electricity that will power the facility and feed into the grid.
- On behalf of the Climate and Clean Air Coalition Municipal Solid Waste Initiative, the U.S. Environmental Protection Agency (EPA) analyzed the potential emissions reduction benefits of the project.
- EPA's analysis builds on several years of support to Naucalpan, beginning with an initial project pre-feasibility study conducted through the Global Methane Initiative.

METHODS
To calculate estimated change in landfill emissions:
- EPA utilized SWEET Version 2.1 to calculate emissions from running the AD facility. Methane emissions from disposal sites are estimated as the amount of CH4 generated, minus the amount collected, destroyed, or oxidized in cover soils.

To calculate gross electricity generation:
- EPA used the amount of biomass produced, the expected biogas production, and the estimated electrical efficiency of the CHP plant.
- EPA considered two scenarios: (1) Lower bound (300 tonnes/day); and (2) Upper bound (400 tonnes/day).

Assumptions:
- Organic waste is 77% food scraps and 23% compostable paper.
- 20-year life of the project through 2028.

RESULTS
Reductions of 58,000 to 77,000 tonnes of CO2e per year.
1.16 to 1.54 million tonnes of CO2e over the project life.

DISCUSSION
The data and findings from this analysis can be used to inform the city's efforts to:
- Further assess technology selection, infrastructure investment, and facility program sizing;
- Secure funding and other types of support (e.g., political) for the installation of an AD in Naucalpan; and
- Serve as an example to cities throughout Mexico and around the globe as they seek to reduce emissions and curb the effects of climate change.

The Climate and Clean Air Coalition Municipal Solid Waste Initiative unites national and local governments, international organizations, and other partners to reduce emissions of short-lived climate pollutants, such as methane and black carbon, from the municipal solid waste sector.

www.wccacoaliition.org
Abstract: Presentation of ZERØ, a digital platform developed by Teimas Desenvolvemento S.L. (Spain), a technology-based company, pioneer in creating and deploying business solutions and strategic tools specifically designed for sustainability and circular economy. Founded in 2008, Teimas relies on a solid experience and expertise in the development of technology and innovation for public and private entities in the recycling and circular economy field. ZERØ undertakes the challenge of helping to drive a greater circularity in corporations. It optimises and automates corporate processes for resources and waste management, transforming operational data into key business indicators in order to improve the circularity strategy of companies.

Key words: circular economy, software platform, corporate circularity, resources and waste management.

1. Introduction: Waste management in the European Union (EU)

The Circular Economy (CE) is a new economic paradigm presented as an alternative to the current lineal model of production and consumption, with the potential to solve environmental challenges, while opening up business opportunities and economic growth.

In recent years the CE model has become a priority in the policies of the EU. In this context, the EU has developed an extensive environmental regulatory framework that increasingly affects the transparency and traceability of industrial waste management. These regulations establish a system of “Extended Producer Responsibility” [1] that obliges the producer to maintain responsibility for the waste until its final treatment.

In order to comply with the waste management obligations, companies have to adopt operational processes that involve the generation of certain indicators, as well as the preparation and custody of documents to support the traceability of these processes.

In this regard, innovation becomes the key element to achieve the transition to a CE: waste producing companies need to equip themselves with adequate information systems in order to efficiently and cost-effectively support the waste management process in accordance with legal regulations. In addition, it is estimated that compliance with waste legislation can have a high impact on the gross added value of the companies.

2. ZERØ: Circular economy platform

ZERØ, developed by Teimas Desenvolvemento S.L.[2], arrives as a solution for sustainability management. It is available as SaaS, as well as a license sale that can be installed on other servers. With regards to SaaS, once ZERØ has been configured according to the characteristics of the client, it is hosted on Teimas servers in the cloud, and a support service is provided to the company.

2.1. Implementation

The implementation of ZERØ in a company involves: consultancy and functional analysis (capturing waste data in order to configure the tool); development and setup (elaboration of a functional system, adapted to the needs of the company, including the integration with other company's systems on demand); launch of ZERØ helpdesk for the preventive, reactive and legal maintenance of the solution; and, optionally: adaptations, customizations, integrations or developments for the company. Moreover, either Teimas or its associated partners will be able to offer an operation service (data entry, information review, and audit, among others).

2.2. ZERØ development stage

ZERØ is in a development phase, starting in March 2018. The first operative version of ZERØ was presented on September 2018.

For its development, Teimas has relied on its more than 10 years experience as developer of following ICT solutions to the waste management sector: Teixo [3], a framework aimed at implementing software solutions for waste managers and carriers; Gaia [4] and Singer [5], 2 e-government platforms for the control of environmental traceability; and, finally, GReTel [6], a tool used by the Spanish corporation Telefonica to produce registers of all the waste generated in its work centres, regardless of the country in which they are located and their activities.
(office, base stations and R+D+i centres). This solution generates useful information such as key performance indicators, reuse ratios, waste recovery and recycling, among others.

2.3. ZERØ key features

ZERØ is up-to-date with regulatory and process requirements for sustainability management. It is compatible with corporate control, management and supply chain systems, and instantly accessible from any remote device. Moreover, it is multi-user, multi-business, multilingual and multi-country. Besides, this digital tool brings together, aligns and optimises the corporate processes of operational, documentary and financial waste management, providing internal management to centres, production units and material flows, as well as supervision of external suppliers.

In addition, ZERØ enables instant access to data repositories, and the creation of reports that can be exported to the most common formats, ensuring documentary traceability and compliance with legal regulations on environmental matters. In this sense, it allows the corporations to effectively build, automate, and visualise business and progress indicators, as well as executive dashboards. Moreover, it assists in the preparation of inspections, audits and reports on sustainability and corporate social responsibility.

In addition, ZERØ enables instant access to data repositories, and the creation of reports that can be exported to the most common formats, ensuring documentary traceability and compliance with legal regulations on environmental matters. In this sense, it allows the corporations to effectively build, automate, and visualise business and progress indicators, as well as executive dashboards. Moreover, it assists in the preparation of inspections, audits and reports on sustainability and corporate social responsibility.

As a result, the data collected by ZERØ provide information for the Social Responsibility reports of the corporations, and improve the definition of the sustainability strategies and policies, with impact as well on the competitiveness of the company.

3. Conclusions

Taking into account the complex legal frameworks posed by the transition to the CE, the requirements to ensure the transparency and traceability of the waste management by the companies have increased, becoming a challenge in terms of fulfilment of legal obligations, administrative processes, costs and efficiency. Companies with no procedures at a corporate level will require as well an efficiency improvement, in order to consolidate and monitor the whole process. In this context, waste management will require new technologies, processes, services and business models in order to obtain data and information for decision making and resource allocation.

Systems as ZERØ represent an opportunity to ease the whole procedure and improve the responsiveness to the demands required by the recycling and circular economy fields.

References

**Introduction**

- The current model of production and management of resources, goods, and services is leading the planet to an unsustainable situation.
- Governments are increasingly developing green economy policies and undertaking actions that support the move to a circular economy.
- Private companies need to adopt circular economy principles in order to fulfill the norms, improve their performance, and be environmentally responsible.

**Circular economy platform**

- Digital tool that optimizes and automates corporate processes for resources and waste management, transforming operational data into key business indicators.
- By Teimas (Spain), pioneer in the development of ICT solutions in the recycling and circular economy field.

**Challenges**

- Compliance: complex and changing regulations, waste and resources traceability control, administrative costs (time and money).
- Reliability: poor data quality, multiplicity of formats and stakeholders, loss of traceability in the supply chain.
- Strategy: Difficulty in extracting strategic information for reporting purposes and for the company’s circular economy policy.

**Cirularity Roadmap**

- Ambitious: From waste to resources, for all flows, business units, legal entities and countries.
- Challenging: Rethinking procedures and the relationship with the value chain.
- Satisfactory: Situate the company as a pioneering and relevant company in circularity, with operational and image benefits.

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**Teimas, 15 years of experience**

- Teixo: most popular enterprise cloud software for waste managers, warehouses and carriers.
- Gain and Singer: Spanish e-government platforms for the control of environmental traceability.
- GRteTel: Grupo Telefónica global tool for waste management and circular economy strategy.

**Key features**

- Easy to use and instantly accessible from any device (phone, tablet, PC).
- Compatible with corporate control and management systems.
- Multi-user, multi-business, multilingual and multi-country.
- Ensures traceability and compliance with environmental regulations.
- Support in the preparation of inspections and of sustainability and CSR reports.
- Advanced reports, KPI and executive dashboards.

**Contact details**

- [http://zeroteplatform.com](http://zeroteplatform.com)
- Miguel.Varela@teimas.com
- Pascual Veiga nº 7, Ent. A, 15706 Santiago (Spain)
- +34 647 49 87 13
SEVERE WEATHER IMPACTS ON SOLID WASTE DISPOSAL FACILITY OPERATIONS

In 2018, the mid-Atlantic region of the USA experienced record-setting precipitation and numerous severe weather events. The solid waste disposal facilities (landfills) that the majority of municipalities in these eastern states rely upon as an integral component of their solid waste management programs experienced dramatic consequences associated with these climate-related conditions.

This presentation will review the impacts of severe weather events and excessive precipitation on landfill operations and explore the potential design and construction strategies for mitigating the challenging consequences. The implications of severe weather events (and other changes in climate that introduce substantial increases in moisture content within the waste mass) on landfill stability, settlement and consolidation, waste biodegradation, gas production, and leachate generation will be examined. This presentation will review how landfills throughout the region are adjusting standard operating procedures associated with waste placement activities, such as waste tipping protocols, compaction efforts, and cover material deployment, fill sequencing, as well as stormwater management, erosion and sediment control, slope maintenance, and access road construction. The manner in which these facilities are adapting to maintain functionality and effective operations of their landfill gas collection and control systems, leachate management and treatment systems, gradient control systems, groundwater monitoring network, and other environmental control systems will be discussed. The presentation will summarize the recent efforts employed by the solid waste disposal facilities throughout the mid-Atlantic region of the USA to address increased odors resulting from the record-setting precipitation recorded at these facilities.

The adaptations and technological innovations employed by these facilities have broader applications on an international scale in that many landfills throughout the world are experiencing similar changes in climate and are seeking to implement modifications in operating procedures and other technical solutions.

Presenter and Lead Author:

Robert E. Dick, PE
Vice President
SCS ENGINEERS
15521 Midlothian Turnpike, Suite 305
Midlothian, VA 23113-7313
804.378.7440 (Office)
804.400.4179 (Mobile)
804.378.7433 (Fax)
BDick@scsengineers.com
Throughout the world, the solid waste disposal facilities (landfills) that communities rely upon as an integral component of their solid waste management programs have experienced dramatic severe weather and climate-related consequences, which reduce their capacity to function properly.

One specific example occurred in 2018, when the mid-Atlantic region of the USA experienced record-setting precipitation and numerous severe weather events, resulting in the introduction of substantial increases in moisture content within the waste mass, which contributed to landfill instability, increased differential settlement and consolidation, accelerated gas production (likely due to increased rate of waste biodegradation), and substantial increases in leachate generation.

Landfills attempt to respond to these severe weather and climate related conditions by adjusting standard operating procedures associated with waste placement activities, such as waste tipping protocols, compaction efforts, and cover material deployment, fill sequencing, as well as stormwater management, erosion and sediment control, slope maintenance, and access road construction. However, it is often nearly impossible to operate the necessary heavy equipment and perform earthwork activities during, and immediately after, these periods.

The potential design and construction strategies for mitigating the challenging impacts of severe weather events and excessive precipitation on landfill operations are as follows:

- Incorporation of “Mezzanine-Level” leachate collection layers and infrastructure, comprised of aggregate, geocomposite drainage nets, and perforated piping, to be installed within the waste lifts.
- Utilization of interim exposed geomembrane covers (EGC) in conjunction with larger stormwater conveyance and management features.
- Surface drainage trenches that function as “canals”, along with portable pumps, to reduce ponding water caused by differential settlement.
- More frequent deployment and diligent maintenance of erosion and sediment control features (“super” silt fence, matting/blankets, rip rap check dams and outlet protection, straw bales, filter socks, etc.) to prevent mass erosion, sediment transport, and soil loss.

These landfill facilities are adapting to maintain functionality and effective operations of their landfill gas collection and control systems, leachate management and treatment systems, gradient control systems, groundwater monitoring network, and other environmental control systems.
THE ROLE OF ECO-LABELLING IN PLASTIC PACKAGING CIRCULARITY

C. Magrini (1), E. Foschi (1), A. Bonoli (1)

1: Department of Civil, Chemical, Environmental and Materials Engineering-DICAM/University of Bologna, via Terracini 28, 40131 Bologna, BO, Italy.

Abstract: Recycling plastic packaging waste is getting a big challenge in the current waste management system, in the transition towards circular economy. The EU has proposed increasing targets to encourage the recycling of plastic packaging. Ecolabelling can be a real tool to promote recycling. This study analyses the ecolabels in use in EU-28 countries in packaging applications, aiming at identifying their potential contribution to plastic circularity. Each ecolabel has been deeply analyzed, according to some criteria, like geographical diffusion, managing organization, conformity assessment process. Potential improvements in eco-labelling have been outlined.

Key words: Plastic, Packaging, Europe, Labelling, Circularity.

1. Introduction

Packaging represents an important part of our economic system and it has increasingly become more important, due to the change of our lifestyles. In fact, while in the past the unpackaged and bulk market was the priority of the trades, nowadays, packaged goods are fundamental to respect the hygienic and conservation conditions expected by consumers. Packaging must be therefore light, resistant, handy, useful, easy to transport and to storage: this makes packaging always less suitable in a circular economy model. In addition, overpackaging doesn’t support sustainable development and waste hierarchy, where prevention is preferred to recycling and other actions. [1]

In Europe (EU28+NO/CH), packaging represents the largest conversion sector for the plastic industry, accounting for 20.3 Mt, the 39.7 % of the total plastics demand in 2017. The main polymers used in packaging industry were PE, PP, PET, PVC, PS. [2] Considering waste treatment, in Europe the 40.8% of plastic packaging waste was recycled, the 38.8% was treated with energy recovery, and the 20.4% was landfill in 2016. [2]

The EU Commission is hardly working to improve the sustainability of plastics. The European Strategy for Plastics in a Circular Economy states that all plastics packaging placed on the EU market will be either reusable or recyclable in a cost-effective manner, by 2030, and more than half of plastics waste generated in Europe will be recycled, by 2030. [3] In Directive 2018/852/UE, the target sets for plastic packaging recycling is 50% by 2025, and 55% by 2030. [4]

This paper studies the contribution of ecolabelling to plastic packaging recycling, identifying potential improvements in order to reach the recycling target set by European Union.

2. Tools and methods

“Ecolabelling” is a voluntary method of environmental performance certification and labelling that is practiced around the world. Three core objectives are generally established and pursued:

1. Protecting the environment
2. Encouraging environmentally sound innovation and leadership
3. Building consumer awareness of environmental issues

After a preliminary analysis of existing standards and laws on ecolabelling and packaging in Europe, a research was conducted using the Ecolabel Index database, the largest global directory of ecolabels, currently tracking 463 ecolabels in 199 countries, and 25 industry sectors [5]. The analysis focuses on packaging sector, in the EU-28 Member States. The results have been clustered according to several criteria: geographical diffusion, managing organization, conformity assessment process. Further analysis has been conducted in order to identify the requirements to obtain every label and the stages of product’s life involved.

Moreover, the paper studies other national schemas and logos associated to packaging recycling, which are widespread in Europe, like Green Dot.
3. Results

In Europe, a wide variety of ecolabels is currently in use. Classifying these labels by country, Germany is the one with the largest number of ecolabels (102), followed by the United Kingdom (88) and France (72).

Limiting the analysis to packaging sector, the research in database identifies 42 ecolabels; 18 of these can be found at least in one EU-28 country. Three of resulting ecolabels are managed by a government organization, 11 by a no-profit organization, 2 by an industrial association and 2 by a for-profit organization. It is interesting observing that EU Ecolabel, the voluntary scheme managed by European Commission, DG Environment, does not have a specific category applying to packaging.

A further classification of ecolabel has been done, in order to investigate how much each ecolabel can contribute to the improvement of packaging recycling performances. In fact, each label can give information about the proper final disposal of packaging, the content of recycled material or the attention of producers to a specific environmental issue.

The analysis considers also the so-called Green dot, which is mandatory in some European countries. Conversely to what many people think, the only information which this pictogram supplies is that the producer is settled to consumer a fee with a body approved to collect the waste, even takes care of it himself. An analysis of diffusion and country peculiarity of this schema has been undertaken.

4. Conclusions

In Europe, there are multiple eco-label schemes and logos, developed by a variety of operators and according to different characteristics. In order not to confuse the consumers, it should be recommended a process of standardization, driven and defined by policy makers, in strict collaboration with stakeholders, considering costs and benefits of the proposed solution. In a circular economy approach, it would be useful a label showing buyers not only recycled content of products, but also which products will not become waste and including end-of-life instructions for a proper disposal. Furthermore, there is a need of mandate clear labelling and information for biodegradable plastics and improvement of associated standards. The current innovations on IoT and Artificial Intelligence could make a real contribution to emphasize transparency, clarity and complete dataset by a digital content.

Acknowledgements

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References

Introduction
In Europe (EU28+NO/CH), packaging represents the largest conversion sector for the plastic industry, accounting for 20.3 Mt, the 39.7% of the total plastics demand in 2017. The main polymers used in packaging industry were PE, PP, PET, PVC, PS. Considering waste treatment, in Europe the 40.8% of plastic packaging waste was recycled, the 18.8% was treated with energy recovery, and the 20.4% was landfilled in 2016. In Directive 2018/852/EU, the target sets for plastic packaging recycling is 50% by 2025, and 55% by 2030.

Tools and methods
The core objectives of ecolabelling are:
1. Protecting the environment
2. Encouraging environmentally sound innovation and leadership
3. Building consumer awareness of environmental issues

A research was conducted using the Ecolabel Index database, the largest global directory of ecolabels, currently tracking 463 ecolabels in 199 countries, and 25 industry sectors. The analysis focuses on packaging sector, in the EU-28 Member States.

Results
Table 1 reported the top 10 European countries for number of ecolabels in use, according to the database analyzed.

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of ecolabels in use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>102</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>88</td>
</tr>
<tr>
<td>France</td>
<td>72</td>
</tr>
<tr>
<td>Belgium</td>
<td>61</td>
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<tr>
<td>Italy</td>
<td>60</td>
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<tr>
<td>Spain</td>
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<td>Sweden</td>
<td>55</td>
</tr>
<tr>
<td>Austria</td>
<td>54</td>
</tr>
<tr>
<td>Denmark</td>
<td>50</td>
</tr>
</tbody>
</table>

Table 1 - List of 10 EU-countries with the biggest number of ecolabels in use

Limiting the analysis to packaging sector, the research in database identifies 42 ecolabels; 18 of these can be found at least in one EU-28 country.

It should be noticed that EU Ecolabel, the voluntary scheme managed by European Commission, DG Environment, is not included because it does not have a specific category applying to packaging.

Some results of the analysis of 18 selected ecolabels are reported in figure 1 and 2.

Conclusions
In Europe, there are multiple eco-label schemes and logos, developed by a variety of operators and according to different characteristics. In order not to confuse the consumers, it should be recommended a process of standardization, driven and defined by policy-makers, in strict collaboration with stakeholders, considering costs and benefits of the proposed solution. In a circular economy approach, it would be useful a label showing buyers not only recycled content of products, but also which products will not become waste and including end-of-life instructions for a proper disposal. Furthermore, there is a need of mandate clear labelling and information for bio-degradable plastics and improvement of associated standards. The current innovations on IoT and Artificial Intelligence could make a real contribution to emphasize transparency, clarity and complete dataset by a digital content.
THE SPHERICAL URBAN FOREST

E. San José (1), S. Gómez (1), R. Sánchez (1), M. González (1)

1: CARTIF Foundation, Parque Tecnológico de Boecillo, 205, 47151, Boecillo, Valladolid, Spain

Abstract: The present document sets the bases for a comprehensive design of the Spherical Urban Forest (SUF). This concept is related with the optimization of this Nature Based Solution (NBS) taking into account the principles of low carbon economy throughout the whole cycle: design, implementation and management. In fact, it considers aspects such as initial soil preparation using compost from organic waste, multicriteria assessment for species selection focused on carbon sequestration, as well as management of forest incomes and outcomes based on principles of sustainability and bioeconomy.

Key words: Urban Forest, Circular Economy, Recycling Urban Waste, Carbon Sink, Nature Based Solutions, Low Carbon Economy.

1. Introduction

Carbon (C) flows through ecosystems forming a cycle, not continuous, but it accumulates along them. There are processes that encourage the C accumulation on the atmosphere as a gas, which Carbon Dioxide (CO₂) is the most abundant and well-known relation to the greenhouse effect. Plants can act removing atmospheric CO₂ throughout autotrophic processes and adding organic matter which is stored as their own biomass [1]. As a result, the C keeps immobilized temporally within a process known as “carbon sequestration” [2], a measurable effect by quantifying the total amount of plants biomass [3]. Cities can act as a C source increasing its release to the atmosphere as CO₂ from human activities related to combustion processes (traffic, industry and energy). The Urban Forests (UF) are proposed as a nature-based solution in urban areas [4] due to its role as carbon sink, balancing part of this gas emissions.

The idea of the spherical forest is scoped to improve this concept of UF by combining the use of compost from organic solid waste, the urban carbon sink, and a specific management plan of the forest. All combined to obtain not only circular, but spherical forest contributing to a low carbon economy.

2. Design of the spherical urban forest

The design of the SUF involves 3 different aspects: soil preparation, multicriteria species assessment and incomes and outcomes management.

2.1. Soil composition

One of the main issues related to urban soils is degradation mainly due to the lack of land management policies, soils are subject to sealing, compaction, erosion and contamination [5]. Therefore, when designing a forest in an urban environment it is especially necessary to carry out the improvement and preparation of the soil to ensure the success of the plantation.

On the other hand, compost from municipal solid waste is a good option to achieve this objective. In fact, it is well known [6] that adding compost to soil enhances the physical properties (edaphic structure, water retention capacity, organic matter content, etc), biological properties (increment on microbiotic biomass, enzymatic activity, soil metabolism), and chemical properties (conductivity, C mineralization, better C/N relation, etc).

While adding compost from recycled fonts 3 different effects are achieved related with the carbon cycle: avoid C emissions to the atmosphere from combustion or degradation processes; obtain better soil conditions without using industrial products and therefore, avoiding C emissions from industrial activities; enhancing the microbiotic activity and its biomass and therefore, C fixation [7].

2.2. Multicriteria species assessment

Multicriteria species assessment is required, focused on C fixation capacity, in addition with other aspects [8], such as native vegetation, easy management, aesthetics, health, ecological coherence [9] and integrity criteria [10]. Impacts derived from UF implementation must be evaluated on medium-long term, since to C fixation capacity of the species is highly related to the maturity grade of the taxons [3]. Nowadays, UF are included in NBS categorization as a natural way to solve climate challenges in cities. URBAN GreenUP project [11] incorporates an UF as a Carbon Sink whose aim is to reduce the CO₂ concentration in cities through the CO₂ fixing capacity of their biomass.
2.3. Incomes and outcomes management

The last part of the design process claims to achieve a sustainable management of the incomes and outcomes of the forest. “Outcomes” from an urban forest consist mainly in organic wastes from conventional maintenance works such as pruning, spacing and cleaning. On the other hand, the main “incomes” for urban forests are water supply, fertilizers and other nutritional requirements, and plants provision.

The management of those incomes and outcomes is a key spot to close the sphere once the forest is established. Otherwise, the C captured and fixed as biomass can be released back again to the atmosphere. Therefore, the following actions should be considered within the management plan:

- Minimize organic waste volume production. In deciduous forests, leaving the layer of leaves on the topsoil will contribute to improve its structure and water retention capacity, and will minimize the volume of waste produced. In any case, the waste produced must be composted in situ and reused in the same ecosystem to avoid CO2 emissions due to transport. In case of excess material, the transport of the already composted material also minimizes the load volume.

- Optimize water supply requirements. Introducing water requirements in the multicriteria species assessment, in order to minimize the water supply requirements. If water supply is needed, its origin must be recycled, not drinkable water.

- Optimize fertilizers supply requirements by using compost and organic fertilizers.

3. Conclusions

Urban Forests are proposed as a nature-based solution in urban areas due to its role as carbon sink, balancing part of this gas emissions. In order to achieve and optimize this effect, it is necessary to consider the whole process, in a spherical model based on low-carbon economy principles. That includes soil preparation using compost from solid waste, specific criteria for taxon selection composition and typology. Likewise, it will be essential to take into account to establish a management plan to avoid the release of C to the atmosphere once it is fixed.

References
[11] “URBAN GreenUP New strategy for re-naturing cities through Nature-Based Solutions (NBS)” This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 730426.
Urban Forests are proposed as a nature-based solution in urban areas due to their role as carbon sinks, balancing part of this gas emissions. In order to achieve and optimize this effect, it is necessary to consider the whole process, in a spherical model based on low-carbon economy principles. This includes soil preparation using compost from organic waste, multi-criteria assessment for species selection focused on carbon sequestration, as well as management of forest incomes and outcomes based on principles of sustainability and bioeconomy.

**INTRODUCTION**

Carbon (C) flows through ecosystems forming a cycle, not continuous, but it accumulates along them. There are processes that encourage the C accumulation on the atmosphere as a gas, which Carbon Dioxide (CO₂) is the most abundant and well-known to its relation to the greenhouse effect. Plants are able to act removing atmospheric CO₂ throughout autotrophic processes and adding organic matter which is stored as their own biomass. As a result, the C keeps immobilized temporarily within a process known as “carbon sequestration”, a measurable effect by quantifying the total amount of plants biomass. Cities can act as a C source increasing its release to the atmosphere as CO₂, from human activities related to combustion processes (traffic, industry and energy). The Urban Forests (UF) are proposed as a nature-based solution in urban areas due to their role as carbon sink, balancing part of this gas emissions.

The idea of the spherical forest is scoped to improve this concept of UF by combining the use of compost from organic solid waste, the urban carbon sink and a specific management plan of the forest. All combined to obtain not only circular but spherical forest contributing to a low carbon economy.

**DESIGN**

**MULTICRITERIA SPECIES ASSESSMENT**

Multicriteria species assessment is required, focused on C fixation capacity. In addition with other aspects, such as native vegetation, easy management, aesthetics, health, ecological coherence and integrity criteria. Impacts derived from UF implementation must be evaluated on medium-long term, since C fixation capacity of the species is highly related to the maturity grade of the taxons. Nowadays, UF are included in NBS categorization as a natural way to solve climate challenges in cities.

**SOIL COMPOSITION**

One of the main issues related to urban soils is degradation mainly due to the lack of land management policies, soils are subject to sealing, compaction, erosion and contamination. When designing a forest in an urban environment it is especially necessary to carry out the improvement and preparation of the soil to ensure the success of the plantation.

On the other hand, compost from municipal waste is a good option to achieve this objective. In fact, it is well known that adding compost to soil enhances the physical properties (pedogenic structure, water retention capacity, organic matter content ...), biological properties (incenement on microbiotic biomass, enzymatic activity, soil metabolism) and chemical properties (conductivity, C mineralization, better C/N relation ...), while adding compost from recycled forest strips different effects are achieved related to the carbon cycle: avoid C emissions to the atmosphere from combustion or degradation processes; obtain better soil conditions without using industrial products and therefore, avoiding C emissions from industrial activities; enhancing the microbiotic activity and its biomass and therefore, C fixation.

The management of those incomes and outcomes is a key spot to close the sphere once the forest is established. Otherwise, the C captured and fixed as biomass can be released back again to the atmosphere. Therefore, the following actions should be considered within the management plan:

1. **Optimize water supply requirements.**
   - Introducing water requirements in the multicriteria species assessment, in order to minimize water supply requirements. If water supply is needed, its origin must be recycled, not drinkable water.

2. **Optimize fertilizers supply requirements by using compost and organic fertilizers.**

3. **Minimize organic waste volume production.**
   - In deciduous forests, leaving the layer of leaves on the topsoil will contribute to improve its structure and water retention capacity, and will minimize the volume of waste produced. In any case, the waste produced must be composted in situ and reused in the same ecosystem to avoid C emissions due to transport. In case of excess material, the transport of the already composted material also minimizes the load volume.

**INCOMES AND OUTCOMES MANAGEMENT**

Achieve a sustainable management of the incomes and outcomes of the forest. “Outcomes” from an urban forest consist mainly in organic wastes from conventional maintenance works such as pruning, spacing and cleaning. On the other hand, the main “incomes” for urban forests are water supply, fertilizers and other nutritional requirements, preservation, phytosanitary treatments and plants provision.

**CONCLUSIONS**

Urban Forests are proposed as a nature-based solution in urban areas due to its role as carbon sink, balancing part of this gas emissions. In order to achieve and optimize this effect, it is necessary to consider the whole process, in a spherical model based on low-carbon economy principles. This includes soil preparation using compost from solid waste, specific criteria for taxon selection composition and typology. Likewise, it will be essential to take into account to establish a management plan to avoid the release of Carbon to the atmosphere once it is fixed.
RESULT RELIABILITY IN COMPARATIVE SOLID WASTE PROCESSING EXPERIMENTS
K. Khodier (1), R. Sarc (1), M. Lehner (1)
1: Department of Environmental and Energy Process Engineering / Montanuniversitaet Leoben, Austria

Abstract: Performing comparative experiments with solid waste, confidence levels of differences between values of target variables at different levels of manipulable ones are often ignored, while being of high importance for the reliability of conclusions. In this work an approach for determining the confidence interval with acceptable effort – in relation to the typical extent of waste processing experiments – is presented, based on confidence intervals for t-distributed variables, with standard deviations determined in previous comparable experiments.

Key words: Solid waste, Confidence interval, Significance, Comparative experiments, t-statistics.

1. Introduction
There are various reasons for performing comparative experiments with solid wastes: comparing designs when developing new machines, comparing machines of different types or manufacturers when planning investments or comparing different machine-parametrisations (e.g. sieve angle or rotation speed) for process improvement.

Especially in applications with mixed municipal solid wastes, downscaling experiments is hardly possible, as the waste, being the input material, cannot be reliably downscaled. Thus, experiments are performed with very large material masses, demanding for material sampling when material qualities are being assessed. This sampling always involves a sampling error, usually of a much higher magnitude than just the analytical error of a scale for example. Furthermore, material variability causes compositional and physical differences between the total input material of one experimental run and the other. This not only influences determined material qualities, but also process behaviour, e.g. throughput or energy demand.

Therefore, when interpreting results of such experiments, result significance needs to be assessed through confidence intervals and should be considered in result interpretation.

2. Assessment of standard deviations
Fig. 1 shows a representation of a system and its variables. In the following a shredder will be used as an example. The output of the system is described through the target variables, e.g. throughput, energy demand or product particle size distribution. Manipulable variables are those, that can be set and changed on purpose. These are for example gap width or rotation speed of the shredder. Disturbance variables are those that cannot be controlled. They cause uncertainties when trying to evaluate the influence of manipulable variables. Examples are wear of the cutting tools, sampling errors or influences from composition and particle size distribution of the input material.

To assess the magnitude of the disturbance, standard deviations $S$ of the target variables at constant levels of manipulable variables need to be determined through replications, quantifying the determination error. In case that sampling and analytical errors are the only expected disturbances, this can be done through a replication experiment according to [1], where sampling is performed multiple times on a singular experiment. Considering further disturbances, like inter-experimental material changes, wear or random process behaviour like material jamming, the standard deviation should be assessed by replicating the whole experiment including analytics and sampling.
3. Confidence

Performing a two-series experiment where each series contains replications at one level of a manipulable variable (alternated between each run or performed in random order), confidence intervals for the difference of the target variables can be determined using the student-t distribution. If a certain minimum difference between the mean values $\bar{x}$ and $\bar{y}$ of the target variable for the two settings is desired, one-tailed confidence intervals will be used.

Assuming, that the number of replications of each series is $n$, the lower limit of a one-tailed confidence interval for the difference of the real means $(\mu_y - \mu_x)$, is calculated according to Equation (1), where $(1 - \alpha)$ is the confidence level, $s_1$ and $s_2$ are the target variable standard deviations of the two series, $\bar{x}$ and $\bar{y}$ are the series-means and $t_{1-\alpha,df}$ is the $(1 - \alpha)$-quantile of the student t-distribution with $df = 2n - 1$ degrees of freedom.

$$
(\mu_y - \mu_x)_{1-\alpha} \geq (\bar{y} - \bar{x}) - t_{1-\alpha,df} \cdot S \frac{\sqrt{\frac{2}{n}}}{\sqrt{n}}
$$

In many cases though only one single run per setting is performed, to save experimental costs. It is then still desirable to be able to interpret results regarding significance through confidence intervals. For doing so, an estimation of the standard deviation is required. Such an estimation needs to be based on observations under comparable conditions. The basic assumption for doing so is, that the standard deviation in stable conditions is constant. For this, an experimental setup needs to be defined, including used material (with a certain heterogeneity characteristic, e.g. mixed household waste), sampling (if necessary), experimental duration and analytics. The standard deviation is then determined through an experimental series of $n^*$ replications at constant manipulable variables and inserted for $S$ in Equation (1). The confidence interval is then calculated with the t-distribution with $df = (n^* - 1)$ degrees of freedom and $n = 1$ according to Equation (1). In case of insufficient significance, additional runs can be performed, making the confidence interval smaller, as $n$ increases.

Fig. 2 shows the probability density function for observing $(\bar{y} - \bar{x})$ for different real values $(\mu_y - \mu_x)$ and the positive influence of higher $df$- and $n$-values on reducing the size of confidence intervals. The vertical lines show the lower limit of a left-tailed 95% confidence interval.

4. Conclusion

Interpreting comparative experiments with solid wastes, it is particularly important to estimate result significances, as waste variability usually causes high levels of uncertainty and thus large confidence intervals. In this work, evaluations based on confidence intervals for t-distributed variables as well as their application on single-run experiments is discussed. In practice, the assumption of the constancy of $S$ should be verified regularly if needed accuracy exceeds evaluating orders of magnitude. The choice of confidence level for judging observed influences of manipulable variables is subject to to experience, impact of wrong decisions and corporate risk aversion.

Acknowledgements

The Competence Center Recycling and Recovery of Waste 4.0 – ReWaste4.0 – (860 884) is funded by BMVIT, BMWFW and the federal province of Styria, within COMET – Competence Centers for Excellent Technologies. The COMET programme is administered by FFG.

References

Introduction

This work is a result of the COMET programme Recycling and Recovery of Waste 4.0. There are various reasons for performing comparative experiments with solid wastes: comparing designs when developing new machines, for example, machine parametrisation or choice. Because many types of solid wastes, like mixed municipal waste, cannot be downscaled, material masses processed in an experiment tend to be huge, requiring sampling for analysis. This sampling, as well as material differences between experimental runs, leads to high scattering of the data. Therefore, when interpreting such experiments, result significance needs to be assessed through confidence intervals.

In the experiments, the reaction of a system (e.g. a sieve, or a whole plant) to inner and outer influences is examined. 

**Manipulable variables** are those that can be set and changed on purpose, e.g. the gap width of a shredder. 

**Disturbance variables** are those, that cannot be controlled, for example, the exact material composition when working with real waste. 

**Target variables** are the measures of the system’s reaction, examples are throughputs and energy demands, as well as particle size distributions.

Confidence

Performing a two-series experiment where each series contains \( n \) replications at one level of a manipulable variable (alternated between each run or performed in random order), confidence intervals for the difference of the target variables can be determined using the student-t distribution. To examine whether a minimum difference between the population means \( \mu_Y - \mu_X \) is significant on a \((1 - \alpha)\)-significance level, the probability density function for measuring a certain difference of sample means \( \bar{y} - \bar{x} \) and a left-tailed confidence interval, as shown in Fig. 1 can be calculated.

Experimental runs on such a scale are very costly. Therefore it is suggested, to assess the sample standard deviation once for every kind of situation and then transfer the information to comparable situations. Fig. 1 shows that increasing \( \alpha \) for the assessment of \( S \) has a low influence on significance, while in practice \( \alpha \) could be increased iteratively to obtain the desired significance.

Conclusion

Neglecting the question of significance because of experimental effort is not an acceptable option, due to the high scattering of waste processing data. Transferring information about the standard deviation from comparable situations can be a practicable way of estimating significance with reasonable effort.
THE OPERATION AND REGENERATION OF LOW TEMPERATURE SCR CATALYST IN WASTE INCINERATION PLANT

T. Yu(1), L.L. Feng (1), H.L. Liu (1), Y.F. Lao (1)

1: Shanghai SUS Environment Co., Ltd., Songqiu Road 9, 201700 Shanghai, China

Abstract: At the end of 2018, China has over 400 waste-to-energy plants in operation. With more WTE plants to be constructed and put into operation, the standard for controlling flue gas emission becomes more stringent year by year. SCR system has been installed or reserved in many waste incineration plants in order to meet the increasingly strict NOx emission limits. In this paper, China’s Ningbo Mingzhou municipal solid waste-to-energy plant is taken as an example to discuss the operating performance of low temperature SCR catalysts. The denitration efficiency of imported catalyst and domestic catalyst was compared in this plant. Moreover, the reasons for the degradation of catalyst performance were analyzed. Different regeneration schemes of catalyst and their advantages and disadvantages were studied. Then the final regeneration scheme was determined.

Key words: waste incineration, SCR, low temperature catalyst, catalyst deactivation, thermal regeneration.

1. Introduction
The conventional flue gas cleaning process employed in domestic waste incineration plant is “SNCR De-NOx + SDA+ hydrated lime injection+ activated carbon injection+ Bag Filter(BF)” [1]. In recent years, the standard for controlling flue gas emission becomes increasingly strict. For example, in some economically developed and environmentally sensitive regions, the nitrogen oxide (NOx) emission is not permitted to exceed 50mg/Nm³, which is even lower than the emission limits stipulated in EU’s Industrial Emission Directive (2010/75/EU). Therefore, for meeting this new and stringent emission standard, many new de-NOx technologies other than traditional selective non-catalytic reduction (SNCR) process are being researched and developed, including exhaust gas recirculation, low temperature plasma denitrification, ozone denitration, ceramic filter tube denitrification, polymer non-catalytic reduction (PNCR) and selective catalytic reduction (SCR), etc. SCR system has been installed or reserved in many waste incineration plants. SCR system is usually placed after the Bag Filter. Given that the BF outlet flue gas temperature is approximately 150°C, choosing low temperature catalysts can significantly reduce the service power consumption rate for waste incineration plants [2]. Thus higher economic efficiency can be achieved by employing low temperature catalysts.

Two main types of catalyst for waste incineration plants are honeycomb catalyst and corrugated plate catalyst, each has their own advantages and disadvantages. (1) Honeycomb: This type of catalyst gained its structure through extrusion process. After being dried, calcinated and cut into the elements that can meet the requirement, these catalyst elements are housed in a steel module in order to facilitate the installation in the SCR reactor. Honeycomb catalyst has large specific surface area per unit volume and it occupies 60%-70% of the market share [3]. (2) Corrugated plate: This type of catalyst employs glass fiber plate or ceramic plate as the base material. Compared with honeycomb catalyst, corrugated plate catalyst has higher mechanical strength [4]. In this paper, the operating condition of 2 types of catalyst in a domestic waste incineration plant was compared and analyzed. This plant has 3 incineration lines. SCR and wet scrubber are installed after the bag filter. Line #1 and #2 employed an imported brand honeycomb catalyst( since the operating data of line #1 and #2 are very similar, only the data of line #2 are presented), while line #3 used a domestic brand corrugated plate catalyst. This plant has been in service since September 2017. The SCR inlet conditions are shown in Table 1.
2. **SCR catalyst operating conditions**

In this section, the daily average SCR inlet NOx, stack NOx and NH3 concentration were collected. The NOx removal efficiency, ammonia slip and pressure drop of the catalysts during the initial operating period and after the first year of operation were collected and analyzed.

3. **The cause of catalyst performance degradation**

In this section, the catalysts were tested by XRD and Scanning Electron Microscopy and the catalyst composition before and after use were compared. The cause of catalyst performance degradation was analyzed.

4. **The comparison of catalyst regeneration methods**

In this section, different catalyst regeneration methods were compared and the best regeneration scheme was determined.

5. **Conclusions**

   (1) Compared with honeycomb catalyst, corrugated plate catalyst has low dust resistance. Over time the pressure drop of corrugated catalyst increases significantly;

   (2) Since the fact that dust and NH4HSO4 can poison catalyst, “thermal + vacuum cleaner” is recommended to regenerate catalysts;

   (3) In order to guarantee the stable operation of catalyst, low inlet dust and low inlet SO2 are required. Meanwhile it is recommended to raise the operating temperature to extend catalyst operating life.

**Acknowledgements**

We would like to express our sincere thanks to Ningbo Mingzhou municipal solid waste-to-energy plant and Shanghai SUS Environment Co., Ltd. for their supports and helps.

**References**


ENGINEERED SOLUTIONS FOR THE “TUNING” OF EXISTING WASTE-TO-ENERGY PLANTS

Dr. Oliver Gohlke (1)

1: DUBLIX TECHNOLOGY ApS, Grusbakken 10, 2820 Gentofte/Copenhagen, Denmark

Abstract:

Smart engineered solutions are presented, which have the capacity to boost the performance of waste incineration or waste-to-energy plants (WTE). The focus is on the existing more than 1600 WTE [1], which operate sometimes with quite old or even outdated equipment to generate power and heat from mixed municipal waste. This concerns a treatment capacity of over 200 million tons of waste per year. The potential for performance increase is important and, in many cases, more sustainable than complete new construction. In this paper are described concrete examples how the performance was drastically increased on old plants in a safe manner: Optimization of combustion control (Fuzzy logic, neural net, model predictive controllers, machine learning); Improved combustion grate systems and grate bars; Double-jet overfire air system with supersonic steam as core jet for improved flue gas mixing and burnout; Sulfation generator for avoiding fouling and corrosion caused by Chloride containing fly ashes; Water-jet cleaning of the boiler with a self-propelled turning nozzle introduced to the boiler through the ceiling on a flexible steel hose.

Key words: Waste-to-Energy (WTE), waste incineration, combustion optimization, upgrades of existing plants

1. Introduction

The use of waste for the generation of energy and heat is further developing. Numerous new technologies are developed, and further important market growth is expected in countries, which are developing their environmental technology infrastructure. The focus in this article will be on technologies customized for older existing WTE plants. Sometimes these solutions can also be used for new built plants. But in many cases older plants need different approaches to improve the safety, energy efficiency, availability, throughput and emissions. In fig. 1 and the following section are described examples of such solutions.

![Fig. 1: Solutions for improving the performance of existing WTE plants](image-url)
2. Solutions

2.1 Combustion stability with optimization of combustion control
The main control challenges on WTE plants are uncontrolled variations in the waste heating values and long delays from a control action to full process response. Classical PID controllers are not efficient to cope with such control challenges. Consequently, many WTE plants operates partly in manual operation mode and become extremely dependent on the attention of the operator in charge of the combustion.

Upgrades of existing control systems are possible with systems using Fuzzy logic, neural net, model predictive controllers or machine learning. At the IVOO plant in Oostende (Belgium) the result of the implemented FuzEvent system was 10% more electricity production and the registered annual waste treatment capacity has increased by 6.5% [2].

2.2. Increased availability with upgrades of combustion grates
The core component of most WTE plants is the combustion technology with the stoker grate system. Many older plants suffer, because their original grate is not designed for an increased heating value and chloride content of the waste. Combustion grates can be upgraded by improved
- grate bar design leading to reduced grate siftings (riddling) and reduced maintenance times.
- materials as used in composite grate bars with an upper layer of casted Cr-Ni alloys on a standard steel basis. Water cooled grate systems can be installed at existing plants. But in many cases the issues related to the use of water cooling are outweighing the advantages of reduced thermal wear. Some successful upgrades consisted of removing water cooled grates with smart designs of air-cooled grate bars

2.3. CO reduction with double-jet secondary air system with supersonic steam
The BoosterSteam technology consists of installing steam injection ports in the secondary air nozzles. The supersonic injection of steam has a very intense effect of mixing which allows a better burnout of the CO. This also results in a potential reduction of secondary air flow, flue gas flow/velocity and flue gas temperatures at superheater inlet. Furthermore, it is avoided that the secondary air nozzles are slagging with “trumpets” due to the back flow with suction of hot fly ash against the boiler wall around the nozzles. Overall increased performance as well as reduced fouling and corrosion are the consequences. The Technology was developed at the Muellkratwerk Schwandorf by Dr. Joerg Krueger and is successfully operated there for over 5 years [3].

2.4. Preventing boiler fouling and corrosion with sulfation generator
The Sulfation generator (Krueger-Sulfation) is a new technology, which consist of the injection a sulfur-based reactant through the secondary air. This is done in a way, that chlorides on fly ash and deposits are efficiently transformed to sulphates. Stickiness of fly ash and hardness of deposits are drastically reduced. This effect is due to the increased melting point when alkali chlorides are transformed to sulphates. First plants being upgraded with this technology are in Weener (Germany) and Plymouth (United Kingdom).

2.5. Keeping the boiler clean with water-jet cleaning
The flue gas temperatures can be reduced by 50 to over 100 °C by using washing nozzles introduced to the boiler through the ceiling on a flexible steel hose. These systems are particularly efficient if the nozzle is slowly turning and generating a directional beam of water reaching the boiler walls with low pressure. Reduced flue gas temperatures lead to less fouling and corrosion of the convective passes. The availability and performance of WTE plants can be drastically improved with such systems. Examples of successful realization of such upgrades are in Como (Italy) and Shinseung (South Korea).

References
Engineered solutions for the “tuning” of existing waste-to-energy plants.

Oliver Gohlke, og@dublix.com, Dublix Technology ApS (Denmark)

Introduction
Many of the existing more than 1600 waste-to-energy plants (WTE) operate with quite old or even outdated equipment. The potential for performance increase is important and, in many cases, more sustainable than complete new construction.

Solutions

1. High level combustion control - FuzEvent
   - Standardized and modular
   - No “black-box”
   - Existing control stays in place
   - Reduced fluctuation

2. Combustion grate upgrades – DUB3
   - For Volund type grates
   - Reduced outage time
   - Reduced siftings

3. Double-jet secondary air - BoosterSteam
   - Supersonic steam for better penetration
   - Reduced secondary air flow
   - Reduced CO and slagging of secondary air nozzles

4. Sulfation Generator - SulfGen
   - Sulfur injected with overfire air
   - Sulfation of Chlorides in fly ash/deposits
   - Reduced fouling and corrosion

5. Water-jet cleaning – DD-Jet
   - Self propelled turning nozzle
   - Efficient up to 6 m
   - Reduced flue gas temp. at superheater inlet

6. Pressure wave cleaning – DX-Wave
   - Automated micro-explosions
   - Removes ash and fouling
   - Increased service time and availability
LEGAL OBSTACLES FOR CIRCULAR ECONOMY: A CASE STUDY OF ILLEGAL DUMPING IN THAILAND

A. Otwong (1), T. Phenrat(2)

1: Faculty of Law / Naresuan University, Phitsanulok, Thailand, 65000
2: Research Unit for Integrated Natural Remediation and Reclamation (IN3R), Department of Civil Engineering, Faculty of Engineering / Naresuan University, Phitsanulok, Thailand, 65000

Abstract: Circular economy becomes one of the effective solutions to address huge amount of waste and simultaneously stimulate sustainable development. As this concept is pursued to maintain the value of products and resources in the economy for as long as possible, recycling is undeniably its key component. However, in Thailand, many recycling projects unfortunately are viewed as a source of pollution to environment and human health mostly due to infamous illegal dumping cases associated to recycling facilities. As a result, recycling facilities have been increasingly opposed by local communities. The study therefore aims at analyzing legal frameworks on waste regulations in Thailand and identifying legal loopholes in the regulations creating opportunities for recycling industry to avoid proper waste management. A case study of illegal dumping in Ratchaburi province in central Thailand is utilized to illustrates the legal insufficiency in practice leading to develops feasible recommendations.

Key words: Circular Economy, Recycling facility, Illegal dumping, Thailand.

1. Introduction

Circular economy is defined as an economy “where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimized”. To reduce dependence on primary resources, increasing rate of recycling is undeniably key in driving the transitional process from a linear “take-make-dispose” economy to circular “make, use, return” economy. However, in the context of Thailand’s waste management, illegal dumping linked with recycling factory is a serious problem. The rate of recycling in Thailand is only 1.5 percent of all the nation’s hazardous wastes, while 75 percent is disposed illegally. This study thus aims to analyze the legal obstacles impeding the development of circular economy in recycling sectors in Thailand. It focuses on a case study of a factory in Ratchaburi province (Factory A) that received permits for recycling varied types of industrial wastes but was alleged by local community that it illegally disposed of the wastes inside the factory site causing serious groundwater contamination in that area. Evaluation of sufficiency of Thai waste laws and regulations, and effectiveness of law enforcement is discussed in this study.

2. Methodology

As Tanapon Phenrat, one of the authors of this study, is an expert witness appointed by the civil judge in the case that the affected communities brought a lawsuit against the Factory A demanding remedy and remedial actions, we are able to attain meetings in mediation process and access to important documents concerning environmental monitoring for this project. Along the process, we had visited the factory site and asked further details from the owner of the company. In addition, we took environmental samplings inside the factory site and surroundings, and observed meetings between the affected villagers, local government and their attorney. To understand legal frameworks and how it is applied in practice, we also interviewed the officials at Department of Industrial Works (DIW). Additionally, there are reports and papers discussing Thailand’s waste management and development of circular concept in policy level that we reviewed and utilized in this study.

3. Results and discussion

After reviewing the existing waste laws and regulations and studying its enforcement through the Factory A case, we summarize the loopholes of Thailand’s waste regulations and problems of law enforcement as described below.

3.1 Lack of mass balance monitoring

According to the 2005 Notification of Ministry of Industry on treatment and disposal of wastes or unusable materials, recycling facility must report amount of waste they receive from outside and generate from their recycling process to the officials, but they are not required to record the quantity of their recycled products and the details of buyers of such products. This loophole opens opportunity for the recycling company to dumps their waste illegally inside their area instead of recycling it as required under conditions of the permit. In Factory A
case, the villagers claimed that some buyers dumped the recycled products at public area right after they got from the factory. There is no further investigation to prove whether it is recycled products or unusable materials.

3.2 Poor groundwater and soil contamination regulation
To prevent environmental harm from industrial pollution, the Ministry of Industry passed the 2016 Ministerial Regulation on Soil and Groundwater Contamination Control in Factory Area. It requires the industry to conduct soil and groundwater inspection and submit the report to the DIW officials before start of its operation or after the law effective date. If the contamination level is above the standard set by the Department of Industrial Works (DIW standard), the company must present mitigation action plan to DIW officials. However, the DIW standard is 50-200 times higher than environmental standard outside factory area issued by Ministry of Natural Resources and Environment. A problem occurred in the case of Factory A when the contamination level of trichloroethane, chlorobenzene and trichloroethane inside the factory site is compliant with DIW standard but once these contaminants cross the boundary of factory through groundwater it exceeds the environmental standard. Although it pollutes soil and groundwater that the locals use for agriculture, the company claimed that they complied with the factory regulations and have no legal obligation to submit any action plan to mitigate and control the pollution in their area. The objective of the Ministerial Regulation seems unachievable in the reality.

3.3 Lack of transparency in monitoring process
As the 2016 Ministerial Regulation grants the DIW officials a duty to review the inspecting report, capacity of the government to check accuracy of the report is still in question. According to the monitoring reports conducted by the Factory A, there is no data on contamination level of groundwater in dry season because there was no water inside monitoring wells that they could collect samplings. The responsible officials have no response to this missing data. After reviewing the inspecting report and investigating the case, we found that the cause of this problem was that the company deliberately filled a large amount of rocks and soil on the factory area to make the ground level much higher than natural level, so that the monitoring wells built by the company are not deep enough to reach the groundwater level. This highlights necessity of access to information and transparent monitoring process. However, based on the interview with the DIW officials, the government generally denies to open data on soil and groundwater contamination inside the factory area in the inspecting report.

3.4 Soft punishment
The Factory A has been complained by local community for almost two decades. Although Pollution Control Department, Department of Groundwater Resources and others had found excessive contamination level of volatile organic compounds (VOCs) in the project site and the surroundings, and confirmed that the recycling facility is the source of pollution, they have limited legal power over the factory. Meanwhile, although DIW and Provincial Industry Office that have direct authority to regulate the factory has punished the company for more than 20 times - including orders to rectify the operation, suspension and partial closure - it allowed the factory to reopen again and again. More serious punishment is needed to push the company to take pollution control measures seriously.

4. Conclusions and recommendations
Recycling industry has been expected to be one of key sectors to promote circular economy in Thailand. Public acceptance of the recycling is an essential element for the establishment of the industry. Unfortunately, several poorly regulated recycling factories cause environmental harms and adverse impacts to local communities living nearby the projects by illegal dumping. Lesson learned from the case study of Factory A can drive improvement of waste regulations and law enforcement in order to ensure that circular economy can be settled firmly in Thailand.

Acknowledgements
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References
To reduce dependence on primary resources, **boosting recycling rate is the key** to drive the transitional process from a linear “take-make-dispose” economy to circular “make, use, return” economy.

**Thailand’s hazardous waste management:**
- Rate of recycling: 1.5%
- Illegal disposal: 75%

**Research objective:** to examine legal obstacles impeding the development of circular economy in recycling sectors in Thailand through a case study of a recycling factory in Ratchaburi province (Factory A).

**Methodology:**
- Being expert witness in civil trial
- Observation of mediation process in court
- Document review on environmental monitoring
- Site visit and environmental samplings with the affected community
- Interviews with regulatory officials

**Loopholes of Thailand’s waste regulations and problems of law enforcement**

**Inconsistency between regulations made by different agencies**

**Lack of transparency in monitoring process**

**Lack of mass balance monitoring**

**Soft punishment**
PRESS WATER FERMENTATION FROM MIXED HOUSEHOLD WASTE

I. Eickhoff (1), N. Engler (1), M. Nelles (1,2)

1: University of Rostock, Department of Waste Management and Material Flow, Rostock, Germany
2: Deutsches Biomasseforschungszentrum GmbH (DBFZ), the Centre for Biomass Research in Germany, Leipzig, Germany

Abstract: In 2015, the German company Sutco RecyclingTechnik GmbH introduced a new fermentation technology called “BioPV” (biowaste press water fermentation). This wet fermentation process is an alternative to dry fermentation and acts as pre-treatment to direct composting of separately collected biowaste. The new process has proven to have many advantages over conventional biowaste treatment methods with regard to energy efficiency, space requirements, financial viability, logistical processes and sustainability. Therefore, Sutco RecyclingTechnik GmbH, in conjunction with the Erbenschwanger Verwertungs- und Abfallentsorgungsgesellschaft mbH (EVA) and the University of Rostock are partaking in a three-year R&D project “PV-R” (mixed household waste press water fermentation) to analyze how the technology can be adapted for the treatment of the organic fraction from mixed household waste. For this, a pilot plant is implemented in an existing mechanical-biological treatment (MBT) plant as well as several experimental investigations are planned.

Key words: press water digestion, mixed household waste, mechanical-biological treatment, R&D project.

1. Introduction

In 2016, the organic fractions food and green waste accounted for an average value of 44 % of the global MSW production with values exceeding 58 % in some Middle Eastern and North African countries [1]. Since many countries still lack a proper waste separation, the organic material is often disposed of in the mixed household waste. This high amount of wet, organic material makes the mixed household waste suitable for fermentation.

In 2015, the German company Sutco RecyclingTechnik GmbH introduced a new fermentation technology called “BioPV”. This wet fermentation process is an alternative to dry fermentation and acts as pre-treatment to direct composting of separately collected biowaste. By transferring the readily available organics from the waste into a liquid phase, the yet unused energy potential in composting is utilized. At the same time, the proportion of organics enriched in the liquid relieves the conventional composting process. Furthermore, since the fermentation operates in parallel with the composting process, with the digestate being constantly recycled, the whole process operates in a closed cycle, thus avoiding external disposal costs.

During the previous “BioPV” project, the new fermentation process has been successfully implemented into a composting plant in Gescher, Germany. However, the existing process has been solely developed and optimized for the operation with biowaste. Without adaptation, optimization and validation, a transfer to different types of material compositions such as mixed household waste is not possible. Therefore, Sutco RecyclingTechnik GmbH, in conjunction with the Erbenschwanger Verwertungs- und Abfallentsorgungsgesellschaft mbH (EVA) and the University of Rostock are partaking in a three-year R&D project “PV-R” to analyze how the technology can be adapted for the treatment of mixed household waste. For this, a pilot plant is implemented in an existing mechanical-biological treatment (MBT) plant and several experimental investigations are planned.

2. The “PV-R” Process

During a mechanical pre-treatment, a shredder disintegrates the mixed household waste and a drum screen separates the < 60 mm fraction. The pretreated waste is then mixed with process water from the MBT plant to transfer the readily available organics from the waste into a liquid phase. Afterwards, a pneumatic screw press separates the liquid phase and the resulting press water is fermented in a series of biofilm reactors at a hydraulic retention time of approx. 4 to 8 days. In the current plant layout, two fixed bed fermenters and two post fermenters connected in series are used upstream of a stirred tank fermenter. The resulting biogas is used to power a combined heat and power (CHP) unit.

In 2016, first economic viability estimations based on different pressing tests with varying press settings (pressure, torque, etc.) were calculated (See Table 1). In comparison to biowaste, mixed household waste produces less press water. However, although the amount of press water is lower, the gas formation potential for mixed household waste is almost twice as high as for biowaste.
Table 1. Economic viability estimations from mixed household waste (MHW).

<table>
<thead>
<tr>
<th>MHW + Digestate [Mg]</th>
<th>Resulting Press Water [Mg]</th>
<th>Retention Time in Fermenter [d]</th>
<th>Biogas [m³ per Mg Press water]</th>
<th>Biogas [m³ per Mg MHW]</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 + 60</td>
<td>60</td>
<td>4-8</td>
<td>90</td>
<td>54</td>
</tr>
</tbody>
</table>

3. Scientific and Technical Objectives of the Project

Optimization of the Press Technique: One objective of the new project is to adapt the screw press to the new input material mixed household waste and optimize the press technique accordingly. For this, special emphasis is on the press water and press cake. Interesting parameters for the press water analysis are total solids (TS) and volatile solids (VS). Based on the results, the filter basket’s perforation will be adapted. Interesting parameters for the press cake are loss of ignition and dissolved organic carbon content (DOC), which define the efficiency of the composting process.

Optimization of Fermentation Process: Another objective of the new project is to adapt the fermentation process and optimize the plant layout accordingly. Special emphasis is on the press water, especially its DOC content, TS and VS, ammonium content and FOS/TAC value. For this, various samples will be taken at 10 sampling points within the different fermenters. Furthermore, the sand discharge will be analyzed with regard to DOC, loss of ignition and anaerobic degradation tests.

Landfilling of Residues: Main objective of the mixed household waste treatment process is safe and proper waste disposal. Since the products of the composting process do not meet the high legal requirements for the use in agriculture or landscaping, these output streams are to be landfilled. There are very comprehensive criteria for landfilling, based on the German landfill ordinance, which have to be analyzed. Relevant tests include the DOC, loss of ignition, upper heating value and anaerobic degradation tests.

4. Conclusions

Based on first experimental results, the new project has great potential and it is much likely that the existing press and fermentation technology can be successfully adapted to mixed household waste although there are many fundamental and complex differences. The new process has to be studied in such a versatile way that it can be economically and efficiently implemented into different MBT plants, without forcing extensive changes in the respective overall system technology.

At the moment, the project is in the commissioning phase of the pilot plant with first experimental results available in April. Since the pilot plant is still in commissioning, no further information are available at this time. However, any new experimental results and updates will be presented at the conference.

5. Acknowledgements

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6. References


Presswater Digestion from Mixed Household Waste

M. Sc. Isabell Eickhoff, Dr. Ing. Nils Engler, Prof. Dr. mont. Michael Nelles

Advantages of Process
- Small reactors → Low investment costs
- User-friendly, easy-to-maintain and low-wear system technology → Low maintenance costs
- Recycling and reuse of process water and digestate → No wastewater, no sanitation → Low external disposal costs
- High methane content (60-70%) in biogas → Cost savings through internal use
- High throughput → Fast amortization

Presswater Digestion Process

Contact: M. Sc. Isabell Eickhoff
E-Mail: isabell.eickhoff@uni-rostock.de | Phone: +49 381 498 3409
University of Rostock | Faculty of Agricultural and Environmental Sciences | Department of Waste and Resource Management | Justus-von-Liebig-Weg 6 | 18059 Rostock | Germany