1. Background of Research

Hydrothermal liquefaction (HTL) is a promising technology, currently being developed, for converting various biomass feedstocks into biocrude oil. Municipal sewage sludge (MSS) is often landfilled in the absence of any use. The cost of biosludge disposal alone could contribute to the 50% cost of the wastewater treatment facilities. On the contrary, because of the intrinsic calorific value of the biosludge, energy recovery, as bio gas or bio-oil, could simultaneously reduce the volume of sludge and contribute to offsetting the cost and energy balance of the sludge management. The key nutrients in the MSS are N and P, which are distributed into various products of the HTL process. The presence of N and P in the biocrude is not desirable, instead if these are partitioned from raw MSS to the byproducts of the HTL process, it could offer improved nutrients recycling opportunity. While earlier studies on HTL of MSS mainly focused on the biocrude yield and quality, it would be, therefore, necessary to study how HTL process parameters could optimize the partitioning of these nutrients into the byproducts that can be efficiently recycled.

2. Goals and Objectives

i. Characterization of the wet sludge
ii. Development of HTL process for energy recovery and maximize the release of N, and P from the sludge
iii. Characterization of the HTL products and byproducts
iv. Development of microalgae cultivation system using the aqueous phase byproducts of HTL process
v. Recovery of the metals
vi. Study the feasibility of large-scale microalgae cultivation by using the aqueous phase liquid (APL) obtained at 350 °C and different holding time

3. Methodology

• Wet sludge was collected from local wastewater treatment plant. The sludge was dried by in oven at 105 °C to determine moisture content.
• Ash content in the dried sludge was determined by keeping the sample at 530 °C in a preheated muffle furnace for 4 hours.
• Elemental analysis was conducted in a Flash 2000 CHN analyzer, oxygen was calculated based on difference. Sulfur was analyzed separately.
• Metals in the samples were determined by digesting the samples in 100 mL digestion reactors using concentrated HNO3, and were analyzed using Agilent 7700 ICP-MS.
• HTL trials were conducted using 10 mL Swagelok valve at preset temperature in a muffle furnace for a duration of 30 – 120 minutes.
• The aqueous phase liquid (APL) was added in the seawater and freshwater to cultivate Chlorella sp., respectively. The growth of these strains using APL was compared with control cultures
• Higher heating value was determined using Duelog formula: Higher heating value (MJ/kg)=−0.33C+1.42H−0.89S
• Microalgal recycling efficiency of the nutrients from the APL was strain dependent.
• Under the optimized conditions, 58% of the calorific value could be recover as biocrude.
• Picochlorum sp. was more efficient in nutrients recycling from the APL compared to Chlorella sp.
• The metal concentration in the biochar was much lower than raw sludge; therefore, biochar could be used as soil additive or adsorbent for wastewater treatment

4. Results

4.1 Energy recovery

Table 1: Properties of the biocrude oils - obtained at 350 °C and different holding time

<table>
<thead>
<tr>
<th>Holding time (min)</th>
<th>C (%)</th>
<th>H (%)</th>
<th>N (%)</th>
<th>O (%)</th>
<th>HHV (MJ/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>72.4±0.1</td>
<td>7.6±0.0</td>
<td>6.2±0.1</td>
<td>13.8±0.2</td>
<td>32.9±0.1</td>
</tr>
<tr>
<td>45</td>
<td>73.2±0.2</td>
<td>8.0±0.0</td>
<td>5.1±0.0</td>
<td>13.7±0.2</td>
<td>33.8±0.1</td>
</tr>
<tr>
<td>60</td>
<td>73.1±1.6</td>
<td>9.0±0.2</td>
<td>5.8±0.3</td>
<td>11.8±1.7</td>
<td>35.6±0.6</td>
</tr>
<tr>
<td>90</td>
<td>74.7±0.4</td>
<td>9.3±0.1</td>
<td>5.9±0.2</td>
<td>10.1±0.3</td>
<td>36.8±0.4</td>
</tr>
<tr>
<td>120</td>
<td>73.6±2.0</td>
<td>9.3±0.2</td>
<td>5.8±0.1</td>
<td>11.3±1.8</td>
<td>36.2±0.9</td>
</tr>
</tbody>
</table>

5. Significance

• Optimal HTL conditions could recover 58% energy of the MSS with an EROI value of 3.5.
• Increasing HTL reaction time reduced the TOC and increased TN in APL.
• Metals concentrations in the biochar get reduced compared to raw MSS.
• TP in the biochar increased with increase in HTL reaction time.
• Microalgal recycling efficiency of the nutrients from the APL was strain dependent.

6. Post-project recommendations and plans

Close the loop for sewage sludge management and enhance circular economy:

i. Develop a continuous HTL reactor
ii. Study the feasibility of large-scale microalgae cultivation by using the aqueous phase
iii. Field application of the biochar as soil conditioner
iv. Recovery of the metals
v. Study the potential of using aqueous phase as a soil additive
vi. Additve or adsorbent for wastewater treatment
vii. Study the feasibility of large-scale microalgae cultivation by using the aqueous phase
viii. Field application of the biochar as soil conditioner