# Wastewater from bio-waste treatment; some issues and solutions

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SUMMARY: The treatment of wastewater from a biogas reactor and a solid waste incinerator was treated with electrocoagulation (EC) and adsorbents to retrieve solids and nutrients from the liquid. The wastewater from a biogas reactor typically contained almost 3000 mg/l NH4-N, 100 mg/l Tot-P, suspended solids of almost 6000 mg/l, and a conductivity of near 18000 μS/cm. The wastewater from the incinerator contained about 160 mg/l NH4-N, 300 mg/l Tot-S and with a conductivity above 25000 μS/cm. Also, the pH was high at 9.0 due to the addition of calcium carbonates. The combination of EC treatment and adsorbents resulted in a near complete removal of P, N and solids from wastewater from a full-scale biogas plant fed with commercial organic waste. The method was also effective in removing hydrocarbons coming from cooking oil in the waste. The removal of N from wastewater from incineration plants proved more difficult, probably due to a high concentration of competing ions, although a removal of more than 40% was obtained for ammonia-N.

## 1. INTRODUCTION

Recycling of recourses is very high on the political agenda. There are, however, a large number of practical and economical issues involved in making the recycling successful and meaningful.

Table 1. Organic waste in Norway (in tonnes, 2013). SSB, 2017.

| Category | Material recycling | Biogas | Compost | Incineration | Landfill | Other | Total | % Biogas |
|---|---|---|---|---|---|---|---|---|
| Food waste/wet organic waste | 1207 | 73944 | 94446 | 4190 | | 148 | 173935 | 43 |
| Park, garden | 4129 | 674 | 179936 | 5205 | | 4507 | 194453 | 0.3 |
| Wood | 41 | | 6484 | 248093 | | 114 | | 0 |
| **Total** | **5377** | **74618** | **280866** | **257488** | **0** | **4769** | **368388** | **20** |
| Sewage sludge | | | | | | | 120000 | ? |
| Manure | | | | | | | 5680000 | |
| WW from pulp | | | | | | | ? | |
| Aquaculture | | | | | | | 90000 | ? |

According to Enova, there is potential of 6 TWh of biogas production in Norway,, while the total annual production in 2015 was 287 GWh. Most plants operate at 25-50 GWh/year, but more plants are under construction, with a projected capacity of 250 GWh/year (Biokraft AS). The biogas reactors are usually run as wet digesters producing a significant amount of wastewater high in ammonia (Table xx),.

Waste incineration at the local plant in Oslo (Haraldrud) takes place in two lines. The flue gas is treated to prevent toxic emissions, most importantly particles containg dioxins and related compounds, and gases such as $NO_x$ and CO. Oxygen and ammonia is added directly to the incineration chamber at maximum temperature (850 ˚C) in order to prevent the CO and $NO_x$ production.

The wastewater is produced by a counter flow to the flue gas in a scrubber. The ammonia is dissolved in the wastewater (Table xxx).

## 2. METHODS

The EC unit provides electrons and gases to a reaction chamber to separate the solids and the liquid. The sorbents used for the biogas wastewater, zeolites and biochar, also showed promising capacity for ammonia extraction from the treated liquid. The zeolites used in this experiment is from Geoprodukt KFT, Bartok Bela, Hungary, and consists of 38% Si, 4.8% Al, 1.5% K, 0.7% Fe, 0.7% Ca, 0.3% Mg and 0.1% Na. The biochar is a 50/50 mix from woodchips and sewage sludge.

Table 2. Wastewater (ww) characteristics*

| | $NH_4$-N | TOT-S | pH | El | Vol |
|---|---|---|---|---|---|
| Biogas ww | 2720 | | 7.93 | 18362 | |
| Incin ww 1 | 170 | | | | 1-2 |
| Incin ww 2 | 154 | 302 | 9.2 | 25600 | 5 |

*mg/l, $\mu$S/cm and $m^3$/hour

a) A sample of 20 litres of wastewater was collected from the output of the biogas reactor at Hadeland and Ringerike Avfallsselskap (HRA) and used directly for the experient. A bench scale electrocoagulation unit was used, with Fe and Al sacrificial electrodes. The EC treatment results in sludge solids separating from liquid, and PAX and $FeCl_3$ coagulants were used in order to speed up the separation. The clear liquid phase was used to study nitrogen removal. A 10:1 liquid to adsorbent weight ratio was applied, before shaking at low speed for 24 hours. The adsorbents used were zeolite and a mix of zeolite and biochar of different concentrations. Total and ammonium nitrogen were measured in the decanted liquid phase.

b) Two samples from a waste incinerator wash water/wastewater of 20 L was sampled in a plastic container at times with an interval of 3 months. The wastewater was treated in the EC chamber in 3 modes; untreated, and with added 10 g and 100 g of zeolites per 6 litres of wastewater.

## 3. RESULTS AND DISCUSSION

a) Wastewater from biogas production was

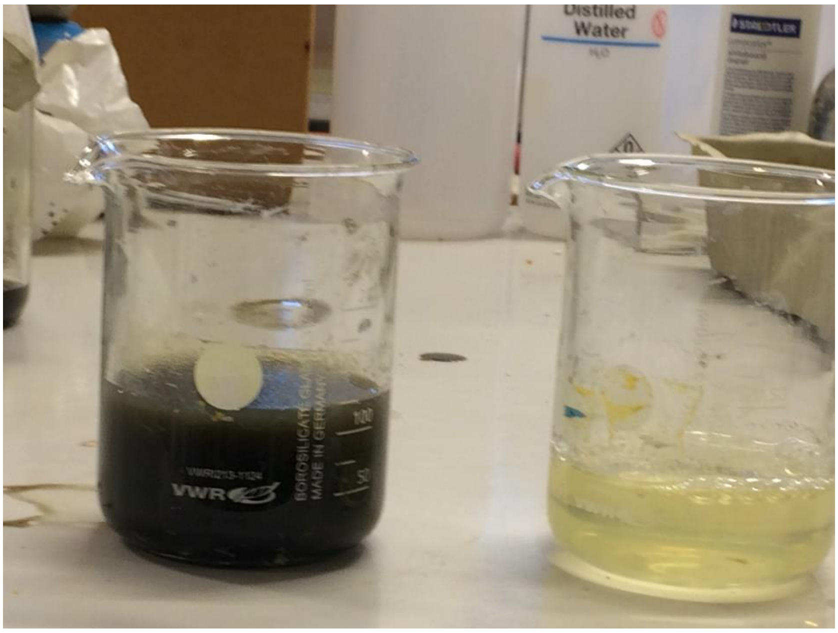


Figure 1. Untreated biogas wastewater (left) and EC treated (right).

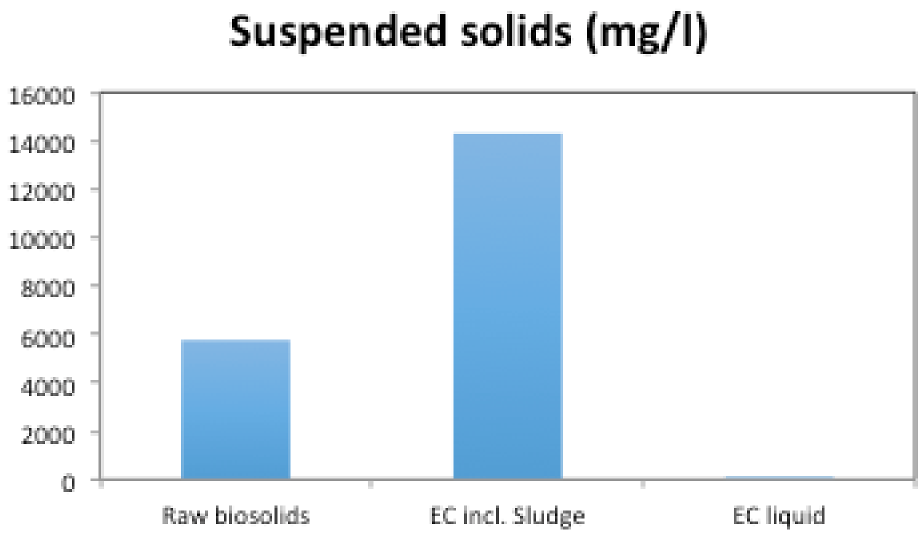


Figure 2. Concentration of suspended solids in the biogas wastewater (raw biosolids), in the EC treated before sludge separation, and in the separated liquid.

Due to the coagulation in the process, chamber the concentration of SS increase after the EC process, but only to be reduced by nearly 90 % to a final concentration of 66 mg/l (Figure 5).

Figure 6 and 7 shows that phosphorus and organic carbon are also effectively removed from the liquid phase and can be find in the sludge. Further studies will investigate if this sludge is superior in comparison to sludges produced by other methods regarding supporting plant growth.

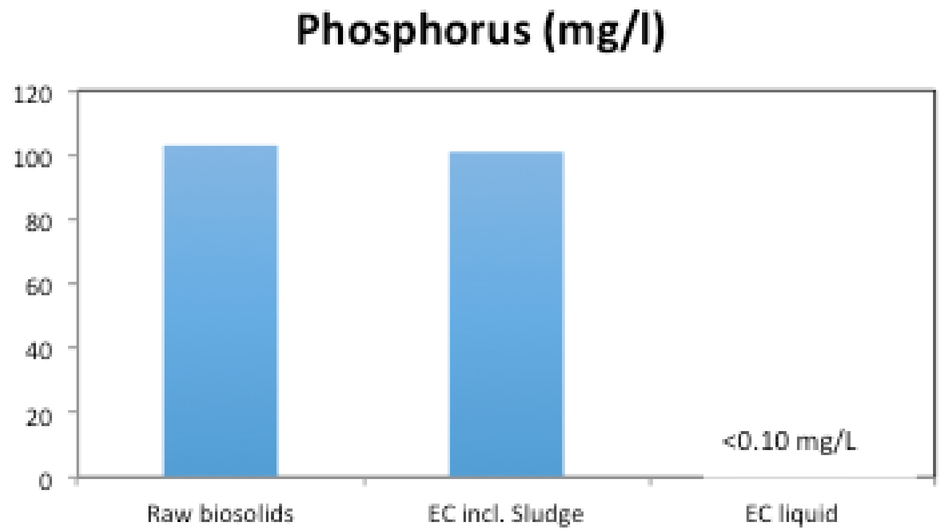


Figure 3. Concentration of phosphorus in the biogas wastewater (raw biosolids), in the EC treated before sludge separation, and in the separated liquid (<10 mg/l).

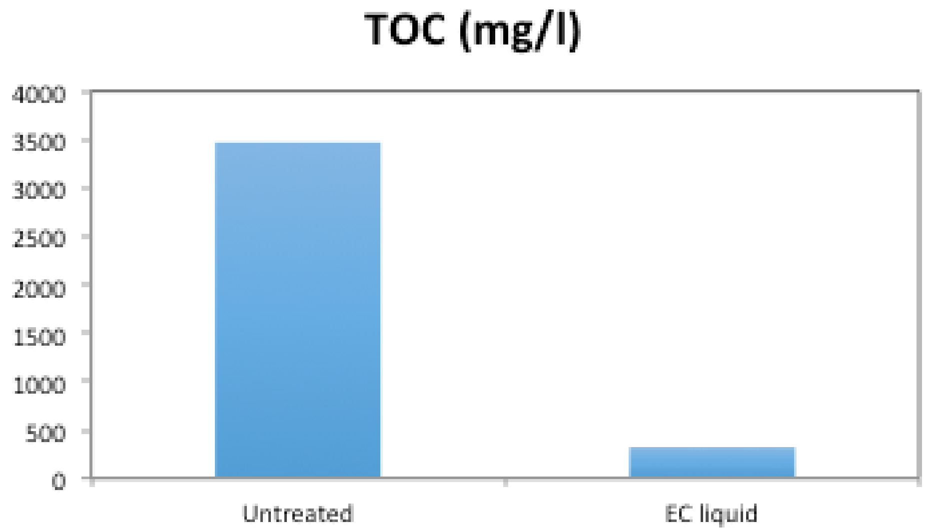


Figure 4. Removal of total organic carbon.

Figures 8 and 9 show that the EC treatment removed about half of the nitrogen in the liquid phase but the levels are still unacceptably high (ca 1,500 mg/l) for the water to be released into watercourses or groundwater. With adsorption this concentration can be significantly reduced to below an acceptable level.

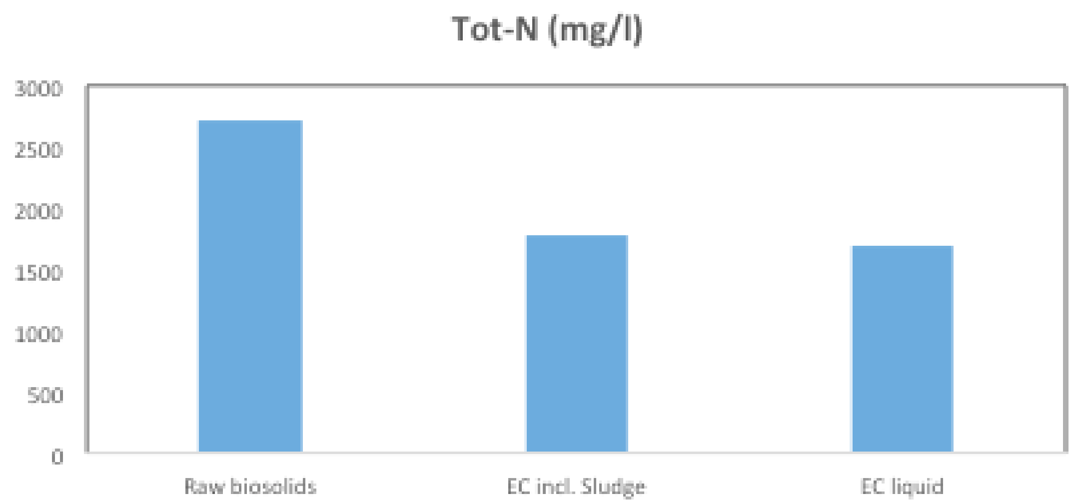


Figure 5. Concentration of total nitrogen in the biogas wastewater (raw biosolids), in the EC treated before sludge separation, and in the separated liquid.

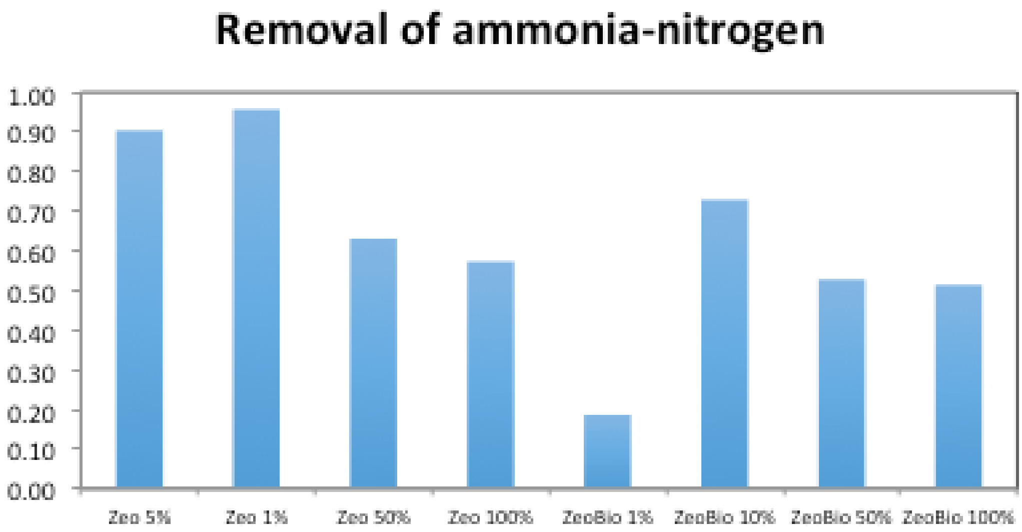


Figure 6. Removal of $NH_4$-N (ratio) from the liquid phase by adsorption. The removal of ammonium was higher when using zeolite compared to a mix of zeolite and biochar.

Table 3. Concentration of hydrocarbons (HC) in wastewater (Biorest), treated wastewater (EC treated) and in the final sludge.

| Date | | 21.2.17 | 16.6.17 | 13.9.17 | 21.2.17 | 21.2.17 |
|---|---|---|---|---|---|---|
| | Unit | Biorest | Biorest | Biorest | EC treated | Sludge |
| Dry matter (%) | % | | | | | 6,48 |
| Fraction $C_5$-$C_6$ | mg/kg | | | | | <2.5 |
| Fraction $C_6$-$C_8$ | mg/kg | | | | | <7.0 |
| Fraction $C_8$-$C_{10}$ | mg/kg | | | | | <10 |
| Fraction $C_{10}$-$C_{12}$ | µg/l | 657 | 3950 | 673 | 315 | <10 |
| Fraction $C_{12}$-$C_{16}$ | µg/l | 2730 | 683 | 171 | 6 | 120 |
| Fraction $C_{16}$-$C_{35}$ | µg/l | 77500 | 11600 | 2350 | <30 | 1800 |
| Fraction $C_{35}$-$C_{40}$ | µg/l | 7210 | 1370 | | <10 | |
| Fraction $C_{10}$-$C_{40}$ | µg/l | 88100 | 17600 | | 353 | |
| Sum $C_{12}$-$C_{35}$ | µg/l | 80200 | 12300 | 2520 | 6 | 1900 |
| Sum $C_5$-$C_{35}$ | µg/l | | | | | 1920 |
| TOC | mg/l | 3470 | 6260 | | 319 | 25 |
| Reduction | % | | | | 99.6 | 2.2 |

Due to a high fraction of cooking oil in the feed (Figure 10), high concentrations of hydrocarbons were detected in the wastewater. The main fractions of HC are the medium to long chained ($C_{16-35}$ and $C_{10-40}$), both in the water and sludge (Table 3). There was a near complete removal of HC from the wastewater, and the final content in the sludge was 2.2 % of the starting concentration (Table 3). Cooking oil contain according to Hart et al, 1995 mostly saturated fats ($C_{16}$ palmic) and unsaturated ($C_{18}$ oleic).

Figure 7. Incoming organic waste with cooking oil cans.

b) Incinerator wastewater

Figure 8. Gas wastewater mixed with zeolites and EC power source and reaction chamber.

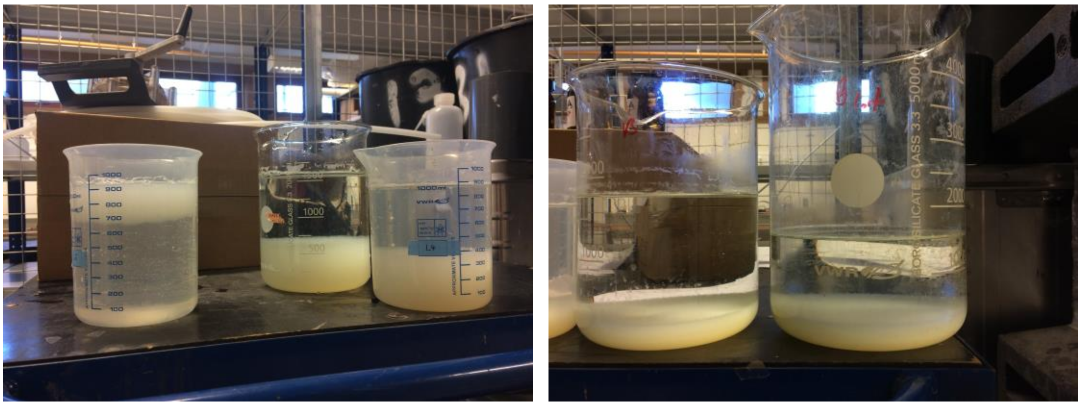

Figure 9. After EC from left: gas wastewater, mixed with 10 g and 100 g zeolites, and 100 g zeolites after 24 hours settling.

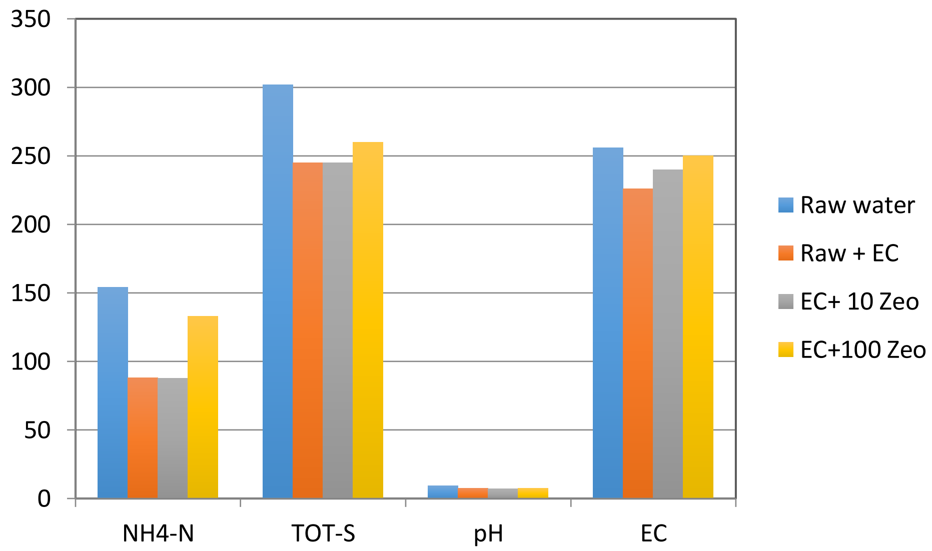


Figure 10. Ammonia, Tot-S (mg/l), pH and electrical conductivity (mS/m) in the wastewater before and after treatment.

## 4. CONCLUSIONS

- Electrocoagulation (EC) is very suitable for treating wastewater from biogas plants
- EC can produce a liquid phase free of particles and phosphorus and hydrocarbons
- Nitrogen can further be removed from the liquid phase by adsorption

- Removal of N from incinerator gas wastewater proved more difficult, but was above 40%

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