NITROGEN RECOVERY FROM BIOGAS PLANT DIGESTATES VIA SOLID-LIQUID SEPARATION AND STRIPPING

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1 INTRODUCTION

The installation of anaerobic digestion plants has progressed extensively in Germany. Anaerobic digestion has the benefit of biogas but also produces residues (referred to as digestate). The amount of digestate generated is parallel with the increase of anaerobic digestion treatment for agricultural waste, municipal biowaste or energy crops. The digestate has high nitrogen content which is favourably valued for its fertiliser potential. However, approach to apply the digestate directly in agricultural field has adverse impacts, such as odorous effect, nitrous oxide (N_2O) emission and nitrate leaching (Dittert et al., 2009; Dorno et al., 2009), due to its high content of ammonia. Another disadvantage is related to its transport to the needed areas, since anaerobic digestion plants can be located in the city or in agricultural areas with surplus of nitrogen. The transport problem is mostly attributable to the high volume of digestate required. It is reported that transportation costs can be reduced by half by increasing its solid content as much as 1.5% to 5% (Noone, 1990). As transport costs continue to rise, reprocessing digestate to a more concentrated or solid form is inevitable. An alternative of digestate treatments for nitrogen removal and recovery is stripping, thus transforming the digestate into a suitable form of fertiliser and transportable product. Stripping method also is preferred due to the availability of heat in the process. Since the limiting factor for stripping is the energy requirement for high temperature process (Bonmati and Flotats, 2003), the heat from the biogas engine can be further utilised and therefore makes stripping as the best proposed treatment. The focus of the study is the development of a treatment of digestate that can avoid the adverse environmental impacts, minimise the loss of nitrogen contents and increase the solid contents in its end-product, thus making it technically and economically feasible as fertiliser.

2 MATERIALS AND METHODS

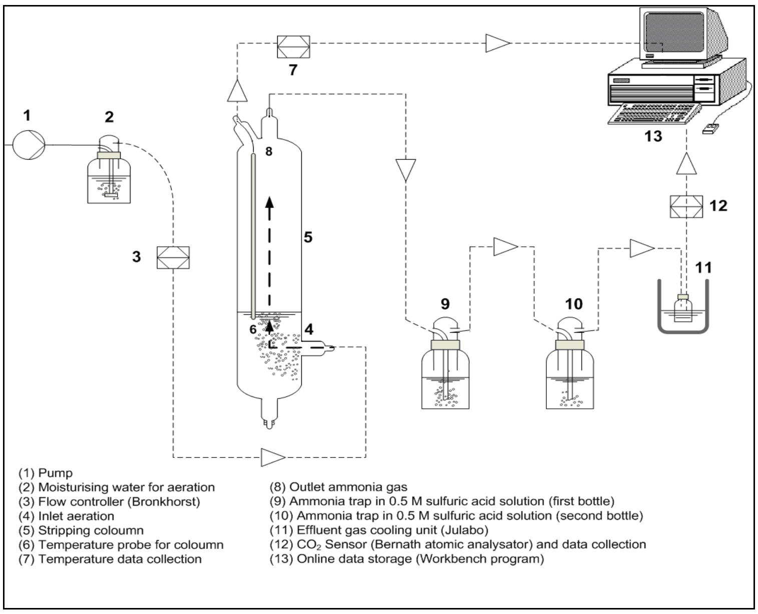

FIGURE 1 **Experimental set up of stripping unit**

Experiments were performed with digestate from a biogas plant treating grass mixed with cow manure as the feedstock. Digestate was preserved in the refrigerator at 4-5°C prior to the treatment. The treatment of digestate consists of solid-liquid separation and stripping. The solid-liquid separations of the digestate were performed with filter bag and manual pressing. The filter bag is a standard polypropylene material of 195 micron rating. Stripping was performed for solid and liquid digestate after solid-liquid separation. Stripping with diffuse aeration was chosen due to difficulty in further separation of the liquid part of digestate. The stripping retention times for liquid and solid digestate were 6 hours and 14 days, respectively. Ammonia was recovered in sulphuric acid solution (0.5 M) with volume of 200 mL. Stripping were performed with the variations of aeration flow rate (50, 150 and 300 L/h), digestate temperature (20 and 35°C) and digestate pH (pH 8 and 12). Sampling and analysis of sulphuric acid solution were performed after stripping. Sampling was performed hourly for liquid digestate and daily for solid digestate. The analyses that were performed on raw digestate are pH, NH_4-N, and Total Nitrogen/ Total Kjeldahl Nitrogen (TN/TKN) analysis. NH_4-N analysis was performed on post-treatment digestate and the absorbent solution, sulphuric acid. In addition, separate analyses were performed for solid and liquid digestate, namely water content and loss-in-ignition analyses for solid digestate, while density, total solids and conductivity analyses for liquid digestate.

3 RESULTS AND DISCUSSION

3.1 Characteristics of raw digestate and solid-liquid separation

Anaerobic digestion transforms nitrogen compounds in the feedstock into ammoniacal nitrogen (NH_4^+/NH_3) (Schievano et al., 2009) and the process can accumulate NH_4^+/NH_3 in the substrate (Fricke et al., 2007) and in the digestate. The digestate samples for the experiment has the ammonia content of 3173 ± 375 mg/L, which is 20-30% lower than Total Nitrogen (TN) content (average of 4299 ± 916 mg/L). Analysis on the physical characteristics such as density of digestate can provides information for the solid-liquid separation and stripping treatment since density affects filtration effectiveness with filter bag. The digestate's density is 1.04 ± 0.1 g/cm^3 (at digestate temperature of 18°C). Water content of digestate is 87.6 ± 1.2%. Loss-in-ignition is 72.12% to 76.88 ± 1.2% and pH is 7.65. The filtration process generated a solid fraction with a water content of 83.5 ± 1.5%. After separation, 58% Total Kjeldahl Nitrogen (TKN) of the raw digestate is present in the solid digestate, while 86% NH_4-N of raw digestate is found in the liquid part.

3.2 Effect of stripping duration on ammonia recovery

The relationship of ammonia recovery from liquid and solid digestate with time can be seen from Figure 2 and 3. The correlation relationship of parameters is indicated by the Pearson correlation (r; -1 < r < 1), whereas positive r value indicates positive correlation and, vice versa, negative r value indicates negative correlation. It could be concluded that the large amount of ammonia in the solid digestate was immediately stripped out in a relatively short time during the beginning of the experimental run, regardless of the stripping parameter variations, while liquid stripping required a high pH (pH 12) to achieve the similar effect.

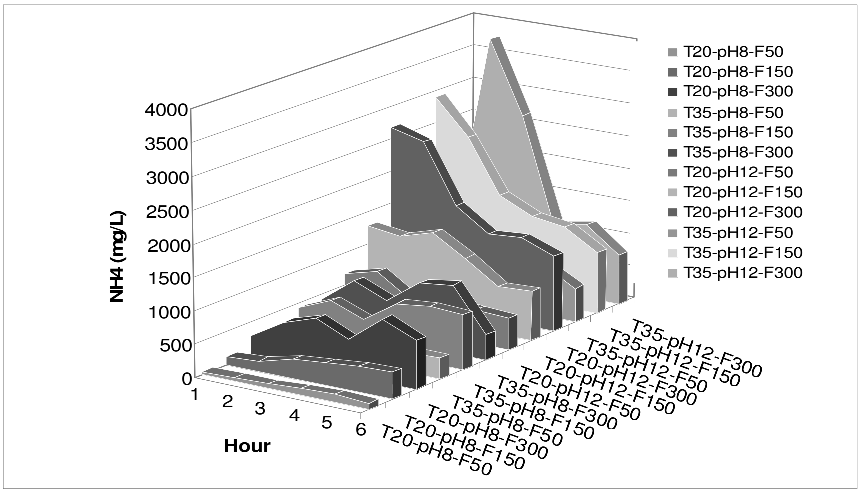

FIGURE 2 **Liquid digestate stripping: Ammonia recovery vs. stripping duration**

The total recovery for solid stripping is 51% at temperature of 20°C, pH 12 and aeration flow rate of 50 L/h, while the first 3 days of stripping can yield ammonia recovery as high as 26%. Hence, half of the ammonia recovery from solid digestate in the 14-day operation had occurred in the first 3 days.

For the stripping of liquid digestate, the highest ammonia recovery is 68% at the temperature of 20°C, pH 12 and aeration flow rate of 300 L/h, with first 3 hours stripping operation can achieve 47% of total recovery. While 6 hours stripping operation for liquid digestate is still sufficient for achieving high efficiency, reduction on duration time for solid stripping while optimising other parameter is possible.

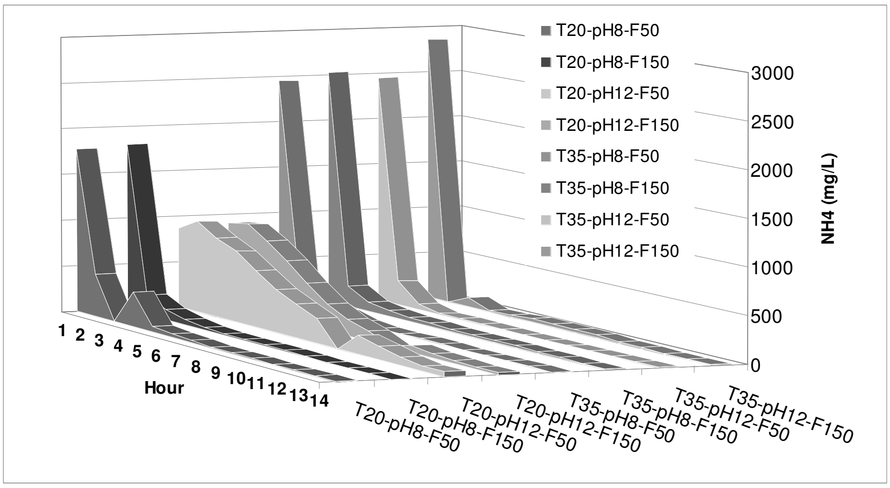

FIGURE 3 **Solid digestate stripping: Ammonia recovery vs. time**

3.3 Effect of stripping parameter variation on ammonia recovery

The stripping was performed with the variations in three parameters, namely aeration flow rate, digestate temperature and digestate pH. The dependence of the ammonia recovery on stripping duration varies with the pH value. For the digestate in the pH 12, ammonia recovery from liquid and solid digestate generally reduced with the stripping time. On the contrary, ammonia recovery from digestate in the pH 8 increased with the stripping time, especially for lower aeration flow-rate. From Figure 4 it can be seen that solid digestate stripping produced a total ammonia recovery rate of 51% as the highest which was occurred by a temperature of 20°C (pH 12, aeration 50 L/h) compared with 25% rate for the same pH and aeration rate but higher temperature. This is probably due to loss of ammonia during one-night acclimatisation period (for T35°C samples to increase the temperature).

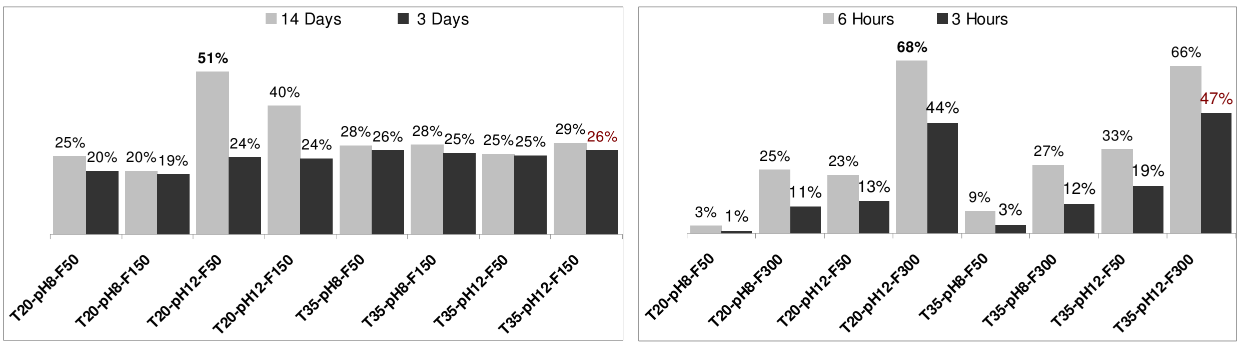

FIGURE 4 **Comparison of ammonia recovery for stripping of solid (left) and liquid digestate (right)**

3.4 Mass calculation and recovery rate

80% of Nitrogen (3.4 g) in raw digestate (4.3 g) was presented in the liquid digestate after filtration. 53% of the Nitrogen in liquid digestate (1 L) was trapped in H_2SO_4 liquid after 6 hours stripping process; which is 42% of the Nitrogen in raw digestate. 57% of Nitrogen (5.2 g) in raw digestate (9 g) was presented in solid digestate after filtration. 10% of the Nitrogen in solid digestate (250 g) was trapped in H_2SO_4 liquid after 14 days stripping process; which is 6% of the Nitrogen in raw digestate.

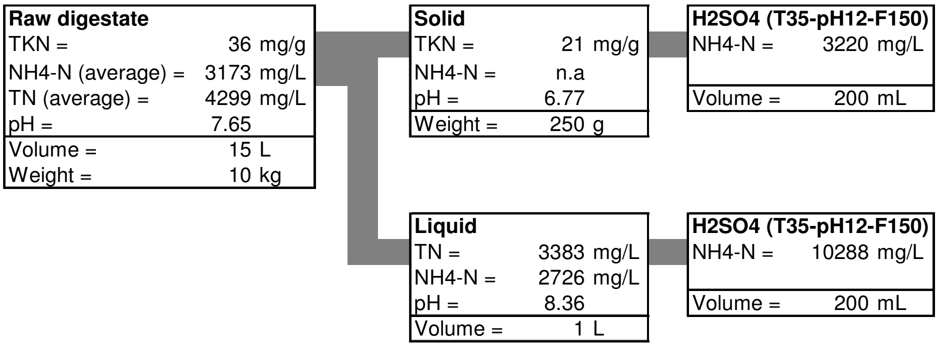

FIGURE 5 **Data for mass calculation**

This means that the stripping process for liquid digestate had a higher recovery rate of nitrogen than for solid fraction. However the duration of the stripping process of 14 days for solid digestate and 6 hours for liquid digestate was needed to be noted. The results of the calculation are showed in Table 1.

TABLE 1 **Results of mass calculation**

	Raw digestate	Liquid digestate		H2SO4 Liquid
TN	4299 mg/L	3383 mg/L	**A**	10288 mg/L
V	1 L	1 L	**V**	200 mL
mN	4.3 g	3.4 g	**mA**	2.1 g
			mN	1.8 g

	Raw digestate	Solid digestate		H2SO4 Solid
TKN	36 mg/g	21 mg/g	**A**	3220 mg/L
W	250 g	250 g	**V**	200 mL
mN	9 g	5.2 g	**mA**	0.6 g
			mN	0.56 g

Note
TN Total Nitrogen
TKN Total Kjeldahl Nitrogen
V Volume
W Weight
A Ammonium-Nitrogen (NH4-N)
mN mass Nitrogen
mA mass Ammonium-Nitrogen

Recovery rates of solid and liquid digestate stripping were calculated to allow a comparison. The calculations were performed on data NH_4-N of stripping of solid digestate for first day result for the most optimal variation of temperature 35°C, pH 12 and flowrate 150 L/h (T35-pH12-F150) and first 6 hours for stripping liquid digestate (T35-pH12-F150 same variations) (input data in Figure 5.). The result is 23.9 mg/h as recovery rate for solid digestate and 342.9 mg/h for liquid digestate. Stripping rate ratio of liquid to solid digestate is 14 times. 53% of the Nitrogen in liquid digestate (1 L) was trapped in H_2SO_4 liquid after 6 hours stripping process ; which is 42% of the Nitrogen in raw digestate. 10% of the Nitrogen in solid digestate (250 g) was trapped in H_2SO_4 liquid after 14 days stripping process; which is 6% of the Nitrogen in raw digestate. However, comparison apple to apple for solid and liquid digestate stripping could not be performed due to unavailable data of stripping yield of solid and liquid digestate.

4 CONCLUSIONS

The stripping process should only be applied to liquid fractions. The digestate had a high water content of 87.6±1.2%, with solid-liquid separation resulted in 5% difference for solid-liquid part of digestate. After separation, 58% TKN of raw digestate is present in solid digestate, while 86% NH_4-N of raw digestate is found in the liquid. The study showed max.68% of recovery for stripping of liquid digestate (for temperature 20°C, pH 12 and flowrate 300 L/h) and 51% for solid digestate (for temperature 20°C, pH 12 and flowrate 50 L/h). There is significant relationship of the amount of ammonia recovery in solid and liquid digestate with time. Efficiency can be increased by improved solid-liquid separation (e.g. by screw-presses application) and by higher NH_4 recovery rates from the liquid (e.g. by regulation of pH, temperature, aeration). The removed ammonia which was concentrated in sulphuric acid can be treated further e.g by crystallization to produce solid, easily transportable fertilizer. The energetic efficiency of such a process can compete with the common nitrogen fertilizer production (Haber-Bosch).

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