23 April 2021

TECHNOLOGY FACT SHEET

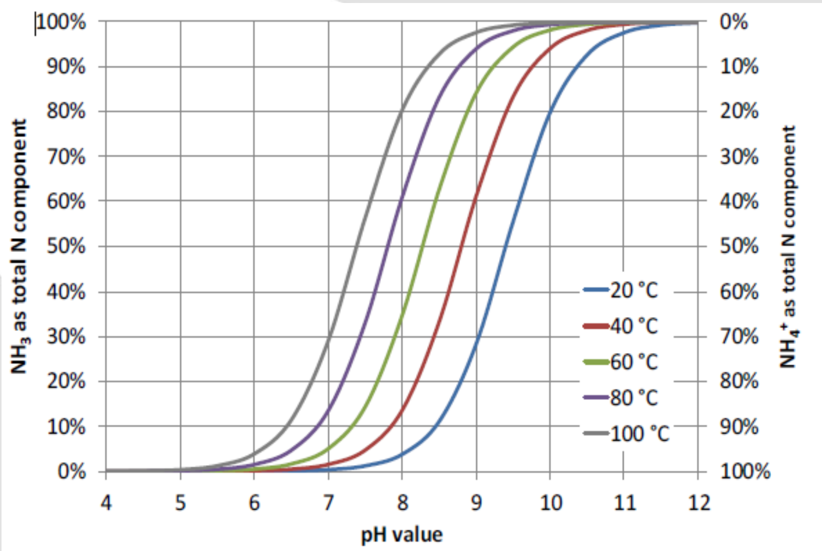
Evaporation

Evaporation is a technique that is applied to reduce the water content of liquid streams, concentrating the nutrients. In addition to the food industry sector, evaporators are installed at AD plants to evaporate (liquid fraction of) digestate.

The liquid is heated to vaporize the water, which will reduce the volume of the initial product, often up to 80% (personal communication SYSTEMIC biogas plants, 2020). Some other components in the liquid also have a tendency to "escape" the liquid based on their vapour pressure. When evaporating (liquid fraction of) digestate, this will mainly be volatile organics (e.g. volatile fatty acids, CO_2 from carbonates) and ammonia.

A solution like (liquid fraction of) digestate, contains anhydrous ammonia dissolved in water, in which the ammonium ion in solution exists in equilibrium with unionized (free) ammonia, which can volatize.
NH_3 (gas)=NH_3 (aq) + H_2O = NH_4+(aq) + OH^-(aq)
This equilibrium or the "urge to escape as a gas or stay in solution" depends on pH and temperature [[1]].

Increasing pH and/or temperature pushes the equilibrium from soluble ammonium (NH_4^+) towards gaseous strippable ammonia. The partial pressure of NH_3 will also rise with the falling pressure (when working under vacuum conditions).
During evaporation, dissolved ammonium in the (liquid fraction of) digestate will transfer to the gas phase as ammonia (NH_3).



Equilibrium of NH_3 and NH_4^+ in water at different pH and different temperatures

[1] The base ionization constant is Kb = 1.8×10−5 and within the temperature range of 0°C-50°C and a pH range of 6.0 to 10.0, the relation with temperature is pKa = 0.0901821 + 2729.92/Tk where Tk is temperature in degrees Kelvin, Tk = °C + 273.2.

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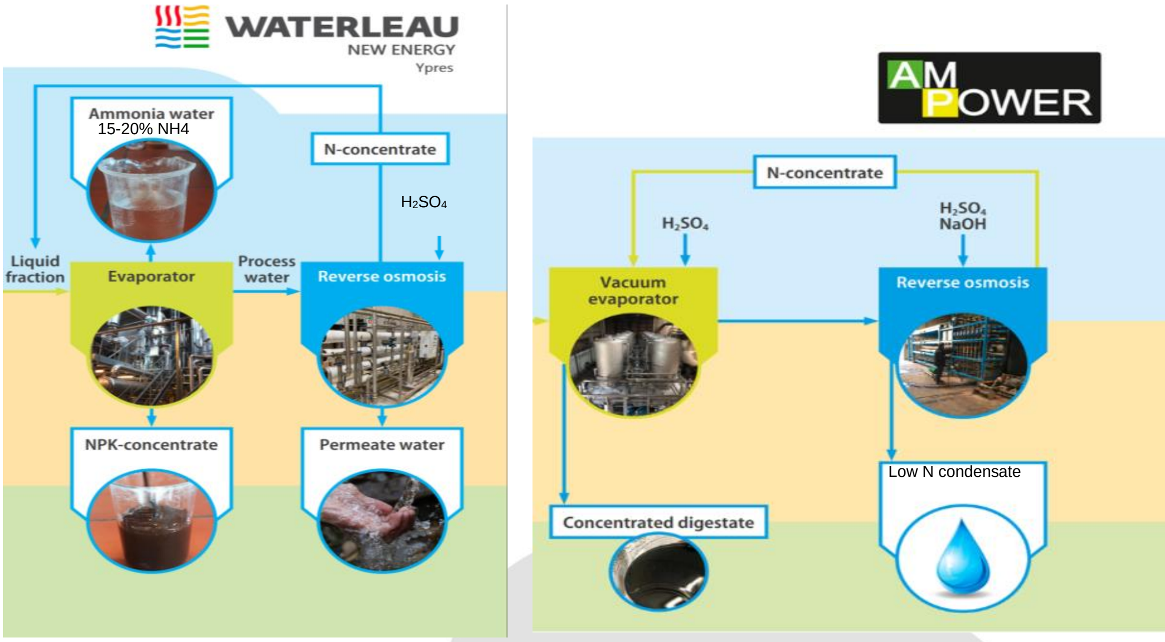
After evaporation, the water vapour containing volatile components is recovered by cooling it down. The result is a condensate or distillate containing a solution of ammonia that is salt-free with pH of >9 (Scheme Waterleau New Energy).



Evaporation cascade at Waterleau New Energy (left) without acidification, and AM-Power(right) with acidification.

To prevent volatilisation of ammonia during the evaporation step, the pH of the influent of the evaporator can be adjusted to <6,5 by adding acid. This approach will cause only the water (and some volatile components) to evaporate and create a more concentrated digestate which still includes the ammonia (Scheme AM-Power). However, acidification can cause foaming due to the release of carbon acid.

The produced concentrate remains fluid or slurry-like and contains all non-volatile components (e.g. organic matter, nutrients and salts).

Unlike ammonia stripping, the goal of evaporation is usually not to strip ammonium out but to reduce the volume of the digestate hereby concentrating the nutrients in it. Therefore, the evaporation process does not usually include a pH increase step by means of CO_2 stripping or alkali addition.

Configurations

Different configurations of the evaporator determine the amount of heat that can be re-used from the evaporation (Gruwez 2012).

Operating the evaporator at negative pressure (i.e. vacuum evaporation) will reduce the boiling temperature of the liquid. This way, low energy, recovered heat (e.g. from a CHP) can also be used to heat up the evaporator.

Another way to reduce the heat input is by using an evaporator that works in multiple steps. In each subsequent step, part of the heat from the previous step is re-used.

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Next to the configuration for energy recovery, there are also different types of evaporators possible based on the mode of heat transfer and viscosity. For evaporation of (liquid fraction of) digestate mostly long vertical tube evaporators with falling film, spray-film or forced circulation evaporators with external heat exchangers are used because they have proven to be more suitable for viscous and heat-sensitive liquids (Vondra, Máša, and Bobák 2017).

Falling film evaporators work best on flows with low to medium viscosity. Other systems, working with a heat exchanger in the boiling chamber are also applicable for evaporating digestate. (Automated) cleaning of the heat elements needs to be taken into account here.

Read more about the recovery efficiencies, use of additives, energy requirements and costs in Chapter 2.2.5 of D 3.2 Final report on schemes and scenario's for nutrient recovery and Reuse.
www.systemicproject.eu/downloads →"project deliverables"

References

Gruwez, Jan. 2012. *Wegwijs in de Industriële Afvalwaterzuivering*. edited by H. Suijkerbuijk. Wolters Kluwer Belgium.

Vondra, Marek, Vítězslav Máša, and Petr Bobák. 2017. "The Energy Performance of Vacuum Evaporators for Liquid Digestate Treatment in Biogas Plants." *Energy*.

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