Mineral concentrate

Technology description

Mineral concentrates come from the processing of manure or digestate (Figure 1). The first step of the process is a solid-liquid separation by means of a decanter centrifuge, auger press or belt press. This leads to a solid fraction and a liquid fraction. The liquid fraction is processed further to remove particles. DAF (Dissolved Air Flotation units), ultr-filtration, nano-filtrations and paper filters are technologies used to remove particles. Coagulation and flocculation processes can be stimulated by use of flocculants. The cleaned effluent enters a Reverse Osmose (RO) unit (Photo 1). Water is pushed under pressure through semi-permeable membranes, leading to a concentrate of minerals and a permeate (cleaned water). Fouling of the membranes by salts and micro-organisms requires regular cleaning and maintenance. The permeate can require an additional treatment by means of an ion exchange resin before discharging to surface water or the soil becomes possible. Initially, mineral concentrates were obtained by a single Reversed Osmosis treatment step. In recent years, multiple (repeated) concentration steps are more often used.

Photo 1. A Reverse Osmosis (RO) installation.

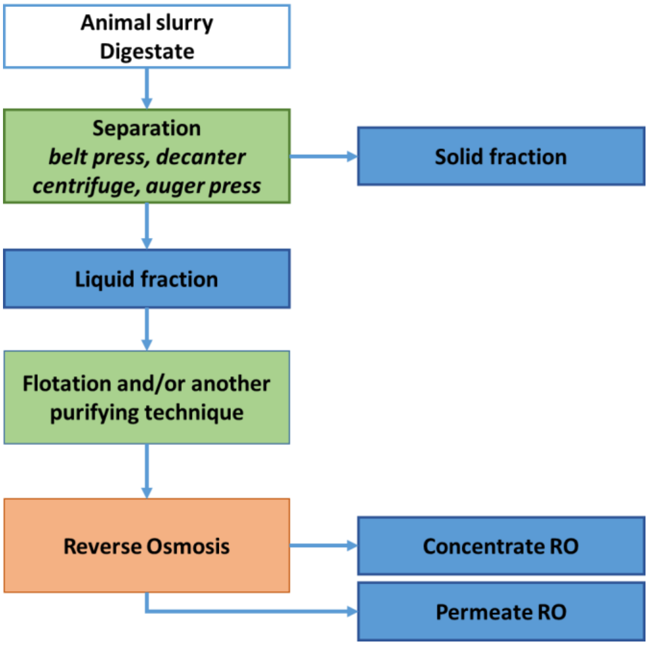

Figure 1. Example of a scheme for treatment of animal slurry or digestate using Reverse Osmosis.

Product characteristics

Mineral concentrates (Photo 2) predominantly consist of ammonium-nitrogen and potassium. Surveillance across ten pilot plants in the Netherlands showed that on average 90% of the total nitrogen of the mineral concentrates is NH_4-N.

Photo 2. Mineral concentrates from different reverse osmosis installations.

Horizon 2020

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These values corresponded with a single RO concentration step (Table 1 below). The ingoing liquid fraction contains some organic matter which is present in mineral concentrates (1.3% organic matter or 0.6% C_{org}). Compared to pig slurry the ratio between NH_4-N to Total N increased from 66% to 90%. Currently, studies are undertaken to increase the concentration by repeated cycles of RO.

Parameter	Mineral concentrate	Pig slurry	Liquid fraction pig slurry	Solid fraction pig slurry
Dry matter, g/kg	33.4	72.1	17.1	269.3
Organic matter, g/kg	13.3	51.1	7.8	203.5
Total N, g/kg	7.1	6.3	3.6	11.8
NH_4-N, g/kg	6.4	4.1	3.0	5.2
NH_4-N/Total N	0.9	0.7	0.8	0.4
P, g/kg	0.2	1.6	0.1	6.8
K, g/kg	7.2	4.1	3.4	3.6
Ca	0.2	1.9	0.2	8.7
Mg	0.1	1.0	0.1	5.0
S	1.1	0.7	0.6	2.9
Na	0.2	0.9	0.8	0.7
pH	7.9	7.7	8.0	8.2

Table 1. Average chemical composition of mineral concentrates, fattening pig slurry, liquid and solid fraction of fattening pig slurry (Velthof, 2015, Ehlert & Hoeksma, 2011)

Agronomic aspects

Agronomic effectivity of mineral concentrates has been tested under controlled conditions in pot experiments and in field experiments on arable land and grassland. Potassium is equally effective as mineral potassium fertilisers. The nitrogen fertiliser replacement values (NFRV) are given in Table 2 below.

Experiment	Range
Pot experiment grass	86 - 96[a]
Pot experiment Swiss chard	87[a]
Field experiment arable land, potato	75 - 84[a]
Field experiment arable land, silage maize	72 - 84[a]
Field experiment grassland	54 - 81[a]
	79 -102[b]

Table 2. Nitrogen fertiliser replacement values[1] of placed or injected mineral concentrates (MC) compared with chemical reference fertilisers calcium ammonium nitrate (a) or liquid ammonium nitrate (b) in percent (%) compiled from several publications.

[1] Nitrogen Fertiliser Replacement Value (NFRV, %):

$$NFRV = \frac{((\text{crop N uptake}_{mc} - \text{crop N uptake}_{control})/\text{total N applied}_{MC}) *100}{((\text{crop N uptake}_{reference} - \text{crop N uptake}_{control})/\text{total N applied}_{reference}}$$

The fertiliser value of the reference chemical fertiliser is set at 100% although this does not mean that chemical fertilisers are 100% effective. To prevent ammonia volatilisation, mineral concentrates require shallow placement or need to be injected into the soil.

The lower values of NFRV, shown in Table 2, coincide with the earliest experiences with mineral concentrates. The higher values are based on more recent data. This points on a learning process of the production method and successful efforts to increase mineral nitrogen contents. NRFV depends on the used chemical fertiliser as reference. Under controlled conditions (pot experiments) mineral concentrates are only slightly lower compared to calcium ammonium nitrate (NFRV is approaching a full replacement value of 100%). In the field trials however, NFRV values were more variable presumably due to atmospheric losses. More research is needed on the effect of the application techniques on N uptake efficiency.

Environmental aspects

The environmental performance of mineral concentrates was tested by looking at their effect on nitrate accumulation in soil, nitrate accumulation in groundwater, ammonia volatilisation and emission of greenhouse gasses.

There is no evidence that mineral concentrates increase nitrate concentration in groundwater. In fact, relatively low nitrate values are measured in groundwater under fields fertilised with mineral concentrates compared with fields receiving Calcium Ammonium Nitrate (CAN) or manure (Figure 2). Similar results were found in another four-year field trial where no significant differences in nitrate concentrations in soil of fields treated width mineral concentrates, manure or CAN were found (Figure 3).

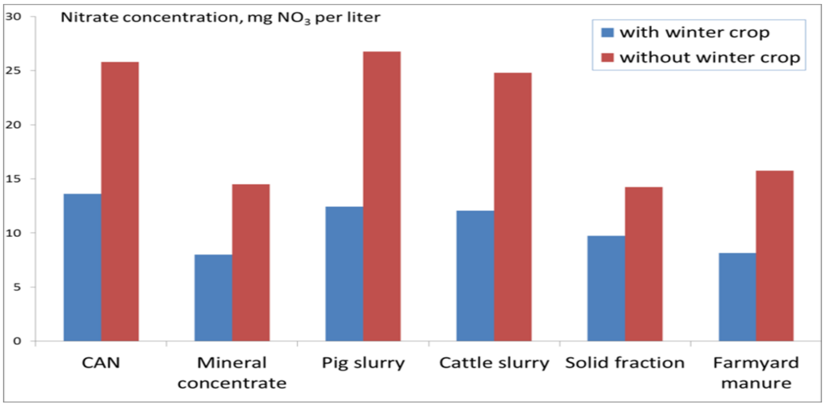

Figure 2. Average nitrate concentration (mg NO_3-N/L) in upper groundwater in a field experiment with silage maize for different fertilising products with and without a winter crop (Schröder et al, 2012)

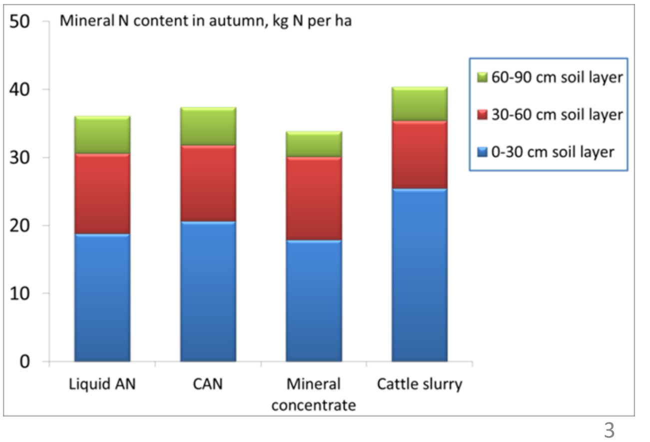

Figure 3. Average mineral N contents (0-90 cm soil layer) at the end of the season, grassland field experiments in the period 2009 (Holshof and Middelkoop, 2017).

Incorporation into the soil prevents ammonia volatilisation but enhances emission of the greenhouse gas N_2O due to de-nitrification (Figure 4). The level of N_2O emissions are between the levels of CAN (low) and urea (high).

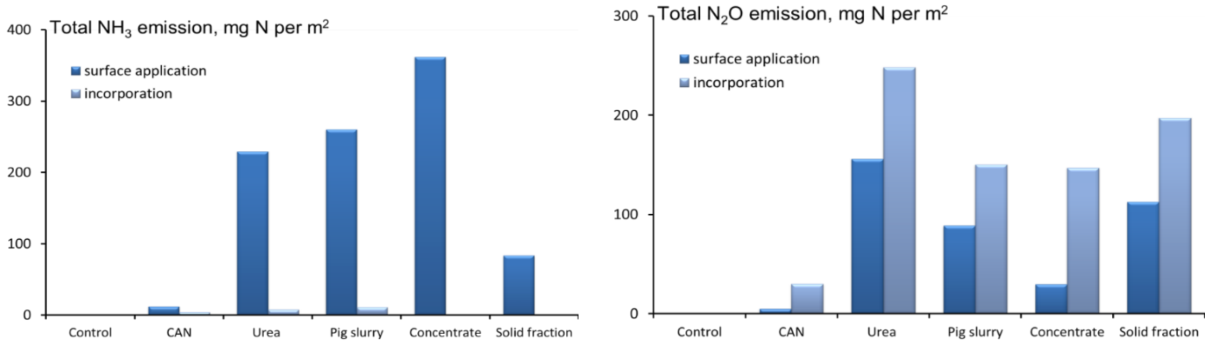

Figure 4. Average NH_3 (left) and N_2O (right) emission in a laboratory study with arable soil from calcium ammonium nitrate (CAN), urea, pig slurry, mineral concentrate (concentrate) and solid fraction. Fertilising products were surface applied or incorporated into the soil. Fluxes of NH_3 and N_2O were determined during incubation of one month, using a photo-acoustic gas monitor (Velthof and Hummelink, 2011).

Current legal view on ammonium sulfate

Mineral concentrates showed under controlled conditions (e.g. pot experiment) a nearly similar agronomic effectivity as CAN but its effectivity is somewhat lower under field conditions. There is no evidence that mineral concentrates lead to a higher risk of accumulation of nitrate in soil or groundwater. Nonetheless, under field conditions attention has to be paid to the method of application. To prevent ammonia volatilisation, mineral concentrates need to be incorporated into the soil. N2O emission caused by mineral concentrates are higher compared to CAN but lower when compared with the chemical fertiliser urea.

Overall agronomic and environmental performances of mineral concentrates is in line with chemical nitrogen fertilisers. Overall, N use efficiency of MC is only slightly lower than of CAN and similar to that of LAN under the condition that MC has been injected or acidified to reduce ammonia volatilisation. The technique of placement of a mineral concentrate requires fine tuning.

Main references

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