Annex 4 - State of play of the pilot plant in Arborea – IT at 31 July 2022

Subject: Innovative ammonia stripping plant for fertiliser extraction from animals sludges and nitrate on groundwater reduction

The stripping pilot plant start-up has been on July 2021 and until the 31 of December 2021 were produced the first 1000 litres of the sulphate of ammonium (fertilizer) from Arborea sludges.
From 1 January until 31 July 2022, were produced a further 2000 litres of ammonium sulphate, and until today the pilot plant continues to operate.

First 1000 litres of ammonium sulphate

Moreover were carried out analysis of the wastewater samples in and out the plant and analysis of the ammonium sulphate sample during the different phases of the process.
The cooperative of Arborea and the Livegreen company both stakeholders of the project, are involved on the activity of experimentation on the cultivations in the period of analysis.
With regard to the plant, we can say that production is going it requires continuous adjustments, given the type of product, the digestate, which is not always constant beyond the surrounding chemical-physical conditions. The technicians are always busy in the field and thanks to the contract consultant it is possible to detect problems in real time. Please note that this is the only case in Italy and Europe that treats livestock waste by semipermeables membranes and all the problems that have emerged will be needed to build an industrial plant in the future in full line with the circular economy, also facilitating energy savings and spending on fertilizers and feed.
Thanks to the experience in progress, the Cooperative is strongly motivated to produce its own fertilizer once the system has been developed. For the MEDISS project it certainly represents an important success.

Process analysis on plant

The experimental activity aims to verify the potential of the membrane gas extraction technique for the recovery of high-purity concentrated ammonia solution from the centrate of an anaerobic digester for the treatment of manure produced in the plain of Arborea (Italy). The plain is a very extended area devoted to intensive cattle farming and agricultural activities and represents an excellence in the Sardinian agro-livestock system. Due to the intensive agricultural practices the plain of Arborea is a Nitrate Vulnerable Zone.

The chemical-physical quality of the digestate, analyzed during the experimentation, showed a high content of ammonia nitrogen present in the digestate compatible with the stripping removal technique. The results of the digestate analyzes are shown below:

parameters	unit	Value
pH	pH units	7,64
Total Suspended Solids	g/L	32,10
N-NH4+	**mg/L**	**1.899**
N-Organic	**mg/L**	**1.351**
Ca++	mg/L	993
Mg++	mg/L	355
k+	mg/L	1.605
Na+	mg/L	773
PO4--	mg/L	987
Cl-	mg/L	1.684
SO4--	mg/L	181
Dry residual (105°C)	%TS	3,21
fixed Residual (550 °C)	%TVS	12,80
Volatile Suspended Solids	g/L	19,30
COD	mg/L	30.493
Conductivity	mS/cm	17,65
TDS	g/L	9,44
Total Nitrogen	**mg/L**	**3.281**
Total P	mg/L	414
Total Alcalinity	mg/L	
Bicarbonates	mg/L	
NO3--	mg/L	
NO2--	mg/L	
Dry residual (180°C)	mg/L	
Total Hardness	°F	

The analyzes show that about 42% of the nitrogen present in the digestate is found in ammonia form. This is the nitrogen fraction that can be eliminated through the stripping pilot plant.

The principle of the technique is to apply a difference in vapour pressure for ammonia over a hydrophobic gas permeable membrane to transfer gaseous ammonia from the feed digestate solution into a stripping solution in order to produce concentrated ammonium sulphate which can be used as a fertilizer. The pilot

plant is equipped with a pre-treatment unit that hold back particle size greater than 50 µm followed by six membrane modules with a total flow capacity of about 450 - 750 L/h. The treatment follows a batch type scheme. Each cycle, about 250 liters of digestate, rich in ammonia (about 1'800 mg/L of total ammoniacal nitrogen), is brought into caustic feed that crosses the membrane modules where an acid stripping solution of about 60 liter provides to strip the ammonia and to convert it in ammonium sulphate solution (NH4)2SO4 that continually enriches in the stripping side as digestate feed rich in ammonia is replaced.

The following table summarizes the **amount of ammoniacal nitrogen that can be removed from the digestate** through the pilot plant at the end of **each experimental cycle**.

PLANT AMMONIA REMOVAL EFFICIENCY	
92%	
Ammonia recovery for each cycle	412.500mg NH4

The results showed that about 92% of ammonium content in the digestate solution could be transferred to the acid stripping solution.

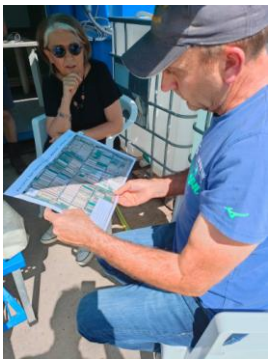
After several enriching cycles,N-NH_4 fraction has been recovered as ammonium Sulphate fertilizer that has been stocked and reused in controlled way. In the 2022 the plant has recovered about 40 Kg NH_4 , stocked in 2'000 liter of ammonium sulphate solution of 8% in $(NH_4)_2S0_4$ (20'000 mgNH_4/L).

The residual total ammoniacal nitrogen, 142 mg/L of total ammoniacal nitrogen, confirms the suitability of the treatment and that this stripping process is an excellent technology to recover ammonia from the digested livestock waste and can contribute to reduce the impact of agricultural activity on the environment.

Use of the fertilizer on site

With the first 1000 liters produced on 2021 at medium concentration, the fields cultivated with oats (forage for breeding) were irrigated and used on an area of about 20 ha as an example to test the reaction and absorption capacity of the soil. Frequent rains have not always facilitated the spreading of fertilizer, which must also be dispensed according to the vegetational cycles. The first results were good and the growth of the plant was well monitored (see next figures).





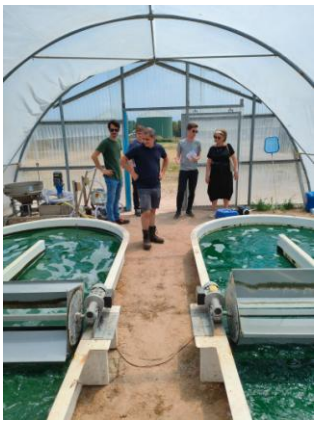
Spreading fertilizer on the oat field and meeting with Enas and Cooperative agronomist during the meeting about the fertilizer behaviour on field-crop

After this first experimental test, as for the field experimentation, three irrigated plots (one more respect to the project) located two in the installation area of the piezometers 1 and 2 (see figures) and one close to the treatment plant are tested by the fertilizer. The area is cultivated by corn and oats and the fertlizer applications starts on May according with the cycle of vegetation considered.

Fertilizer Test on greenhouse – Spirulina algae.

At the same time, has been a very important experimentation on the use of ammonium sulphate produced on the cultivation of spirulina algae in greenhouses, an internationally known reality hosted in the Arborea cooperative, was started and still continues.

The results of the experimentation carried out from April to July (annex1 1 of the 3 Interim report) show satisfactory results and suggest in the future important repercussions on the territory given the multiple uses of the seaweed both in the food sector (also used in third countries such as Africa for the important load energetic), aesthetic, medicinal.

The use of fertilizer on spirilina alga cultivation in green-house by Live-green company

A letter of intent was signed to activate the collaboration between the LifeGreen and Mediss project like stakeholders.

According to the results obtained in the preliminary laboratory tests using ammonium sulphate produced from the digestate by MEDISS project, a first test was performed in two mini-tanks for the cultivation of Spirulina.

The purpose of the experimentation is to evaluate the growth of Spirulina with ammonium sulphate in an environment that simulates the environmental conditions of growth, so as to be able to hypothesize a scaled-up process for feeding the entire production plant of Livegreen (Project SpiralG).

The experimentation was carried out starting to April 2022 using two long tanks 10 m and 2 m wide for a total photosynthetic activity surface of 18.5 m2. The depth of the culture was set at 15 cm.

The sampled product for our study is ammonium sulphate with a nitrogen concentration of 6 g L-1 N-NH4 + and a pH of 2 (the acid product is particularly appreciated by algae). The sample are derived for the first 1000 litres of plant production.

The results of this study (that has been better described in the extended report) showed that ammonium sulfate can be used in such a way efficient as a nitrogen source in industrial Spirulina cultivation. I'm underway and in it schedules further tests in the production plant in order to clearly evaluate fertilization long-term with ammonium sulphate produced from locally recovered digestate.