Desktop study for performance potential of N2 Applied plasma unit for Tywi Farm Nutrient Partnership

This report has been created to demonstrate the expected effects of implementation of a N2 Applied mk4.5 plasma unit at the Gelli Aur Farm site as part of the Tywi Farm Nutrient Partnership. Here is set out a brief description of the N2 plasma technology, analysis and assessment of the various substrates available from the slurry and existing treatment processes in the project, a treatment estimation based on chemical analysis of these substrates, and a plan for the practical implementation of the N2 unit on-farm.

The N2 Applied plasma technology

N2 Applied have developed a novel plasma technology which fixes nitrogen (N) from the air and absorbs it into livestock slurry, increasing the fertiliser N content, reducing ammonia (NH_3) loss, and preventing methane (CH_4) formation from the slurry. The technology operates solely on electricity which it uses to ionise a flow of air, splitting the nitrogen and oxygen molecules therein, and generating a reactive nitrogen gas. The gas is then absorbed directly in the liquid phase of the livestock manure. Consequently, the manure is enriched with nitrate (NO_3) and its pH is lowered. This stabilises the ammonium in the manure, preventing its loss as NH_3, whilst also providing conditions which inhibit the formation of CH_4. The resultant substrate is then called a Nitrogen Enriched organic (NEO) fertiliser. A diagram demonstrating a simplified version of the N2 plasma process is shown in Figure 1.

Various research projects and field trials have been conducted and have shown up to 95% reduction of NH_3 loss in storage, up to 91% of NH_3 reduction on field application, and >99% control of CH_4 emissions in storage. The preservation of this NH_3-N and CH_4-C in the slurry allows for the return of these nutrients to soils. Additionally, the addition of renewably produced NO_3-N from the plasma process means a virtuous cycle can be created locally on-farm, supporting soil organic processes and crop growth, and reducing the carbon footprint of agriculture. This carbon footprint reduction comes from the offset of Haber-Bosch produced nitrogen fertiliser, a reduction in indirect nitrous oxide emissions from ammonia loss, and direct elimination of CH_4 emissions from slurry storage.

As part of this project with Coleg Sir Gar at Gelli Aur Farm N2 Applied seek to further validate the results previously gathered and to demonstrate the implementation and impact on a working Welsh dairy farm. Additionally, incorporating the N2 technology into the existing project infrastructure and working with the other partners and solutions involved presents a fantastic opportunity to expand our knowledge. Both of the chemical processes involved in the treatment of various substrates and in the practical implementation of the N2 technology alongside other complementary technologies on a working dairy farm.

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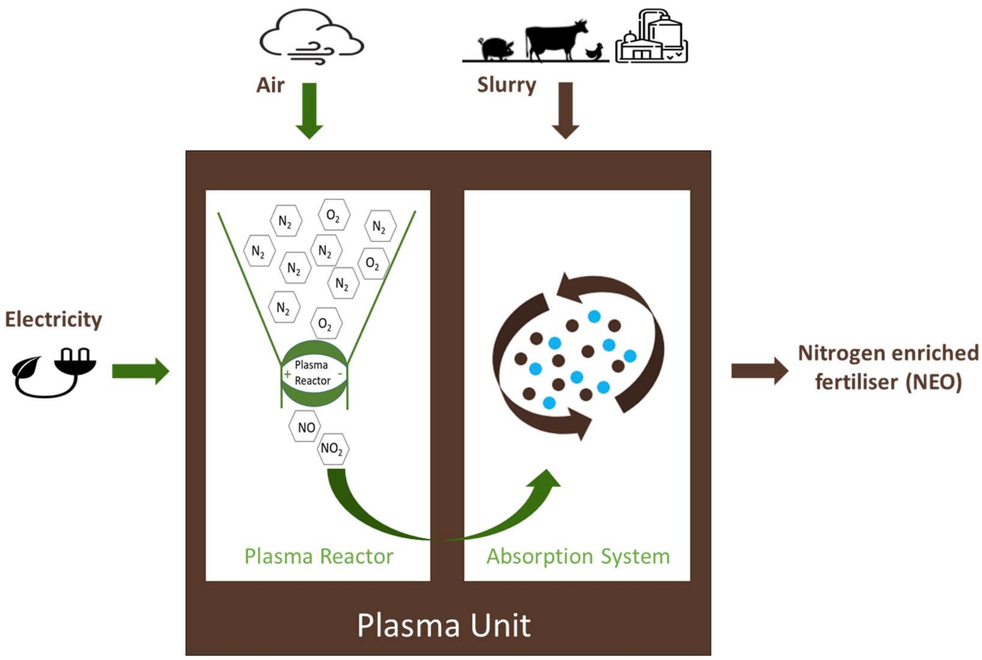

Figure 1 - A simplified diagram showing the two-stage process of the N2 Plasma Unit. In the first stage, air is passed through an electric plasma arc to generate NOx gas. In the second stage, this gas is then absorbed into the slurry to provide the treatment effect resulting in NEO fertiliser.

Chemical analysis of Gelli Aur substrates

During a site visit on 10th August 2021 one sample each was taken from several points in the existing treatment setup at the farm, including separated slurry, diluted slurry from the storage tower, slurry which had undergone chemical separation, and surface sludge from the Dissolved Air Flotation (DAF) process. A diagram demonstrating the layout of the existing treatment setup is shown in Figure 2.

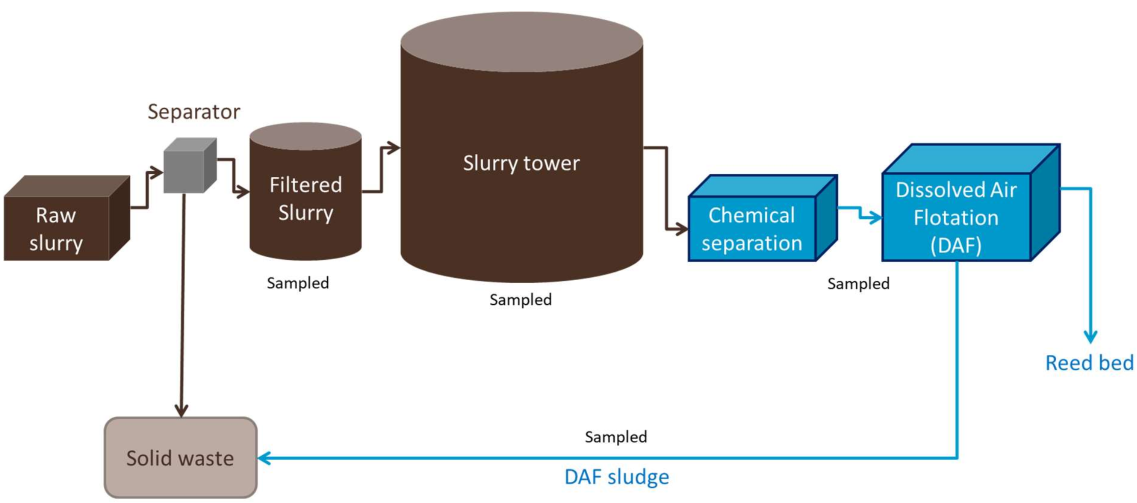

Figure 2 - Gelli Aur Farm existing treatment setup. Points sampled for analysis are indicated.

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Collected samples were sent to NRM laboratories for chemical analysis with the results included in Table 1. The results show interesting effects during progress through the treatment system. The raw slurry loses approximately 25% dry matter, but all soluble nutrients remain roughly at the same levels. Of particular interest to the N2 system is the total N and ammonium N which show minimal change from raw to separated but are relatively low compared to other dairy slurries which have been analysed by N2 Applied. The P and K are at similar levels to other slurries, with moderate P content to satisfy crop requirement upon land application, and high K content.

Between separation and storage in the tower the slurry is diluted with washing water, and this is evident in the lowering of all chemical and physical factors by around a factor of 4 in the tower from separation, though nutrient levels remain proportional. After chemical separation most of the P is stripped from the solution, as are several other nutrients, and half of the total N is lost, but ammonium-N levels remain fairly stable by comparison. K also remains at a relatively stable level. Post-DAF sludge shows a proportionally high level of many of the remaining nutrients, indicating they are removed from the resultant water from the DAF, but these levels may be concentrated up. However, these samples were taken as an indication of the best place for implementation of the N2 treatment, and no conclusions about the performance of the existing system can be drawn.

Table 1 - Chemical analysis of samples taken at different points in the Gelli Aur treatment process. Analysis provided by NRM laboratories.

Laboratory Reference		SLUR111978	SLUR111979	SLUR111980	SLUR111982	SLUR111981
Sample Reference		CSG RAW	CSG SEP	CSG TOWER	CSG PRE DAF	CSG DAF SLUDGE
Determinand	Unit	LIQUID WASTE	LIQUID WASTE	LIQUID WASTE	LIQUID WASTE	LIQUID WASTE
Oven Dry Solids	%	5.63	4.21	1.07	0.380	0.370
Total Kjeldahl Nitrogen	% w/w	0.20	0.19	0.04	0.02	0.02
Nitrate Nitrogen	mg/kg	<10	<10	<10	<10	<10
Ammonium Nitrogen	mg/kg	941	1005	249	186	123
Total Phosphorus (P)	mg/kg	354	340	101	<5	<5
Total Potassium (K)	mg/kg	2760	2744	702	629	423
Total Magnesium (Mg)	mg/kg	440	423	103	83.4	61.5
Total Copper (Cu)	mg/kg	1.96	1.85	0.62	<0.2	<0.2
Total Zinc (Zn)	mg/kg	14.4	9.70	3.08	<0.5	<0.5
Total Sulphur (S)	mg/kg	304	278	65.4	20.8	19.6
Total Calcium (Ca)	mg/kg	973	859	312	225	178
Nitrite Nitrogen	mg/kg	<1	<1	<1	<1	<1
Total Sodium (Na)	mg/kg	279	271	105	99.8	266
pH 1:6 [Fresh]		7.52	7.57	7.18	7.34	7.04

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N2 estimated treatment effects

Using the analysis of the separated slurry it is possible to conduct a treatment estimation of the effects of the N2 unit and the resultant NEO fertiliser. The N2 plasma treatment process adds crop available N to the slurry in the form of nitrate and nitrite, whilst also eliminated methane loss and lowering the pH. The lower pH prevents ammonia loss, meaning more of the ammonium-N is retained in the digestate both in storage and on field application. Usually around 50% of the ammonium-N can be lost before reaching the crop. The estimated total and crop available N increases are detailed in Table 2 and Figure 6 below. These are based on an average of empirical data from our database of previously treated samples.

Table 2 – Predicted changes in total and crop available nitrogen in Gelli Aur Farm slurry after N2 treatment.

	From analysis	Estimated after treatment	Increase in N
Total N	1.90kg N/tonne	3.37 kg N/tonne	+ 77%
Plant available N	1.01 kg N/tonne	2.47 kg N/tonne	+ 145%

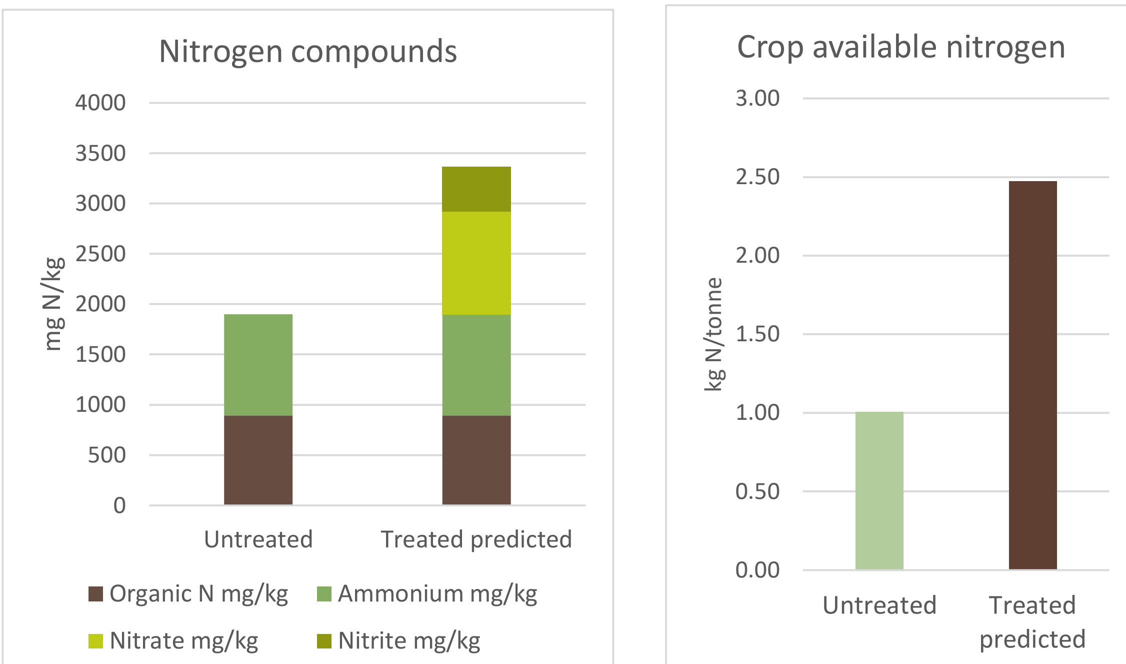

Figure 3 - Graphs displaying expected treatment effects on nitrogen content of slurry from Gelli Aur Farm.

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As can be observed in Table 2 and Figure 6 the proportion of available N in the slurry would be greatly increased upon treatment through additional nitrate and nitrate. The organic N content of the digestate will remain unchanged, and all other nutrients such as P, K, Mg, S etc. will also remain at the same quantities. This means that the soil conditioning effects of the slurry are still present, but with a higher N dose per unit volume application, and no ammonia loss.

N2 unit implementation

Based on the analysis results there are several different options for implementation of the N2 unit on-farm for treatment of the different substrates. These are detailed below. As part of this project, we will seek to further explore and test these ideas.

Separated slurry

Based on the analysis results presented in Table 1, the most optimal substrate for treatment with the N2 Applied plasma system appears to be slurry directly after mechanical separation. At this point there is a high level of ammonium content in the slurry to allow for absorption and enrichment with nitrate, and to provide the maximum benefits in terms of ammonia and methane reduction. The N2 unit also requires separation of the solids before treatment, so this stage is the simplest to implement. However, treating the slurry at this stage, though providing a good option for the N2 system in isolation, may not allow for full integration with the other technologies. This is due to part of the following process requiring the pH to be raised. Raising the pH would likely undo the treatment process of the N2 unit, favouring the formation of ammonia gas and possibly leading to loss of the added nitrate. NEO could therefore not be fed into the beginning of the existing treatment process but could find use as a side stream of production for direct field application. This layout is demonstrated in Figure 3 below.

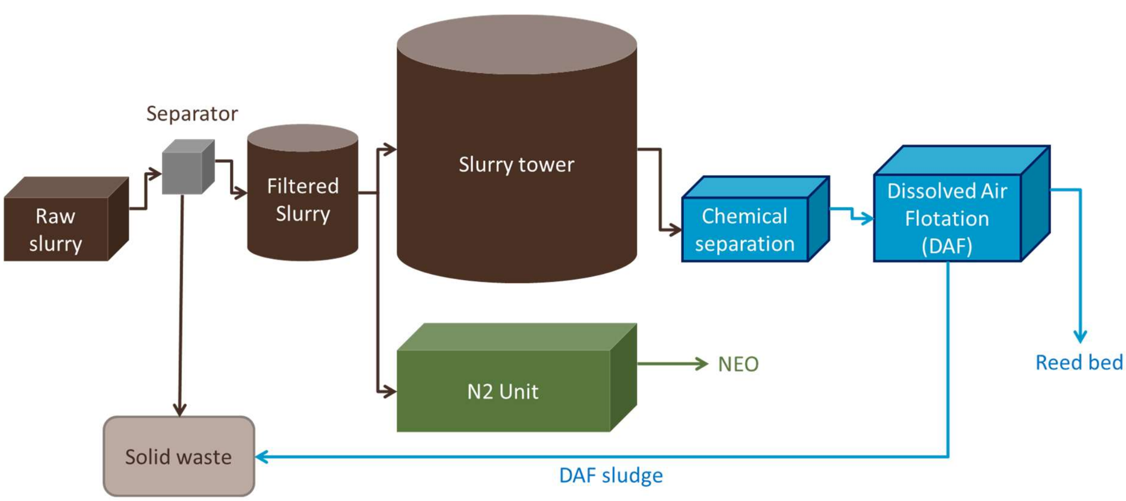

Figure 4 - Implementing the N2 unit as a side stream of production to generate NEO fertiliser for direct field application.

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DAF sludge

An alternative treatment option could be to treat the DAF sludge. This contains some ammonium to allow for absorption capacity but is lower than slurry and so would likely treat very quickly. The N2 unit should be able to handle very high volumes of this liquid sludge. The current use of this sludge is to be applied to the separated solids from the slurry to enhance its fertiliser value. This route could still be utilised and enhanced by the N2 treatment, increasing the N content of the solids with additional nitrate, and making it a more valuable fertiliser product.

In terms of practical implementation, if the DAF sludge could be stored in small volumes of >1m^3 it might allow for periodic treatment of the sludge as a side stream alongside treatment of the separated slurry. This could allow for upgrade of part of the slurry stream as NEO fertiliser whilst allowing the rest the be treated to dischargeable water, as well as enhancing the value of the solids. This would also increase the output volume of both systems, as there would be two separate streams of production each running at full capacity if needed. This setup would mitigate any high influxes of slurry or washing water/rainwater or could allow for expansion of the number of cows that the combined system could handle. A demonstration of this setup is shown below in Figure 4.

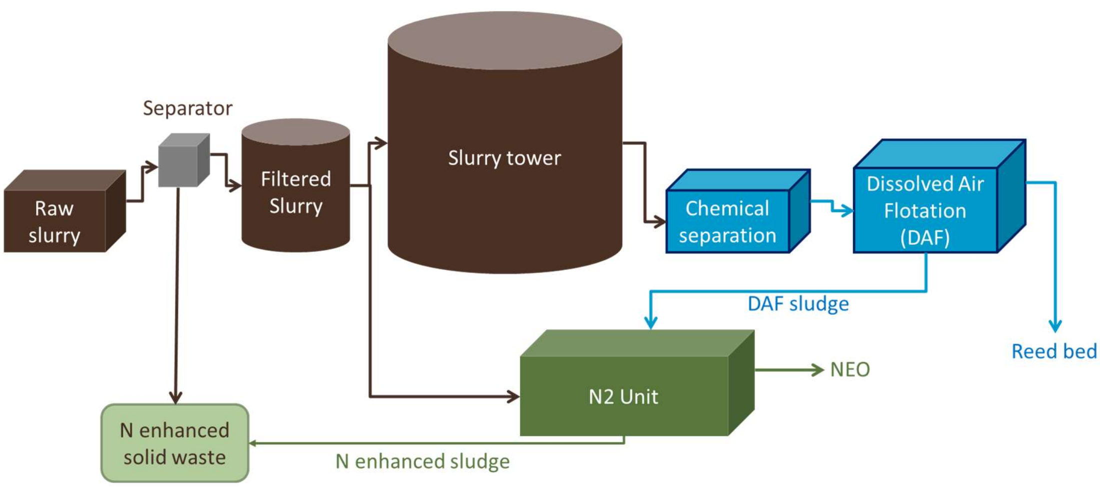

Figure 5 - NEO as a side stream of production and used to treat the DAF sludge for application to the separated solids.

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Pre-DAF

Another alternative implementation of the N2 unit could be to treat liquid post-chemical separation and before entering the DAF. There is a low ammonium content present in the pre-DAF liquid that should offer some treatment capacity. If the dilution effect from the slurry tower was removed and the ammonium content remains high this could provide a good medium for nitrate absorption. The uncertainty here is whether the nitrate is then separated out with the DAF sludge or, more likely, that it remains in solution. This could cause a problem with achieving discharge standard for the water, as nitrate which remains in solution is considered a pollutant if it finds its way into waterways. However, a water with nitrate content could provide an excellent option for fertigation if utilised alongside the Netafim irrigation as part of this project. The implementation has the most questions associated with it and will require further investigation. A demonstration of this setup is detailed in Figure 5 below.

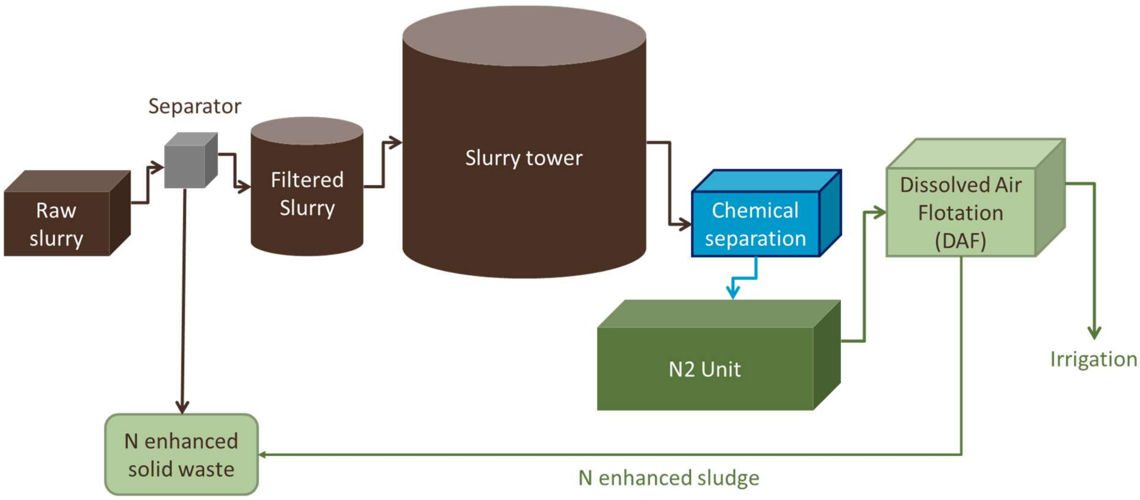

Figure 6 - N2 unit implemented to treat liquid post-chemical separation and pre-DAF.

Conclusion

I hope this report provides some interesting information and insight into the N2 Applied technology and its potential and planned implementation as part of the Tywi Nutrient Partnership project at Gelli Aur Farm. As further work is carried out and more information is gathered we look forward to providing updated results and moving forward with the practical implementation on the farm site.

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