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Tywi Farm Nutrient Partnership: Interim report concluding 2021

Executive Summary

Recent innovations in dewatering technologies now increases suitability for the agriculture sector. The separation of liquid and solid from dairy slurry is demonstrated to reduce bulk volume, alleviating the pressure on farm storage capacity. Alongside successive wastewater treatment, we have seen overall removal rates of ~95% Nitrogen (N), 99.9% of Phosphate (P) and ~80% Potassium (K), in the separation of dilute slurry (typically 1% total solids). Capturing these nutrients presents an opportunity for potential cost-savings by reducing the need for artificial fertilisers. Importantly, this also helps farmers in Wales to show compliance with recent legislation changes, in addition to preventing environmental pollution (particularly from excess runoff). Further investigation will now incorporate more industry-leading technologies (such as N enhancement, an advanced oxidation process, and precision application techniques) whilst utilising raw dairy slurry.

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Introduction

Agricultural slurry is a valuable organic manure, concentrated in nutrients essential to plant growth and organic matter which can improve soil health. Effective slurry utilisation has repeatedly been shown to improve overall soil fertility across multiple settings, whilst producing yields equal to (or better) than those gained from NPK compound and standalone N fertilisers [1,2]. Nevertheless, farmers can be left with surplus slurry due to intensive systems of livestock production; land-use changes limiting the acreage suitable for spreading; and the introduction of new regulation such as Nitrate Vulnerable Zones in Wales which will outright prohibit traditional spreading between 15th October and 15th January, depending on soil/field type [3]. Across the UK, the dairy industry is the single largest producer of slurry and is demonstrated by the ~7.8 metric tonnes produced per farm each day, considering an average herd size of 148 and 53kg of excreta per milking cow [4]. Overall, there is growing need for technologies which help alleviate pressure placed on farm storage, support effective nutrient management, and mitigate the environment impacts associated with traditional storage and spreading.

Dewatering has been shown to reduce bulk slurry volume and the demand for costly artificial fertilisers, and prevent pollution through reduced nutrient leaching, agricultural runoff and atmospheric losses that are known to contribute to Climate Change [5]. A sector-wide review [6] indicated that dewatering is becoming increasingly popular within intensive indoor systems of dairy and beef production. Essentially, it is the process of separating liquids from solids, producing a liquid fraction which can undergo wastewater treatment or be used in irrigation/fertigation, and a solid fraction which can be used as a stable and stackable fertiliser that is higher in dry matter and more nutrient-dense than raw slurry. Previous cost benefit analysis has shown that operation and expenditure costs can be set against potential savings by reducing the need to purchase artificial fertilisers – estimated to be in the region of £8,454 per annum [7]. An additional saving of £7,694 per annum (as calculated for a 100-cow farm) may also be attributed to reduced water usage and spreading costs associated with diesel and labour/contractors. However, these figures are expected to be much higher given the current issues with the supply chain and energy price hikes which increase the overall production costs of artificial fertilisers.

Site Overview & Recent Developments

Based at the Agriculture Research Centre at Gelli Aur farm (Coleg Sir Gâr), the Tywi Farm Nutrient Partnership is a research collaboration between Welsh and internationally based organisations, each bringing their unique set of skills and industry-leading expertise. As the first further education institution in Wales to receive funding from the European Regional Development Fund SMART Expertise 2014-2020, our connection with N2-Applied, Power & Water, Netafim, GEA, Natural Resource Wales (NRW), Dŵr Cymru, Honesty foods, and Aquatreat, is unique by the fact we are working towards one common goal. This is to create a tried-and-tested nutrient management package through maximising the efficiency of a modular dewatering system and successive wastewater treatment, alongside the integration of precision farming techniques. As demonstrated by the process flow diagram found below (Figure 1), raw slurry is initially fed through a screw press to remove the bulk of the coarse solids (which are taken to solid store) and the remaining liquid (filtrate) held in a storage tank. The filtrate is then pumped into the reaction tank where the coagulation-flocculation process takes place, binding suspended and dissolved solids together through chemical addition. A decanter centrifuge finally removes these solids through centrifugal force (again, these are taken to solid store), and the remaining liquid is sent to a dissolve air flotation (DAF) unit for polishing. After, the liquid can either be delivered via the drip irrigation system, used to washdown the yard, or sent to the reedbed where the residual contaminants are removed by natural processes.

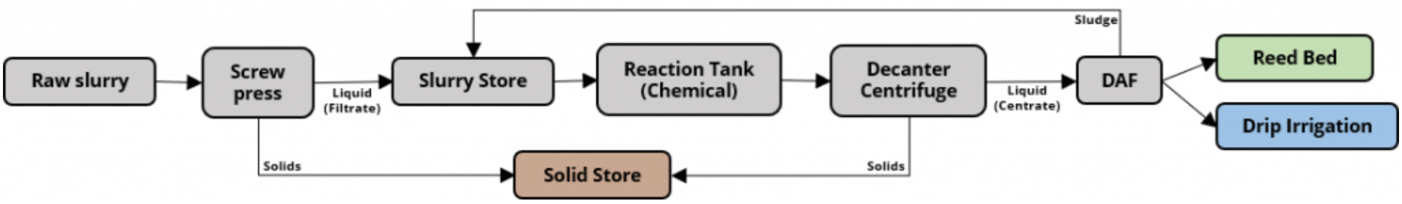

Figure 1. Flow diagram of the dewatering process. Up until now, filtrate in the storage tank has been diluted with rainwater after it has been used washing down the yard/parlour. In future, filtrate will not be diluted and will go straight to the reaction tank.

Since spring 2021, operations have primarily focused on developing the constructed wetland, refining the plant's infrastructure and chemical amendment process, alongside the installation of a pressure-compensated fertigation system (possibly the first kind in the UK within a grassland setting!). Widespread nutrient mapping and soil analysis has been conducted to enable the accurate application of the produced fractions using new variable rate equipment. Additionally, extensive water quality monitoring throughout each of the applied processes, in addition to the surrounding tributaries (to indicate potential environmental benefits), have been established, and the data from these are actively feeding into decision-making. Several dissemination events have been held with much interest received from farmers, industry leaders, researchers, and businesses alike, both nationally and internationally. Within the dewatering process, there are several key areas which required close attention to gain a deeper understanding and enable the development of economical, low-maintenance and efficient separation, that not only caters for the specific characteristics of the slurry but also considers ease of use by the end user.

Mechanical Separation

The screw press and decanter centrifuge are two common forms of mechanical separation, although the former is more frequently used within agricultural settings. Their separation efficiencies have been previously compared on several slurry types including cattle, pig, and anaerobic digestate, and ages thereof. However, this is the first research project where these machines have been applied in unison on dairy slurry. Agreeing with multiple studies, we have so far found the decanter centrifuge to have a higher separation potential for all measured determinants, and is capable of removing much smaller particles sizes [6, 8].

Thus far, trials have been conducted using dilute slurry (a blend of raw slurry and rainwater) as the feedstock which is typically under 1% total solids (TS) (see figure 2 and 3 for nutrient analysis). This meant that it has been difficult to run at higher flow rates due to the risk of 'blowing the plug' (which is formed by the solids in the machine) and spoiling the solid cake. Whilst this is thought to amend itself as we switch over to using feedstock higher in TS, several upgrades are in the pipeline to appropriately mitigate this issue.

Several concerns have been raised relating to the running costs and associated maintenance of these mechanical separators. It is important to remember that pressure such as the current global shortage of fertiliser (particularly phosphorous) may make on-farm nutrient recycling a necessity and, therefore, dewatering increasingly viable [9]. Additionally, dewatering can provide farmers with financial security and boost production sustainability – in light of soaring artificial fertiliser prices that threaten national food production (currently over £600/tonne, 207% increase from last year [10]), the nature of the supply chain, and pressure to focus upon circular systems of agriculture.

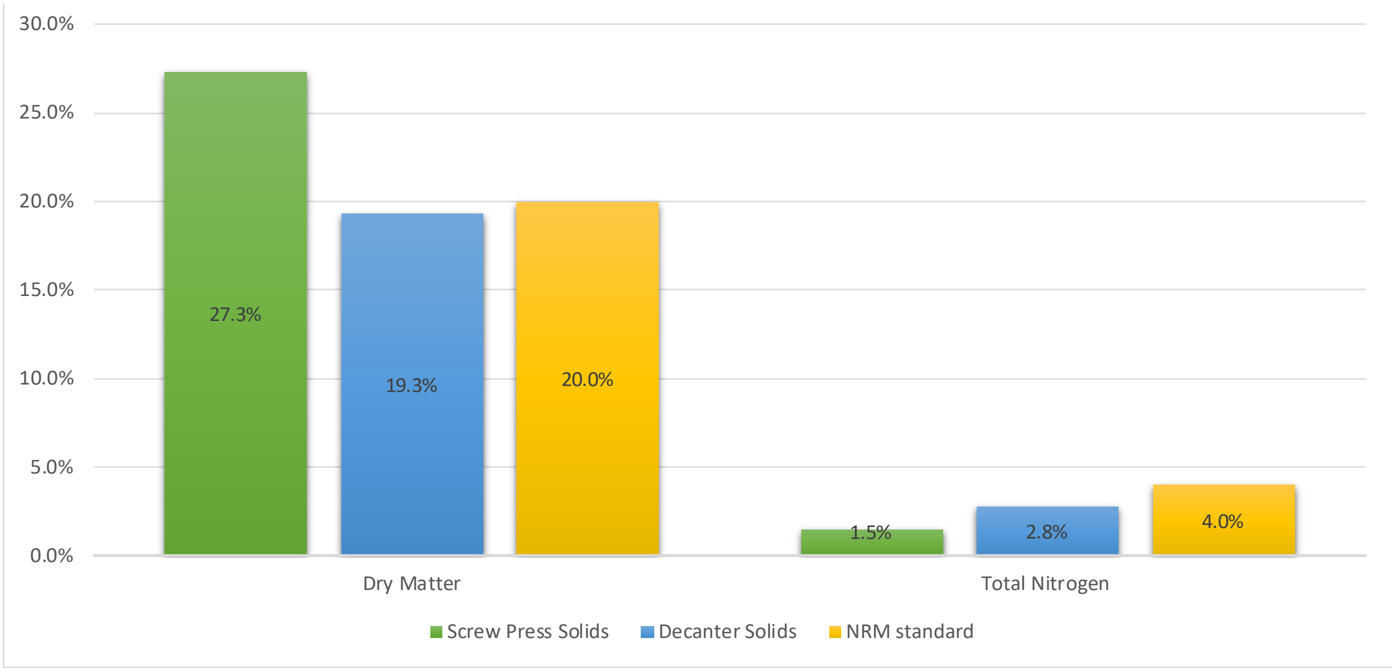

Figure 2. Comparison between solids obtained from the screw press and decanter centrifuge, with reference to benchmark data. Separately, screw press solids are much higher in DM content albeit lower in TN, possibly indicating that a substantial proportion of inorganic nitrogen is dissolved (and, therefore, chemical separation is needed). However, as these solids are mix together within the store, the combined TN content of 4.3% and DM is higher than the standard. Nutrient analysis undertaken by NRM laboratories.

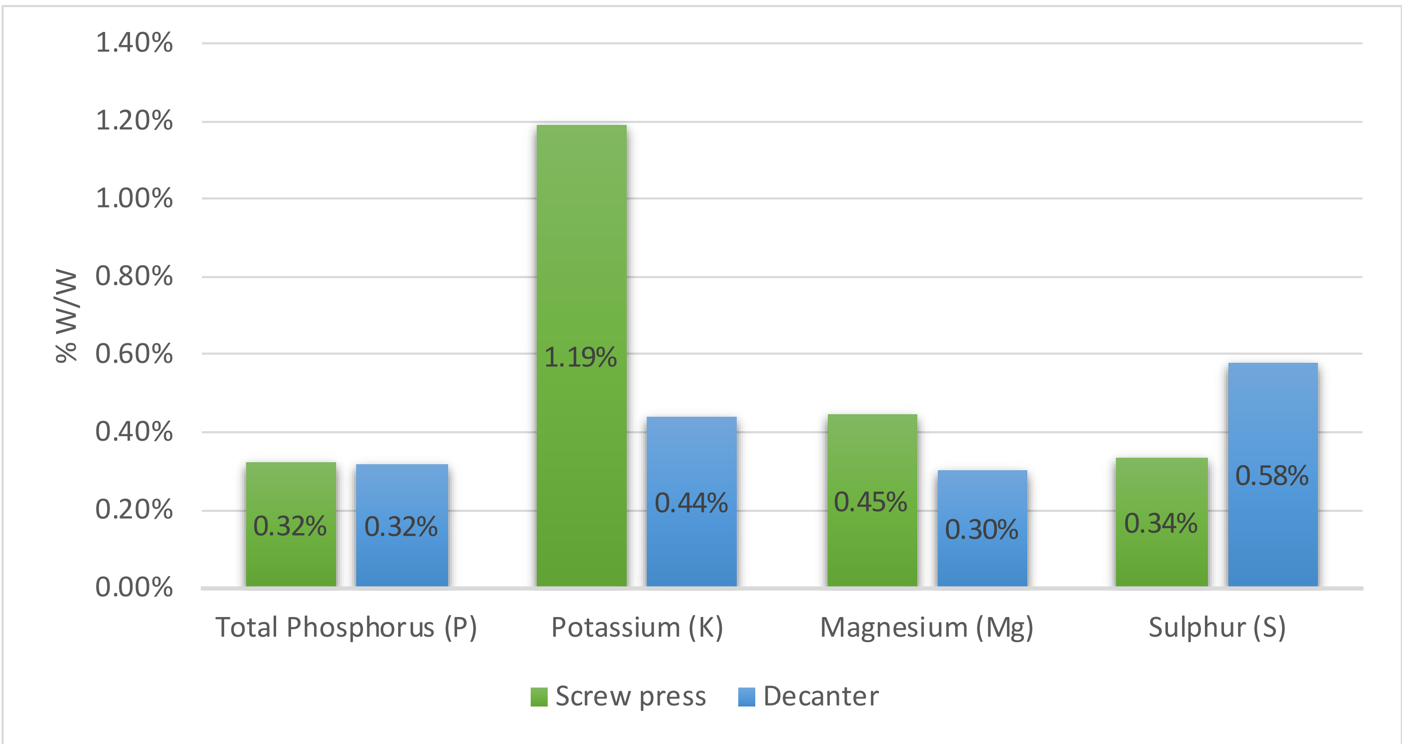

Figure 3. Comparison between several nutrient concentrations within the screw press and decanter centrifuge solids. The screw press is shown to obtain the bulk of these nutrients, nevertheless, the decanter (with chemical amendment) is more effective at removing P and S from the dilute slurry considering there is a lower concentration of these in the respective feedstock.

Chemical Separation

Coagulation-flocculation is extensively used as a pre-treatment before mechanical separation in industrial wastewater treatment [11]. It is used to control particulates (i.e., suspended/ dissolved solids, inorganic ions and heavy metals) by the inclusion of chemical coagulants and flocculants, in this instance polyaluminiumchloride and polyacrylamide, respectively. Initial trials at the plant also incorporated the use of ferric chloride; however, difficulties quickly arose when using this product with the DAF (sludge blockages) and the additional health and safety risks created through ecotoxicity and handling. Reliable floc formation has been a key challenge encounter when using the dilute feedstock. Observations taken throughout the plant and findings from jar testing support the notion that pH is an important but does not appear to be a standalone factor affecting the dewatering process. One potential explanation of poor/ inconsistent floc formation relates to the limited capacity to resist acidification (alkalinity) within a feedstock that is highly fluctuating. We found that the addition of polyaluminiumchloride can rapidly change the pH, beyond the optimal ranges for efficient charge neutralisation when using this coagulant. Additionally, when feed is taken from pockets of increased alkalinity, more chemical is required to destabilise the carbonate particles and achieve charge neutralisation. This indicates a stoichiometric relationship between chemical dosage and feedstock alkalinity, which is supported by previous findings made in the literature [12, 13]. By overcoming this challenge, dosing rates are now known for the treatment of dilute slurry, and provides a basis for a starting dose rate when switching over to slurry higher in TS. Nevertheless, trials using alternative chemical regimes are being undertaken with thought to environmental toxicity, cost, and potential risks when handled by the user.

Wastewater treatment

DAF units are primarily used in the treatment of sludge from industrial wastewater. The process works by dissolving air under pressure within water, so that, when that pressure is released, small micro bubbles are formed which come into contact with solid particles, sweeping them up to the surface where they form a sludge blanket. There are few instances where DAF units have been previously used in this setting [14], however, given the limited amount of data available, it was important to gradually increase the flow and solid loading to prevent ineffective nutrient capture. Removal rates indicate that this equipment is extremely crucial within the treatment process, and can be visibly noted in the turbidity (cloudiness) of the water (Figure 4). We are continuing to trial different ways to further incorporate the produced sludge back into the system for better separation and volume reduction, increasing overall nutrient capture efficiency.

Figure 4. Difference in turbidity – a comparison between the Decanter centrate (left), secondary chemical amendment within the DAF (middle) and DAF outlet (right).

Incorporating the aforementioned processes (both mechanical/chemical separation and DAF), regular analysis undertaken by laboratories at NRW have shown promising removal rate in a range of nutrients (Table 1)

Parameter	Removal %
Total Suspended Solids (TSS)	99.20
Total Nitrogen (TN)	94.80
Total Phosphate (TP)	99.94
Dissolved Phosphate (OP)	99.83
Total Potassium (K)	79.37
Total Aluminium	99.42

Table 1. Nutrient removal rates from dilute slurry store to DAF outlet.

Commissioned in late summer, our constructed wetland (reedbed) is an engineered system that uses natural ecological processes of plants and microorganisms (biofilm) to remove a number of pollutants (including pathogens, nutrients, and heavy metals) and reduce chemical oxygen demand (COD). They have been used in traditional farm management for decades, however, what makes this design different from a standard system is the inclusion of forced aeration (Figure 5).

Figure 5. Constructed wetland and the 'beehive' structures which house the aeration pumps that are said to increase the removal rate of COD and organic contaminants, allowing for a faster turnover.

A recent visit from NRW was held to discuss the feasibility of regulating such systems across multiple settings. While the reed bed is still in its infancy, removal rates are expected to increase as the reeds begin to colonise the surface of the gravel. Nevertheless, reductions in the measured parameters are currently seen across the board, particularly when considering COD and Aluminium (Table 2).

Parameter	Removal %
Chemical Oxygen Demand (COD)	96.47
Total Suspended Solids (TSS)	95.92
Total Nitrogen (TN)	90.27
Total Phosphate (TP)	94.36
Dissolved Phosphate (OP)	85.56
Total Potassium (K)	78.21
Total Aluminium	>97.69

Table 2. Provisional nutrient removal rates from DAF outlet to the reed bed outlet. NB: these values are expected to change ~180 days after switching to the raw dairy slurry, given the time it takes for effluent to percolate through the reed bed.

Further investment in water quality equipment now allows for rapid on-site nutrient analysis – the result of which informs same day decision-making, and complements result from the aforementioned analysis later received. Additionally, ongoing research and development for the incorporation of an advanced oxidation process (AOP) is being conducted with Power & Water. In practical terms, this would provide a similar function to the reed bed albeit with near-instant results. In theory, the process aims to break the chemical bonds of recalcitrant molecules by means of chemical oxidation into less harmful substances.

Nutrient application

Poor nutrient management and traditional methods of slurry spreading can cause a significant impact on the surrounding environment, predominantly through over-fertilisation, runoff/ leaching polluting water ways, and the emission of greenhouse gases. For example, the use of a ‘splash’ plate has been shown to result in ≤100% loss of the total ammonia content, impacting the climate and human health by reduced air quality [15]. This also poses a significant loss of nutrients and yield for the farmer. However, when combined with low-impact methods of slurry spreading, the high organic matter content of the produced solids is thought to regenerate soil health and increase soil carbon, preventing soil erosion and mitigating climate change. We hope to demonstrate several, sustainable ways for the eventual application of the concentrated solid and liquid fertilisers produced by the dewatering plant.

In October, Netafim led the installation of a drip irrigation system in a grazing field adjacent to the plant. This system will test the suitability of the liquid coming out of the DAF for fertigation by means of two different dripper technologies, both of which are pressure compensated to ensure no variation in flow. We hope to demonstrate its cost-effectiveness through reduced spreading/contractor costs. Additionally, this may also lead to less greenhouse gas emissions (specifically, ammonia and methane from nutrient volatilisation and carbon dioxide from spreading machinery), leading to better air quality and reducing the farms overall carbon footprint. A key principle of this technology relates to the efficient uptake of nutrients as the fertiliser is delivered directly to the plant root system, leading to less chance of run-off when compared to more traditional nutrient application. It is planned to be fully commissioned during early 2022 in preparation for the growing season. (Figure 6). Surface trials conducted over the course of several months have proved successful with no major blockages reported.

Figure 6. Installation of the drip irrigators and field overview

Additionally, nutrient mapping and soil analysis, conducted by Map of Ag, has provided an overview of the soil nutrient stocks here at the farm. This will ensure the delivery of the right amount of fertiliser, particularly in areas of nutrient deficiencies and also areas of nutrient surplus where additional savings can be made. Over the long term, this will also show how the applied dewatered solids effect carbon stocks within soil. In order to utilise this data, software linking our variable rate application muck/slurry spreaders is set to be installed on our tractors in time for the ending of the closed period.

Conclusion

Dairy slurry and subsequent wastewaters are complex colloidal systems made up of water, organic matter, nutrients, undigested feed, bedding and other suspended particles, continually variable by season, weather, and farm management practices. So far, the dewatering system illustrated above has proven successful in the treatment of dilute slurry, and during its reception to industry and visiting public, most, if not all, have been quietly impressed. Costs incurred through the implementation and maintenance of the described technologies may on the surface seem expensive. However, the tightening of legislation Water-resources-control-agricultural-pollutionwales-regulations-2021 (NVZ in Wales) and present economic factors (such as inflated fertiliser costs) will make it a worthwhile solution for some dairy farmers now, but many more in the near future.

It goes without saying, continued pressure created by the pandemic and Brexit has led to several setbacks – mainly relating to the ability to replace faulty equipment, especially when sourcing from overseas. Despite this, the plant remained functional since the beginning of the project, and we are ready for a tight-schedule of testing planned throughout 2022. As we move away from dilute slurry, one key challenge is the ability to match the flow rate with the volume of slurry produced by large-scale dairy farms, at the same time as producing a liquid suitable for fertigation. Forthcoming works include the installation of a nitrogen fixing unit, made by N2 – Applied, which will increase the N content of slurry whilst reducing atmospheric losses during storage; commissioning of the fertigation system by Netafim; and conducting field trials using the produced solids to investigate any effect on plant growth.

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If you would like to find out more, or wish to get involved with the project, please feel free to contact us via https://arc-csg.cymru/ or call 01554 748 570.

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PARTNERIAETH MAETHOLION FFERM TYWI

Mae’r prosiect yma wedi ei sefydlu ar lwyddiant datblygu proses dad-ddyfrio Prosiectslyri. Mae’r canlyniadau rhagorol o wahanu maetholion a dŵr yn dangos potential i wella effeithiolrwydd defnydd gwrtaith a lleihau allyriadau.

Mae’r prosiect diweddaraf wedi derbyn arian cyfalaf o Lywodraeth Cymru ac arian Ewropeaidd I addasu’r cyfarpar ac arian cyfatebol i weithio hefo partneriaid masnachol. Bydd yr arian yma yn galluogi ni i weithio tuag at fanteision masnachol i'r partneriaid yn ogystal gwelliannau amgylcheddol.

TYWI FARM NUTRIENT PARTNERSHIP

This project is based on the successful outcome of the original treatment project, Prosiectslyri. The very impressive nutrient separation achieved has shown that de-watering has the potential to maximise nutrient recycling on farm, whilst reducing emissions and water pollution.

Adaptions to infrastructure identified has attracted grant funding from Welsh Government as well as EU smart expertise, matching pound for pound money generated from industry partners. We have agreed a program of activity with partners that should return commercial benefit to them as well as general potential environmental improvements.

Undeb Ewropeaidd / European Union
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