A COMPARISON OF THE STRATEGICALLY SIGNIFICANT FACTORS BETWEEN THE APPLICATION OF BIO-SOLIDS CAKE AND OMF

Sprigings, A.[1] and Le, M.S.[1]
[1]Engineering and Capital Delivery, United Utilities Water PLC,UK
Corresponding author email: Andrew.Sprigings@uuplc.co.uk

The implementation of the Nitrates Directive has driven the replacement of digested liquid with bio-solids cake in the agricultural recycling market. However, the change has not been universally welcome, particularly by grassland farmers. Whereas the liquid contains readily available nutrients, which produce a rapid response from the crops, the effect from a cake product is less visible. The logistics of moving and storing cake is also fraught with difficulties. In recent years Organo-mineral fertilisers (OMF) have been developed in order to overcome such drawbacks. By incorporating designer formulations into bio-solids granules, the new OMF product provides a means for rapid delivery of the nitrogen component during the high demand period while at the same time replenishing the reserve of other nutrients such as P, K, S and other micronutrients that would be available for the following crops. OMF will be a farmer friendly product that may be bagged, transported stored easily and conveniently applied with a common fertiliser spreader. OMF could provide a novel end-of-waste solution, a step-change in the practice of bio-solids recycling. This paper will take into account the importance of securing the sludge to land recycling route, making comparison between sludge cake and OMF and their prospective places in future agricultural practice. Factors to be considered will include:

- Logistics
- Impact on land bank
- Agronomics
- Nutrient management
- Supply-demand balance
- Sustainability

Keywords

End-o-waste, Bio-solids, Nutrient management, Organo-mineral fertiliser, Sustainability

The importance of sludge recycling

It is now acknowledged that many of today's environmental issues are due to unsustainable human development. Accelerated by global industrialisation, this process has rapidly stripped the earth of valuable commodities and caused huge disruption to geochemical cycles (Christie 2007). Global warming caused by severe disruption to the carbon cycle is one such case, but human activities have also influenced other cycles such as the nitrogen and phosphorus cycles. The problem now faced is how to support an ever growing global population with a dwindling supply of raw resources. Recycling of nutrients is one such step in sustainable development; a step in which bio-solids can play a key role. The United Kingdom is responsible for producing 1.7 million tonnes (ds) of sewage sludge per year, of which 84% is recycled to land as bio-solids, the digestate produced by sludge treatment (Water UK 2011). Over the next 25 years this figure is expected to increase due to forecasted population growth, increased stringency of wastewater effluent discharge consents and the continued enforcement of the Urban Wastewater Treatment Directive (91/277/EEC). Agricultural spreading is generally recognised as the best practicable environmental option

(BPEO) for bio-solids disposal. Conversely, other options such as landfilling and incineration are regarded as unsustainable and are being progressively limited by EU legislation such as landfill restrictions, taxation and CO2 reduction strategies (Antille *et al* 2011). Land spreading is a beneficial practice as it recycles essential plant nutrients such as nitrogen (N) and phosphate (P) back to the soil (*Gedara et al* 2009), whilst the organic content of the material aids soil structure and water retention (Wallace *et al* 2009). This reduces agricultural dependence on chemical fertilizers, thereby contributing to the conservation of finite mineral P resources (Deeks *et a*l 2013). Thus, the use of bio-solids is both environmentally sustainable and sound agronomic practice provided application rates are followed carefully. One must also consider the economics of disposal; spreading is on average less costly than landfill and both mono and co-incineration (Gendebien *et al* 2010). The disposal of residual incinerator ash also poses possible environmental concerns due to its high levels of metals and toxins (Wei et al 2003). For these reasons recycling to land has become the disposal route of choice for UK utility companies; it is crucial that the sludge to land route is preserved and the market widened to ensure this vital resource is utilised to its full extent. However, there are several major difficulties which hinder their usefulness. The bulk and physical properties of the material are akin to soil, making logistics and storage an issue. The nutrient content and nutrient supply rates are also somewhat variable and are not always present in the required amounts (Whitehead *et al* 2007). Bio-solids have therefore become viewed more as a soil improver than a fertilizer. Furthermore, despite recycling's environmental credentials, the public's perception of this practice is not necessarily positive; concerns regarding the safety of bio-solids could threaten the security of the sludge to land disposal route. Heavy metals such as cadmium (Cd), chromium (Cr), lead (Pb) and other potentially toxic elements (PTEs) are often present in raw sludge along with bacterial, viral and parasitic pathogens. Recycling has therefore been controlled through the UK Sludge (Use in agriculture) regulations and voluntary agreements. Indeed, bio-solids are now the most researched and well regulated of organic materials applied to land (Water UK 2006). Nevertheless, this has impacted on the use of bio-solids, severely limiting their usage. Further restrictions brought about through knee-jerk public reactions could threaten the sludge to land (STL) disposal route or in the worst case scenario, cause its complete closure leaving utility companies with only limited and expensive options for sludge disposal. Clearly then, bio-solids need to be adapted to fit in with modern agricultural practice and efforts must be made to have bio-solid derived products re-classified to avoid the regulatory red tape which surrounds material classed as waste under EU legislation. Failure to address these issues, including allaying the public's fears regarding safe usage could lead to further restrictions on land disposal or even closure of this most valuable recycling route.

The development of OMF

In order to overcome these issues, attempts have been made to design Organo-mineral fertilizers (OMF) based on bio-solids, optimising their fertilising potential. According the to the Food and Agriculture Organization of the United Nations, "*Organo-mineral fertilizers are obtained through blending or processing one or more organic materials with one or more mineral fertilizers to enhance their nutrient content and fertilizing value. (FAO,2010)*. The technology to produce OMF exists; bio-solids have been fortified with one or more of the three primary plant nutrients nitrogen, phosphorous pentoxide (P_2O_5) and potash (K_20). Work done under END-O-SLUDG suggests that OMF formulations of most interest are those fortified with nitrogen 15:5:0 (OMF_{15}) and 10:5:0 (OMF_{10}) (N:P:K); these have been designed for landbank which is primarily grassland. Further studies have also been undertaken on formulations 4:10:0 for replacing phosphate utilised by spring crops and potash enhanced products for areas which suffer from K deficiencies.. In order to satisfy modern agriculture practice the physical properties of the bio-solids are altered using sludge drying and granulation methods to produce bio-granules, quality sludge pellets with a dry solids (ds) content of ≥85%. (Figure1)

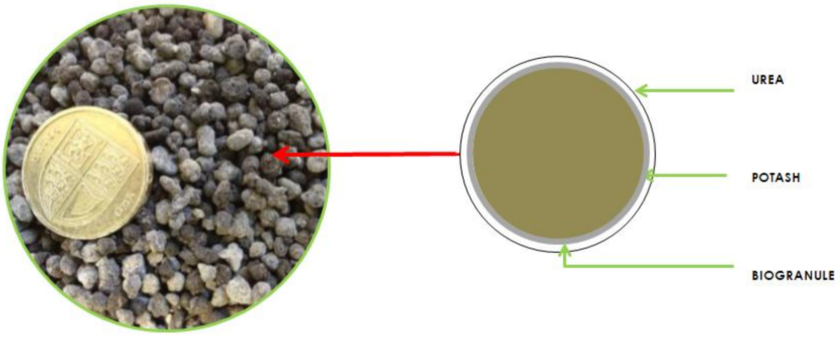

Figure 1: Schematic representation of an OMF granule.

The advantages of such processing are already widely understood. Indeed, it has been demonstrated that a dried sludge product has a much wider potential customer market when compared to liquid or sludge cake (*BSi PD CEN/TR 15473, 2007*). Thermal drying reduces the pathogen load to undetectable levels making granular sludge a more attractive option to farmers and food producing consortiums. However, conventional sludge pellets are not necessarily suitable for OMF production. It is recognised that OMF must be a quality product in order to facilitate its utilisation by the end users and ensure security of outlet. Conventional sludge drying facilities can be notoriously difficult to operate and the product size distribution and crush strength are highly variable. Thus when combined with sludge handling issues, the requirement for reactive maintenance and high energy costs can outweigh the benefits of producing such material. In order to avoid this the END-O-SLUDG approach involves researching the most suitable design for a full-scale production plant taking into account CAPEX, OPEX, quality and the possible integration of novel process units. It is theorised that such a plant would be based at a centralised sludge treatment centre (STC) and operate alongside existing sludge treatment facilities utilising the CHP heat with close proximity to feedstock. A recent demonstration of OMF production involved an indirect multi-try granulator dryer (Waterleau *Puttart*™ technology) (Figure 2).

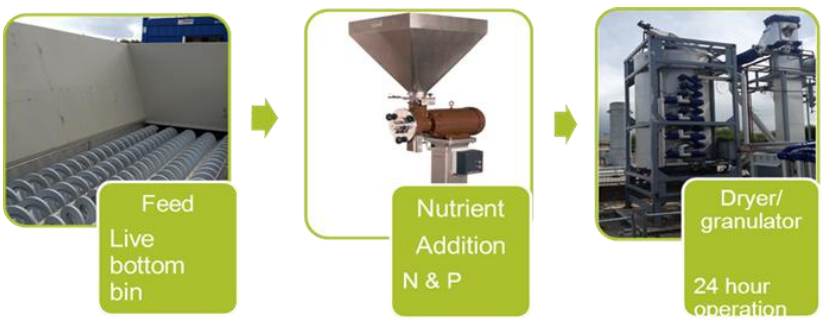

Figure 2: An overview of the demonstration plant

Designed as a continuous process, undersized pellets are continuously back-mixed into the incoming cake until the correct particle size is attained. This granulation process is considered to be both mechanically and thermally efficient compared to other drying technologies (BSi 2007), an important consideration in the economics and sustainability of OMF production. Nutrient addition was achieved by blending ground chemical fertilizer into the cake prior to it entering the granulator. Quality standards were stipulated for the output to cater the product to the target market. These include a tight particle size distribution (2-6mm), suitable crush strength (≥2 kg/Force) and nutrient homogeneity. The high quality of the physical qualities will allow the product to be utilised in standard agricultural spreaders, equipment that most farmers already own making OMF convenient to use. However, the process requires the use of premium fuel or electricity to heat the thermal oil required for drying. This is a significant cost; in future production scenarios a novel cold granulation and dehydration system which utilises waste heat to dry the bio-granules in a batch process would prove more sustainable. It is envisaged this will reduce OPEX through reduction in man power and the consumption of premium fuel. When combined with balancing of the nutrient content, this will allow the production of an environmentally sustainable and potentially profitable product.

Economic considerations

Feasibility studies for bio-granule suggest a cost of approximately £109/t (gas and electricity costs), for a Puttart plant with a throughput of ~25 tds/day based on current figures. This figure can be significantly reduced by using energy or waste heat derived from CHP engines instead of premium fuel. Current investigations are now focusing on a novel cold granulation and packed bed dehydration system utilising waste heat to dry the bio-granules. It is envisaged this system will increase the sustainability of sludge drying and significantly reduce OPEX. Results from the pilot trial in 2013 have yielded encouraging results with the potential of producing bio-granules for less £50/t. Figure 3 is a schematic of the novel dehydration system under development.

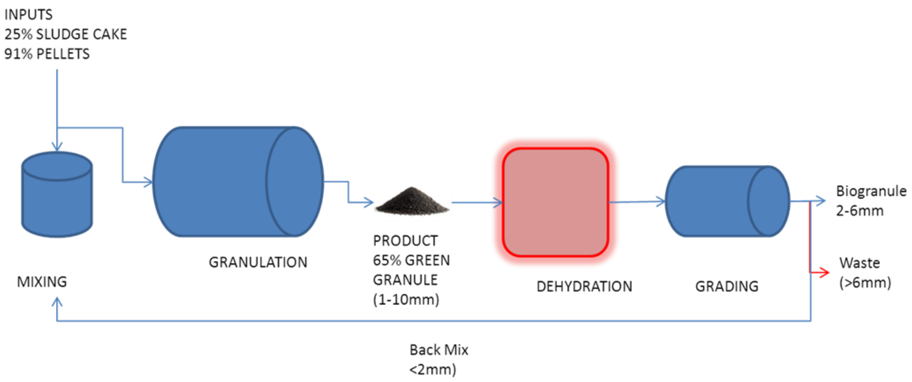

Figure 3: **Novel bio-granule and OMF production system**

Should this become a reality, bio-granules and thus OMF could be sold at a profit which is clearly an advantage for the manufacturer.

Sludge regulations and the strive for End of waste (EoW) status

Despite being classified as a waste under EU law (Waste Framework Directive 2008/98/EC*)* bio-solids have been deemed safe for use in agriculture provided regulations are followed and correct agricultural practice is employed. Recycling of bio-solids falls under the UK Sludge (Use in agriculture) regulations 1989 (EU Sludge Directive 86/278/EEC*)* which has been designed to regulate the "*use of sewage sludge in agriculture to prevent harmful effects on soil, vegetation, animals and humans*". The regulations stipulate maximum permissible levels for metals in bio-solids, soil and for average annual loading rates in order to prevent the accumulation of PTEs. Further amendments were added in the UK regulations to ensure the risk from pathogenic bacteria entering the food chain were minimised. UK utility companies have also entered into voluntary agreements such as the Safe Sludge Matrix (SSM). Designed to provide reassurance to the public, farmers and food producing consortiums, the SSM designates the type of crops that bio-solids can be utilised with and the interval between bio-solids application and planting (*Safe Sludge Matrix, ADAS*). Using *E.coli* and S*almonella*, the SSM defines two classes of bio-solids- 'conventionally treated' (Class B) and 'enhanced treated' (Class A) which have different land application protocols based on the perceived health risks. The agreements restrict the planting, grazing and harvesting of certain crops following the application of both sludge types. Whilst designed to protect the public and inspire confidence in STL, the regulations are restrictive and prevent full utilisation of this valuable resource.

However, the same Waste Framework Directive contains a section detailing EoW, a set of criteria which specifies when '*a certain waste ceases to be waste and obtains a status of a product or raw secondary material'*. Attainment of EoW status for OMF would increase the likelihood of securing the STL route. The requirements to reach this goal are extensive but the main steps are:

1. The material must be '*consistently and deliberately produced so as to be analogous in composition to established or primary (non-waste) products*.
2. *Can be used directly without the need for any further treatment and has equivalent status in terms of risk to human health and the environment as comparable products*.
3. *Certainty of use*. (Adapted from Miller, J 2010)

On completion of this process, the material will no longer be restricted by waste legislation allowing OMF to be sold freely on the open market. Overall success of the product will be based on market uptake, benefits imparted to the user and economic viability. The following sections will now consider the advantages of OMF in comparison to bio-solids, and their prospective places in future agricultural practice.

Logistics

Logistically, OMF has several advantages over bio-solids. First and foremost is the reduction in bulk and weight achieved through drying and granulation. By increasing the dry solids content of the sludge, transport costs can be reduced substantially. Using a local sludge treatment centre (STC) as example, the site produces approximately 16,000t of sludge cake (wet weight) annually which is transported to local farms and spread by a registered waste handling company. Prices for transport and spreading are £6.78/t and £1.74/t respectively based on the 2013 tariffs. This equates to an approximate yearly cost of £136,320 to handle all of the sites sludge. If half of this STCs sludge was converted to OMF the cost per annum would be £85,523.76 a 37.2% saving. Although a relatively small sum of money, with respect to overall treatment expenditure it would certainly contribute to a reduction in the OPEX costs relating to sludge disposal. Furthermore, handling tariffs are based upon zones around each STC; as one would expect the further the distance the farm, the greater the transport cost. Savings for other STCs where bio-solids are transported further would therefore be greater than those stated here. However, in the long term a successful EoW application would mean OMF did not need specialised waste handling. In such cases product could be sold directly to the end user or a fertilizer company could distribute OMF in bulk reducing haulage costs and opening markets further afield. Indeed EoW would allow OMF to be exported across international boundaries allowing the product to be sold abroad; something which is not possible with waste products.

Another important advantage of OMF may be seen during its application. Bio-solids application is usually applied based on crop N requirements. Due to the concentration effect of drying and urea addition, the need for repeated or split-applications to achieve the desired nutrient addition will not be required. Table 1 demonstrates the nutrient content of both dewatered and thermally dried bio-solids and OMF. The high nutrient content of OMF also means the amount of spreading required will be reduced significantly, saving the end user time and money on fuel. Where large amounts of bio-solids are required for arable applications, the reduction in truck volume brought about by the use of OMF may have a positive impact on the local community through the reduction of traffic volume, noise and dust; another step which may contribute to public acceptance of bio-solids (National Agronomy Manual 2011).

The drying and granulation process also confers several other advantages to bio-solids. Despite processing through mesophilic anaerobic digestion (MAD), the large amount of organic material and its water content results in bio-solids that are unstable and continue to breakdown due to environmental and bacterial action. Furthermore, when bio-solids are not immediately incorporated into the soil, nitrogen can be lost due to ammonia volatilisation reducing their fertilising value and polluting the atmosphere (DEFRA 2010). Where bio-solids are not stored undercover, nutrient leaching caused by rainfall will also cause nutrient loss and in some cases can become a pollution issue. Thermal drying removes enough water to effectively render the material inert. Moisture removal allows OMF to be bagged in regular fertilizer sacks making transport and handling easier. Packaging the product in the same way as chemical fertilizers also means that farmers can continue to load spreading equipment in the manner in which they are accustomed allowing for ease of use; an important consideration in the marketing of OMF. Packaging also helps facilitate storage protecting the material from rehydration and extending the ‘shelf-life’ of the product. This use of packaging could positively influence public perception of the material; in essence demonstrating its move away from a treated residue into a legitimate, environmentally friendly fertilizer.

Impact on land bank

In terms of land application, bio-solids cake when used as a top dressing can become malodorous due to the bacterial production of volatile organic sulphur compounds (Chen *et al* 2011). This often means that cake must be quickly incorporated into the soil to prevent complaints from local residents. Even, when there is no odour bio-solids which are usually applied with a muck spreader are unsightly, do not spread evenly and can remain on the surface for several weeks. In contrast OMF is odour free, does not form clumps and is relatively inconspicuous when applied as a top dressing. Thus the end user has the choice of whether to incorporate the fertilizer into the soil. Despite sludge to land regulations, worries regarding *E.coli* reactivation and regrowth in dewatered bio-solids ensure issues surrounding the microbial safety of bio-solids (Higgins et al 2006) and the land bank on which they are applied, still exist. The thermal treatment used to dry OMF ensures that all plant and animal pathogens are destroyed and as such there is no risk of bacterial contamination of any land bank or food chain through the use of OMF.

Non-deliberate misuse of bio-solids can cause several issues. Bio-solids are not homogenous and the nutrient content can be highly variable. Nutrient mis-management caused by this variability can lead to over application of N and P causing nutrient loss both at field and catchment scales (Whitehead et al 2007). Run-off and leaching of N into lakes and rivers is a particular problem and can cause eutrophication; this has led to the further guidelines for nitrate vulnerable zones (NVZs) which restrict the use of N containing fertilizers (including bio-solids) near polluted or 'vulnerable' water courses (EC Nitrates Directive 91/676/EEC). Nitrogen leaching can also affect ground water contaminating valuable water supplies. Additionally, attempts to apply optimum nitrogen requirements through bio-solids alone can lead to an excessive phosphate index due to the unbalanced nature of the nutrient content. The increase in phosphate index above those required by crops or silage grass has no agronomic benefit and can exacerbate phosphate losses primarily caused by soil erosion, in-drain flow and direct run off (DEFRA 2011). In order to address these issues, the nitrogen content in OMF has supplemented with additional N using urea (a mineral form of N). As well as having several agronomic benefits, the additional nitrogen balances the N:P ratio, allowing crop specific requirements to be met whilst maintaining the P index. Recent work by Deeks *et al,* 2013, has demonstrated this theory in field trials using a variety of crops. Over three years (2009-2011), the trial demonstrated there was no significant increase in the soil P content (mg l^{-1}) from the baseline figures determined in 2008 using a prototype OMF product (~15:5:0). Thus OMF can be shown to deliver crop specific nutrient requirements without excessive application of phosphate and other nutrients. As additional advantage, the supplementation of nitrogen means that less fertilizer will be required overall reducing the amount of PTEs added to the land bank. Furthermore, during the OMF production process, the N content of the sludge is monitored to ensure homogeneity, increasing the accuracy of nutrient calculations.

The agronomic value of bio-solids vs OMF

The nutritional value of bio-solids are widely recognised and are regarded as a useful source of N,P and S. However it is difficult to determine the exact amounts in bio-solids. The table below demonstrates the nutrient content of different forms of bio-solids from the same source determined in a fertilizer laboratory:

Table 1: **Sludge nutrients (as received basis, figures in %w/w)**

Sludge type	Total N	Ammonical N	Ureic N	Total P_2O_5	Total K_20	Total SO_3	dm
Bio-solid cake	1.07	0.27	<0.1	1.70	0.10	0.70	23.60
Bio-granules	4.09	0.48	<0.1	5.91	0.22	2.88	87.50
OMF_{10}	10.40	0.50	6.70	4.77	0.24	2.55	89.60

*Ureic acid is provided by the addition of urea and is not generally present in digested sludge. dm =dry matter

As a guide it is possible to determine the approximate value of the nitrogen, phosphate and sulphur within these materials using equivalent fertilizer costs to determine a value for these materials:

Table 2: **Total fertilising value of bio-solids in *pence* and OMF based on fertilizer equivalents:**

Bio-solids type	ratio (N-P-K-S)	N (p)	P (p)	S (p)	Total value £ / t
Bio-solid cake	1-2-0-1	661.7	1445.7	348.0	£24.55
Bio-granules	4-5-0-3	2646.7	3614.1	1044.0	£73.05
OMF10	10-5-0-3	6616.7	3614.1	1044.0	£112.75
OMF15	15-5-0-3	9925.0	3614.1	1044.0	£145.83

Costs based on 2013 prices for fertilizer from *Indexmund.com*: nitrogen from urea (66.2p/kg) and phosphorus pentoxide from TSP (72.3p/kg). Elemental S is an assumption based on online figures (13.9p); bio-solid SO_3 has been converted to elemental S in the calculations. The phosphorus content of the bio-granules and OMF have been averaged for ease. OMF_{15} figures based on those determined for OMF_{10}.

However, the table does not take into account nutrient variability and nutrient release rates. As a guide DEFRA's RB209 manual has determined nutrient release rates for bio-solids (table 3).

Table 3: **Bio-solid nutrient release rates**

Sludge Nutrient	Available 1st year (%)	Available 2nd year (%)	Available 3rd year (%)
N	15	10	5
P_2O_5	50		
SO3	*100		

*Current work by HGCA is researching SO_3 availability. However, until research is complete this report assumes 100% availability. (HGCA research and development, Annual Project Report, 2010-2012)

Thus the fertilising value of bio-solids and OMF should really be based on those which are available to crops in the first year. Table 4 shows fertilising value of bio-solids and OMF amended using the information in table 3.

Table 4: Nutrient availability of bio-solids and OMF the first year

Bio-solids type	Ratio (N-P-K-S)	N (p)	P (p)	S (p)	Total value £ / t
Bio-solid cake	1-2-0-1	99.3	722.8	348.0	£11.70
Bio-granules	4-5-0-3	397.0	1807.1	1044.0	£32.48
OMF10	10-5-0-3	4760.7	1807.1	1044.0	£76.12
OMF15	15-5-0-3	7228.7	3614.1	1044.0	£118.87

Bio-solids are usually sold at minimal cost ranging from anywhere between £1 to £11 per tonne of cake and £25-50 per tonne of bio-granules (Farmers Weekly 19/06/2010). The calculated figures are similar to those cited and provide reasonable prices for the sale of OMF. In order to make a profit manufacturing OMF, production costs must not exceed the total values in table four which should act as a guideline marketing price.

Nutrient management

The implementation of the Nitrates Directive has driven the replacement of digested liquid with bio-solids cake due to the reduction in leaching, excessive run off and to facilitate storage ready for the spreading season. There is a trade-off however; whereas the liquid contains readily available nutrients which produce a rapid response from the crops, the effect from a cake product is less visible. During dewatering a proportion of the available N, in the form of ammonia is lost. The remaining N is mainly organic N bound in the cellular material. As demonstrated in table 3, organic N is not readily available but can be released the process of mineralisation, part of the nitrogen cycle. The amount of plant available nitrogen (PAN) in soil is known as the soil mineral nitrogen (SMN) and is comprised of the nitrate and ammonium-N. This process can take from several months to several years, making bio-solids an excellent source of slow release nutrient. Similar processes are required to release non-labile P into plant available forms. Like other fertilizers, bio-solids need to be applied in the early stages of the growing season to allow maximum nutrient uptake by plants. However, the slow release nature of bio-solids means that they are not necessarily suitable for use with arable crops. A sufficient SMN is required to support the initial stages for growth of food crops (barring legumes which can fix nitrogen from the atmosphere) and develop profitable yields. The national agronomy manual, 2011 states that "*bio-solids are rarely able to supply all of the target crop's N requirement*". Thus additional chemical fertilizers like ammonium nitrate or urea are required to increase the amount of SMN. Bio-solids are therefore regarded more as a soil improver than a true fertilizer. By fortifying OMF with mineral nitrogen in the form of urea, both the amount of nutrients and the release rate of bio-solids have been altered. During incubation studies Antille, D.L, (2011) demonstrated that the greatest N release from OMF_{15} occurred during the first 30 days; this can be directly attributed to the mineral nitrogen adjustment. This data clearly shows that N-OMF formulations can rapidly deliver N during the high demand stages of crop growth. In the field trial conducted by Deeks *et al,* 2013, the performance of OMF products was compared directly with chemical fertilizer using a variety of crops. It was found that in all but one case, there was no significant difference in crop yield. The graph below demonstrates the yields for each crop:

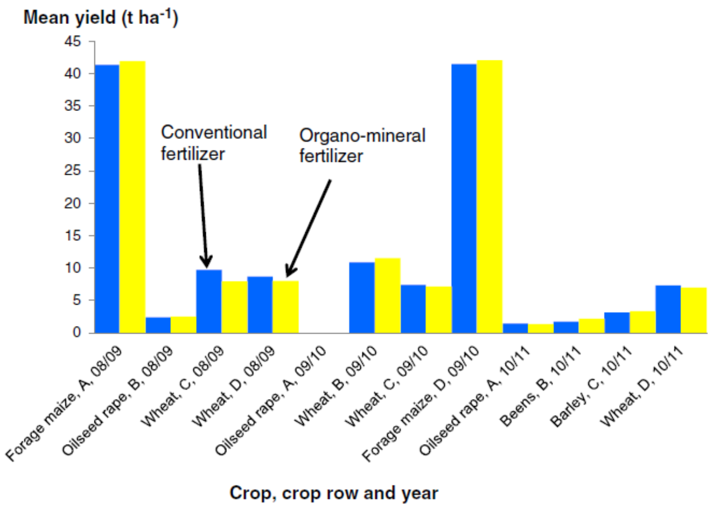

Figure 4: OMF versus conventional nitrogen fertilizer

This data is important as it demonstrates that OMF can be used as a direct replacement for chemical fertilizer, a significant advancement in securing to the STL recycling route. Another advantage of bio-solids is the micro nutrients present in sludge are also useful in rectifying unforeseen nutrient deficiencies (National Agronomy Manual 2011). Furthermore, OMF retains the slow release nutrients of standard bio-solids which can replace nutrients lost through harvesting and provide nutrients to subsequent crops (Gedara, 2010).

Supply-demand balance

Generally, the supply demand relationship for bio-solids favours the users; utility companies are reliant on farmers to accept the material or face increasing stock piles. Wastewater treatment works often have limited space for storage and as such bio-solids are sold at minimum cost or in some cases provided for free to preserve the throughput. Farmers then store the material until the spreading season. OMF is the key to balancing this relationship; the product has reduced bulk and can be stored indefinitely provided it protected from moisture. This makes it far easier to stockpile, reducing the pressure on the producer to dispose of the material immediately allowing them to create a demand for this 'premium' product; the attainment of EoW should open up other markets further increasing the demand. Furthermore, the production of the 'premium' OMF product will reduce the amount of bio-solids cake available. This will create competition for both OMF and the remaining cake allowing manufacturers to sell OMF in accordance with its nutrient content and perhaps recuperate some of the OPEX through cake sales. The cost of both products will no doubt be determined through fertilizer costs, OPEX and the availability of other bio-wastes such a PAS100 digesate and composts. The true OPEX of OMF has yet to be established but there is no doubt that OMF will have a positive effect on the demand for bio-solids as a whole and confer security to the recycling route long term. Whilst it is unlikely that a sludge undertaker would convert all its bio-solids into OMF, it could be an option if a blanket ban on bio-solids recycling became a reality.

Sustainability

Recycling the nutrients in bio-solids will reduce reliance on finite mineral P reserves and energy intensive chemical fertilizer production. It will also enable the closure of so-called nutrient loops (Lloyd 2007), a process which supports geochemical cycles rather than the unsustainable, linear model of extract-utilise-waste that has caused so many pollution issues. Closing nutrient loops is an important principle in striving for the sustainable intensification of agriculture, a key factor in securing future global food supplies (The Royal Society 2009). As the UK population increases so too will the amount of bio-solids produced; it seems logical then that bio-solids should replace the nutrients removed through agricultural activities. OMF increases the sustainability of bio-solids, encouraging its utilisation through enhanced performance, OMF usage ensures that overall the use of such chemicals is reduced. One must also remember that OMF and the technology required to produce it are still in their infancy. Through sustainable technologies it will be possible to reduce the ecological footprint of OMF production, moving away from premium fuel usage and energy intensive processes by utilising waste heat and electricity created through biogas production. Recent work regarding nutrient reclamation technologies, could hold the key to obtaining sustainable N and P for OMF production by scavenging beneficial nutrients from recycling streams and adding them into the sludge in the desired ratios. Current work with Biopol, (Le 2013) a phosphate extraction technology could allow STCs to increase bio-solid N:P ratios making an OMF product suitable for P saturated land bank. With the current interest in reclamation technologies it is hoped future operations will produce OMF from 100% recycled nutrients.

Summary

Whilst some aspects of the product are still in development, the advantages of OMF are clear. OMF increases the sustainability of bio-solids cake and the sludge to land recycling route. It encourages end user utilisation through enhanced agronomic performance and convenience of use. Advantages include a balanced nutrient content tailored to crop specific requirements, increased stability through thermal treatment, enhanced physical properties simplifying product logistics and its reclassification to a non-waste. OMF will enhance the business of recycling bio-solids, providing farmers with a choice of affordable products which can be used as a sustainable replacement for pure chemical fertilizers. Work now must concentrate on delivering EoW status for the product, small scale production for market research and the design of ergonomic, OPEX reducing technologies to simplify production and reduce unit costs. Finally, the strive continues to make OMF 100% sustainable by the integration of reclamation technologies instead of using products from the chemical industry.

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