EQual Poultry litter ash field trials

Summary report

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Introduction

Background

The EQual LIFE+ programme aims to promote the re-use and recycling of waste materials whilst protecting human health and the environment. Deriving value from waste materials by turning them back into safe, high quality products is an essential element in the move towards a more circular economy. Offering both economic and environmental benefits, if supported and regulated appropriately, waste-derived products improve business resource efficiency and competitiveness, reduce reliance on landfill, and help to conserve virgin raw materials.

The Environment Agency led the programme with six partners: Rijkswaterstaat (the Netherlands' Ministry of Infrastructure and the Environment), The Chartered Institution of Wastes management, Organics Recycling Group, Environmental Services Association, Northern Ireland Environment Agency and Energy UK.

As part of the EQual programme, field trials were carried out for four waste derived materials to improve understanding of the behaviour of these materials in the environment. The evidence base obtained from the trials will support the appropriate use of these materials in place of non-waste materials

Two of the field trials focused on the construction industry (pulverised fuel ash and incinerator bottom ash aggregate), and two on agricultural use (poultry litter ash and paper sludge). This document reports the poultry litter ash (PLA) field trials.

PLA is a waste-derived material from the combustion of predominately poultry litter (straw, woodchip and sawdust) which has been designated for use as a phosphate and potash fertiliser. The Quality Protocol for PLA sets out the end of waste criteria for the production and use of PLA as a phosphate ($P_2O_{5)}$ and potash (K_2O) fertiliser in the UK[Error! Bookmark not defined.], enabling PLA that is compliant with this Quality Protocol to be used as a non-waste.

Previous research on PLA has largely focused on the P_2O_5 and K_2O fertiliser replacement benefits of such applications, with limited research on the impact of applications to the wider environment (i.e. water, crop and soil quality) and human health.

Aims

PLA field trials were carried out to further understanding of the environmental (soil, terrestrial organisms and controlled waters) and human health risks of land application of PLA to agricultural soils compared with non-waste-derived alternatives.

The aims of the field trials were to:

1. assess the environmental impacts of the application of PLA to agricultural soils;
2. provide data to inform future generic Quantitative Risk Assessment (QRA); and
3. improve understanding of the magnitude of agricultural benefits derived from PLA compared to non waste-derived alternatives.

Aims 1 and 2 were the primary aims of the field trials.

Methodology

The field trials were carried out by ADAS UK Ltd and Harper Adams University College at two existing experimental sites at ADAS Gleadthorpe (loamy sand textured soil) and Harper Adams University (sandy loam textured soil).

The field trials comprised three sets of study plots at each site:

- Control plots;
- Plots with PLA applied; and
- Plots with an 'industry standard' comparator to PLA –Triple Super Phosphate (TSP) and Muriate of Potash (MOP) – applied to match the P_2O_5 and K_2O loadings of the PLA); termed the 'P&K' treatment.

a) Harper Adams; spring barley June 2014 b) Gleadthorpe – spring barley; June 2013

Figure 1. Field trials sites

Topsoil samples were taken in January 2013 to determine the baseline against which to assess results. The samples were analysed for:

(a) Total Al, Sb, As, Ba, Be, B, Cd, Ca, Cr, Co, Cu, Fe, Pb, Li, Mg, Mn, Hg, Mo, Ni, P, K, Se, Ag, Na, Sr, Tl, Sn, Ti, V and Zn;
(b) CrVI;
(c) Dry matter & pH;
(d) Soil microbial biomass C and N; and
(e) Aggregate stability.

Comparator fertiliser plots were also analysed for dioxins, furans & dioxin-like PCBs.

PLA and the industry standard comparator to PLA (TSP and MOP) were applied by hand in February 2013 and Autumn 2013. At Gleadthorpe, treatments were incorporated by ploughing. At Harper Adams, the treatments were top-dressed to the growing winter wheat crop in February 2013 and incorporated by disc in October 2013. Samples of the materials applied at each site were taken to enable material variability to be taken into account.

All plots, including the control plots received recommended rates of manufactured fertiliser nutrients based on the 'Fertiliser Manual, RB209[1], to minimise potential confounding interactions and ensure (as far as was practically possible) that no major nutrient limited plant growth. At Gleadthorpe this included the application of 5 t/ha lime as the pH across the site was *c.*6.0 in December 2012 ahead of the planting of spring barley, a crop sensitive to soil acidity[2].

[1] DEFRA, 2010. The Fertiliser Manual (RB209). The Stationery Office, Norwich
[2] MAFF (1983) Lime and Liming. MAFF Bulletin 35, HMSO London.

Topsoil samples were taken in April 2013, *c.*2 months after the first annual application of PLA, and again in April 2014, *c.*6 months following the second annual application of PLA. The samples were analysed as for the baseline samples (above).

Crop yields were determined in August 2013 and 2014 at both sites, with samples of the grain analysed for the substances listed in (a) above.

Storage study

An additional study was carried out to evaluate the effect of PLA storage on the environment and the fertiliser properties of PLA. Three heaps of PLA (*c.* 5 tonnes each) were established at Gleadthorpe in August 2013 in a series of hydrologically isolated, sloping concrete bunkers. Leachate from each heap was collected, and sampled on a monthly basis and analysed for total N, ammonium-N, nitrate-N, Total P, orthophosphate-P, BOD, pH, Total Al, Sb, As, Ba, Be, Cd, Cr, CrVI, Co, Cu, Fe, Pb, Mn, Hg, Mo, Ni, Se, Ag, Te, Tl, Sn, Ti, U, V and Zn.

Figure 2. Construction of the PLA storage heaps

During construction of the heaps, triplicate samples of the PLA were taken for analysis and four 'litter' bags, each containing *c.*2 kg of the PLA material, were buried at known separate locations within each heap. These were retrieved after 1, 3, 6 and 12 months for analysis. Measurements of the quantity of leachate from each storage heap were taken and related to rainfall volumes.

In November 2013 (*c*.3 months after establishment), the drainage pipe from one of the PLA heaps became blocked by potash crystals (Figure 3), and it was not possible to collect leachate from this heap for the remainder of the storage period. As the other two PLA heaps were functioning normally this did not present a problem for the validity of the storage study. As PLA should not be stored outside (for extended periods), this crystallisation should not pose a problem during normal operational use of PLA if good practice is followed.

Figure 3. Salt crystals on the pipework within PLA Heap 3

Results

Statistical analysis was carried out on the field trials and storage study results, to answer the following research questions:

How do physical and chemical properties of soil in the plots change over time?

There was very little change in soil properties on the control and P&K treatments over the course of the field trials. However, where PLA had been applied at Gleadthorpe, topsoil extractable P concentrations increased over time following two annual applications of PLA. This confirmed its value as a P fertiliser useful for building up soil P levels on low index soils.

PLA applications also caused a temporary increase in topsoil sodium (at both sites) *c.*2 months after application in April 2013, which had disappeared by April 2014 (*c.*6 months after the second annual application). This was most likely due to dissolution and equilibration into the topsoil, as well as over-winter leaching. Topsoil strontium was also temporarily elevated at Harper Adams in April 2013, most likely due to the presence of PLA material within the soil sample as the material had been top-dressed onto the growing winter wheat crop, whereas PLA applications prior to the 2014 sampling where incorporated into the soil *c.*6 months prior to soil sampling. This pattern was also evident for total and extractable potassium, total beryllium, iron and titanium at Gleadthorpe, and pH at Harper Adams.

How do physical and chemical properties of soil in plots with application of PLA compare with those in plots with industry standard alternatives/equivalents and control plots?

Two applications of PLA resulted in an increase in topsoil extractable P concentrations at Gleadthorpe relative to the control and P&K treatment. This was not apparent at Harper Adams, where soils were already well-supplied with P.

There was no significant effect of PLA additions on topsoil extractable K concentrations at either site in 2013 or 2014. At Gleadthorpe, extractable K concentrations suggested additional K was required to maximise yields (Index 1). Concentrations were higher at Harper Adams Index 2-), with no significant difference between treatments. The higher K loading on the PLA treatment had no impact on topsoil extractable or total K levels. These results suggest that all the K supplied with the treatments (both the PLA and MOP) was either utilised by the crop (particularly at Gleadthorpe where the soils were low in extractable K) or was leached.

Sandy soils, such as those at Gleadthorpe and Harper Adams, typically have a low cation exchange capacity and are therefore less likely to retain mobile cations like potassium. Consequently, they often require annual potash applications to maintain crop yields and soil K status.

PLA applications resulted in a temporary increase in topsoil sodium and strontium concentrations shortly after the first application in 2013. Although higher than the control and P&K treatment, concentrations of both elements were still at the low end of the range of reported values for soils in England and Wales.

Concentrations declined over the subsequent 12 months such that by April 2014 there was no significant difference between the treatments, despite a second application of PLA in Autumn 2013. It is thought the initial increase was due to the presence of PLA within the soil sample (which was taken *c.*2 months after application and incorporation in Spring 2013, and at Harper Adams the PLA was top-dressed onto the growing crop, without soil incorporation).

The PLA and equivalent P&K additions also had no significant effect soil aggregate stability in 2013 or 2014.

To what extent are potential substances of concern taken up by crops grown with application of PLA, and how does this compare to uptake by crops grown with application of industry standard alternatives/equivalents and in control plots?

The application of PLA caused no significant additional uptake of potential substances of concern relative to the untreated control or the conventional P&K treatment over the timescales of the study.

How does the total soil microbial biomass change over time in soils with application of PLA, and how does this compare with application of industry standard alternatives/equivalents and in control plots?

There was no significant change in soil microbial biomass over time where PLA had been applied, or between the PLA treatment, industry standard P&K treatment or untreated control. The absence of any treatment effects at both sites suggests the applied PLA did not have a significant effect on soil biological functioning.

How do storage durations affect key properties of the PLA (e.g. nutrient content, pH, pathogens)?

The storage study demonstrated that unprotected storage outside in field heaps results in a decline in the fertiliser value of the material (i.e. a loss of both major and trace nutrients, specifically potassium, boron, molybdenum and selenium); and leads to the generation of a highly reactive alkaline leachate containing elevated concentrations of soluble P, which would be highly detrimental if it entered surface water bodies in an un-diluted form.

The PLA Quality Protocol (QP) states that producers, distributors and users should follow good practice for the storage of PLA, treating it as an agricultural fertiliser. For inorganic fertilisers, this means storing the material undercover in a cool, dry shed. The safety data sheet provided by the PLA industry recommends storage in a cool, dry, well-ventilated place away from direct sunlight. PLA should therefore not be stored in field heaps in normal operational practice and following on-farm deliveries, spreading almost always occurs within days to avoid compression of the product before spreading.

The results of the storage study highlights the importance of the QP recommendations, i.e. that PLA should not be stored outside in field heaps.

How do the yields of crops grown with application of PLA compare with those grown with application of industry standard alternatives/equivalents and in control plots?

There was no significant difference in crop yields between the PLA, industry standard P&K fertilisers and the untreated control at either of the sites over two cropping seasons. Both sites had adequate soil P reserves at the outset of the trials.

The baseline extractable K concentrations at Gleadthorpe suggested additional fertiliser K would be required, whereas at Harper Adams, the higher concentrations suggested only a maintenance dressing was necessary (to balance crop offtake). As all treatments received recommended rates of N & K fertiliser as required (following the ‘Fertiliser Manual – RB209; Defra, 2010), this clearly balanced the nutrient supply across all treatments resulting in similar yields.

In order to evaluate the fertiliser value of PLA, experiments should be conducted on lower index soils, and include a range of inorganic P and K fertiliser rates as treatments (to generate a yield response relationship) compared to PLA applied at recommended rates (with no additional inorganic fertiliser).

The results from the field trial demonstrated that two years of PLA applications had no significant detrimental effects on crop yields relative to the industry standard and control.

How do the yield benefit-costs of PLA compare to those of industry standard alternatives/equivalents?

PLA is typically *c*.20% cheaper than the equivalent amount of Triple Super Phosphate-TSP and Muriate of Potash -MOP[3]). As there was no significant difference in the yields between treatments, this would suggest PLA may be economical compared to the industry equivalents. However, given both soils were adequately supplied with P, there was no crop requirement for additional P fertiliser.

Likewise, all treatments received recommended rates of K fertiliser (including the PLA treatment). It is therefore not possible to assess robustly the yield benefit-cost for PLA from the field trials, further work would be needed. In order to evaluate fully the economic benefit of PLA, a future study bespoke study on lower index soils would be recommended.

Conclusions

This study evaluated the impact of PLA relative to an industry standard equivalent (i.e. inorganic P and K fertiliser) on selected chemical, physical and biological properties of sandy soils growing cereals in a temperate climate over a two year period.

The results demonstrated that PLA is beneficial as a fertiliser and indicated that PLA can be used for building up soil P levels on low index soils.

The results showed no significant negative effect on a range of soil chemical, physical and biological properties, or on the uptake of potential substances of concern by cereal crops, over the timescales of the study. This clearly demonstrated that the two applications of PLA to agricultural soils presented no significant environmental or human health risks.

However, the storage study reinforced the need to store PLA in a dry environment, in accordance with the Quality Protocol for PLA, in order to prevent the generation of potentially harmful leachate.

The field trials have improved understanding of the environmental impacts and agricultural benefits of the application of PLA to agricultural soils. The study also demonstrated the importance of adhering to the Quality Protocol with respect to storing PLA materials in temporary field heaps to prevent surface water pollution.

It would be beneficial to undertake a longer term study to assess whether potential substances of concern build up through long-term use. It may also be beneficial to carry out further research on low P and K index soils, to provide additional information with regard to the magnitude of economic benefits of PLA applications compared to non-waste derived alternatives.

[3] www.nutrifocus.co.uk