Development of Synthetic Terra Preta (STP): Characterisation and Initial Research Findings

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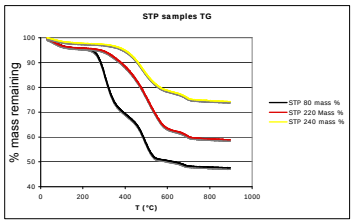
Introduction

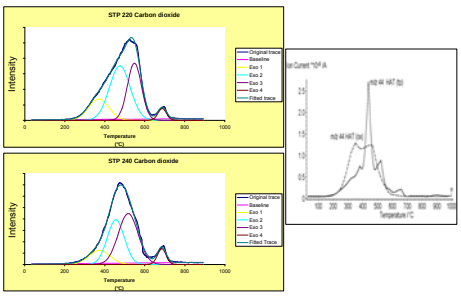
Amazon Dark Earths (Terra Preta) are unique soils that have a high soil organic carbon content and are rich in P, Mg, Zn, and Mn. They have a higher water holding capacity than the surrounding soil, higher pH, higher cation exchange capacity (CEC), and thus sustain higher fertility. Examination of these soils has revealed that they are composed of micro-aggregates that have been formed by the interaction of organic matter, clay particles, residual fired clay, sand, micro-organisms and decomposed/cooked food.

A development program has been initiated at the University of NSW, in collaboration with Cornell University, the New South Wales Dept. of Primary Industries and Western Australia Dept. of Agriculture & Food to develop synthetic high mineral organic micro-aggregates, otherwise known as synthetic Terra Preta (STP) that could be as effective in promoting plant growth and in sequestering carbon as Terra Preta (TP). The principal components of STP are biomass, clay, crushed brick and waste products with high calcium content. This poster outlines the work undertaken to date in terms of its production and characterisation. It will be shown that the particles produced have some similar characteristics and microstructure to Terra Preta

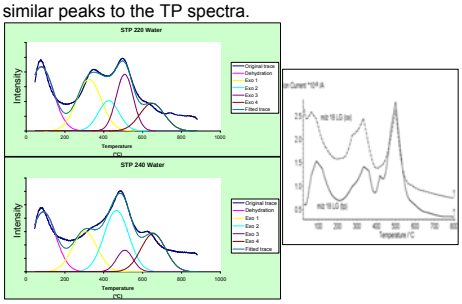
TG-MS Analysis



The figure above shows the weight loss curves of STP. The main weight loss region occurs at around 500°C which is attributed to the loss of water in kaolinite.



The figures above show the evolution of CO_2. Both the STP and the TP samples have a major peak at around 480°C. The deconvoluted spectrum of STP also shows similar peaks to the TP spectra.



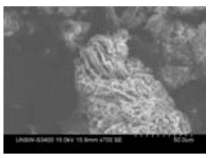
The figures above show the evolution of water. Both the STP and the TP samples have a major peaks at around 80°C, 340°C and 500°C. The biggest peak located at around 500°C also agrees with the weight loss curve in showing that the major loss of water occurs at this temperature.

Production of STP

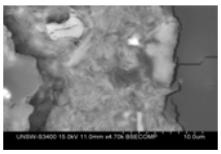
STP was produced using a 50/50 mixture of sawdust and chicken manure, a 50/50 mixture of bentonite and kaolinite clay, crushed brick and waste product from a cement kiln that had a high calcium content. Samples were manufactured at 220°C (STP 220) and 240°C (STP 240) in an oxidizing environment for 8 hours.

SEM and TEM results

STP 240

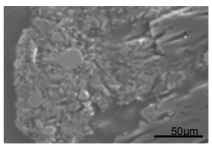


Wood particle covered with clay (SEM)

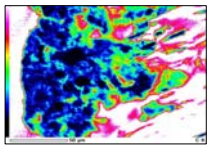


Cross-section of a wood/clay complex (SEM)

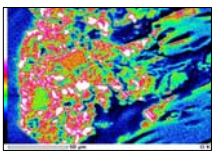
SEM elemental mapping of STP 240°C



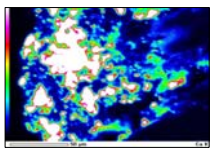
Original SEM image



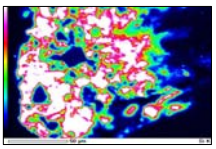
Carbon Map



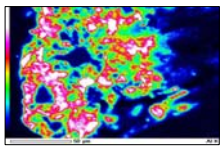
Oxygen Map



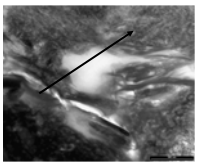
Calcium Map

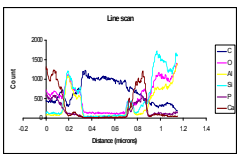


Silicon Map



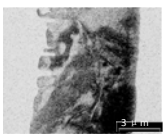
Aluminium Map



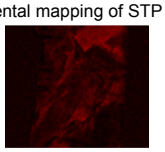


A elemental analysis line scan performed along the arrow shown on the adjacent TEM image. Total length of the line scan is 1.15µm.

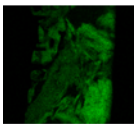
TEM elemental mapping of STP 240°C



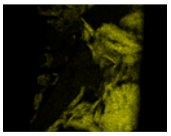
STEM image



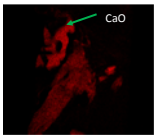
Carbon Map



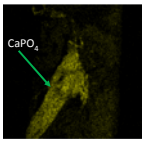
Oxygen Map



Silicon Map



Calcium Map



Phosphorus Map

The TEM line scan and elemental mapping shows a complex mixture of compounds, which includes aluminium silicates, $CaPO_4$ and CaO. The overlapping of these compounds with the carbon map suggest that there are some reaction occurring between the organic and mineral phase.

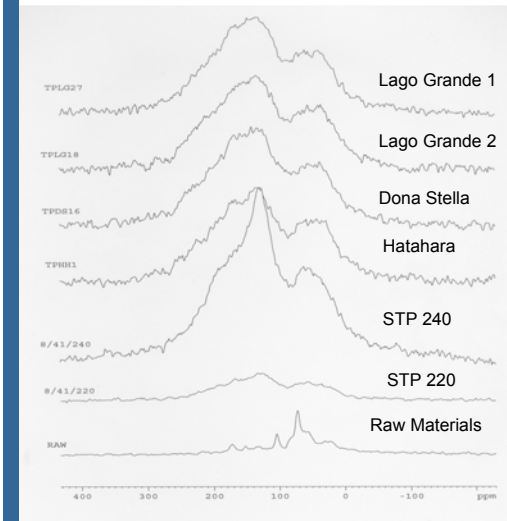
Characterisation of STP

The agronomic impact of STP is being tested by Western Australian Department of Agriculture (STP 220 and STP 240, applied at 10 tonnes/hectare to in-field tube trials growing wheat) and NSW Department of Primary Industries (glasshouse pot trials of STP 240 applied at 10, 50 and 100t/ha) .

All of the STP samples were initially examined using scanning electron microscopy (SEM). Elemental analysis of the different chemical phases on the surface were carried out using energy dispersive spectroscopy (EDS). The samples were sectioned using a focused ion beam instrument and examined using a Philips CM200 transmission electron microscope (TEM) to investigate STP structure at higher resolution. Thermogravimetry-mass spectrometry (TG-MS) was performed to determine the weight lost and evolution of gas molecules of STP as a function of temperature. NMR (nuclear magnetic resonance) was carried out to determine the surface chemical composition and functional groups.

NMR Results - ^{13}C Solid State CPMAS

(cross-polarisation magic angle spinning spectra)



Lago Grande, Dona Stella and Hatahara are different TP samples extracted from 3 different archaeological sites in Brazil. Initial NMR results show that the spectra of the Terra Preta samples and the STP both have a major peak at ~ 130 ppm arising from aromatic carbon, typically found in charcoal, with much weaker contributions from aliphatic carbon at ~30-40 ppm. Closer inspection reveals that STP 220 gives a better match to Terra Preta than STP 240. Note also that the spectrum for the Raw material has the opposite, with greater contributions from the cellulosic components at 60 -105 ppm, and weaker contributions from aromatic carbon at 130 -150 ppm, such as lignan that has not yet been charred.

Conclusion & Future Work

1. STP is a relatively stable organo-mineral complex that appears to have similar compositional and structural properties to Terra Preta
2. STP produced at 240°C has a greater aromatic C content to that produced at 220°C
3. Field and glasshouse trials show that STP promotes plant growth, and increases availability of nutrients and CEC compared with untreated soil. (data not shown – see poster by Blackwell et al)
4. Future work will include trials to monitor impact of STP on greenhouse gas emissions

STP appears to have similar properties to Terra Preta soils. In situations where waste heat is available for its manufacture, STP could prove to be a low-cost stable organic soil amendment.