STRATEGIC MANAGEMENT OF NON-POINT SOURCE POLLUTION FROM SEWAGE SLUDGE:

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ABSTRACT

The basic premise of this research programme is we believe that not all land has an equal risk of contributing nutrients derived from sludge applications to land to receiving waters. We are currently investigating whether it is possible to minimise nutrient loss by applying sludge to land outside critical source areas (CSAs) regardless of soil P Index status. A 24 ha field site situated near Stansted Mountfitchet, Essex, UK is being used to examine nutrient losses outside CSAs after sludge application. Catchment geology is dominated by glacial sand and gravel overlying the Upper Chalk. However, the sands and gravel at the site appear to have at varying depths clayey/silty lenses that contribute to the complex heterogeneity of the system. The soils consist of a mix of sandy/clayey loam with boulder clay present on the eastern edge of the site. The site receives an annual rainfall of around 600 mm with only one field drain present, which drains the boulder clay area. Runoff from this drain flows into a large field ditch that passes onto a roadside culvert. The field ditch separates the north side of the site from the south. After sludge application of a total of 31 piezometers have been installed along with 2 flumes, a Delta-T weather station, 3 TDRs at depths of 0.3, 0.6 and 0.9m, 15 teflon samplers and five zero tension samplers. A multi-level approach was taken with the piezometer installation with depths ranging from 1 to 15m. The two flumes were installed at either end of the ditch to examine the external input into the site and the contribution from the site itself. Both flumes have installed solnest pressure transducers, which record water depth (cm) within the ditch at 15 minute intervals. 5 piezometers were also installed with solnest pressure transducers again logging water depth (cm) at 15 minute intervals.

KEYWORDS Strategic management, critical source areas,

INTRODUCTION

The rate of application of sewage sludge to land is limited at or above ADAS Soil P Index 3 by the UK Code of good Agricultural Practice for the Protection of Water (MAFF, 1998) applied on a field by field basis. We suggest that such potential restrictions on sludge recycling to land are based on limited information and may not optimise the available capacity of the agricultural system. We believe high risk is associated with *critical source areas* of diffuse pollution where source and transport risks coincide (Heathwaite, et al 2000). Where connectivity does not exist between source and receiving waters, a high nutrient source does not necessarily constitute a high nutrient risk Essentially, the export of phosphorus (P) from agricultural land depends on the coincidence of source and transport controls. P source areas have a high potential to contribute P but they are often spatially limited and may include land of high soil P status or reflect agricultural land uses which increase surface P concentrations, for example, intensively grazed grassland, certain arable crops and land receiving excess nutrient applications. Transport factors describe the hydrological processes, which translate P source areas into P loss areas. Not all catchment areas are equally vulnerable to P loss; certain areas contribute runoff (both surface and subsurface) more readily than others. For example, hillslope hollows become saturated through the confluence of subsurface water with the consequent rise in the local water table and increased risk of saturation-excess surface runoff. In terms of P transport, such areas do not pose a risk unless they are *coincident* with P source areas. This means that within an agricultural catchment it is possible to have areas with a high potential to contribute P but no P transport to the receptor if the hydrological connectivity does not exist; conversely we may have areas with high hydrological connectivity but no P transport because they do not link to P source areas.

Evaluating the environmental risk of sludge to land recycling is integral to our research programme. Policy decisions regarding the efficacy of sludge to land need to be made at the catchment scale but current knowledge draws largely on small-scale empirical data. Our project integrates nested field experiments with hillslope to catchment scale models to evaluate the risk of land to stream contaminant transport that is scaled to account for the variation in contaminant contributing areas within a catchment. We are using the understanding gained to develop a predictive and spatially-sensitive model of the critical thresholds for sludge application to land. Our research is being disseminated as a practical advice matrix called the NERM (Nutrient Export Risk Matrix) which will provide our end-users with a methodology to determine acceptable sludge quantities that may be applied to catchments without detriment to the environment and receiving water quality. Our work is focussed on deriving a more environmentally-sensitive risk tool for sludge-derived pollutants that will be of use to land managers.

SITE DESCRIPTION

Figure 1 shows the general layout of the main field site (NGR TL:5077:2777) located near Stansted Mountfitchet, Essex, UK, with the instrumentation identified. Catchment geology is dominated by glacial sands and gravels overlying the Upper Chalk. The soils range from sandy loam to clay loam boulder clay present on the eastern edge of the site. The area receives an annual rainfall of around 600mm. A total of 31 piezometers have been installed along with 2 flumes, a Delta-T weather station, 2 Sigma 900 automatic water samplers, 3 TDRs at depths of 0.3, 0.6 and 0.9m, 15 Teflon samplers and five zero tension samplers. A multi-level approach was taken with the piezometer installation with depths ranging from 1 to 15m. However due to changing field conditions some of the equipment has been removed A ditch with an average width of 2 metres and depth of 1 metre runs from the south west to the north east of the site.

To asses the flow rates within the ditch two flumes were installed which continuously logged water depth at 15 minute intervals using solnest pressure transducers. Five piezometers were also installed with solnest pressure transducers again logging water depth (cm) at 15 minute intervals. The site received a sludge application of digested sludge and lime stabilised sludge in October 2001. Digested sludge was applied at 50 t ha and lime stabilised sludge was applied at 25 t ha, equivalent to 1100 mg total P kg $^{-1}$ and 7000 mg total N kg $^{-1}$ for the digested sludge cake and 9000 mg total P kg $^{-1}$ sludge and 15000 mg total N kg $^{-1}$ sludge for the lime stabilised sludge.

Water samples were collected and analysed from the piezometers on a fortnightly interval and from the ditch when it was flowing November 2001. The samples were pre-filtered through a 0.45µm millipore filter on-site and stored around 4^o C before analysis within 24 hours of sample collection. Laboratory analyses for PO_4^{3-}, NO_3^- and NH_4^- was carried out using Flame Injection Analysis (FIA); pH, temperature, redox potential and total dissolved solids were determined on site using a Camlab ultra-meter. Soil samples were collected using a randomised grid selector from selected locations at surface and 30 cm depth from the site prior to the sludge being applied and post sludge application. The soil samples were analysed for moisture content, pH, TP, TN, and selected cations (Al, Fe and Ca). Samples for total P and TN were digested using the TKN method developed by Foss with the selected cations determined by an acidic digest.

RESULTS

Figure 2 shows the soil Total Phosphorus (TP) concentration at the site for pre and post sludge application. Where pre sludge samples were collected one month before the sludge was applied and post sludge samples were collected three months after the sludge was applied. It highlights the relatively little difference in soil TP concentrations after the sludge was applied, even though the sludge had a TP concentration of around 1000 mg l^{-1}. Soil TP concentrations range from 30 to 65 mg l^{-1} before the sludge was applied and 30 to 65 mg l^{-1} after the sludge was applied.

Figure 3 highlights the range of variation in P concentrations across the 14 ha site and the relatively small concentration range for the dissolved reactive phosphate (DRP) fraction in comparison with TP. The DRP concentrations recorded in the piezometers were consistently below 0.1 mg l^{-1}. The TP concentrations, however, exceeded 1 mg l^{-1} at one location, with the majority of samples demonstrating TP concentrations above 0.2 mg l^{-1}.

Figure 4 shows the DRP concentration along the ditch separating the field after a storm event for two sampling events. The majority of the dissolved phosphate levels are generally constant for both sampling events with values ranging from 0.4 to 0.6 mg l^{-1}. However one sample was recorded with a DRP concentration of 0.1 mg l^{-1}.

CONCLUSIONS

The results presented above illustrate that at this field site P concentration in the soil is not increased three months after the application of sewage sludge. However, piezometers installed at various locations around the site illustrate moderate TP levels with minimal concentrations of DRP at various levels within the sub soil. However, figure 3 also highlights the spatial variability in P concentration in the piezometers, which suggests there is greater P loss from these areas or P is bound up within the subsurface. Again suggesting that where connectivity does not exist either via pathways or due to adsorption a high nutrient source does not necessarily constitute a high nutrient risk. Increased DRP concentrations are reflected in the ditch which are not seen in the piezometers, which may reflect adsorption processes that are occurring in the subsoil but not evident in the ditch where the transport process that favour DRP transport are more prominent.

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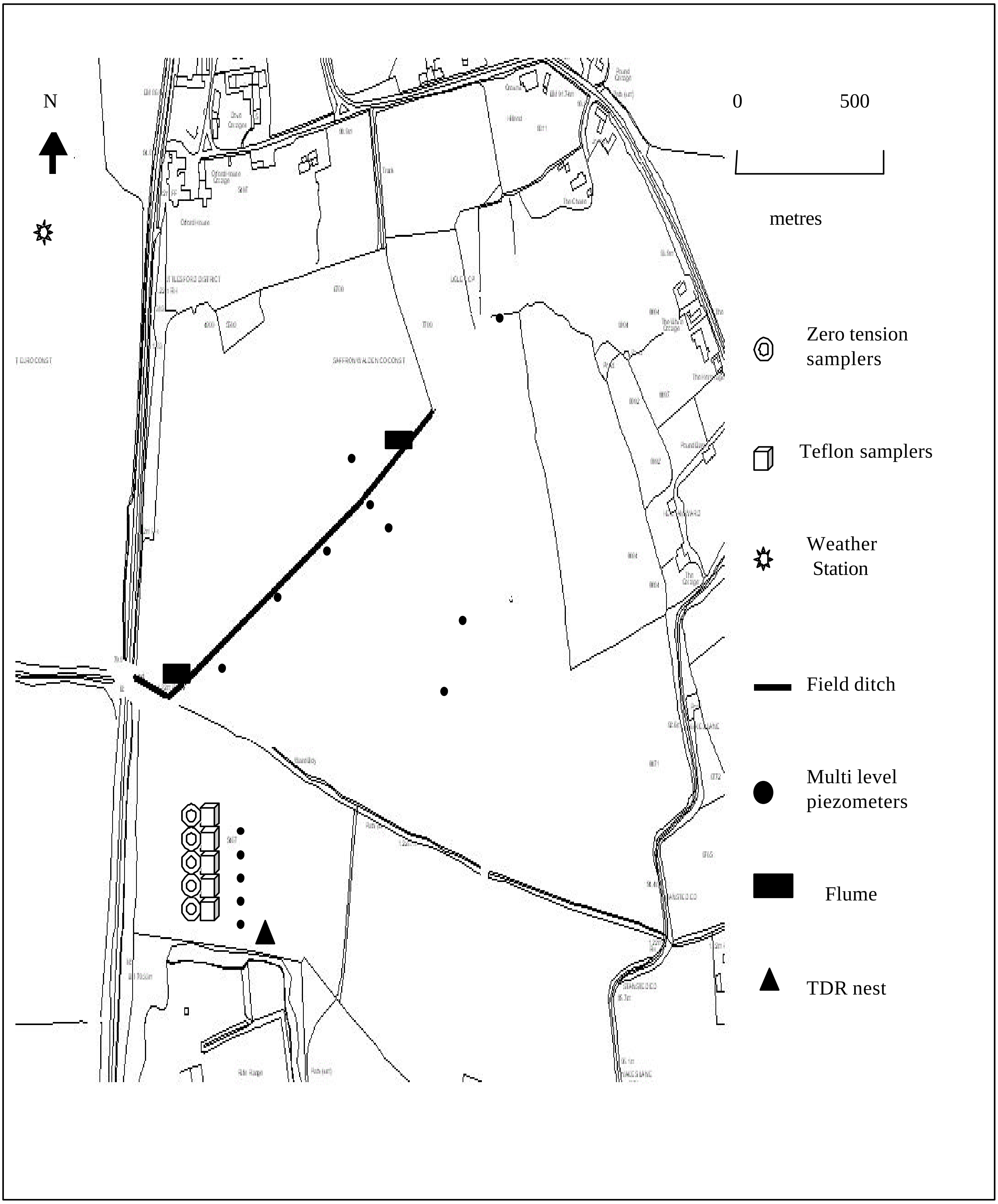

Figure 1 The general layout of the main field site

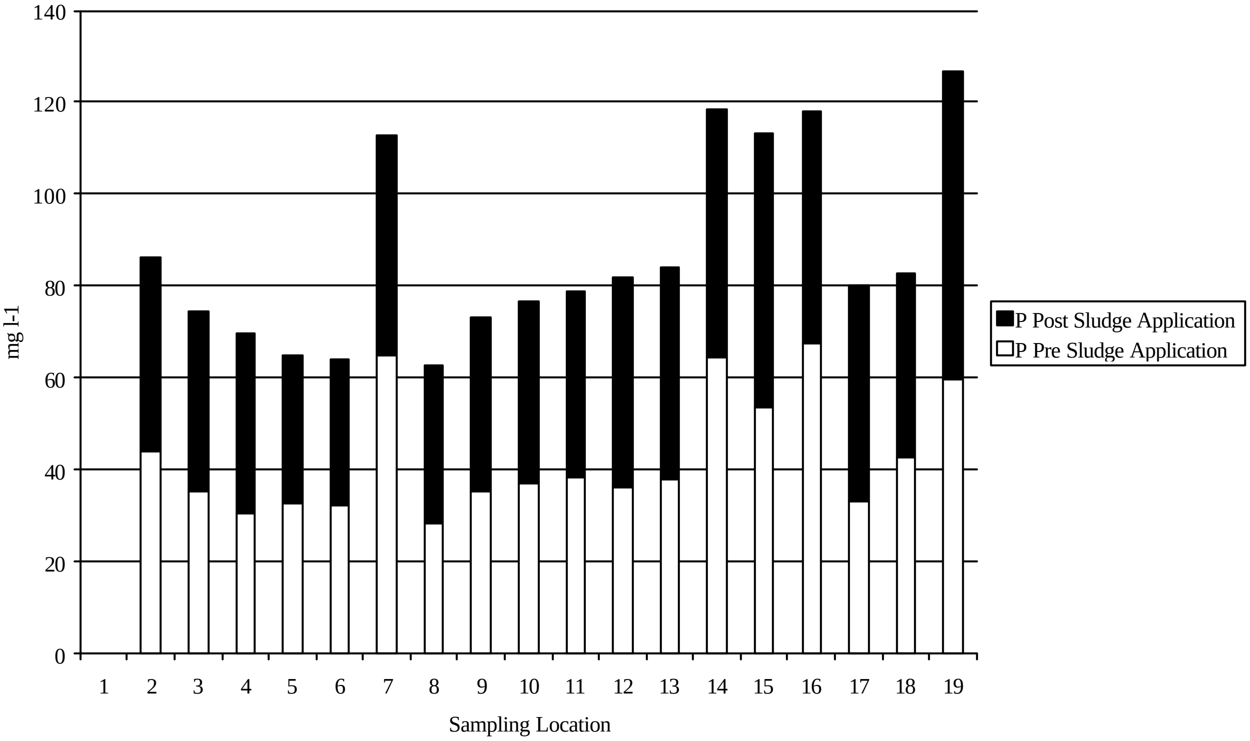

Figure 2 Soil TP concentration of the site with Pre and Post sludge application from selected locations. The sludge had a TP concentration of 1000 mg l^{-1}.

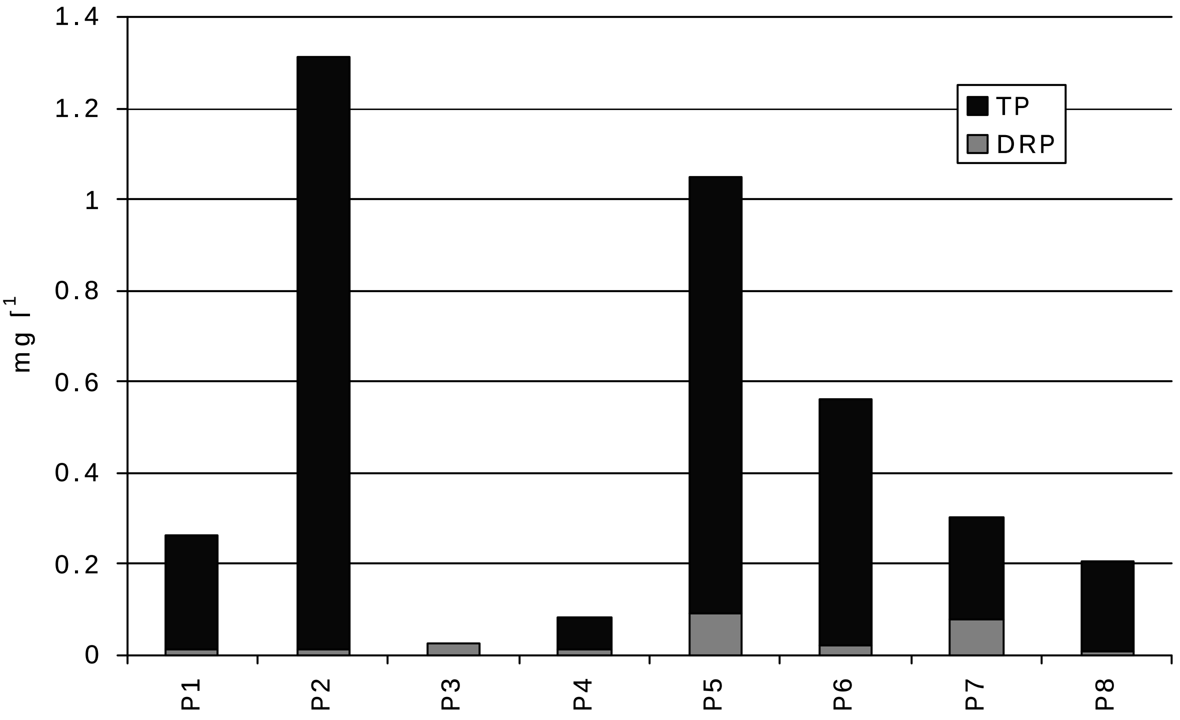

Figure 3. The variation in DRP (<0.45 µm) and TP (mg l^{-1}) at a range of locations across the field site

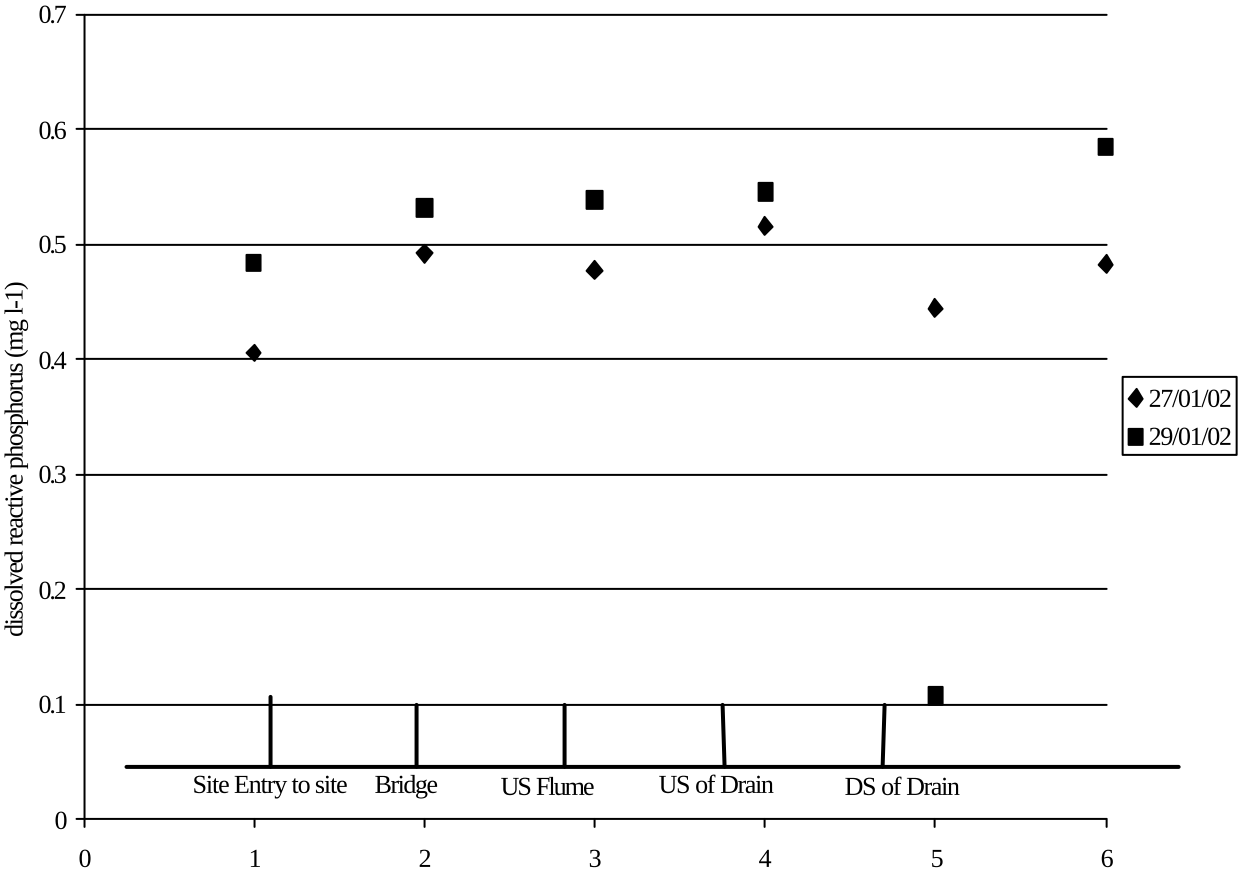

Figure 4 Dissolved phosphate concentrations along the ditch with two different sampling events