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TITLE: A critical review of nitrogen mineralization in biosolids-amended soil, the associated fertilizer value for crop production and potential for emissions to the environment

Author: Rigby, H., B.O. Clarke, D.L. Pritchard, B. Meehan, F. Beshah, S. R. Smith, and N.A. Porter

Source: Sci. Total Environ 2016 541:1310-1338

Abstract: International controls for biosolids application to agricultural land ensure the protection of human health and the environment, that it is performed in accordance with good agricultural practice and that nitrogen (N) inputs do not exceed crop requirements. Data from the scientific literature on the total, mineral and mineralizable N con- tents of biosolids applied to agricultural land under a wide range of climatic and experimental conditions were collated. The mean concentrations of total N (TN) in the dry solids (DS) of different biosolids types ranged from 1.5% (air-dried lime-treated (LT) biosolids) to 7.5% (liquid mesophilic anaerobic digestion (LMAD) biosolids). The overall mean values of mineralizable N, as a proportion of the organic N content, were 47% for aerobic digestion (AeD) biosolids, 40% for thermally dried (TD) biosolids, 34% for LT biosolids, 30% for mesophilic anaer- obic digestion (MAD) biosolids, and 7% for composted (Com) biosolids. Biosolids air-dried or stored for extended periods had smaller total and mineralizable N values compared to mechanically dewatered types. For example, for biosolids treated by MAD, the mean TN (% DS) and mineralizable N (% organic N) contents of air-dried mate- rials were 3% and 20%, respectively, compared to 5% and 30% with mechanical dewatering. Thus, mineralizable N declined with the extent of biological stabilization during sewage sludge treatment; nevertheless, overall plant available N (PAN = readily available inorganic N plus mineralizable N) was broadly consistent across several major biosolids categories within climatic regions. However, mineralizable N often varied significantly between climatic regions for similar biosolids types, influencing the overall PAN. This may be partly attributed to the increased rate, and also the greater extent of soil microbial mineralization of more stable, residual organic N frac- tions in biosolids applied to soil in warmer climatic zones, which also raised the overall PAN, compared to cooler temperate areas. It is also probably influenced by differences in upstream wastewater treatment processes that affect the balance of primary and secondary, biological sludges in the final combined sludge output from waste-water treatment, as well as the relative effectiveness of sludge stabilization treatments at specific sites. Better characterization of biosolids used in N release and mineralization investigations is therefore necessary to improve comparison of system conditions. Furthermore, the review suggested that some international fertilizer recom- mendations may underestimate mineralizable N in biosolids, and the N fertilizer value. Consequently, greater in- puts of supplementary mineral fertilizer N may be supplied than are required for crop production, potentially increasing the risk of fertilizer N emissions to the environment. Thus greater economic and environmental savings in mineral N fertilizer application are potentially possible than are currently realized from biosolids recycling programmes.

Document#: BIN.NIAV.GR.5.1

TITLE: Decomposition and plant-available nitrogen in biosolids: laboratory studies, field studies, and computer simulation

Author: Gilmour, J.T., C.G. Cogger, L.W. Jacobs, G.K. Evanylo, and D.M. Sullivan

Source: J. Environ. Qual. 2003 32: 1498-1507.

Abstract: This research combines laboratory and field studies with computer simulation to characterize the amount of plant-available nitrogen (PAN) released when municipal biosolids are land-applied to agro- nomic crops. In the laboratory studies, biosolids were incubated in or on soil from the land application sites. Mean biosolids total C, organic N, and C to N ratio were 292 g kg1, 41.7 g kg1, and 7.5, respectively. Based on CO2 evolution at 25C and optimum soil mois- ture, 27 of the 37 biosolids–soil combinations had two decomposition phases. The mean rapid and slow fraction rate constants were 0.021 and 0.0015 d1, respectively, and the rapid fraction contained 23% of the total C assuming sequential decomposition. Where only one decomposition phase existed, the mean first order rate constant was 0.0046 d1. The mean rate constant for biosolids stored in lagoons for an extended time was 0.00097 d1. The only treatment process that was related to biosolids treatment was stabilization by storage in a lagoon. Biosolids addition rates (dry basis) ranged from 1.3 to 33.8 Mg ha1 with a mean value of 10.6 Mg ha1. A relationship between fertilizer N rate and crop response was used to estimate observed PAN at each site. Mean observed PAN during the growing season was 18.9 kg N Mg1 or 37% of the biosolids total N. Observed PAN was linearly related to biosolids total N. Predicted PAN using the computer model Decomposition, actual growing-season weather, actual analytical data, and laboratory decomposition kinetics com- pared well with observed PAN. The mean computer model prediction of growing-season PAN was 19.2 kg N Mg1 and the slope of the regression between predicted and observed PAN was not significantly different from unity. Predicted PAN obtained using mean decomposi- tion kinetics was related to predicted PAN using actual decomposition kinetics suggesting that mean rate constants, actual weather, and ac- tual analytical data could be used in estimation of PAN. There was a linear relationship between predicted N mineralization for the growing season and for the first year. For this study, the mean values for the growing season and year were 27 and 37% of the organic N, respectively.

Document#: BIN.NIAV.GR.5.2

TITLE: Biosolids processing effects on first- and second-year available nitrogen

Author: Cogger, C.G., A.I. Bary, D.M. Sullivan, and E.A. Myhre
Source: Soil Sci Soc. Am. J. 2004 68: 162-167
Abstract: Simple, reliable estimates of biosolids N availability are needed to develop land application programs that will benefit crops without risk of excess nitrate leaching. This study was conducted to assess the effect of biosolids processing on plant available nitrogen (PAN) re- lease during the first and second growing seasons after application. We compared 14 sources of biosolids and a range of inorganic N rates in two replicated field experiments on established tall fescue (Festuca arundinacea Schreb.). The biosolids encompassed a range of treatment and dewatering/drying processes. A single biosolids application was made in May of the first year, and tall fescue yield and N uptake were measured by harvest for the next two growing seasons. Inorganic N was split across multiple applications each year. Fertilizer efficiency regression equations were developed for the inorganic N treatments, and used to calculate biosolids PAN from N uptake data. Year 1 PAN was similar across a range of biosolids treatment processes. For nonlagoon biosolids, PAN averaged 37 5% of total biosolids N. Lagoon biosolids PAN ranged from 8 to 25% of total N, with the oldest, most stable biosolids having the lowest PAN. Year 2 PAN averaged 13 2% for nonlagoon biosolids, excluding heat-dried materials, which were lower (5 to 8%). Our calculations indicated that about half of the Year 2 PAN became available during the cool season, suggesting that winter cover cropping may be needed to reduce the potential for nitrate leaching loss in summer annual cropping systems.

Document#: BIN.NIAV.GR.5.3

TITLE: Biosolids-derived nitrogen mineralization and transformation in forest soils

Author: Wang, H., M.O. Kimberley and M. Schlegelmilch
Source: J. Environ. Qual. 2003 32:1851-1856
Abstract: Utilization of biosolids through land application is becoming increasingly popular among wastewater managers. To minimize the potential contamination of receiving waters from biosolids-derived nitrogen (N), it is important to understand the availability of N after land application of biosolids. In this study, four secondary biosolids (two municipal and two pulp and paper industrial biosolids) were used in a laboratory incubation experiment to simulate N mineralization and transformation after land application. Municipal biosolids were from either aerobically or anaerobically digested sources, while pulp and paper industrial biosolids were from aerated wastewater stabilization lagoons. These biosolids were mixed with two New Zealand forest soils (top 100 mm of a volcanic soil and a brown soil) and incubated at two temperatures (10 and 20C) for 26 wk. During incubation, mineralized N was periodically leached from the soil– biosolids mixture with 0.01 M CaCl2 solution and concentrations of NH4 and NO3 in leachate were determined. Mineralization of N from aerobically digested municipal biosolids (32.1%) was significantly more than that from anaerobically digested biosolids (15.2%). Among the two pulp and paper industrial biosolids, little N leached from one, while as much as 18.0% of total organic N was leached from the other. As expected, mineralization of N was significantly greater at 20C (average 22.8%) than at 10C (average 9.7%). It was observed that more N in municipal biosolids was mineralized in the brown soil, whereas more N in pulp and paper industrial biosolids mineralized in the volcanic soil. Transformation of NH4 to NO3 was affected by soil type and temperature.

Document#: BIN.NIAV.GR.5.4

TITLE: Managing nitrogen from biosolids

Author: Henry, C., D. Sullivan, R. Rynk, K. Dorsey, and C. Cogger
Source: Washington State Department of Ecology 1999 #99-508
Abstract: Both the art and the science of biosolids management have evolved rapidly in the last few years. As the business of biosolids management has evolved, so has the recognition that nitrogen management in biosolids and other organic byproducts is a complex proposition.

In 1993, the Washington State Department of Ecology (Ecology) published the first draft of Biosolids Management Guidelines (WDOE 93-80). These guidelines provided a much needed approach for determining biosolids application rates. After release of the draft, it was recognized that even more comprehensive information and guidance on biosolids nitrogen management would be useful. A strong and cooperative working relationship between Ecology, the Northwest Biosolids Management Association, and universities in the Pacific Northwest presented an ideal opportunity for compiling existing information on nitrogen in biosolids and combining it with the most current scientific knowledge on the behavior of nitrogen in the environment.

This manual, Managing Nitrogen from Biosolids, is the outcome of this collaboration. It is written for professionals and other persons interested in developing a comprehensive understanding of biosolids nitrogen management and learning an exacting approach to determining biosolids application rates. It does not purport to have broad applicability for management of nitrogen in residuals other than biosolids. It is hoped, however, that those managing nitrogen in other materials can find some support for their efforts in this manual. Nor is this manual considered a final and definitive work. It will be updated and improved as our knowledge of nitrogen management grows. For those with a less critical need to manage biosolids nitrogen, Ecology’s Biosolids Management Guidelines is recommended for those in Washington State; publications approved by appropriate regulatory agencies and academic institutions are

recommended for those in other states and in British Columbia.

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