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Land application of poultry manure and its influence on spectrofluorometric characteristics of dissolved organic matter

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ABSTRACT

Land application of manure is a common practice that is used to supplement nutrients from fertilizers as well as to reuse and recycle waste in agricultural watersheds. Excess application of manure can however result in elevated exports of organic and inorganic nutrients in runoff. We evaluated the concentration and composition of dissolved organic matter (DOM) in runoff from cropland (corn) receiving poultry manure. Manure was applied once every three years at the rate of 9 Mg ha^{-1} in early spring and was incorporated into the soil during application. Surface runoff and soil water sampling was performed for eight natural storm events with one storm event prior to manure application. Samples were collected from the field edge, upland and lowland riparian zones and a receiving stream. Concentrations of dissolved organic carbon (DOC) were highest at the field edge (mean: 94 mg L^{-1}) and then declined sharply for the riparian and stream locations. Temporally, DOC concentrations in field runoff were highest for the first storm event following manure application and then declined quickly over the next 1–3 weeks. DOM composition in runoff following manure application had low aromaticity and a microbial/tryptophan-like character. These characteristics evolved with time toward more aromatic, more humic, and a terrestrial-like DOM composition. The decrease in runoff DOM was attributed to sorption and microbial degradation. Our observations suggest that while concentrations of DOM can be low in manure runoff, a short period (1–3 weeks) following manure application could be an environmentally sensitive and vulnerable period for runoff water quality.

1. Introduction

Land application of animal wastes is an important practice in many agricultural landscapes across the US. Animal manures provide an important source of nutrients for crops and can be used to supplement inputs from synthetic fertilizers. In addition, land application of manures allows reuse and recycling of the waste, a useful practice for states like Delaware which has a surplus of poultry manure (Dutta et al., 2012a,b; Pote et al., 2011; Sims, 1987). While the benefits of appropriately-applied and timed manure application are apparent, over-application and loss of manure with runoff can pose a threat to water quality (EPA, 2013). Runoff exports of inorganic nutrients like nitrogen and phosphorus from agricultural lands receiving manure application have been shown to enhance algal growth and eutrophication in aquatic ecosystems (Diaz et al., 2010; EPA, 2013; Pote et al., 2011, 2003). Similarly, increasing attention is also being paid to emerging contaminants such as hormones and antibiotics in manure runoff (Dutta et al., 2012b; Hanselman et al., 2003; Lee et al., 2007). In contrast, few studies have investigated the impacts of organic constituents of manure such as dissolved organic carbon (DOC) and nitrogen (DON) and other humic and bioavailable constituents. These organic constituents can not only contribute to water quality degradation but can also impact a suite of other ecological processes and functions in aquatic ecosystems (Aitkenhead-Peterson et al., 2003; Bolan et al., 2011). Elevated organic C and N constituents can contribute to eutrophication of receiving surface waters (Seitzinger et al., 2002). Not surprisingly then, Stanley et al. (2012) have called for the need to pay greater attention to these organic constituents especially in landscapes impacted by human activities.

The use of spectrofluorometric techniques has been valuable for characterizing the composition of dissolved organic matter (DOM) (Cory et al., 2011; Fellman et al., 2010). These techniques have been successful in discriminating DOM into humic, aromatic

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and labile constituents and thus providing a better estimate of the water quality impacts of DOM (Fellman et al., 2010). Many of these studies have however been conducted in forested ecosystems (Inamdar et al., 2012, 2011) and their use in agroecosystems has only recently gained momentum (Baker, 2002; Dalzell et al., 2011; Graeber et al., 2012; Hunt and Ohno, 2007; Petrone et al., 2011; Vidon et al., 2008). Agricultural practices can dramatically alter the DOM response from watersheds. These practices include type and intensity of tillage, irrigation, types of crops grown and the harvesting practices adopted, use of synthetic and organic fertilizers including manure and other animal wastes, hydrologic modification through tile drainage and ditching, and alterations of riparian and wetland ecosystems (Stanley et al., 2012). The impact of these agricultural practices on watershed exports and composition of DOM has been mixed since some of the practices increase the supply/input of DOM in agricultural soils whereas others decrease the supply of C (e.g., tillage; Bolan et al., 2011; Stanley et al., 2012).

Land application of manure can increase the organic matter and content of agricultural soils and therefore influence the amounts and character of DOM (Hunt and Ohno, 2007; Naden et al., 2010; Old et al., 2012). Most of these studies report an increase in the bioavailability of DOM through an increase in the tryptophan-like character of DOM (Naden et al., 2010; Old et al., 2012). However, many of the studies have been performed at laboratory and/or experimental plot scales. Studies are needed that investigate DOM under typical cropland settings where the seasonal timing, methods, and the rate of manure application are dictated by the agronomic needs of the crop.

Our overall objective in this study was to determine how land application of poultry manure influences the concentration and spectrofluorometric composition of DOM in runoff and if this poses any threat to water quality. This work was conducted in a "working" cropland watershed on the coastal plain soils of Delaware (DE) and was part of a larger study that investigated manure-derived concentrations of hormones and antibiotics in runoff (Dutta et al., 2012b). Poultry manure was applied on the cropland by the farmer in early spring (April, 2010) prior to planting of crop. This timing of manure application is typical for agricultural lands in coastal DE. Runoff sampling for DOM was performed before and after manure application for multiple natural storm events from March through July 2010. Surface runoff and soil water samples were collected from the cropland edge, upper and lower riparian locations and a receiving stream. DOM composition of runoff samples was characterized using ultraviolet (UV) and fluorescence metrics. In addition to DOM, we simultaneously evaluated nitrate-N and ammonium-N concentrations in runoff and surficial soils following the approach of Naden et al. (2010). Elevated concentrations of ammonium-N in runoff from land receiving manure can be indicators of contamination from fresh manure (Naden et al., 2010). Ammonium concentrations in runoff can however decline with time because of nitrification and soil sorption and thus are indicative of transformation or ageing of manure. The shifts in DOM concentration and composition were evaluated in light of these changes in inorganic N.

Specific questions that were addressed were:

(1). How does DOM in agricultural runoff change with time after manure application?
(2). How does the concentration and composition of DOM change with landscape positions (field edge, riparian and stream locations)?
(3). How does DOM from poultry manure compare against other agricultural sources and what are the broader environmental implications?

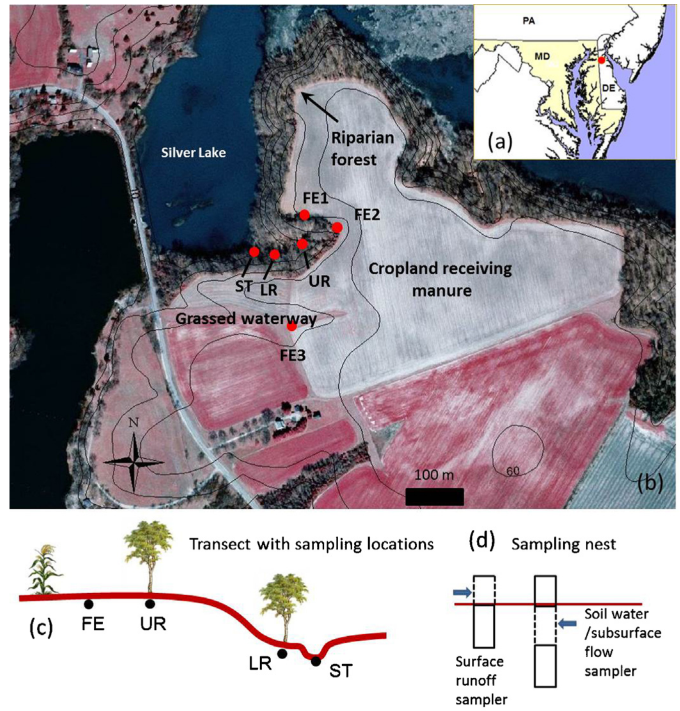

Fig. 1. (a) Location of study site in Delaware (inset). (b) Aerial view of sampling locations: field edge (FE1, FE2, and FE3), upland riparian (UL), lowland riparian (LR) and stream (ST). (c) Schematic illustrating the sampling locations along the hillslope transect (not to scale). (d) Schematic of sampling nests with the surface and subsurface flow samplers. Dashed lines indicate the screened portion of the PVC pipe where the runoff entered while the lower solid portion of the pipe is where the runoff was collected.

2. Site description and methods

2.1. Site description

The study site and sampling locations have previously been described in Dutta et al. (2012b). Briefly, the study watershed is located near Middletown in New Castle County, Delaware (39.43°N, 75.67°W; Fig. 1). The watershed includes a 10 ha cropland that drains toward a riparian forest along the northwestern edge (Fig. 1). Average annual precipitation for New Castle County is 1130 mm (USDA-SCS, 1970). Precipitation during the summer is associated with low-pressure systems from the south that produce high-intensity convective storm events. Rainfall data was available from a climate station located in Middletown, Delaware (DEOS, 2012) within 3 km of the study site. Average annual temperature is 54 °F (12 °C) with maximum temperatures occurring during the latter part of July. Corn (*Zea mays* L.) is the primary crop on the agricultural fields with wheat as a cover crop during the winter. In 2010, corn was planted during the first week of May with harvest during the month of September. The cropland has received conventional tillage every year for more than 5 years (as of 2010). Raw poultry manure has been applied to the fields once every 3 years, is typically applied only in spring, and is incorporated into the surface soil (5–10 cm) during application using a mechanical spreader. In 2010, manure was applied on April 10 at the rate of 9 Mg ha^{-1} (air-dry weight). This cropland did not have tile drainage.

Runoff sampling "nests" were established at the field edge (FE), and at the upland (UR) and lowland riparian (LR) forest/wetland locations (Fig. 1). Each nest was composed of two PVC (13 cm diameter, 46 cm length) pipes—one for surface water (screened for a length of 15 cm above the soil surface with a lid on top) and the