Leaching Risk of Micro-pollutants during Wastewater Irrigation on Turfgrass

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Abstract

Many by-products are formed during wastewater treatment, including *N*-nitrosodimethylamine (NDMA), a highly potent carcinogenic compound that is frequently found in municipal wastewater effluents. NDMA is miscible in water and negligibly adsorbed to soil, and therefore may pose a threat to groundwater when treated wastewater is used for landscape irrigation. A field study was carried out in the summer months of 2004 under arid Southern California weather conditions to evaluate the leaching potential of NDMA in turfgrass soils during wastewater irrigation. Wastewater was used to irrigate multiple Bermuda turfgrass plots at 110-160% ETo for about 4 months, and leachate was continuously collected and analyzed for NDMA. Although the input wastewater contained high levels of NDMA (114-1820 ng/L; mean 930 ng/L), NDMA was seldom detected in the leachate regardless of the soil type or irrigation schedule. At a method detection limit of 2 ng/L, NDMA was only detected in 9 out of 400 leachate samples at trace levels. Under conditions typical of turfgrass irrigation with wastewater effluent it is unlikely that NDMA will contaminate groundwater.

Introduction

The scarcity of water supply in many arid regions, combined with the need for disposal of large volumes of wastewater, has led to an increased use of treated wastewater for groundwater recharge or landscape irrigation. However, public health officials recently have begun to express concerns about the potential for wastewater-derived contaminants to contaminate potable water supplies. *N*-Nitrosodimethylamine (NDMA), a compound that is known for its high cancer potency, is detected frequently in municipal wastewater effluent at concentrations up to 1000 ng/L. Earlier studies showed that NDMA has negligible affinity for soils but relatively long persistence in soil. These characteristics suggest that NDMA may easily leach through soil and contaminate groundwater if NDMA-containing wastewater is applied at the soil surface. The purpose of this study was to evaluate the leaching risk of NDMA during the use of treated wastewater for irrigating turfgrass soils. Treated wastewater was used to irrigate mature turfgrass plots in the summer months under the weather conditions typical of the arid southwestern regions of the U.S., and leachate was monitored for about 4 months for breakthrough of NDMA.

Materials & Methods

Source of Wastewater: Nitrified, filtered wastewater effluent, collected after chlorine disinfection was obtained from a local wastewater treatment plant. The wastewater effluent was stored in a 6000-gallon opaque polyethylene tank at the study site. A total of five tanks of treated wastewater were used for irrigation over a period of 113 d. During the study, triplicate samples were taken once a week from the tank and analyzed for NDMA concentrations.

Field Site and Soil Properties: The field study was carried out in turfgrass plots located near the Campus of University of California Riverside. The turfgrass plots were constructed in 1992 and transplanted with a hybrid Bermuda grass. Each plot was 3.7 × 3.7 m in dimension and was equipped with a separate sprinkler system with four pop-up sprinklers situated at the corners. At the time of construction, the top 89 cm was filled with soil, either a sandy loam or a loamy sand, while the bottom layer (7.6 cm) was paved with gravel. At the center of each plot, a cluster of five 55-gallon steel drums were similarly filled with the soil and gravel. Leachate from each drum drained under gravity through a galvanized steel conduit pipe to an outlet at the edge of the field (at a lower elevation). Both soils, regardless of the turfgrass variety, contained little organic matter below the surface layer, and may be considered highly conducive for water movement (**Figure 1**).

Irrigation Treatment and Leachate Collection: Eight Bermuda grass plots, four for each soil type, were used for the irrigation study. The field study was conducted from June 15 to October 8 in 2004. Four treatments, each in two random plots, were considered in this study: two soil types (a sandy loam soil and a loamy sand soil), and two irrigation schedules. Irrigation occurred at night (from 10:30 PM) or in the daytime (from 7:30 AM). The irrigation rate was maintained at 110-130% of ETo during the first 11 weeks and was increased to 160% ETo thereafter to further increase the leachate flux (**Figure 2**). Leachate from each plot was collected in an opaque polyethylene container with a small opening. Three times a week, the leachate samples were extracted and analyzed for NDMA.

Figure 1. Retrofitted turfgrass plots and leachate collection for NDMA analysis

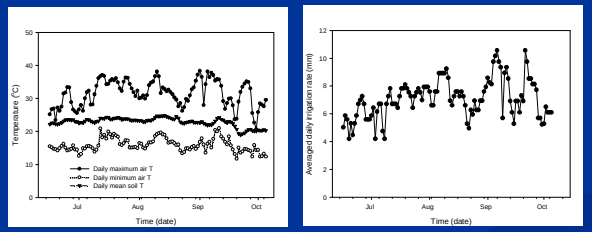

Figure 2. Air and soil temperatures (ºC) and averaged daily irrigation rate (mm)

♦ **NDMA Analysis:** A 1000-mL water sample was transferred to a 2-L glass separatory funnel and fortified with 0.1 mL of 10 mg/L d6-NDMA (surrogate) in methylene chloride. The sample was extracted with 100 mL methylene chloride for three consecutive times. The solvent phase was then collected, concentrated to 0.1-0.2 mL, and analyzed for NDMA by GC-MS. The MDL was 2 ng/L for this procedure.

Results

♦ **NDMA in Input Water:** The concentration of NDMA in the wastewater effluent used for irrigation was relatively high, with a mean concentration of 930 ng/L (**Figure 3**).

♦ **NDMA in Leachate:** From June 16 through October 12, 2004, leachate from each test plot was sampled and analyzed for a total of 50 times, at a frequency of 3 times per week. In most samples, NDMA was not detected (**Figure 4**). At a method detection limit (MDL) of 2 ng/L, of the 200 samples taken from the daytime irrigated plots, only 4 samples, or 2%, gave positive NDMA detection (**Figure 4A, 4B**). When detected, NDMA concentrations were low, with the highest concentration at 5 ng/L. Of the 200 samples taken from the nighttime irrigated plots, only 5 samples, or 2.5%, had positive detection of NDMA (**Figure 4C, 4D**). Similarly, even when detected, the NDMA level was very low, at ≤ 5 ng/L.

♦ **NDMA Leaching Potential:** Given that the NDMA concentration in the input water was always about two orders of magnitude higher than the limit of quantification of the analytical technique and that excessive irrigation rates were used, it may be concluded that NDMA has little potential for leaching to groundwater when treated wastewater is used to irrigate turfgrass systems such as golf courses, parks, or lawns.

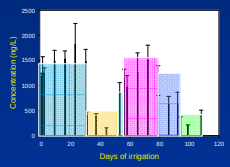

Figure 3. High levels of NDMA in the input treated wastewater

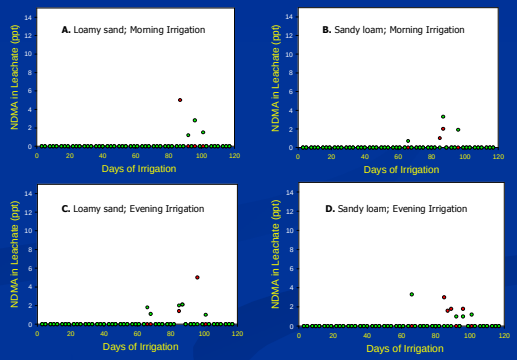

Figure 4. NDMA in leachate samples collected throughout the 113-day irrigation study

Conclusions

In conclusion, NDMA introduced through surface irrigation of treated wastewater was found to not leach through a <100 cm profile of turfgrass soil under field conditions. The limited NDMA leaching was likely a result of plant uptake of NDMA, rapid NDMA volatilization, or both. As the field irrigation study was carried out under scenarios that were conducive to rapid leaching of NDMA, it may be concluded that most of the NDMA applied to the soil will not leach to groundwater if treated wastewater is used to irrigate golf courses, parks, or other landscaped areas. Further research is needed to characterize the importance of plant uptake and volatilization in facilitating NDMA dissipation and preventing its leaching following wastewater irrigation.

References

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Gan, J., S. Bondarenko, F. Ernst, W. Yang, S. Bries, and D. Sedlak. 2005. Leaching of *N*-nitrosodimethylamine (NDMA) in turfgrass soils during wastewater irrigation. *J. Environ. Qual.* (in press)

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