The Influence of Effluent Irrigation on Specific Soil Microbial Populations and Parameter

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INTRODUCTION

Effluent water is a valuable resource in the desert Southwest for irrigating landscape and turfgrass plants. Turfgrass-related facilities use 57,000 ac-ft of potable water annually in the Tucson and Phoenix Groundwater Active Management Areas. This represents 15.4% of the total water used by the municipal and industrial sectors. The use of effluent water and other water management strategies could reduce municipal water use by as much as 25% (Arizona Dept. of Water Resources). However, effluent is lower quality than potable water; the influence of effluent on soil, plant and water quality must be better understood before widespread public acceptance can occur.

Turfgrass areas are ideally suited for effluent irrigation for several reasons: a) turfgrass is grown the year round. This permits year-round disposal of effluent; b) although turfgrass requires nitrogen at a fairly constant level, its dense and vigorous root system is much more efficient in removal of nitrogen from the soil than many other crops (Allison, F.E. USDA Technical Bulletin 1199:1-62). Pepper et al. (OWRT Project B-072-Ariz) found the nutrient content of effluent could be reduced to safe levels by turf. Mancino (1983 M.S. Thesis, Univ. of Massachusetts, Amherst) found the same to be true after nitrogen fertilizer application to turf on sand soils; c) the turf root-soil system was shown by Mancino and Torello (Plant-Soil 96:145-151) and Mancino et al. (Agron. J. 80:148-153) to have a high potential for the removal of nitrogen from soil via the denitrification. This would be equivalent to the tertiary treatment of effluent at wastewater treatment plants; and d) turfgrass is a non-consumable crop; effluent water of questionable quality could still be used to irrigate it.

The purpose of this initial study was determining how the application of effluent water to bermudagrass turf influenced specific microbial populations and their activity. If populations involved in nitrogen cycling are influenced it will be important to know of these changes to allow better management of nitrogen fertilizer inputs. If denitrifying populations are increased, the turf-soil system could be exploited as a nitrogen removal system. Further studies into the actual loss of nitrogen through denitrification and the overall management of this soil will be pursued.

A concurrent study by Pepper and Hayes (Dept. of Soil-Water Science) is evaluating the influence of this irrigation source on the chemical properties of this turfgrass soil.

MATERIALS AND METHODS

Arthur Pack Golf Course (15 Km north of Tucson) is a privately maintained public golf course constructed approximately twelve years ago. It has been irrigated continuously with effluent water supplied by the Ina Road Wastewater Treatment Plant. A virgin piece of desert soil was cleared and planted to 'common' bermudagrass turf in 1986 by Pepper and Hayes. The turf plot was then divided into 6 plots. Alternate plots were and are irrigated with effluent water while the remaining plots receive potable irrigation water. The turf has been maintained under golf course fairway conditions and irrigated to prevent drought stress.

Six soil samples were removed from each plot on 1 July 1988 and combined to give a composite sample for each irrigated plot. Soil samples were also taken from the adjacent desert soil receiving irrigation water as a result of overspray. Replicated composite dry desert soil was also collected. Samples were collected during monsoons so that the dry desert was receiving rainwater (Casarini et al. Wat. Sci. Tech. 19:167-176).

The microtiter procedures described by Rowe et al. (Appl. Environ. Microbiol. 33:675-680) and Staley and Griffin (Soil Biol. Biochem. 13:385-388) were used to enumerate the nitrifying and denitrifying populations of the soil samples. Total aerobes were enumerated by direct plate counts (Volz, M.G. Soil Sci. Soc. Am. J. 41:337-340). Anaerobic soil respiration was determined using the procedure of Edwards (Pedobiologia 23:321-330). Nitrification potential was determined by placing 6-gram samples of air-dried soil into test tubes and bringing them to 50% of soil saturation with a solution of ammonium phosphate. Final concentration of ammonium phosphate was 50 ugN/gram of soil. Nitrate-N was extracted with water after a 15 day incubation period at 30 C and the concentrations determined by ion chromotography. Total organic carbon and nitrogen were determined on the samples by the University of Arizona Soil, Water and Plant Testing Laboratory.

RESULTS AND DISCUSSION

Total aerobes per gram dry soil increased by 161% in the irrigated plots (when compared with dry desert soil), but the type of irrigation water applied did not matter. Mean populations were 260,000 per gram/dry soil for the dry desert, 390,000 per gram/dry soil for irrigated turf, and 440,000 per gram/dry soil for irrigated desert. The coefficient of variation for the potable plots and dry desert soil could be as high as 35 to 69% of the total aerobic population. Variation in effluent-treated plots was lower at 11 to 16%, regardless of the type of groundcover (turf vs. desert vegetation). This seems to indicate that effluent water allows for a more even distribution of aerobic microorganisms in the soil, while turfgrass roots alone do not.

Irrigation water analyses revealed that effluent water was slightly higher in nitrates than potable water, but ammonium nitrogen was much higher in the effluent. Therefore, nitrogen may be responsible for the more uniform aerobic populations in the effluent-treated soil. However, the total C:N ratio of the soil did not depend on the type of irrigation water, but rather upon the type of vegetative cover. The turfgrass soil had a wide C:N ratio (12.7:1), whereas the irrigated desert was narrower (10.3:1). This means that, overall, the turf soil was nitrogen-deficient.

It was apparent from soil analyses done to %C that all the soils were very low in carbon. This %C ranged from 0.4 to only 0.7%. Turf plots were not higher in organic carbon than the irrigated desert plots, even after a 2-year period. Nitrogen removal by the turfgrass roots helps to explain the wide C:N ratio. It is not due, at this time, to a contribution of carbon to the soil by the turf roots. The lower nitrogen level in the turf plots could explain why the overall irrigated desert aerobic population was higher than the turf soil, but does not account for the variation occurring in population due to irrigation water type. The dry desert soil had a narrow C:N ratio of 9:1 and was low in organic carbon.

Irrigation water had the greatest influence on anaerobic soil respiration with effluent>potable water. Vegetation had no significant effect. Nitrogen available from the effluent probably allowed more anaerobic microbial respiration to occur. Measurement of aerobic respiration might further elucidate the influence of vegetation and water type on this soil microbial process. Increased soil respiration would result in lower oxygen levels, favoring the denitrification process.

Denitrifier and nitrate-reducer populations are responsible for the denitrification process. Populations were highly variable between treatment replicates. Overall, these populations represented from 1.4 to 1.9% of the total aerobic population. The denitrifier/nitrate reducer ratio ranged from 1.3 to 1.6 and was lowest under turf. How these populations will relate to the denitrification potential of these soils is yet to be determined.

Nitrification potential of the turf soil was not affected by irrigation with effluent. This soils nitrification potential was equivalent to that found in the dry desert soil. This was not the case for the irrigated desert soil where nitrification was slightly, but significantly, increased in the effluent plots. Mean nitrification values exceeded that of the turf and dry desert soil by 2 to 6ppm nitrate-N/gram air-dry soil. Nitrifier population was three times greater in the irrigated desert soil when compared to the turf and desert soils which were equal. Effluent irrigated desert soil had 23,200 nitrifiers/gram air-dried soil while the same soil irrigated with potable water had a population of 13,050 nitrifiers/g air-dried soil. Nitrifiers represented 1.5% of the total aerobes for the turf soil, 2.4 % for the dry desert soil, and 4.1% of the total aerobes for the irrigated desert soils.

SUMMARY

It appears that irrigation with effluent water does have some influence on anaerobic soil respiration, uniformity of total aerobes, nitrifier populations and nitrification. How these factors will influence the management of these soils is yet to be determined.

The fact that turfgrass roots had not contributed additional organic carbon to this desert soil after two years is surprising.

This study will continue indefinitely to assess the impact of the long-term irrigation of turfgrass soil with secondarily-treated waste water. Denitrification potential of these soils will be determined in order to reach some conclusion as to how well the turf-soil system can serve as a tertiary treatment for effluent.