EVALUATION OF A TURFGRASS - SOIL SYSTEM TO UTILIZE AND PURIFY MUNICIPAL WASTE WATER[1]

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Introduction

The value of sewage effluent for the irrigation of agronomic crops has been well established. The plant-soil system is capable of utilizing the nutrient in the effluent and at the same time provides quality treatment on the waste water. Most of the current use of sewage effluent is directed toward the production of food and fiber crops.

In studies conducted by Day, Tucker and Vavich, it was shown that municipal effluent can be effectively utilized for the irrigation of small grains. Kardos (1968) at Pennsylvania State University found high nitrogen (N) utilization by reed canarygrass irrigated with sewage effluent. A farm near Lubbock, Texas (Gray, 1968) has been using nearly all of the city's wastewater for the irrigation of small grains and cotton since 1937. This operation has reported that yields with effluent irrigation are up to twice that obtained by normal irrigation farming.

The reclamation of municipal wastewater, emphasizing ground water recharge rather than crop production, has been studied by Bouwer and Lance (1970) at the Flushing Meadows Project west of Phoenix, Arizona. Secondarily treated effluent is given tertiary treatment by soil filtration before reaching the groundwater table. Similar work done at Whittier Narrows in California by McMichael and McKee (1965) indicated that the soil was an effective wastewater

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[1] Journal Paper No. 1966 of the Arizona Experiment Station

treatment system. Wells (1968) has stated that some potential problems associated with sewage effluent recharge of ground water are: chemical mixing of recharge effluent and existing ground water; introduction of disease carrying organisms to the ground water; soil clogging; and aesthetic acceptance.

Nitrogen compounds in sewage effluent or fertilizer applied to the soil can contribute to ground water pollution. Keeney and Gardner (1970) reported instances of increasing ground water contamination from nitrate as a result of effluent and fertilizer applied to the soil. Cases of high nitrate content in ground water have been cited (McGauhey and Krone, 1967) when wastewater was recharged through the soil. Ground water nitrate concentrations increased 1.0 mg/liter/month at the Texas Tech Farm when sewage effluent was used for deliberate recharge (Wells, 1963). Ramati and Mor (1966) also reported increased nitrate concentrations resulting from wastewater irrigation of field crops on shifting sand dunes in Israel.

Under arid and semi-arid conditions turfgrass can utilize large amounts of N. Bermudagrass may require 8 to 16 pounds of N per 1,000 ft^2 during a 12 month growing season (Keen, 1969). Annual ryegrass needs about one pound of N per 1,000 ft^2 per month during the winter season (Schmidt and Blaser, 1969). It is evident that these grass species which are common to the southwest have a high nutrient demand for N and may be used effectively in a year-round system for sewage effluent purification.

This study was undertaken to determine the capacity of selected turfgrass soil systems to purify municipal sewage effluent and to measure the degree of utilization of N in the effluent by turfgrass. These factors, together with potential recharge rates, were examined for sandy loam and silt loam soils.

Materials and Methods

Secondarily treated sewage effluent which had been chlorinated was obtained from the sewage treatment plant of the City of Tucson. The effluent varied from 13 to 26 ppm in total N, 70% of which was generally in the form of NH_4^+-N. Turfgrass was grown in sandy loam (70% sand, 17% silt, 13% clay) and silt loam (22% sand, 61% silt, 17% clay) soils contained in 24 20-liter pots. Twelve of the pots were irrigated with tap water supplemented with N and phosphate (P) in the predominate forms and amounts present in the sewage effluent. The remaining pots were irrigated with sewage effluent. Three levels of irrigation were used: low = 0.71 in.; medium = 1.42 in.; high = 2.13 in. Due to a N deficiency in the turfgrass these levels were later increased to low - 1.28 in., medium = 2.56 in. and high = 2.84 in. Treatments were prepared in duplicate and arranged in a complete factorial combination.

Each pot was instrumented with two suction probes located about 25 centimeters below the soil surface to simulate sub-soil moisture tensions and to extract soil water quantitatively. One of the probes, which was designed to remove gravitational water, consisted of a perforated plastic tube packed with glass wool. The other probe was a ceramic tensiometer cup for removal of soil water at tensions up to 1/3 bar. Both of the probes were connected to suction lines leading to a collection bottle packed in ice (Fig. 1).

Irrigations were made when approximately 60% of the available soil moisture had been depleted as determined from soil moisture blocks three inches below the surface on the low irrigation level treatment. All irrigation levels were applied at the same time for a given soil and quantitative soil water extracts were obtained through the suction probes following each irrigation.

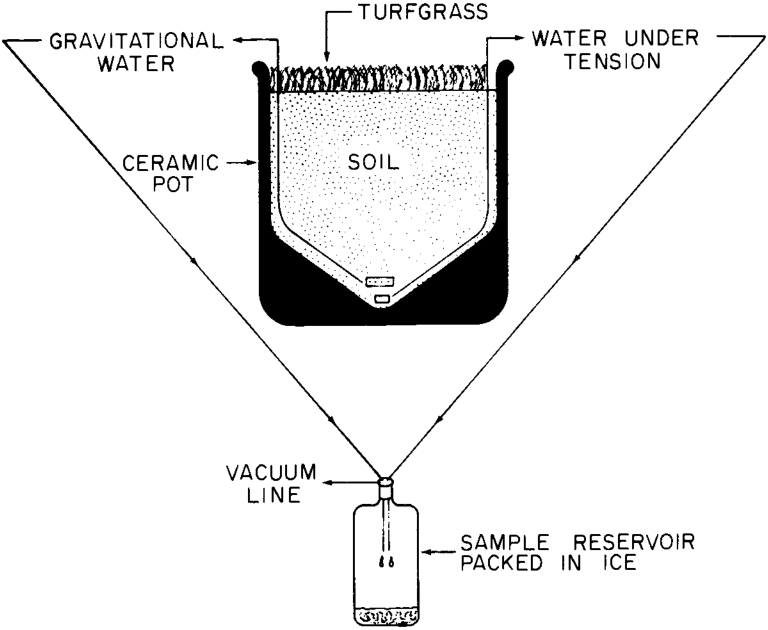

Figure 1. Diagram of experimental system

Soil water samples and turfgrass clippings were combined for three week intervals throughout the study. The volume of leaching water and its content of NH_4^+-N, NO_3^--N, organic-N and total-N were measured for each period. Turfgrass clippings were oven dried at 87°C, weighed, and analyzed for total-N. Total-N NH_4^+-N, NO_3^-, and organic-N analyses were performed on the initial and final soil samples. All analytical methods used have been described by Bremner (1965).

The study was conducted at the University of Arizona Turfgrass Research Center over a period of 30 weeks, from September 3, 1971, to March 30, 1972. Common bermudgrass (*Cynodon doctylon*) was grown for the first month of the study and was then overseeded with annual ryegrass (*Lolium multiflorum*) for the remainder of the period.

The main objectives of the study were achieved by evaluating purification efficiency, utilization, and percent recharge at the end of each three week period and for the entire 30 week study. Purification efficiency, utilization, and percent recharge are defined by the following equations:

$$E = \left[1 - (\Sigma N_1 / \Sigma N_e)\right] 100 \qquad (1)$$

where: E = purification efficiency (for N) of system

ΣN_1 = total N removed in leachate

ΣN_e = total N applied in effluent or nutrient solution

$$U_t = (\Sigma N_t / \Sigma N_e) 100 \qquad (2)$$

where: U_t = utilization of N by turfgrass

ΣN_t = total N removed in turfgrass clippings

ΣN_e = total N applied in effluent or nutrient solution

$$\% R = (\Sigma V_1 / \Sigma V_e) 100 \qquad (3)$$

where: %R = percent recharge

ΣV_l = total volume of leachate collected

ΣV_e = total volume of effluent or nutrient solution applied

All data were analyzed statistically using Student-Newman-Keul's multiple range test using the .05 level of significance.

Results and Discussion

The purification efficiency parameter was developed to account for N in solution moving below the root zone. Since a completely closed N balance is nearly impossible to obtain in a field study because of the difficulty in measuring gaseous losses, it was felt that purification efficiency would give the best estimate of potential N pollution of ground water. As used here, purification efficiency is a measure of the amount of N in the recharge water compared to the amount of N applied. There was no significant difference in purification efficiency among any of the treatments in the sandy loam soil or between the two soils. The high irrigation level on the silt loam soil resulted in a significantly lower purification efficiency than either the low or medium irrigation levels. Apparently under higher irrigation rates the ability of the system to remove N was reduced. A similar tendency was found for the sandy loam soil, (Table 1), although the difference was not significant.

The concentration of NH_4^+-N in the leachate was not significantly different among treatments within either of the soils, however, averaged over all irrigation levels and sources the NH_4^+-N concentration was significantly greater for the silt loam (1.38 ppm) than the sandy loam soil (0.36 ppm). Concentrations of NO_3^--N in the leachate from the sandy loam soil were not significantly different among treatments, whereas, the high irrigation level

TABLE 1. MEAN VALUES FOR PURIFICATION EFFICIENCY, NITROGEN UTILIZATION AND PERCENT RECHARGE.

SOIL TYPE	IRRIGATION SOURCE	IRRIGATION LEVEL	PURIFICATION EFFICIENCY	UTILIZATION OF N BY GRASS	RECHARGE
			%	%	%
SL	EFFLUENT	L	94.4	115.5	22.9
SL	EFFLUENT	M	94.6	83.0	36.9
SL	EFFLUENT	H	94.0	86.7	40.6
SL	CONTROL*	L	95.4	98.0	21.0
SL	CONTROL*	M	94.7	86.0	36.9
SL	CONTROL*	H	94.8	79.4	42.8
SiL	EFFLUENT	L	96.9	82.4	16.1
SiL	EFFLUENT	M	95.6	70.5	27.4
SiL	EFFLUENT	H	91.5	68.8	39.5
SiL	CONTROL*	L	99.1	70.0	11.8
SiL	CONTROL*	M	96.3	83.3	15.7
SiL	CONTROL*	H	94.9	94.9	33.3

*TAP WATER + $(NH_4)_2HPO_4$

resulted in significantly higher NO_3^--N concentrations than either the low or medium levels in the leachate from the silt loam soil. The mean NO_3^- leachate concentrations did not differ significantly between soils. Nitrate concentrations never exceeded 4.0 ppm for any treatments at any time during the experiment.

There was a significantly greater concentration of organic-N in the leachate under low irrigation treatment than in the medium or high levels for the sandy loam soil. The concentration of organic-N in the leachate from the silt loam soil was not affected by treatments. Significantly greater concentrations of organic-N were found in the leachate from the sandy loam than in the silt loam soil. This may be a result of increased mobility of microbial debris in the coarser textured soil. The total-N concentration in the leachate was significantly greater under low irrigation than the medium or high irrigation levels for the sandy loam soil. Apparently a higher percentage of the applied solution was evaporated at this low irrigation level on the coarse textured soil causing the leachate to be more concentrated in dissolved solids. There were no differences in total-N concentration among treatments in the silt loam soil nor between the two soils.

Utilization of N by the turfgrass represents a ratio of N removed in clippings N applied in the effluent or nutrient solution (Table 1). There was no significant difference in the utilization rates among treatments for either soil. The utilization rate was significantly higher for turfgrass grown on sandy loam than on silt loam soil. This may have been due to slightly higher dry weight yield on the sandy loam treatments. Irrigation with nutrient solution resulted in a significantly greater percentage of N in the dry grass clippings than irrigation with effluent for both soils. For both soils the high irrigation treatment resulted in significantly more N in clippings than the medium level, which in turn was more than the low level. No differences in N content of clippings was found between soils.

The potential ground water recharge (expressed as a percentage of the irrigation volume) was higher under the sandy loam soil than the silt loam soil (Table 1). This could be a result of higher infiltration and permeability rates in the coarser textured soil. Low irrigation levels resulted in significantly lower recharge than the other levels for both soils. There was a significantly greater recharge from the high irrigation level than the medium level in the silt loam, but not in the sandy loam soil. Also the effluent treatments were associated with significantly greater recharge than the nutrient solution treatments in the silt loam soil.

Major differences were observed in purification efficiency in relation to time. These differences, illustrated by the data for the sandy loam soil irrigated with effluent (Fig. 2) were not related to specific treatments of soil type. Initially the purification efficiency was high since the bermudagrass was well established when treatments were first applied. The small drop in efficiency during the first part of October was probably due to N leaching caused by the application of excess tap water to aid in establishing the newly seeded ryegrass. The continuing drop in efficiency up to November may have resulted from excessive rain during the period which required leaching extractions to be withdrawn even though treatments were not applied. After exhibiting a higher efficiency level near the end of November, the rate once again dropeed due to excessive rain. The growth of ryegrass was hampered

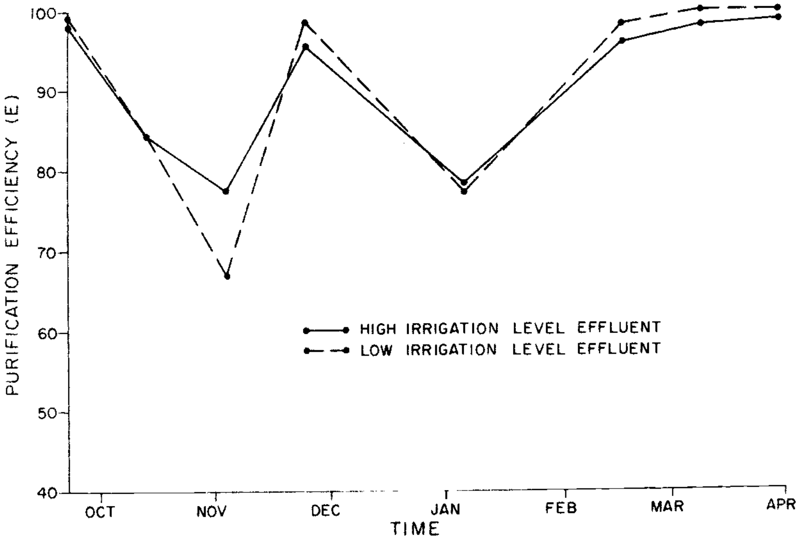

Figure 2. Sewage effluent purification by turfgrass - sandy loam soil system.

by disease. As a result of these low treatment levels and the absence of rain, the efficiency increased during this period. Once the ryegrass recovered from the disease, it grew well and efficiency rates remained very high.

Utilization of N by the turfgrass tended to vary with factors such as cutting height and disease. These variations, shown by the data for the sandy loam soil irrigated with effluent (Fig. 3), were not related to treatments or soil type. The utilization peaks in October and January were associated with scalping the grass plots in preparation for seeding and due to occurrence of disease respectively. The low utilization in February was probably a result of slow recovery of the ryegrass from disease.

Summary and Conclusions

The capacity of turfgrass-soil systems to utilize N and purify wastewater was examined. Results indicate that turfgrass can be irrigated with sewage effluent at common rates without hazard of N ground water pollution

Purification efficiency was greater than 90% for each of three irrigation levels and two different textured soils. Irrigation with effluent in excess of plant water requirements on coarse textured soil resulted in up to 41% recharge with high quality water in terms of N content. This was demonstrated by the fact that NO_3^--N concentrations in the leachate from the sandy loam soil irrigated with effluent averaged about 40 times less than the U.S. Public Health Service limits. Periods of substantial rain and low N utilization by the turfgrass tended to reduce purification efficiency.

Nitrogen utilization by the turfgrass was higher for treatments on sandy loam than silt loam soil. Average utilization rates varied from 79 to 115% for the coarser textured soil. Factors causing major fluctuations in utilization rates throughout the study appeared to be cutting height and disease of the turfgrass.

Acknowledgements:

This research was supported by Allotment Grant number 5010-5351-72 (A.025) of the Water Resources Research Center. The University of Arizona

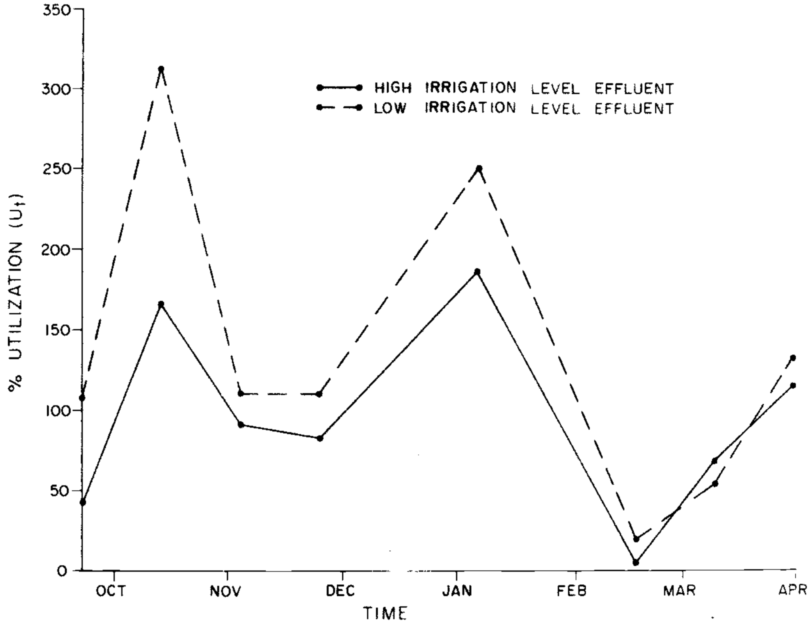

Figure 3. Utilization of nitrogen from sewage effluent by turfgrass grown on sandy loam soil.

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