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# NITROGEN REMOVAL FROM SECONDARY EFFLUENT APPLIED TO A SOIL-TURF FILTER

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## ABSTRACT

This study investigated the potential of a soil-turf filter to renovate secondary effluent applied in excess of consumptive use. Lysimeter plots were filled with a sand and a sand mix, and seeded to winter ryegrass. In spring, plots were scalped and seeded to bermudagrass. Plots were drip irrigated twice a week with secondary effluent at rates of 10, 17, 22, 34, and 43 mm/day. Leachate and effluent were analyzed for $NH_4$-N, $NO_3$-N, and organic-N. Grass clippings were oven dried, weighed, and analyzed for organic-N. Percent of leachate available for groundwater recharge was 50% at the lowest rate and 68% at the highest rate when values were averaged for both soils. The amount of nitrogen removed by the soil-turf filter using sand was 42 to 87% and 52 to 90% on the mix, decreasing as application rate increased. The highest nitrogen removal and utilization occurred at the lowest application rate. Turf utilization of nitrogen was 10 to 28% on sand and 18 to 36% on mix, decreasing as rate of application increased. The sand-turf filter renovated 22 mm/day and the mix-turf filter renovated 43 mm/day, yielding leachate averaging less than 10 ppm $NO_3$-N.

## INTRODUCTION

One-hundred percent of Tucson's water for 450,000 people comes from groundwater. Fifty percent of the water pumped into the distribution systems appears as return flow to sewage treatment plants (Cluff et al., 1972). Groundwater levels have been decreasing 2 to 5 feet per year as use exceeds natural replenishment. Over 30 million gallons of secondary effluent per day are released into the Santa Cruz River without consideration to nutrients in the effluent, groundwater pollution, or water conservation. Cluff et al. (1972) showed that distribution of effluent to farms in Avra Valley, Arizona, would be of economic benefit to farmers, saving on fertilizer costs, and to the city, saving groundwater.

Day et al. (1972) reported on a study covering 14 years of effluent application on a silt loam soil. They found effluent increased soluble salts, nitrate in the C horizon, phosphorus in surface soil, and the modulus of rupture. Infiltration rate decreased. These effects would not be detrimental with proper soil management. Bakersfield, California, has used effluent on agricultural crops since 1912 (Crites, 1975). All the effluent produced, 13 million gallons per day, is used on 2,500 acres. The crops grown had equal or larger yields compared to surrounding farms, except cotton which was 20% lower. St. Petersburg, Florida, used effluent for spray irrigation of parks and golf courses, saving potable water (White, 1975). Effluent is also used to prevent salt water intrusion into groundwater supplies in Florida.

The Environmental Protection Agency (EPA) standard for $NO_3$-N is 10 ppm in potable water, as nitrates cause methemoglobinemia in infants. Hook and Kardos (1978) found white spruce irrigated at 5 cm/week kept $NO_3$-N levels in leachate below 10 ppm, but hardwood forest was less effective. Canarygrass and grass-legume hays renovated effluent applied at 5 cm/week, but corn was not effective at this rate (Kardos and Sopper, 1973). Day (1973) suggested 2 to 7 acre-feet/year could be used to irrigate, depending on the crop. Sidle and Johnson (1972) found turfgrass removed 95% of the nitrogen applied in effluent. Their plots were irrigated with 2.84 inches of effluent whenever available soil moisture reached 40%. Osborne (1975) found peat and sand with stalked blue grass growing removed 46% of the nitrogen from effluent applied at 0.63 cm/hour.

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TABLE 1. RATES USED 24 JULY - 24 DECEMBER

| Rate in multiples of consumptive use | Rate (mm/day) | Liters applied twice a week |
|---|---|---|
| 2 | 10 | 36 |
| 3 | 17 | 58 |
| 4 | 22 | 76 |
| 7 | 34 | 120 |
| 8 | 43 | 152 |

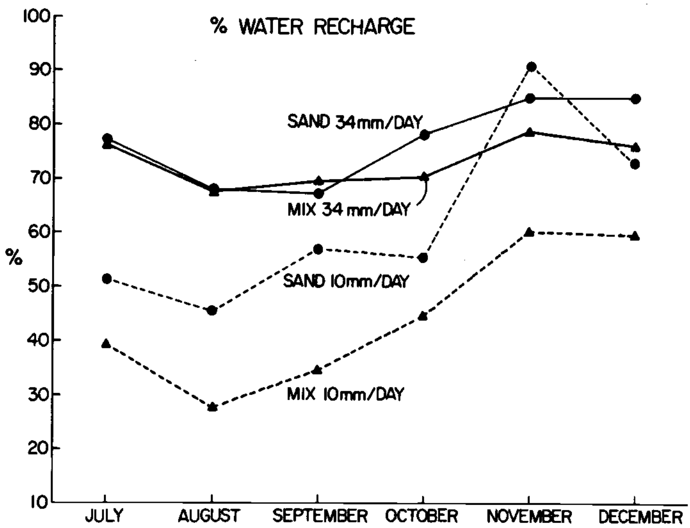


Figure 1. Percent water recharge graph, illustrating percent of water applied available for reuse.

TABLE 2. AVERAGE VALUES FOR 24 JULY - 24 DECEMBER, 1977

| Rate | Recharge | | Purification | | Utilization | |
|---|---|---|---|---|---|---|
| | Sand | Mix | Sand | Mix | Sand | Mix |
| mm/day | ---- % ---- | | ---- % ---- | | ---- % ---- | |
| 10 | 57.6a | 41.0a | 84.0a | 90.1a | 28.5a | 36.2a |
| 17 | 74.8b | 70.0b | 65.4b | 72.3b | 23.0b | 30.8b |
| 22 | 74.8b | 62.5c | 56.0c | 69.7b | 19.1c | 25.4c |
| 34 | 75.7b | 72.3b | 47.7d | 57.4c | 13.9d | 19.8d |
| 43 | 71.7b | 64.8c | 42.3e | 51.9d | 10.4e | 17.7d |

Means in columns not followed by same letter are statistically different at $p = 0.05$ as tested by SNK range test.

Renovation of large quantities of effluent for groundwater recharge can be accomplished using a high rate infiltration basin or aquifer. Flushing Meadows in Phoenix, Arizona, reclaimed 91 m/year removing 30% of the effluent nitrogen (Bouwer et al., 1974). Most quality improvement takes place in the first meter of soil. Vegetated basins filtered suspended solids and maintained infiltration rates. An advantage of collecting reclaimed water underground is the water loses its identity as sewage water (Bouwer, 1968). Reclaimed water can be used in industry, by the city, or for irrigation to reduce the draw on groundwater.

The mechanism of purifying effluent at high infiltration rates is nitrification followed by denitrification. Lance et al. (1973) found a 5-day dry period allowed enough oxygen to enter the soil for nitrification to occur after 6 days of flooding. Subsequent denitrification was dependent on the amount of organic C in the effluent and an anaerobic environment (Lance et al., 1976).

Tofflemin and Farnan (1975) reviewed several studies showing land treatment of wastewater is generally less expensive than tertiary treatment. Young and Carlson (1975) surveyed the southern United States and found land application of wastewater was the lowest cost alternative for improving water quality. Bouwer (1968) estimated filtration basin reclamation costs $8/acre foot compared to a tertiary treatment cost of $37/acre foot.

In this study, the advantage of using turf as a renovating agent was combined with application rates of 10 to 43 mm/wk to determine quality and amount of recharge water available for reuse.

## MATERIALS AND METHODS

This study was conducted at the University of Arizona Turfgrass Research Center in Tucson, on twenty lysimeters, 1 $m^2$ by 60 cm deep. Ten units were filled with 95% sand, 1% silt and 4% clay, (referred to as sand) with a cation exchange capacity (CEC) of 2.1 meq/100 g soil. The other 10 units contained 89% sand, 5% silt, 4% clay and 2% organic matter (referred to as mix), with a CEC of 4.8 meq/100 g soil. Both soils had a pH of 8.3. Units were arranged in a split plot design, with two different soils five application rates, and two replicates of each rate.

Secondary effluent was obtained from the Randolph Park sewage treatment plant in Tucson. Seasonal changes and lagoon storage of effluent at the plant caused the nitrogen content to vary. In summer, the effluent contained: 17 to 23 ppm $NH_4$-N, 0.5 ppm $NO_3$-N, and 2 to 5 ppm organic-N. In winter, values were: 3 to 6 ppm $NH_4$-N, 4 to 16 ppm $NO_3$-N, and 1 to 5 ppm organic-N.

Plots were drip irrigated twice weekly, using 15 mm drip irrigation lines with emitters that could deliver four gallons per hour at 15 lbs. pressure. Effluent was applied to each plot by gravity flow from calibrated barrels. Application rates for effluent were based on a study by Krans and Johnson (1974) which showed maximum consumptive use by bentgrass was 5 mm/day in August. These rates are shown in Table 1. High infiltration rates for both soils eliminated ponding of effluent on the soil surface.

After each effluent application, lysimeters were drained, leachate samples collected, and volume of leachate recorded. Samples of leachate and effluent were analyzed for $NH_4$-N, $NO_3$-N, and organic-N. Plots were mowed to 1.5 inches once a week. Clippings were oven dried at 80 C and total yield recorded. The clippings were then ground and analyzed for organic-N. All nitrogen determinations were made by micro-Kjeldahl technique (Bermner, 1965). All values were averaged over two week intervals.

Three criteria were used to evaluate this soil-turfgrass filter system. Percent water recharge was the parameter used to indicate the ability of the system to supply water for reuse or groundwater recharge.

$$\text{Percent Water Recharge} = \left(\frac{\text{Volume of leachate collected}}{\text{Volume of effluent applied}}\right) \times 100$$

Nitrogen purification efficiency is the amount of nitrogen removed from the effluent by the soil and turfgrass.

$$\text{Percent N Purification Efficiency} = \left[1-\left(\frac{\text{Volume of leachate x Total N ppm}}{\text{Total N applied in effluent}}\right)\right] \times 100$$

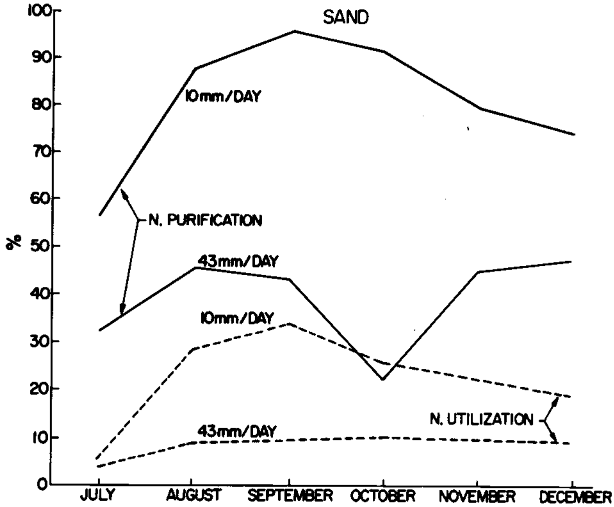


Figure 2. N purification efficiency and percent N utilization of sand-turf filter.

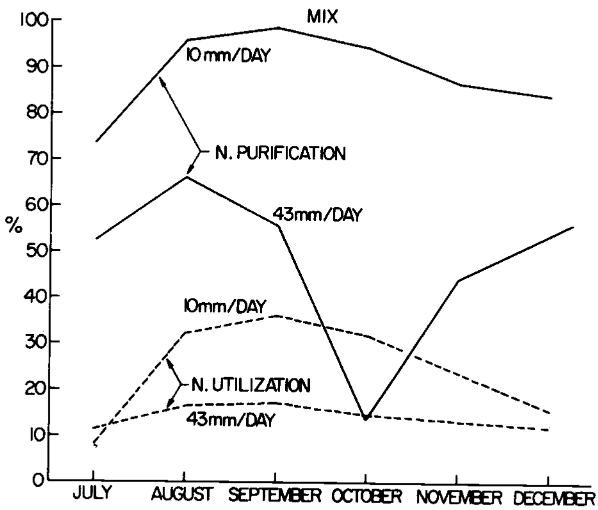


Figure 3. N purification efficiency and percent N utilization of mix-turf filter.

Percent nitrogen utilization is the amount of nitrogen used by the turfgrass.

$$\text{Percent N Utilization} = \left(\frac{\text{Wt. of clippings x \% organic - N}}{\text{Total N applied in effluent}}\right) \times 100$$

All data were statistically analyzed for significant differences at $p = 0.05$ level.

## RESULTS AND DISCUSSION

In a preliminary study, 30 April - 3 June, 1977, effluent was applied to plots seeded with annual ryegrass (Lolium multiflorum) at rates of 5, 10, 17, and 22 mm/day. Purification efficiency for all rates was greater than 90% on both soils. The mix soil was, on the average, 8% more efficient in purification than the sand. Percent utilization on the mix was 6% higher than the sand, averaging all rates. Peak utilization on the winter ryegrass was 41% on mix and 27% on sand, averaging all rates.

On 3 June, the winter ryegrass was removed and common bermuda grass (Cynodon doctylong) reseeded. At this time, effluent application rates were increased to: 10, 17, 22, 34, and 43 mm/day. After scalping, average percent utilization decreased to 10% on mix and 3% on sand, showing the importance of actively growing grass. Purification efficiency decreased to 46% on mix and 31% on sand. Initial high purification efficiencies could be due to $NH_4$ saturation of cation exchange sites in the soils.

The plots were allowed six weeks to equilibrate at the new rates. This study covers 24 July - 24 December, 1977. On 4 November, the bermudagrass was scalped and ryegrass reestablished with daily watering, using tap water. The objective was to determine the maximum rate of effluent that could be applied to a soil-turfgrass filter system and yield leachate containing less than 10 ppm $NO_3$-N, the EPA standard for potable water.

Figure 1 shows percent water recharge for both soils at rates of 10 and 34 mm/day. Percent recharge increased at times of scalping in June and November. This was due to extra watering for seedling establishment and decreased transpiration. Low effluent application rates had the lowest recharge volumes. As rate of application increased, percent recharge increased; but the difference in recharge between soils diminished. The lower water holding capacity of sand and lower grass yields contributed to 8% average higher recharge value over mix (Figure 4). On the sand soil, only the 10 mm/day rate was significantly different from the other four higher rates. On the mix 10, 17, and 22 mm/day were significantly different from each other.

Purification efficiencies are shown for sand in Figure 2 and for mix in Figure 3. Purification efficiencies were lowest during periods of scalping and seedling establishment due to decreased utilization. High rainfall in October decreased purification. The additional soil water from rain could have increased the velocity of effluent movement through the soil, decreasing interaction with the system. On sand, all five rates were significantly different. On mix, all rates except the 17 and 22 mm/day rates were significantly different. For both soils the lowest effluent rate had the highest purification efficiency: 90% on mix and 84% on sand, when averaged over time. At the highest rate, N removal decreased to 52% on mix and 42% on sand. For both soils, the higher rates were most affected by periods of reseeding. Purification efficiency on the mix was 10% higher than on sand when averaged over time and rates (Figure 4).

A good turf stand and favorable climate were necessary to maximize nitrogen utilization by the turfgrass. Figure 2 shows percent utilization on sand and Figure 3 for mix. On sand, all five rates were significantly different. On mix, all rates were significantly different except the 34 and 43 mm/day rates. The similarity at these high rates indicated turf utilization of nitrogen had reached a maximum. At the lower rates, percent utilization was higher; 28% on sand, 36% on mix when averaged over rates and time. At the highest rate, sand utilization decreased to 10% and mix to 18%. Mix had 6% higher utilization than sand (Figure 4).

Utilization of effluent nitrogen was dependent on grass growth. As optimum conditions for bermuda grass ended in October, utilizaton decreased. Cutting height of turf was important in maximizing utilization. If cut too short, growth was slowed, if too long, growth was not stimulated. The optimum mowing height appeared to be 1.25 to 1.5 inches.

Graphs of the data indicate that purification efficiency was related to percent utilization. During bermudagrass establishment, at the lowest rate, utilization increased by 26% while purification efficiency increased 25%, averaging both soils (Fig-

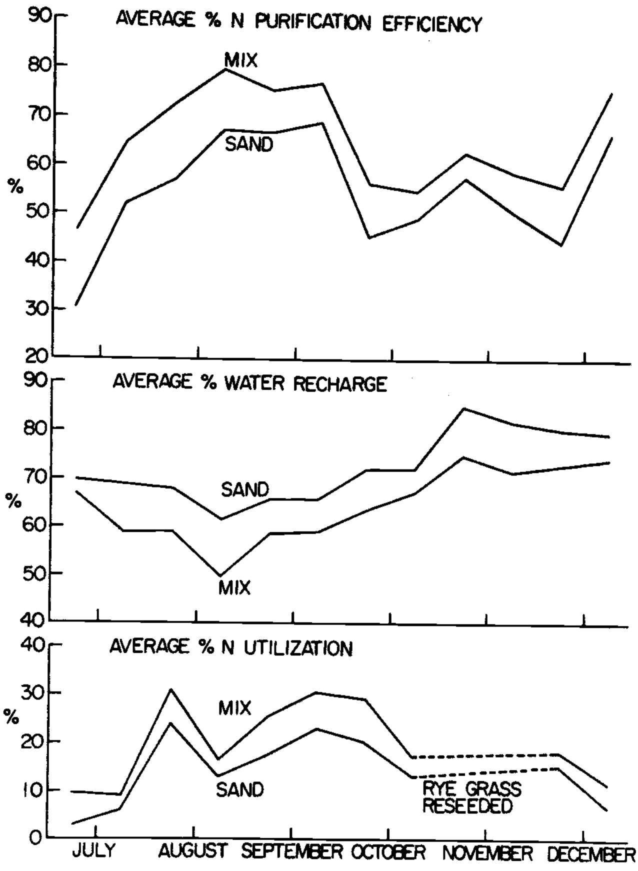


Figure 4. N purification efficiency, percent water recharge and percent N utilization for sand and mix averaged over all rates.

ure 4). At the highest rate, utilization increased 5% while purification increased 13%. Apparently at high application rates, soil adsorption and denitrification are increasingly important for purification. There was a corresponding decrease in utilization and purification when bermudagrass was removed and cool season ryegrass was seeded in November.

An inverse relation can be seen between recharge and purification efficiency in Figure 4. As recharge decreased, purification efficiency increased. Recharge values did not correlate with rainfall. Purification may be decreased by rainfall due to limited mixing between applied effluent and soil water.

## SUMMARY AND CONCLUSIONS

These results indicate that sand had a higher percent recharge than the mix. The mix soil had a higher purification efficiency and percent utilization than sand. The maximum rate of effluent application on the sand that yielded leachate, averaging less than 10 ppm $NO_3$-N was 22 mm/day. On mix, 43 mm/day yielded leachate meeting this criterion.

This study indicates the potential of soil-turfgrass filters as tertiary treatment for secondary effluent. Further investigations using soils with a greater CEC and infiltration rates that prevent surface ponding could maximize the effectiveness of the soil filter. Selecting turfgrass genotypes for maximum nutrient uptake would improve water purification. This system is particularly adapted to arid regions where water is a limited resource. Turfgrass, as a filter, offers the advantage of growing year round and providing recreational uses. Use of effluent for watering parks and golf courses would increase water available for domestic use.

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