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Project Summary

Rapid-Infiltration System for Wastewater Renovation and Beneficial Reuse

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A 16-ha rapid infiltration wastewater treatment system at Phoenix, AZ, was used to treat 90 m/yr of conventionally treated effluent. The reclaimed water was suitable for unrestricted irrigation and aquatic recreation. The renovated water typically contained 7 mg/l nitrogen, 1 to 20 fecal coliforms per 100 ml, 1 virus unit per 100 ml and less than 0.1 mg/l trihalomethanes.

This Project Summary was developed by EPA's Robert S. Kerr Environmental Research Laboratory, Ada, OK, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Sewage effluent can be an important source of water, particularly in water-short areas. Conventionally treated effluent can be used for restricted irrigation (fiber and seed crops, for example). With additional treatment, the effluent can also be used for unrestricted irrigation and aquatic recreation. This study shows how the necessary additional treatment can be obtained with soil-aquifer treatment systems using rapid-infiltration basins to get the effluent into the ground and the wells to pump the renovated water from the aquifer.

Following successful renovation of secondary (activated sludge) sewage effluent by soil-aquifer treatment using small, experimental infiltration basins (the Flushing Meadows Project) in the Salt River bed west of Phoenix, Arizona, a larger system was installed in 1975 to study operational aspects and performance of a full size project, including recovery of the renovated water by wells for irrigation. The system, called the 23rd Avenue Project, was constructed by splitting an existing 16-ha rectangular oxidation pond into four intermittently flooded infiltration basins averaging 89 x 465 m in size. The surface soil in the basins consisted of loamy sand, coarse sand, and coarse sand plus gravel and boulders. Gravel and coarse-sand strata prevailed below 0.5 m depth and continued to a depth of at least 60 m (the depth of the deepest well in the area). A large capacity well was installed in the center of the project as the first of three production wells on the center dike necessary for complete recovery of the renovated water from the aquifer. The well casing was perforated from 30 to 55 m. Groundwater table depths varied from 3 to 20 m. Monitoring wells were installed in the center of the project and on the north and south sides (Figure 1). Their depths ranged from 18 to 30 m.

Initially, the infiltration basins received effluent that had passed through a 32-ha lagoon. High algae concentrations in this effluent produced hydraulic loading rates of only 22 m/yr. This value was increased to 90 m/yr after the effluent was bypassed around the lagoon with a newly constructed channel and after the surface crust of the soil in the infiltration basins was ripped. Flooding

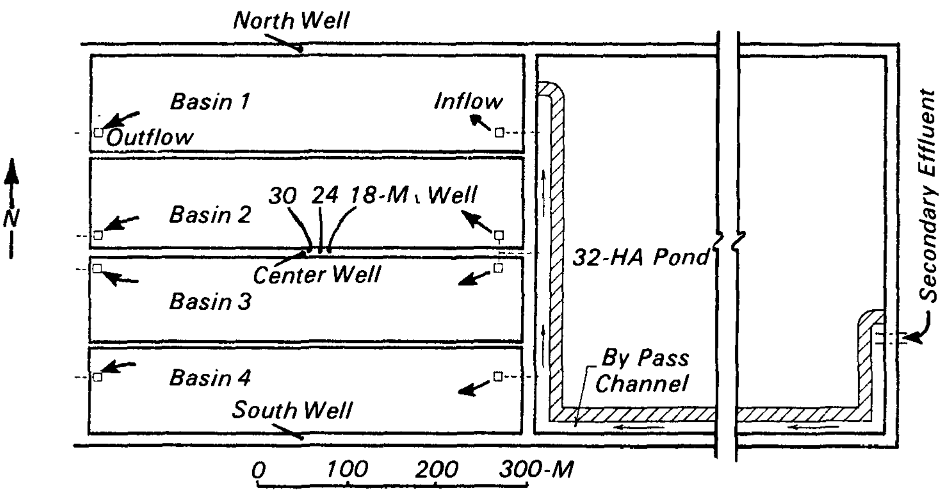

***Figure 1.** Schematic of 23rd Avenue Rapid Infiltration Project.*

and drying periods were about two weeks each.

The renovated water typically contained 750 mg/l dissolved solids, 0.9 mg/l suspended solids, 7 mg/l nitrogen (mostly nitrate), 0.25 mg/l phosphate-phosphorus, 1 to 20 fecal coliforms per 100 ml (average yearly values), about one virus unit per 100 l, and 1.8 mg/l total organic carbon. Except for the dissolved solids, these values were much lower than those for the secondary effluent entering the ground. Total organic carbon in the renovated water included a wide variety of organic compounds, including trihalomethanes (total concentration less than the interim maximum EPA limit of 0.1 mg/l for drinking water), chlorinated aliphatic and aromatic hydrocarbons, pesticides, plasticizers, and others (concentrations generally on the order of nanograms to micrograms per liter). Significant losses of volatile organic compounds occurred in the infiltration basins. Some compounds were also significantly attenuated in the soil-aquifer system.

The renovated water is suitable for unrestricted irrigation and for lakes with primary contact recreation. Reuse for drinking water will require additional treatment (ozonation, activated carbon adsorption, and possibly reverse osmosis).

System Performance

Hydraulic Capacity

The main problem encountered when the system started operation was the low infiltration rates in the basins. This was caused by a high algae content of the effluent after it had first gone through the 32-ha lagoon (Figure 1). The main algal bloom organism was *Carteria klebsii* Dillworth which is a suspended algae that clogged the surface soil in the basins so severely that infiltration rates often dropped from about 0.5 m/day to less than 0.1 m/day in the first two or three days of a flooding period. The relatively large water depth (1 m) in the basins was not sufficient to overcome the hydraulic impedance of the algal "filter cake." Since large water depths decreased the turnover rate of the water in the basins, they actually contributed to the problem by allowing additional algae growth in the infiltration basins. Drying periods of more than two weeks were required to get some recovery in infiltration capacity. Clogging very likely was not only by formation of an algal filter cake on the soil surface, but also by precipitation of calcium carbonate due to the high pH of the effluent as the algae absorbed carbon dioxide for photosynthesis. Thus, hydraulic loading rates initially were a disappointing 22 m/yr.

After it was established that the high algae content was the sole cause of the low infiltration rate (and not, for example, air-pressure buildup in the vadose zone below advancing wet fronts), a levee was constructed on the east, south, and west sides of the 32-ha lagoon to create a bypass channel (Figure 1). This allowed the effluent from the treatment plant to flow directly into the infiltration basins. Use of the bypass channel reduced the suspended solids content of the effluent entering the basins from a range of 50 to 100 mg/l (mostly as algae) to a range of 10 to 15 mg/l. The basins were also ripped to remove residual crusts on the soil. The water depth in the basins was reduced to about 25 cm to increase the turnover rate of the water in the basins and, hence, to decrease the time for suspended algae to develop. As a result, the hydraulic loading rate increased to 90 m/yr. The basins were operated in symmetric pairs using flooding and drying periods of two weeks each. These periods were selected on the basis of previous experimental results from the Flushing Meadows Project, which showed that 2-week rotations yielded high hydraulic loading rates and also maximized nitrogen removal by denitrification in the soil

The flooding depth of 1 m initially used for the basins prevented the development of vegetation. However, when the depth was reduced to about 25 cm, a lush vegetation developed. Main plant species were barnyard grass (Echinochloa Crusgalli) and willow leaf (Polygonum Lapathifolium). The plants were about 0.5 to 1.5 m tall and since they grew well above the water, they provided ideal circumstances for mosquitoes to breed. To minimize mosquito breeding, the vegetation should be periodically mowed and water depths should be large enough to completely submerge the plants during flooding

The hydraulic loading rate of 90 m/yr was 14 percent of the average vertical hydraulic conductivity of the basin soil. At 90 m/yr, the capacity of the 16-ha system thus was 14.4 million m^3/yr or 40,000 m^3/day (11 million gal./day). Since irrigation wells in the area typically have a capacity of about 13,500 m^3/day (2,500 gal./minute), three wells evenly spaced on the center dike will be sufficient to pump renovated water out of the aquifer at the same rate that it arrives from the infiltration basins. This would minimize movement of renovated water into the aquifer around the system. Plans for discharging the renovated water into an irrigation canal for unrestricted irrigation have been discussed with officials from the City of Phoenix and of the Roosevelt Irrigation District.

Groundwater and Aquifer

Depths to the groundwater table varied from 3 to 20 m, depending on time of year (irrigation pumping) and recharge from the nearby Salt River. Groundwater tables in the center typically rose about 1 m in response to infiltration from the two center basins, and declined when the two center basins were dried and the two outer basins were flooded. Small diurnal fluctuations of water levels in monitoring wells were observed in response to daily patterns of barometric pressure. Hydraulic properties of the aquifer beneath the basins were determined with the slug test, step-drawdown test, and Theis pumping test on the production well in the center. They were also calculated from the rise of the groundwater mound in the center of the basin area in response to infiltration from the two adjacent basins. Different values were obtained. However, a transmissivity of 50,000 m^2/day and a specific yield or fillable porosity of 0.05 seemed reasonable for predicting groundwater mounds and underground flow systems.

Quality of Effluent and Renovated Water

Typical quality parameters of the secondary unchlorinated effluent from the treatment plant entering the infiltration basins and of the renovated water pumped from the production well in the center of the project are shown in Table 1. The slight increase in TDS content may have been due to evaporation in the basins (about 1.8 m/yr or 2% of the hydraulic loading rate) and/or dissolution of calcium carbonate in the soil and vadose zone. Nitrogen was almost all in the ammonium form for the secondary effluent and in the nitrate form for the renovated water. The data showed that the soil-aquifer treatment system removed about 60 percent of the nitrogen. This agreed with results from previous field and column studies, which showed that denitrification was maximized when using flooding periods of 9 to 14 days. Most of the denitrification occurred in the top layer of the soil. The nitrogen concentration in the renovated water was close to the 0 to 5 mg/l range where nitrogen in irrigation water will have no adverse effects on crops. It is also below the maximum limit of 10 mg/l for nitrate nitrogen for drinking water. Phosphate removal was about 95 percent. The phosphate phosphorus content in the renovated water was still above threshold values for algae growth but low enough to be used in recreational lakes. The fecal coliform concentration of the renovated water was well below the upper limit of 200/100 ml for unrestricted irrigation in Arizona. In the future, this upper limit probably will be reduced to a mean of 2.2/100 ml with no single sample exceeding a count of 25/100 ml. At the end of 1980, however, the sewage treatment plant started to chlorinate its effluent, resulting in fecal coliform concentrations of a few thousand per 100 ml for the effluent and 0 to 4 per 100 ml for the renovated water with a mean of less than 2.2/100 ml. Thus, the fecal coliform concentrations will be low enough to meet the new requirements for unrestricted irrigation. The virus concentration in the sewage effluent shown in Table 1 was taken from previous studies at the Flushing Meadows Project. The virus level in the renovated water from the 23rd Avenue Project averaged about 1 plaque forming unit (PFU) per 100 l, when samples of 800 to 2,000 l were used. The total organic carbon concentration in the renovated water indicates the trace or refractory organics remaining in the water after the readily degradable organic carbon has been removed. Identification of the residual organic carbon showed a wide variety of compounds, including trihalomethanes, numerous other organohalides, aromatic compounds, anisoles, phthalates, and pesticides. Concentrations often were on the order of nanograms and micrograms per liter. The total concentration of trihalomethanes in the renovated water was below the EPA interim maximum limit of 0.1 mg/l for drinking water. Significant losses of volatile organics took place in the basins themselves. Some compounds were significantly attenuated in the soil-aquifer system whereas others were not. More systematic studies of the organics are planned for the future, including the effect that chlorination of the effluent in the treatment plant will have on the trace organics in the effluent and their fate in the soil-aquifer system.

Table 1. *Typical Quality Parameters of Secondary Effluent from Treatment Plant and of Renovated Water from a Production Well in Center of Project.*

	Secondary Effluent	Renovated Water
Total dissolved solids, mg/l	700	740
Suspended solids, mg/l	13	1
Total nitrogen, mg/l	18	7
Phosphate phosphorus, mg/l	6	0.25
Total organic carbon, mg/l	10	2
Fecal coliforms per 100 ml	10^6	22
Viruses, PFU per 100 l	2100	1

Conclusions

The results of the 23rd Avenue Project showed that large-scale renovation of conventionally treated sewage effluent by rapid-infiltration systems and recovery of renovated water from wells within the project are feasible. Since most of the cost of renovating the effluent with such a system is in pumping the water from the wells, renovating municipal wastewater by soil-aquifer treatment also is cost effective. The renovated water is suitable for unrestricted irrigation and for recreational lakes with primary-contact activities. The renovated water could also be used for drinking after further treatment, including activated carbon adsorption, ozonation and/or reverse osmosis. Advanced treatment of sewage effluent after it has gone first through a soil-aquifer system could be much cheaper and effective than advanced treatment of the plant effluent directly.

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The complete report, entitled "Rapid-Infiltration System for Wastewater Renovation and Beneficial Reuse," (Order No. PB 82-252 941; Cost: $13.50, subject to change) will be available only from:
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