Wastewater reclamation and reuse

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Water reclamation and reuse encompass many subjects and the related literature could be voluminous; therefore, this review continues the reorganization instituted in 1984. Several topics that may be considered as water reclamation and reuse will appear in other review sections in this issue. Specifically, references on agricultural and landscape irrigation are covered in the review on "Land Application of Wastewater." All industrial water reuse references have been covered in the appropriate industrial waste review. Exceptions are reuse applications for multiple industries or for miscellaneous industries not explicitly included in the industrial waste reviews. Also included in this review is the water reuse for groundwater recharge. Finally, references relating to health effects appear in the review on "Health Effects Associated with Wastewater Treatment, Disposal and Reuse."

GENERAL

The major addition in 1985 to the literature on water reclamation and reuse was the publication of the Proceedings of the Water Reuse Symposium III, "Future of Water Reuse."[1] Published in three volumes, these proceedings contained 133 papers on various aspects of water reuse. DeBoer and Linstedt[2] reviewed advances in water reuse applications and covered many areas of water reuse including potable reuse, health effects, treatment developments, and regulatory aspects.

Several books were published which covered fundamental aspects of water quality essential to water reuse: "Water Treatment: Principles and Design" by James M. Montgomery, Consulting Engineers, Inc.,[3] "Water Quality: Characteristics, Modeling, Modification" by Tchobanoglous and Schroeder,[4] "Water Supply and Pollution Control" by Viessman and Hammer,[5] and "Irrigation with Reclaimed Municipal Wastewater—A Guidance Manual" by Pettygrove and Asano.[6] "Water Resources Planning" by Grigg[7] and "Water Management Technology and Institutions" by Viessman and Welty[8] contained chapters on planning and management of water quality and water reuse.

Various aspects of water reuse possibilities in Caribbean countries were presented in a report sponsored by the Pan American Health Organization.[9] A seminar/workshop was sponsored in Spain on reuse of municipal wastewater for agricultural irrigation and groundwater recharge.[10] The Water Re-Use Promotion Center of Japan issued an annual report with profiles and technical information of Japanese research and manufacturing companies.[11]

WATER REUSE PLANNING

Future of water reuse was examined by Miller.[12] Innovative financial opportunities,[13] financial feasibility of water reuse,[14] reuse opportunities due to federal wastewater construction grants,[15] public attitude toward potable reuse in Denver[16] as well as obtaining public support for wastewater reuse projects[17,18] were also discussed.

Crook[19,20] reviewed water reuse in California with special reference to health and regulatory aspects. Kracht and Korbitz[21] and Bouwer and Chase[22] discussed an approach to wastewater reclamation and reuse in Phoenix, Ariz. in which water conservation policies were supported by reclaiming wastewater for beneficial use. Water reuse implementation plans in Naples[23] and Orlando,[24] Fla.; Colorado Springs, Colo.;[25] and Tucson, Ariz.[26] were presented in the context of water resources planning. Master planning a water reuse system was discussed by Corneille[27] and design of system was discussed by Bazlov.[28]

Financing water reuse projects was discussed by Corssmit.[29] Lorenz[30] reported trends in wastewater treatment technologies by evaluating innovative, and cost-effective technologies, as well as exploring alternative financial methods for wastewater treatment.

MUNICIPAL WASTEWATER REUSE

The current status of the Denver, Colo., Potable Water Reuse Project was reviewed by Lauer.[31,32] This project is expected to provide information necessary to evaluate the feasibility of direct reuse at 3.8 mL/d (1 mgd) demonstration plant.

Water reuse in a humid region was discussed based on data obtained at the Potomac Estuary Experimental Water Treatment Plant and the National Research Council's evaluation of the project.[33] In spite of the comprehensive study, the case for

potability of reclaimed municipal wastewater was not conclusively proven; thus, use of estuary water for this purpose was discouraged at present time.

GROUNDWATER RECHARGE

Several groundwater books were published in 1985 which contained chapters on groundwater quality, pollution control, and recharge with freshwater and reclaimed wastewater: "Groundwater Engineering" by Kashef,[34] "Ground Water Quality" by Ward, *et al.*,[35] and "Ground Water Pollution Control" by Canter and Knox.[36] "Artificial Recharge of Groundwater" by Asano[37] emphasized the special use of reclaimed municipal wastewater for groundwater recharge. "Groundwater Treatment Technology" by Nyer[38] summarized the present knowledge and experience in the cleanup of groundwater.

Knorr[39] presented the planning and operation aspects of the El Paso, Tex., Groundwater Recharge Project which consists of a 38 000 m^3/d (10 mgd) advanced wastewater treatment plant, a pipeline system through the Hueco Bolson, and ten injection wells. The Nassau County, New York, water reclamation and demonstration program was discussed by Avendt and Oliva.[40] The results indicated that potable groundwater supply could be augmented using reclaimed water in full compliance with regulatory permit standards. Soil-aquifer treatment systems which met health, agronomic, and aesthetic requirements for unrestricted irrigation were tested in Phoenix, Ariz.[21,22] Potable use of renovated water, however, appeared to require additional treatment.

Fundamental aspects of groundwater recharge were presented by Morel-Seytoux[41] in a discussion on conjunctive use of surface and ground waters; by Oaksford[42] in artificial recharge on methods, hydraulics, and monitoring; by Guymon and Hromadka[43] in modeling of groundwater response to artificial recharge; and by Signor[44] in groundwater sampling during artificial recharge on equipment, techniques, and data analyses. Groundwater recharge operations using reclaimed municipal wastewater or polluted surface water were reported in Israel, Federal Republic of Germany, The Netherlands, Poland, and Japan.[37]

Argo[45] discussed directions of water reuse and provided background information on Water Factory 21 and its groundwater recharge project. Pilot-scale investigation of particle retention during artificial recharge was reported by Vigneswaren *et al.*[46]

INDUSTRIAL WATER RECYCLING AND REUSE

A high efficiency rinse system was developed for electroplating operations.[47] Amy *et al.*[48] described the use of treated municipal wastewater in copper and molybdenum flotation, including information on economic feasibility. In addition, numerous papers addressed removal of sulfate from recycled cooling water;[49] use of treated wastewater for cooling ponds;[50] reuse of coal slurry wastewater;[51] treatment and reuse of petrochemical wastewaters;[52] textile dyebath reconstitution and reuse;[53] water reuse in the U. S. pulp and paper industry;[54] total closed water system for deinking plant;[55] and industrial laundry wastewater.[56]

Chen *et al.*[57] discussed a water chemistry model to predict the maximum concentration factor, that is, the minimum makeup and blowdown rates for recirculating cooling water systems. The effectiveness of using minimally treated wastewater as makeup water for a cooling tower was investigated.[58]

TECHNOLOGY DEVELOPMENT

Design and operation of a clinoptilolite system for nitrogen removal was discussed by Johns *et al.*[59] Lack of field data on the optimization of chemical coagulation-flocculation and filtration of secondary effluents was cited as an obstacle to the establishment of alternative and more cost-effective wastewater reclamation methods.[60] Asano *et al.*[61] evaluated factors affecting the optimization of tertiary treatment systems in municipal wastewater reclamation and reuse. Pulsed bed and dual media filters were evaluated by Rigby *et al.*[62] for water reuse at the Orange County Water District in California. Several innovative treatment systems were reported at the Water Reuse Symposium: flotation-filtration systems,[63] recovery of water by ion exchange,[64,65] and reverse osmosis technologies.[66–68]

Rogers and Klemetson[69] studied ammonia removal in aquaculture water reuse biofilters. Hocking[70] studied a large emergent aquatic plant, *C. involucratus*, for the uptake of nitrogen and phosphorus. This plant would be suitable for wastewater reclamation because of its high dry matter production, and its ability to tolerate high concentrations of N and P in the harvestable portions of the plant.

Levine *et al.*[71] discussed the size characterization of contaminants in wastewater and its importance in treatment and reuse. The Upper Occoquan Sewage Authority advanced wastewater treatment plant was mandated by Virginia regulatory authorities to renovate wastewater for discharge to the principal water supply reservoir in Northern Virginia. A review of major operational characteristics, performance reliability, and operating cost of this plant during 1983-84 period was presented by Robbins and Ehalt.[72] Rebhun *et al.*[73] discussed kinetic studies on chemical and biological treatment for renovation. A comparison was made of substrate removal and growth rate constants, and die-off rates and yield coefficients.

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