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Project Summary

Advanced Treatment for Wastewater Reclamation at Water Factory 21

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The performance and reliability of Water Factory 21 (WF21) in Orange County, California, for removing a range of organic, inorganic, and biological contaminants from activated-sludge-treated municipal wastewater were evaluated. This 0.66 m^3/s (15 mgd) facility includes chemical treatment, air stripping, activated carbon adsorption, reverse osmosis (RO) treatment, and disinfection. The effluent is used to furnish water for a hydraulic barrier that prevents sea-water intrusion into the local fresh water aquifer. This report is the final one of three describing the operation of WF21 over a 5-year period and covers the last 3-year period when analyses were most intensive.

Analyses were conducted for viruses, coliforms, general inorganics, heavy metals, radioactivity, several collective parameters such as total dissolved solids (TDS), chemical oxygen demand (COD), total organic carbon (TOC), total organic halogen (TOX), ultraviolet absorption, and total trihalomethane forming potential (TTHMFP). In addition, mutagenic analyses were conducted, and a broad spectrum of individual organic contaminants were measured, including most of those on the EPA list of priority pollutants.

Some objectives of this study were:

1. **Determine the availability of the treatment plant for producing reclaimed water.**
2. **Determine the plant's reliability in meeting local and state water quality requirements and EPA primary and secondary drinking water standards. However, this report recognizes that existing drinking water standards are inadequate to define the potability of renovated wastewater and that a series of chemical, toxicological and microbiological investigations will yet be required before comprehensive standards and criteria to define potable water regardless of source can be developed.**
3. **Compare the quality of the reclaimed water with EPA priority pollutant health criteria.**
4. **Determine the cost of wastewater reclamation with and without RO treatment.**

This information should prove useful to others who are contemplating advanced treatment for reclamation of wastewaters for beneficial uses.

This Project Summary was developed by EPA's Municipal Environmental Research Laboratory, Cincinnati, OH, 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

Water Factory 21 (WF21) is a 0.66 m^3/s (15 mgd) advanced wastewater treatment plant operated by the Orange County Water District in California. The reclaimed water that is produced supplies injection

water for a hydraulic barrier to prevent sea-water intrusion into the local groundwater supply. The processes used to reclaim activated-sludge-treated municipal wastewater are lime treatment, air stripping, recarbonation, filtration, granular activated carbon adsorption (GAC), RO, and chlorination. The water produced by this series of processes is of high quality, and there is interest in its potential for augmenting a drinking water supply. The results of a broad investigation evaluate the quality of the reclaimed water and the reliability of WF21 so that judgments might be made of its potential for such a purpose. This report is the third in a series describing the overall performance of WF21 from the time operation began in October 1976 through March 1981.

Approach

Primary emphasis in the study was on the performance of the advanced wastewater treatment plant (AWT) defined here as all processes except RO, and the overall plant including RO treatment (AWT+RO). The efficiency of the plant was evaluated by comparing influent and chlorinated effluent samples for AWT and influent and RO effluent samples for AWT+RO. Samples were collected every 6 days from the AWT and AWT+RO influent and effluent and every 12 days from intermediate points to evaluate the performance of individual processes.

The flow rate to the various processes varied throughout the study period. The 0.22 m^3/s (5 mgd) RO facility was operated at near full capacity essentially for the entire period reported, but the AWT chlorinated effluent flow varied considerably (0.05 to 0.37 m^3/s) because of changing needs for reclaimed water and changing operating philosophies. Also, the fans associated with the stripping towers were not operated for essentially the entire period because ammonia removal requirements were modified.

In general, lognormal distribution was used to analyze data to determine geometric mean concentrations, 95% confidence intervals for means, and spread factors. Percentage removals for constituents by individual processes or the overall plant and 95% confidence intervals were also determined.

Sampling and Analytical Procedures

Grab and composite samples were collected and stored under refrigeration before organic and inorganic analyses. Composite samples were prepared by mixing equal volumes of 8 grab samples taken manually at 3-hour intervals over a 24-hour period. Analyses for COD, TOC, inorganic constituents, and heavy metals were conducted on daily composite samples using standard procedures by the WF21 analytical laboratory. Viral analyses were conducted by James Montgomery Engineers, Pasadena, CA. Specific organic constituents were analyzed by the Stanford Water Quality Control Research Laboratory on samples shipped by air in insulated containers that arrived on the same day. Mutagenic analyses were conducted on selected samples using the Ames assay for point mutation in *Salmonella typhimurium* by SRI International, Menlo Park, CA.

Among the organic analyses conducted were a group of collective parameters including ultraviolet absorbance (UVA), TOX, and TTHMFP, as well as COD and TOC. Individual organic constituents were determined by five different gas chromatographic (GC) procedures with emphasis on compounds contained in the EPA list of priority pollutants, although many other compounds found present were also measured. Volatile organic analysis (VOA) measured one- and two-carbon halogenated compounds by pentane extraction and electron capture (EC) detection. A range of volatile aromatic and aliphatic compounds was determined by closed loop stripping analysis (CLSA) using GC equipped for hydrogen-flame detection. Chlorinated hydrocarbon pesticides, PCB's, and similar compounds were determined on hexane extracts and capillary-column GC with EC detection. Other basic and neutral compounds were determined through continuous liquid-liquid extraction (CLLE) with methylene chloride and analysis with a Finnigan GC/MS system model 4000*, controlled by an INCOS data system. Acids and phenols (A/P) were determined in a similar way, but on acidified and methylated samples. The analytical procedures used analyzed quantitatively 100 of the 114 organic priority pollutants. Most of the compounds for which the techniques were suitable could be analyzed with detection limits generally of 0.01 to 0.05 $\mu g/L$.

Findings

- Reclaimed water with and without RO treatment met EPA interim primary drinking water regulations more than 95% of the time (except for coliforms in the unchlorinated RO effluent). Since no comprehensive standards and criteria currently exist to define potable water regardless of source, none of the above should be construed to mean that the described product water was potable.
- Reclaimed water with RO treatment met all EPA secondary drinking water criteria, and without RO treatment, the water met most of the standards except for pH and general mineral parameters such as TDS, chlorides, and sulfates. These conclusions apply to all secondary standards except odor and corrosivity, which were not measured.
- Effluent mean concentrations (even without RO treatment) met the health criteria at the 10^{-6} life-time risk level for most of those priority pollutants not currently covered by EPA primary or secondary regulations and for which the limits are above the analytical detection limit. No judgments can be made for compounds below the analytical detection limit (10 to 100 ng/L) or priority pollutants not quantified by the procedures used. Also, the list of priority pollutants does not include all potentially toxic chemicals.
- Mutagenic activity by the Ames test was detected frequently in influent samples and after points of chlorination, but was reduced by activated carbon treatment. However, mutagenic activity was recreated on terminal chlorination following carbon treatment.
- Brominated alkylphenol polyethoxy carboxylates were tentatively identified in reclaimed wastewater during chlorination and among the major compounds present in the mutagenic organic fractions following chlorination of effluent.
- Mutagenic compounds appeared to be associated with hydrophobic organic acids, and activity was reduced when metabolic activators were included in the test.
- Although enteric viruses generally were present in the influent, they were detected in the effluent in only one case during this phase of the study.
- No evidence was found indicating that this reclaimed municipal wastewater would pose a significant health risk

*Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

when used as a source of municipal water supply, but generally detailed toxicological testing is needed to draw valid conclusions.

- Ultraviolet absorption was not a satisfactory surrogate for monitoring organic material during treatment, partly because of a significant positive chlorine interference and partly because of a lack of good statistical correlation with TOC or any other organic chemicals measured.
- TOC and COD are good surrogates at WF21 for monitoring the performance of GAC columns in removing the trace organic compounds.
- Barium and manganese are promising indicator chemicals for monitoring the range of trace heavy metal removal by lime treatment.
- Promising indicator chemicals for monitoring the range of removals by air stripping are 1,1,1-trichloroethane, tetrachloroethylene, and 1,2- and 1,4-dichlorobenzenes.
- During the 3-year study, the treatment plant through final chlorination was operated 74% of the time. Of the 26% shutdown time, 7.4% was for chlorine basin repair, 7.8% for conducting a hydrogeological study of the groundwater basin, 5.1% for planned general maintenance, 1.6% for external causes, and 5.5% for other equipment failures, repairs, or modifications.
- The treatment plant through RO treatment (not affected by final chlorination basin repairs or the hydrogeological study) was operated 89% of the time. About one-half of the 11% downtime was for planned treatment plant maintenance and the other one-half for external causes and equipment failures, repairs, or modifications.
- Producing blended water for groundwater injection during the 1980-81 year cost $0.43/m^3$; 64% was for operation and maintenance and the remainder for capital depreciation. Costs are increased because the plant was not operated at design flows during this period.
- Projected costs/m^3 of treated water, assuming operation at design flow with 90% plant availability factor, are $0.20 for advanced treatment without RO, $0.22 additional cost for RO treatment, $0.22 for blended water including deep-well water, and $0.30 for blended advanced treated water without deep-well water.

Recommendations

1. Conduct toxicity testing to include a short-term battery of tests and long-term animal tests to further evaluate the relative safety of reclaimed wastewater as a source of drinking water supply.
2. Conduct evaluations similar to those reported here plus the above recommended toxicity testing on typical conventional water supplies throughout the country to develop a comparative evaluation of the health risks associated with drinking waters.
3. Identify compounds causing mutagenicity response in the Ames test following chlorination of reclaimed wastewater to better evaluate their health risks.
4. Evaluate the environmental significance of alkylphenol polyethoxy carboxylates that appeared to become brominated upon chlorination.
5. Continue to develop qualitative and quantitative information on the organic residues in reclaimed water.

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The complete report, entitled "Advanced Treatment for Wastewater Reclamation at Water Factory 21," (Order No. PB 84-148 857; Cost: $20.50, subject to change) will be available only from:
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