United States
Environmental Protection
Agency

Municipal Environmental Research
Laboratory
Cincinnati OH 45268

Research and Development

EPA-600/S2-82-043 August 1982

EPA

Project Summary

Water Reclamation and Automated Water Quality Monitoring

E. L. Jeffers, R. L. Brooks, D. Nibley, J. D. Poel, J. Perreira, R. H. Nuss, K. Nishioka, W. J. Sanchez, Jr., and D. F. Kriege

The Santa Clara Valley Water District owns and operates a water reclamation facility located in the Palo Alto Baylands area in Northern California. The purpose of the facility is to provide reclaimed water suitable for injection into the groundwater, thereby providing a salt water intrusion barrier and, secondarily, to provide a research facility for various ongoing projects. The project results summarized here involved using the NASA/Ames Research Center's Water Monitor System to collect data on the water reclamation process train. The Water Monitor System is a continuous online water quality monitoring system that automatically measures 14 water quality parameters in addition to 9 trace halocarbons. The system was built and operated by Boeing Aerospace Company personnel through a NASA contract. For a period of 3-1/2 years, the system has gathered information on water quality changes at intermittent points throughout the treatment process train. This report presents the results of the last 8-month period, including performance and costs of operation for both the Water Reclamation Facility and the Water Monitor System. These results, especially for the water treatment processes, may be unique to this facility and should be interpreted cautiously.

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

The Santa Clara Valley Water District, in cooperation with the cities of Palo Alto, Los Altos, and Mountain View, embarked upon a developmental program of water reclamation and injection of the reclaimed water into underground aquifers in the South San Francisco bayfront area. The purposes of this program were to demonstrate the technical and economic feasibility of certain reclamation processes and to attempt to provide a freshwater barrier to the intrusion of saltwater into a shallow aquifer. The wastewater supply to this reclamation facility is the effluent from the Palo Alto Regional Water Quality Control Plant.

The Water Reclamation Plant provides tertiary treatment to the secondary effluent from the Palo Alto city plant. In addition to its basic function of providing a supply for groundwater recharge, the reclamation plant can produce water of lesser quality for use in golf course irrigation or as an in-plant supplemental supply for the Palo Alto city plant's Reclaimed Water System. A schematic of the plant is shown in Figure 1.

As an outgrowth of its involvement in water reclamation and water quality monitoring for both spacecraft and domestic applications, NASA's goal was

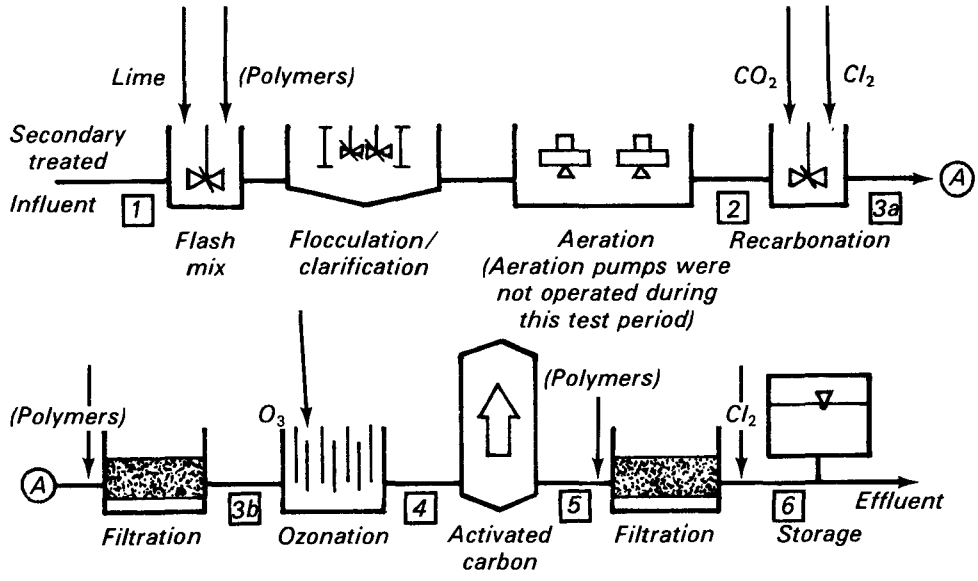

Figure 1. Santa Clara Valley Water District reclamation facility at Palo Alto.

to develop, test, and transfer the automated WMS (water monitor system) technology to civil applications The objective of this project was to develop a system whereby water quality monitoring could be performed as it would be done in a spacecraft, on-line and in real-time. The design goal was to establish the capability to determine conformance to future high quality effluent standards and, thereby increase the viability for reclamation and reuse of wastewater. The WMS includes both commerically available and NASA-developed sensors, an automated sample collection and distribution system, and a computerized data acquisition and reporting system. Figure 2 is a schematic of the system. The assembly and checkout of the WMS portion of the project was completed under separate contract. The field demonstration test phase started in July 1977 and ended on February 28, 1981. The final portion of the test period was from July 1980 through February 1981. This portion of the test period was jointly funded by NASA, the EPA, the California State Department of Water Resources, and the Santa Clara Valley Water District.

Test Program Objectives

This Project Summary highlights the results for the test period July 1980 through February 1981. Operational and performance data for the WMS, as well as subsystem downtime and O&M (operations and maintenance) costs, were recorded. Similar data were recorded by the Santa Clara Valley Water District for the reclamation plant Additional test data were recorded on the water quality at various points within the reclamation plant as measured by the WMS sensors and through grab samples by the city of Palo Alto Laboratory. These data were used to evaluate the performance, reliability, availability, and costs of the reclamation plant, its individual processes, and the WMS and its components. Major problems encountered in the operation of the WMS and the reclamation plant are discussed. Note that the problems and costs reported here may vary considerably from those of a nonexperimental plant or monitoring system.

The objectives of the test program described in this report were as follows:

1. To determine the steady-state performance (ability to remove contaminants) of each unit process in the water reclamation facility based on WMS data.
2. To determine WMS, plant, and unit process availability. Availability is defined as the portion of time that an item operates on demand. Availability was measured as follows:

$$A = 100T/(T + D)$$

where, A = availability, %
T = operating time, hours
D = Downtime for repair hours
T + D = total available operating time, hours

Once established, availability can be used to estimate annual repair time Thus, for a continuously operated item

$$D = (1-A/100)\ (365\ days/year)\ (24\ hours/day)$$

3. To determine WMS and reclamation plant reliability. Reliability is defined as the percentage of the operating time that an item performs within specified limits. For the water reclamation plant reliability was measured as the percentage of time that a water quality parameter was within specified effluent limits. The WMS data were statistically evaluated based on a log-normal data distribution model and compared with an MCL (maximum concentration limit) The MCL's for the plant are shown in Table 1 The percentage of time that a measured parameter was less than the MCL represented plant reliability for that parameter. The product of availability is multiplied by reliability gives the portion of the total available operating time that an item will perform within given limits

$$P = (A)\ (R)$$

where, P = performance achieved

4. To determine WMS and reclamation plant operating and maintenance costs.

Process Performance

Results

1. The following conclusions relative to process performance were based on the WMS data:

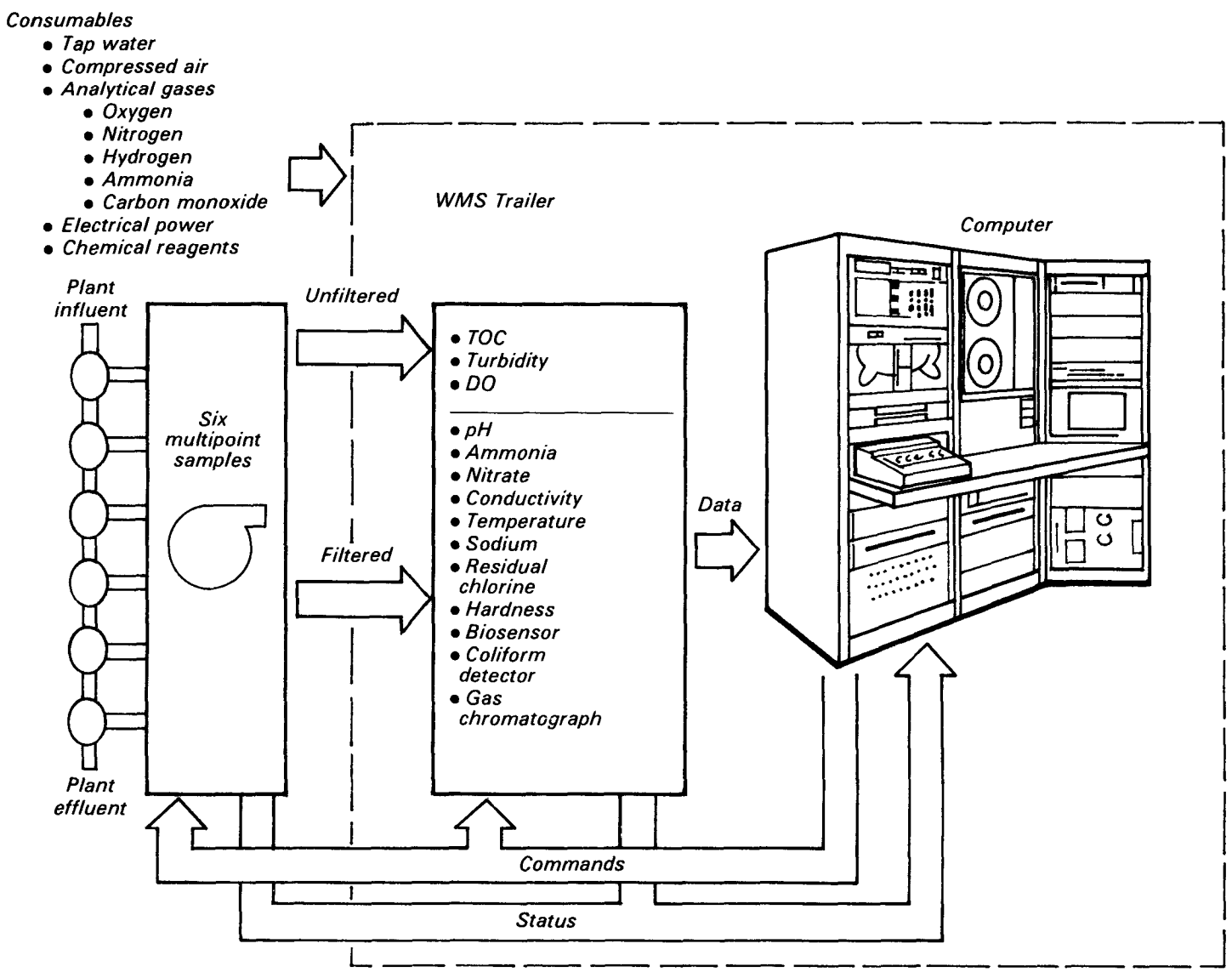

Figure 2. Water monitor system configuration

a. Chemical clarification removed over 90% of the influent suspended solids (biomass) and as much as 30% of the organic contaminants [TOC (total organic carbon)]
b. Flocculation (floc) carryover from the chemical clarification process results in additional loading on the mixed-media filters. This caused decreased filter run times; i.e., more frequent backwashing.
c. Except for some reduction in trace halocarbons and biomass, the contribution of ozone to water quality did not appear to be significant at the concentrations used in the study
d A reduced level or many dissolved contaminants was characteristic of water processed by activated carbon, when its useful life was not exceeded. The chemical oxygen demand effluent limit of 10 mg/L, however, was difficult to achieve without significant cost incurred by continuously regenerating carbon.

2. The capability to collect and process data for convenient and improved analysis of water quality information was demonstrated Over three million water quality measurements were recorded during the test period and are summarized in the full report
3. Automated water quality monitoring will be an economic necessity in the future as effluent quality control restrictions are tightened. The costs of repetitive laboratory analyses will become prohibitive, thereby increasing the demand for automated sensing, analysis, and reporting.

4. There is a need for improved reliability of many of the available components used for automated water quality monitoring.

Recommendations

1. When using lime for chemical clarification, it is recommended that a filtration step be included before GAC (granular activated carbon) sorption. This will reduce the possibility of clogging the GAC with coagulant and/or calcium carbonate precipitant.
2. The potential for reducing activated carbon regeneration costs by operating the towers in a "biologic activated carbon" mode (no regeneration) should be explored.
3. The WMS as configured is not ideal. The mobility design criteria dictated its design. The following factors should be considered in designing an in-place integrated plant water quality monitoring system:
   a. Locate electronic equipment in an area away from potential contact with process or other chemical exposure.
   b. Use state-of-the-art computer technology to simplify the data acquisition system. Improvements to equipment are constantly being made.
   c. The system should be designed for automatic fault detection. If not, the time required to diagnose electronics failures will far exceed the time required to correct the problem.

Water Monitoring System (WMS)

O&M Costs

As part of the project's objective of evaluating performance, the O&M costs for each of the sensors and subsystems were determined. The actual expenses incurred during the test period were scaled to obtain a year's cost. The cost covers all consumables, hardware, and labor required for 12 months of continuous operation. These costs reflect the age of the hardware. The annual O&M costs for the WMS sensors and subsystems were $94,125.

The distribution of costs may be summarized as follows:

	Labor	*Materials*	*Total*
Operations	*18.0%*	*4.9%*	*22.9%*
Maintenance	*57.6%*	*19.5%*	*77.1%*
Total	*75.6%*	*24.4%*	*100.0%*

An additional goal of the program was to determine, when possible, the life expectancy of the various systems. These data are in the full report.

Availability and Reliability

WMS availability (percent of time the subsystem and sensors operated on demand) was monitored during the test period. The downtime recorded for each of the sensors and subsystems included actual repair times and downtime attributed to waiting for necessary reagents or parts.

Sensor and subsystem reliability (percent of operating time the data generated were valid) values were calculated based on the number of hourly averages determined to be erroneous divided by the total number of hourly averages recorded.

Reclamation Facility

O&M Costs

The O&M costs for the reclamation facility, including labor and material, were $311,400 per year. Water production costs were $0.60 per 1,000 gallons.

The distribution of costs may be summarized as follows:

	Labor	*Materials*	*Total*
Operations	*49.4%*	*25.5%*	*74.9%*
Maintenance	*22.5%*	*2.6%*	*25.1%*
Total	*71.9%*	*28.1%*	*100.0%*

Availability of Facility and Process

Reclamation facility and process availability (percent of time the facility and process operate on demand) was monitored during the test period. The objective of operating the facility continuously for the 8-month (5832 hour) test period was met except for 6[illegible] hours when influent was unavailable o[illegible] when facility equipment failed. Equipment failures experienced during the 8 month test period resulted in a[illegible] estimated 20 days per year when th[illegible] facility was not able to deliver reclaime[illegible] water.

There were three dominant problems

1. Calcium carbonate encrustation on equipment caused pump mal functions and scale buildup on th[illegible] inside walls of piping; this reduce[illegible] flow capacity.
2. Plumbing failures within th[illegible] ozonator.
3. Carbon furnace equipment compc[illegible] nent failures.

Limitations

The true measure of performance b[illegible] developmental systems, such as th[illegible] WMS, and by the reclamation facility [illegible] the contribution made toward identify[illegible] ing those key improvements necessar[illegible] for developing effective operationa[illegible] systems. This means identifying prob[illegible] lem areas and testing possible solution[illegible] before designs are committed for opera[illegible] tional systems. Predictions on pe[illegible] formance of some future operation[illegible] system in terms of availability, reliabilit[illegible] and O&M costs based on existin[illegible] preprototypes are approximate an[illegible]

Table 1. *Reliability of Palo Alto Reclamation Facility*

Parameter	*Maximum Concentration Limit*	*Minimum Concentration Limit*	*Reliability*	
			Period A	*Period H*
Chemical Oxygen Demand	*10 mg/L*	—	*65.0%* [1]	*57 8%*
Trihalomethanes	*100 mg/L*	—	*>99 9%*	*>99.9%*
Total Nitrogen	*5 mg/L*	—	*86 1%* [2] *(NH_3)*	*< 0.0%*
pH	*8.5*	*6 5*	*18 7%*	*99.9%*
Dissolved Oxygen	—	*1 mg/L*	*>99 9%*	—
Hardness	*500 mg/L*	—	*78 6%*	*97.3%*
Sodium	*250 mg/L*	—	*>99 9%*	—
Total Residual Chlorine		*1 mg/L*	*76 2%*	*77.5%*
Conductivity	*1600μmho/cm*	—	*>99.9%*	*70 9%*
Turbidity	*5 NTU*		—	—

[1] *Assumes COD/TOC Ratio of 2 5.*
[2] *Based on Ammonia or Nitrate Concentration*

subject to error. Thus, the data developed in this test and presented in the project report should be recognized as such; i.e., measured performance of commercial sensors as well as of preptototype systems (biological analyzers, gas chromatograph analyzer, and computer software).

The full report was submitted in fulfillment of IGA No. AD-80-F-0-054-0 by the NASA Ames Research Center, Moffett Field, CA, under the cosponsorship of the U.S. Environmental Protection Agency

E. L. Jeffers, R. L. Brooks, D. Nibley, J. D. Poel, J. Perreira, and R. H. Nuss are with the Boeing Company, Houston, TX 77058; K. Nishioka is with NASA Ames Research Center, Moffett Field, CA 94035; and W. J. Sanchez, Jr., and D. F. Kriege are with the Santa Clara Valley Water District, San Jose, CA 95118.

***John N. English** is the EPA Project Officer (see below).*

The complete report, entitled "Water Reclamation and Automated Water Quality Monitoring," (Order No. PB 82-227 497; Cost: $18.00, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Project Officer can be contacted at:

Municipal Environmental Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, OH 45268

☆U. S. GOVERNMENT PRINTING OFFICE: 1982/559-092/0456

United States
Environmental Protection
Agency

Center for Environmental Research
Information
Cincinnati OH 45268

Postage and
Fees Paid
Environmental
Protection
Agency
EPA 335