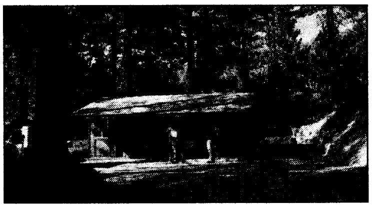


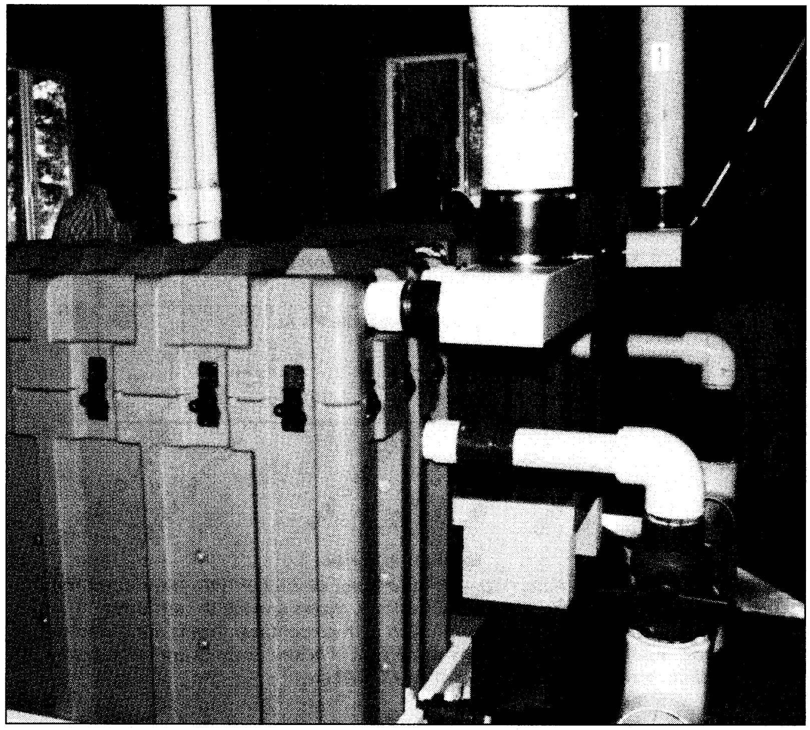
The Idyllwild Water District and Pine Cove Water District are small groundwater systems with multiple wells. Both systems have soft, mildly acidic waters with high carbon dioxide content and dissolved inorganic carbon concentrations of approximately 18 mg/L C, and both systems exceeded one or both of the lead and copper action levels in 1993 and 1994. In 1997, aeration was investigated to increase pH and replace inhibitor or other chemical additions. Four designs were evaluated, and a deep bubble aeration system was pilot-tested. Full-scale systems were designed and built and became operational in October 1998. Aeration raised the pH from 6.1–6.3 to 7.1–7.6, and by January 1999, both systems easily met both the lead and copper action levels. Radon (Rn) samples taken at Pine Cove showed a 99% reduction to 33 ± 8 pCi/L, assuring compliance with the proposed Rn regulation. Using aeration for corrosion control has considerably simplified treatment and improved water quality in most respects. Treatment was integrated with system designs, enabling the use of one treatment plant for the multiple wells at each system, locating the treatment plants above storage to eliminate repumping, and maximizing electricity savings by increasing operation at off-peak times.

CALIFORNIA'S FIRST aeration plants for corrosion control

BY MICHAEL R. SCHOCK, JERRY HOLLDBER, THOMAS R. LOVEJOY, AND JERRY LOWRY

As required by the Lead and Copper Rule (LCR) (USEPA, 2000; USEPA, 1994; USEPA, 1992; USEPA, 1991a; USEPA, 1991b), Idyllwild Water District (IWD) and Pine Cove Water District (PCWD) conducted a sampling and testing program in 1993 and 1994. The program began with an evaluation of local household plumbing to identify the 20 sites in each district that would be the most likely candidates for internal corrosion activity. The sampling and testing program in the IWD found that water used at the identified test sites exceeded the 90th percentile action level (AL) for copper (Cu) of 1.3 mg/L in both sampling rounds and exceeded the AL for lead (Pb) of 0.015 mg/L in June 1994. In 1993, test site water barely passed the Pb AL. Because of the absence of Pb or Cu in the source water, Pb or Cu found in the tests resulted from internal corrosion in household plumbing or fixtures.

PCWD took only one round of LCR samples because although the system met the Pb action level, it was obvious that corrosion-control treatment would be needed for Cu. Monitoring data for IWD and PCWD are summarized in the box plots in Figure 1. To attempt to reduce the Pb and Cu concentrations to below the regulatory ALs, IWD initiated a pilot corrosion-control program utilizing an orthophosphate/polyphosphate corrosion inhibitor. Because of the similarity of water in the two districts, the state of California allowed PCWD to defer action until results of the IWD pilot program were known.



Operations staff work inside the Idyllwild Water District treatment plant, a small groundwater system located in Southern California that operates multiple wells.

BACKGROUND

System descriptions. IWD and PCWD are neighboring districts located at an elevation of 5,000–6,000 ft (1,525–1830 m) in the San Jacinto Mountains of southern California (Figure 2). They are approximately 120 mi (190 km) north-northeast of San Diego and 120 miles east-southeast of Los Angeles. IWD provides water service to about 1,600 customers in its 2,400 acre (9.7 km^2) service area. PCWD serves about 1,100 customers in its 4,100 acre (16.6 km^2) service area. Customers in both districts are primarily residential customers, although IWD does have a small commercial base. All water delivered to customers in IWD and PCWD is supplied by wells penetrating fractured bedrock.

IWD. IWD operates 19 wells with a combined pumping capacity of 630 gpm (2,385 L/min). Capacities of individual wells range from a minimum of 5 gpm (19 L/min) to a maximum of 90 gpm (340 L/min). IWD has 12 ground-level storage tanks with a combined storage capacity of 3.35 mil gal (12.7 ML).

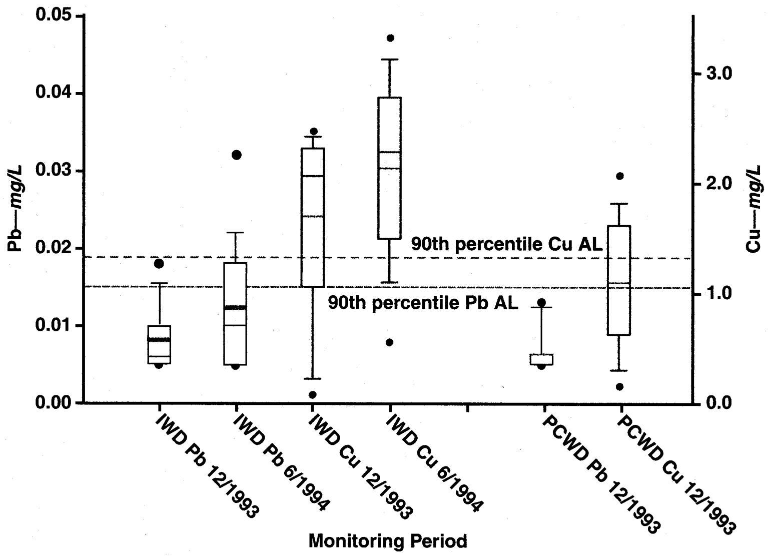
IWD's water distribution system consists of 28 mi (45 km) of pipelines ranging in diameter from 4 to 10 in. (100 to 250 mm). The great majority of the system is made up of welded steel pipe with a cement–mortar lining. A small amount of unlined steel pipe remains in older portions of the system. The distribution system consists of five pressure zones. Water is supplied from the IWD well field to storage tanks in the upper zone. Water is transferred to the main zone through a pressure-regulating station. Two small zones are supplied by pumping stations that deliver water from the main zone to the storage tanks, and the remaining zone is fed from the main zone through secondary pressure-regulating stations.

Total annual water production in IWD is about 110 mil gal (416 ML). Total production rates vary from about 150 gpm (570 L/min) in the winter months to about 350 gpm (1,325 L/min) in the warm summer months.

As shown in Table 1, the source water used by both IWD and PCWD is of very high quality, and the levels of constituents in the water are similar. This result would be expected because the source is groundwater derived from rainfall and snowmelt in the same local watershed. The water is very low in mineral constituents, particularly metals. No organic chemicals have been detected in water supplied by either district. The waters are very soft, with hardness in the range of 20 to 40 mg/L as calcium carbonate ($CaCO_3$). Because of its low pH and hardness and high carbon dioxide (CO_2) concentration, the water tends to be aggressive toward most plumbing and distribution system materials. Other than the corrosion-control treatment, the only water treatment process used in IWD is disinfection with sodium hypochlorite to provide a detectable residual level throughout the distribution system.

PCWD. PCWD produces nearly 40 mil gal (151 ML) per year from 15 deep vertical wells located throughout the district. The system is configured in such a way that 10 of the wells pump directly to the plant. Maximum pumping capacity using these 10 wells is 290 gpm (1,098 L/min), but normal usage is much lower. Pumping levels average

FIGURE 1 Box plots for initial LCR monitoring data



LCR—Lead and Copper Rule, IWD—Idyllwild Water District, PCWD—Pine Cove Water District, Pb—lead, Cu—copper, AL—action level. Boxes span 25th and 75th percentiles; whiskers represent the 10th and 90th percentiles; means are indicated by green lines; medians are indicated by solid lines in boxes; outliers are indicated by solid circles; reference lines are shown for LCR ALs.

from depths of 150–300 ft (46–91 m) in most normal rainfall years. Storage consists of six steel tanks in two locations. The upper 3 mil gal (11.4 ML) is contained in four tanks just below the new aeration plant at a higher elevation, and two tanks are located at a lower pressure zone. The system has always been gravity-fed. With the new aeration plant, all water is now gravity-fed from the new aeration plant through the main storage area to the distribution system. The distribution system consists of 19 mi (31 km) of 4, 6, and 8 in. (100, 150, and 200 mm) main lines, nearly 90% of which are steel pipe and 60% are cement–mortar-lined. The remaining 10% are polyvinyl chloride (PVC) or asbestos cement.

As at IWD, PCWD's only treatment other than corrosion control consists of adding a small amount of sodium hypochlorite to maintain a modest free chlorine residual throughout finished water storage and the distribution system. The general water quality before installation of the aeration plant is shown in Table 1.

EVALUATION OF CORROSION-CONTROL ALTERNATIVES

Prior to initiating a corrosion-control study, the IWD and PCWD carefully reviewed a broad variety of reference documents. Evaluation of alternative treatment schemes looked at capital and operating costs, simplicity of operation, the need for repumping after treatment, and the type and amount of chemical treatment required. Because of customer perception of aesthetic problems associated with a corrosion inhibitor, the districts also wanted to minimize or, if possible, avoid the use of an inhibitor.

Blended phosphate treatment evaluation. Because the effectiveness of a corrosion-control program is uncertain prior to its implementation, a trial passivation program was initiated at IWD. Baseline data were established through sampling and testing water drawn from five homes at various locations in the district. From results of the first rounds of testing in 1993 and 1994, these homes were thought to have the highest probability of corrosion in their internal plumbing and fixtures. A flushing program was instituted to remove loose scale from the older water lines.

The pilot program began in April 1996 with the injection of a 50:50 blend of orthophosphate and polyphosphate at a feed rate of approximately 1.5 mg/L of product, corresponding to a target dose of 0.75 mg/L of orthophosphate as PO_4. The blend was chosen on the basis of advice from various consultants and the experiences of other water systems in the area.

The sampling and testing procedure was repeated on a bimonthly basis to evaluate the effectiveness of the selected corrosion inhibitor. The program continued with the initial dosage and blend for nine months. During this period, an intensive flushing program was in place to control the expected aesthetic problems that could result from release of old corrosion products in the pipelines. Because polyphosphates frequently are reported to have a greater tendency to remove corrosion by-products than orthophosphate formulations, the decision was made to change the inhibitor formulation. After the nine-month trial period, the inhibitor was changed to a 70:30 orthophosphate/polyphosphate blend on the recommendation of the chemical supplier, with the dose remaining at 1.5 mg/L as product (1.0 mg/L orthophosphate as PO_4). Through 1997, the product dose was gradually increased to 2.0 mg/L, yielding a target orthophosphate dose of 1.4 mg/L as PO_4.

Results of IWD's bimonthly tap sampling and testing program for the inhibitor treatment are shown in Figure 3. Water samples tested throughout the pilot program indicated that the dosing of 70:30 (ortho:poly) blended phosphate corrosion-control treatment was more effective in reducing Pb concentrations than the 50:50 blend. The effect on reduction of Cu concentrations was less consistent and was generally inadequate. Flushing appeared to be needed continually to alleviate consumer concerns, and that was labor-intensive and costly. In December 1996,