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Project Summary

An Evaluation of the Secondary Effects of Air Stripping

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At a 2.9 million gallon per day (mgd) well contaminated with several volatile organic compounds (VOCs), principally trichloroethylene (TCE), a packed tower aerator was pilot tested, designed, constructed, and monitored during its first 7 mo of operation. Pilot testing was based on gas/liquid mass transfer theory. Calculated mass transfer coefficients coupled with this theory were used to design the full-scale aerator for TCE control. Modeling of VOC off-gas dispersion was required to obtain a construction permit in Southern California. In addition to liquid-phase VOCs, other parameters including bacteria, temperature, pH, dissolved oxygen, calcium, alkalinity, turbidity, particle counts, noise, and air-phase VOCs were monitored to assess the secondary effects of aeration. Secondary effects refer to the air, water, and ambient quality that might be affected by tower operation for the control of VOCs. Parameters such as calcium carbonate deposition, corrosion, and Legionella were examined. Of the many parameters, only calcium deposition and standard plate count (SPC) bacteria required control. The full-scale aerator was modified to improve VOC control. A capital and operation and maintenance (O&M) cost analysis indicated packed tower aeration (PTA) to be cost-effective.

This Project Summary was developed by EPA's Risk Reduction Engineering 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

Since 1974, researchers have observed widespread contamination of finished drinking water with trace amounts of synthetic organic chemicals, many of which have been linked to adverse health effects. Recent surveys of groundwater quality have discovered equally widespread contamination of groundwaters once thought to be protected. California groundwater has been contaminated principally with TCE and dibromochloropropane.

The Valley County Water District (VCWD) provides groundwater to the City of Baldwin Park and a portion of the City of Irwindale. The District lies in the San Gabriel Valley, roughly 30 miles east of the City of Los Angeles. In December 1979, TCE exceeding 1 mg/L was discovered in one of the District's wells. The California Department of Health Services (CDHS), responsible for enforcing drinking water standards, immediately began an extensive monitoring program. TCE contamination was found throughout the San Gabriel Valley; however, the concentrations observed elsewhere were considerably less than those found in some VCWD wells. In 1980, the CDHS established an action level for TCE of 5 µg/L; wells exceeding 50 ug/L TCE were shut down.

Granular activated carbon (GAC) adsorption and air stripping are the most common technologies for removing organic contaminants. Air stripping by PTA is considerably less expensive than GAC. This study covered the pilot testing, design, and monitoring of a full-scale PTA at the VCWD Lante Well. In addition to TCE, the well contained tetrachloroethylene (PCE) and 1,1,1-trichloroethane (TCA).

Objectives

The viability of PTA has been compared with that of GAC and other processes. Although economics and simplicity of operation and maintenance favor aeration, further work was needed to identify other aspects that could affect its performance and cost. Several states have established policies regarding the emissions from tower aerators in response to the concern over air quality and the issue of trading a water contamination problem for a potential air pollution problem. Some states require that controls be provided regardless of the levels of VOCs in the off-gas. Other states such as California require a study of the effect of VOC dispersion to determine if the level of air pollution is significant and if controls are needed.

The primary objectives of this study were to evaluate the secondary effects of PTA. Secondary effects are those affecting water, air, and ambient quality, and in this study include PTA's influence on mineral scaling, corrosivity, microbiological quality, noise, air quality, and particulate concentration. Pilot-scale tests were conducted to develop design criteria for the full-scale packed tower aerator and to assemble information for an air pollution control permit. The aerator was then constructed, and once in operation, it was monitored to assess secondary effects.

Pilot-Scale Testing and Full-Scale Design

Approach

The design of the pilot-scale testing and the analysis of the data was based on conventional gas/liquid mass transfer theory. This theory established the relationship between a number of factors that affect the design and performance of packed tower aerators — factors including the Henry's coefficients of TCE and the other VOCs, packing depth, air loading rate, water loading rate, air-to-water ratio, and air pressure drop through the packing.

Nineteen pilot runs were conducted. Influent and effluent samples were analyzed for VOCs, calcium, alkalinity, total dissolved solids, turbidity, particle counts, pH, chlorine residual, and temperature. Each run corresponded to a unique set of operating conditions for packing depth and water loading rate. The operating conditions during the pilot study ranged from 1.75 to 9.75 ft of packing depth, 4.3 to 28 gpm/ft^2 water loading rate, and 29 to 160 cfm/ft^2 air loading rate.

Equipment

The pilot-scale unit was designed for countercurrent air and water flow with forced draft air supply. It was constructed of 11.5-in. diameter clear Plexiglas*, supported by a plenum. The shell was assembled in 2-ft sections separated by flow redistributors. The tower was packed with 1-in. polypropylene Super Intalox* saddles. Air was supplied by a centrifugal blower. The blower intake was extended 15 ft from the tower to reduce recirculation of the off-gas. Air flow was adjusted to a predetermined pressure drop across an orifice plate in the air flow meter. An inclined-tube manometer measured differential pressure. Influent water was supplied directly from the well pump discharge. Influent water entered an 18-ft standpipe that maintained a constant influent pressure and water flow. From the standpipe, flow was diverted to a rotameter and then to the packing. Treated water flowed from the plenum to an air break. The height of the air break was adjusted to keep water in the plenum so that gasses would not be lost through the water discharge line.

Testing and Design

Pump tests and pilot-scale studies took place in November and December 1982. Pump tests indicated TCE typically increased from near 70 to near 400 µg/L in 6 hr and leveled off near 500 µg/L at 24 hr. During pilot tests, the pump was operated 4 hr before testing began with the result that influent TCE ranged from 200 to 400 ug/L.

The Sherwood and Holloway correlation was used to determine mass transfer coefficients (K_La's). The data analyses discounted the contribution of end effects, i.e., volatile losses in the distribution and plenum collection of water. For each of the 19 runs, K_La's were determined for TCE, PCE, TCA and for four trihalomethanes that were spiked into the influent water. A computer model (utilizing the theory and design crit described in the Project Report) analy the data for design purposes.

As inputs to the computer model, µg/L influent TCE and 3 µg/L efflu TCE were conservatively chosen ; yielded a design of 99.4% remo based on countercurrent operation. 1-in. saddles used during piloting w also chosen. The least-cost desi based on a 1400 gpm (2.9 mgd) flowr included: 30 gpm/ft^2 water loading r 5600 cfm air loading rate, 30:1 air water ratio, 18-ft packing depth, 7. tower diameter, and an air pressure d of 0.05 in./ft of packing. The design v done in early 1983.

A unique feature of the design v elevating the packed tower aerator o structural platform to allow treated wa to flow directly to an existing, surfa level, 2-mil-gal storage reservoir. Ad tionally, the design called for the ca bility to feed chlorine and sodium he metaphosphate (SHMP) to the aera influent or effluent, as needed, for mic biological or stability control. The aera incorporated ports at its top and bott to allow access to water and distributors and packing material.

Secondary Effects

Pilot testing included an analysis secondary effects. The chlorine dema was found to be less than 0.5 mg Turbidity and particle count data show insignificant change; these data su gested that, even at higher air-to-wa ratios, any entrainment of dust would r measurably affect suspended solid co centration. Aeration raised the pH ab 0.3 units. Calcium and alkalinity leve showed very little change. The calculat Langlier Index indicated a slight increa as a result of aeration, but suggest only slight calcium carbonate scali tendencies. Influent water temperatur were near 64°F and dropped less th 1°F with aeration. Mean effluent a temperatures were the same as efflue water temperatures.

Ambient air was sampled for VOCs the pilot unit when it was not in operatio TCE concentrations between 6 and ng/L were found, with the higher lev attributed to nearby industrial activit Using Henry's law and the pilot-sca hydraulics, the worst-case scenario entraining these VOCs into the treate water was calculated and found to b between 0.02 and 0.2 µg/L. The ca culated levels were lower than thos typically found during pilot testing ar

*Mention of trade names or commercial products does not constitute endorsement or recommendation for use suggest that ambient air would have no detrimental impact of full-scale PTA performance.

Air Quality Modeling

The South Coast Air Quality Management District (SCAQMD) did computer modeling of the dispersion pattern of expected VOC discharges from the designed packed tower aerator. The modeling produced estimates of annual average ground-level concentrations of TCE within 2 mi of the Lante Well. The model utilized projected concentrations of the VOC off-gases and meteorological data from nearby airports. Results indicated that PTA off-gases would create a maximum annual average TCE concentration of 21 ng/L northeast of the well outside a residential area. A maximum annual average in the nearby residential area would be 5.8 ng/L. The CDHS, in reviewing the results, used a 10^6 risk factor of 52 ng/L for TCE. The VCWD received a permit to construct.

Full-Scale Monitoring

Following construction and start-up testing, the packed tower aerator was monitored during the 7 mo period beginning in July 1985. For the first 3 mo, operation was continuous and allowed for corrosion testing. Normally, the VCWD operates the Lante Well on an intermittent basis to maintain distribution system pressure and meet demand. Following the corrosion monitoring, the aerator was operated intermittently, coming on-line at midnight and shutting down near 8:30 am. Samples were typically collected at 7:30 am.

VOCs

Start-up tests began in January 1985. During the first few months of testing, TCE influent concentrations occasionally exceeded 800 µg/L—significantly above the 500 µg/L design criteria. The reason for this is not understood. Because of this increase, effluent TCE concentrations sometimes exceeded the 5 µg/L target level. Control of TCE was as low as 96.9% removal. Several modifications were made in an attempt to improve performance. After start-up, 18 ft of packing had settled to approximately 17-1/2 ft. Further, it was observed that water was not evenly distributed over a series of weir troughs that delivered water to the packing. Adding 6 in. of packing material and stainless steel wire mesh to the weir troughs improved performance. The air inlet was modified from one that delivered air offset from the center of the aerator to one that directed air more symmetrically across the bottom of the tower. This, however, did not improve performance.

During the 7-mo monitoring period, TCE control ranged from 99.1% to 99.5% removal, and effluent concentrations were typically below 5 µg/L. The difference between pilot-scale prediction and full-scale performance may have been due to axial dispersion and side-wall channeling. The consensus of packing manufacturers was that it is not necessary to redistribute water with packing depths less than 20 ft. No redistributors were built into the full-scale tower although they were used in the pilot-scale tower upon which the design was based. At full-scale, redistributors may have improved performance.

Secondary Effects

Microbiological Quality

During the first 3 mo of monitoring, chlorine was fed ahead of the aerator but downstream of the influent sample tap. When prechlorinating, effluent residuals exceeded 0.6 mg/L, and little difference was observed between influent and effluent SPC when either R2A or plate count agar media was used. To evaluate the potential for microbiological growth in the aerator, prechlorination was discontinued. In the following months, effluent plate counts were approximately 2 logs greater than influent counts as a result of aeration. Effluent densities were typically 10^3/mL. Results from the two media were in reasonable agreement.

Legionella were not found in any of the samples. Colonies with morphology similar to Legionella were observed in presumptive tests, however. Subsequent confirmation attempts using fluorescent antibody staining indicated that Legionella were not present.

Similarly, coliforms were not found in any of the samples using the most probable number method. All samples were reported at less than 2.2 colony forming units/100 mL.

Water Temperature

The influent water temperature was consistently in the range of 59° to 63°F. Effluent temperatures were typically within one or two degrees of influent, with a few exceptions when effluent temperatures dropped 5° to 10°F. On these occasions, correlation with dry bulb temperature or relative humidity was not apparent.

Calcium Carbonate Deposition

The VCWD observed calcium carbonate scaling during an earlier project studying spray aeration in the 2-mil-gal reservoir. In this project, after 3 wk of operation, the pump boosting water from the reservoir to the distribution system failed as a result of scaling within the casing. Additionally, scaling was observed on the bottom 3 in. of packing. After SHMP was brought on line at 1 mg/L and the pump was acid cleaned, further scale buildup in the pump and on the packing in subsequent weeks was not evident.

Analyses of the packing showed no calcium scale at the top of the tower, but an increase from less than 1 mg Ca/piece at the bottom at start-up to 131 mg Ca/piece at the bottom after 3 wk. Analyses of dissolved calcium showed very little change across the aerator. Concentrations fluctuated between 66 and 72 mg/L. Coupled with the flow-rate data over the 3 wk period, it was concluded that scaling was limited to the lower 3 in. packing. Analyses of the packing following several weeks of adding SHMP confirmed that further scaling had not occurred.

Influent and effluent alkalinity were nearly constant at 180 mg/L over time. Aeration raised the mean dissolved oxygen (DO) concentration from 5.5 to 9.3 mg/L. The pH level was typically elevated from 7.6 to near 7.9 as carbon dioxide was stripped. Although CO_2 was not measured, its calculated loss, based on carbonate chemistry, was approximately 5.2 mg/L.

The calculated Langlier Index of the water influent to the aerator was near zero. With the increase of pH during aeration, however, the Index was slightly positive, suggesting the treated water had mild scale-forming properties. This could account for the calcium scaling in the bottom of the tower and in the downstream pump. Both of these waters experienced the highest pH.

Corrosion

Mild steel and copper corrosion rates were evaluated during the first 3 mo when the aerator was in continuous operation. Rates were measured with Rohrbach corrator probes and an ASTM procedure for metal coupon weight loss.

Both metal coupons and corrator probes were installed in corrosion test racks located on the influent and effluent sides of the aerator. Coupon analyses indicated a decrease in the rates of both metals over time. Copper displayed little difference in rates between influent and effluent waters, whereas mild steel rates decreased slightly across the aerator. Weekly corrator readings indicated a similar drop in rates for both metals over time, and generally, the readings were within 1 log agreement of rates determined by coupon weight. The slightly higher mild steel corrosion rates in the aerator influent may possibly be a result of the lower pH and lower Langlier Index of that water.

The addition of SHMP after the third week of operation appeared to have little effect on the effluent corrosion rate of either material.

Particulates

Both turbidity and particle counts in the range of 1μ to 60μ were measured. Despite the fact that a residue gradually built up at the blower inlet and at the air inlet within the aerator, no significant difference between influent and effluent turbidity or particle counts were observed. Effluent turbidities averaged 0.29 nephelometric turbidity unit.

Air Quality

24-hr, continuous air samples were collected by a SCAQMD contractor up- and downwind of the aerator. Based on the model and ambient conditions, the downwind sampler was located at a distance suspected of having the highest concentrations of TCE. The detection level provided by the contractor was near 5.8 μg/L for TCE. A lower detection level would have required technologies not routinely used by the SCAQMD. TCE was not found in any of the samples. Because these levels were appreciably higher than the 21.8 ng/L annual average TCE concentration predicted by the model before the construction permit was granted, model predictions could not be checked directly.

Noise

With the aerator operating, noise levels were near 80 decibels (dB) at the blower. At a distance of 100 ft, however, levels dropped to near 55 dB, which was the background level at that distance with the aerator shut down. OSHA restricts 8-hr workplace noise to no greater than 90 dB.

Costs

The capital cost of the tower was near $218,000. This included connecting of the existing reservoir and the chlorine and SHMP feed systems. The amortized capital cost was $0.062/1000 gal. O&M costs, based on the 7-mo monitoring period, amounted to $0.031/1000 gal. A comparison of the capital cost of the elevated tower versus a wet well and repumping indicated comparative costs within 10%. This suggests that the total cost of $0.093/1000 gal can be considered representative of PTA facilities.

Conclusions

The use of gas/liquid mass transfer theory together with pilot testing data provided for the design of a full-scale PTA. Factors such as water distributic over the packing, redistribution onto tł packing, and changes in packing dep can influence full-scale performance fı control of VOCs. The secondary effec observed during pilot testing were a goc predictor of the secondary effect observed during full-scale operation. Th changes in water chemistry as a result ‹ aeration, such as pH, DO, and CO_2, ma affect calcium carbonate deposition c corrosion of some metals. Corrosion ‹ mild steel and copper was insignificant i these studies; however, SHMP wa required to prevent deposition. Bacteri densities, as measured by SPC, ir creased as a result of aeration, bu Legionella and coliform bacteria were nc observed. Moderate levels of chlorin were sufficient for bacterial contro Aeration had no significant effect o waterborne particulates, water tempera ture, or ambient noise levels. The impac of VOC off-gas dispersion and contrc must be considered. In this study, n TCE was found in air at low part-per billion levels during tower operation Modeling of PTA off-gases indicated TCE levels in the low part-per-trillion range which were not significantly different thar measured ambient TCE levels. A PTA total cost of less than $0.10/1000 gal a 2.9 mgd was demonstrated and deemec cost-effective for VOC control.

The full report was submitted in ful fillment of Cooperative Agreement CR 809974 by James M. Montgomery Con sulting Engineers, Inc., under the spon sorship of the U.S. Environmental Protec tion Agency.

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The complete report, entitled "An Evaluation of the Secondary Effects of Air Stripping," (Order No. PB 89-161 517/AS; Cost: $15.95, subject to change) will be available only from:
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