Control of Water Quality Deterioration in Water Distribution Systems:

Part 3. Studies of Methane Removal by Aeration

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Summary

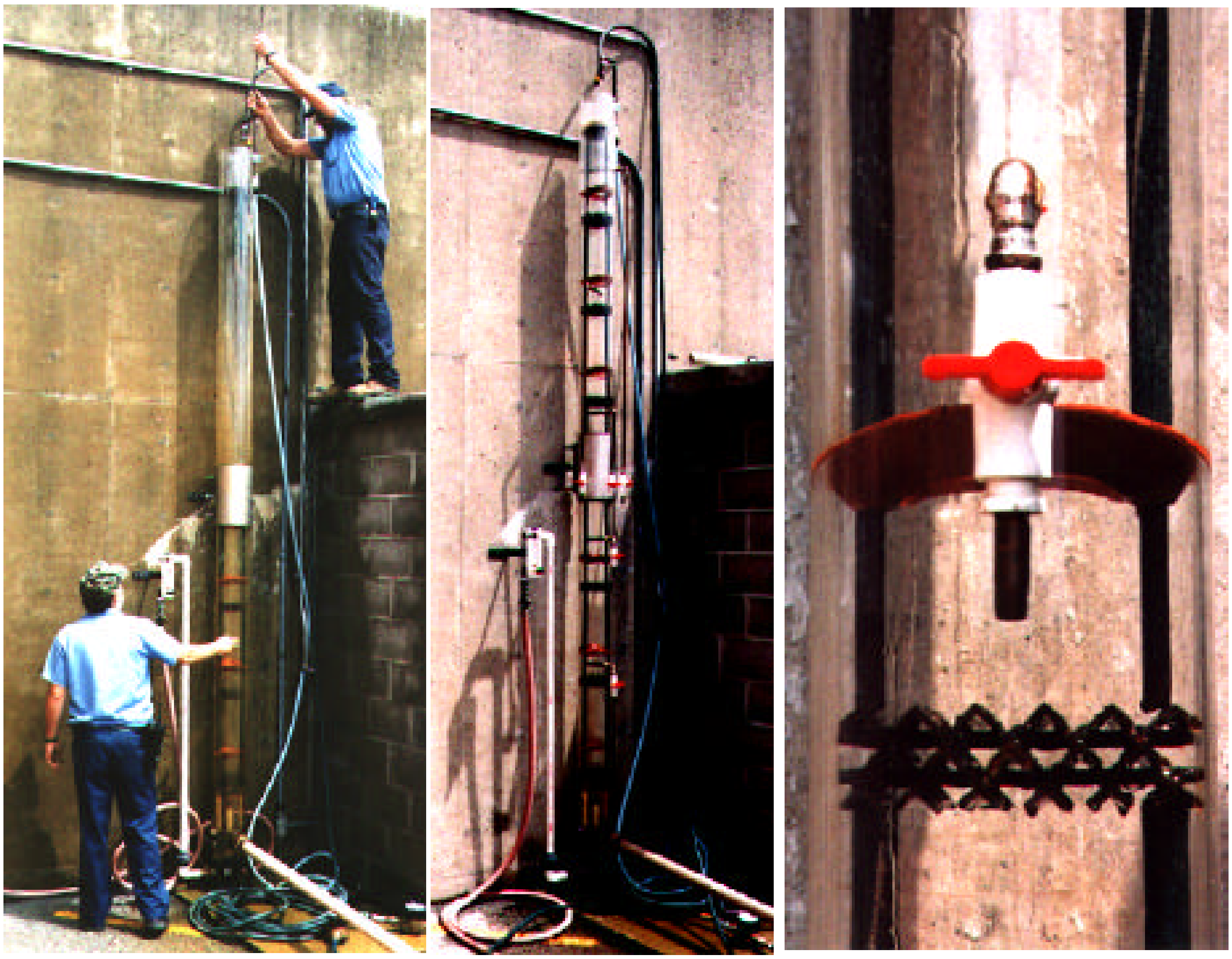
Part 1 of this series documented the widespread presence of methane in Illinois ground waters and assessed its effect on distributed drinking water quality. Evidence was presented for the stimulation of microbial growth by methane.

Part 2 reported on studies of methane removal at the Normal, Illinois water treatment plant. Those results demonstrated that, without adequate aeration, methane penetrated through the plant into the distribution system.

Part 3 of this series details the results of pilot column aeration studies conducted at Normal to assess the ability of improved aeration (tower aerators and diffused air aeration) to achieve more complete removal of methane and carbon dioxide.

Tower Aerator

The tower aerator was constructed using two six-foot sections of 8-inch clear acrylic pipe. Provisions were made for sampling taps to be installed at 2-foot intervals to obtain gas removal profiles as a function of column depth. Rubber (red) deflectors were installed to divert water from the column wall. This appeared to minimize wall effects.

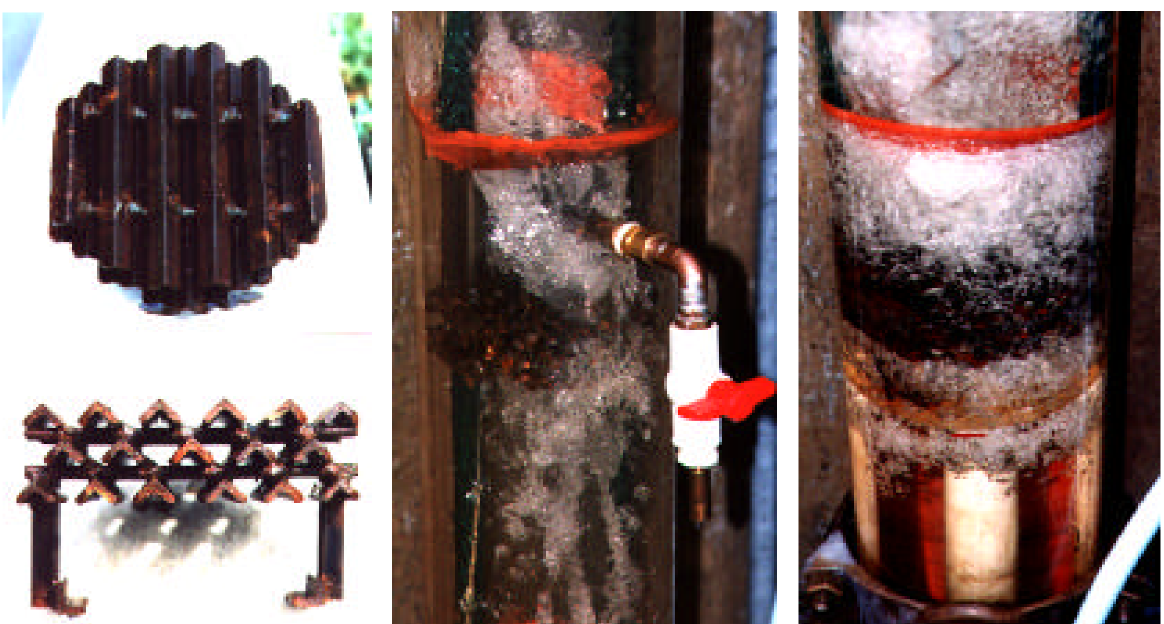


Construction of Tower Aerator and Installation of Iron Gratings Designed and Fabricated at Normal

In addition to surface entrainment of air, compressed air could be introduced near the bottom of the tower aerator to simulate forced air operation. A rotameter allowed the air flow rate to be quantified and controlled.

Operation and Sampling of Tower Aerator under Free-Fall with Iron Grate Packing

Specially-designed column packing units, made of angle-iron clusters, were fabricated for the initial studies. These were spaced at 18-inch intervals within the tower. Tests using this packing were conducted under both free-fall and submerged (column flooded) conditions.



Iron Column Packing Grates used in Tower Aerator under Free-Fall and Submerged Conditions

Subsequently, 1-inch plastic balls (Jaeger Corporation) were added to the column and similar plant influent (well water) conditions were studied. Analyses were made for pH (CO_2), methane and dissolved oxygen.

Installation of Plastic Packing in Tower Aerator

Overall, effective CO_2 and CH_4 removal could be achieved in all aerator configurations provided sufficient air was introduced. The general objectives set for aeration in the pilot study were to increase pH to 7.8 or higher, increase oxygen to 10 mg O/l (90% saturation) or greater and reduce methane to 1 g CH_4/m^3 or less.

Two types of aeration studies were conducted. The first allowed the water to fall freely through the tower, splashing on the iron grates and plastic packing. In this case, air was applied countercurrent to the water flow to purge the gases released into the column. At 9 scfm column air flow, only a moderate increase in pH, equivalent to the pH obtained in the modified full-scale Normal plant aerator, was achieved.

In an attempt to improve gas transfer in the aerator, the upward air flow rate was increased to 40 scfm. As a result, the pH increased to 7.8 while oxygen increased to 9.3 g O/m^3. However, methane removal was incomplete. At the nine-foot column level, 2 g CH_4/m^3 remained.

For the second series of studies, the column effluent flow was adjusted to allow for the media in the column to be partially submerged. At a reduced influent flow of 5.7 gpm (25 gpm/sq. ft.) and an air flow of 9 scfm, gas transfer improved markedly. At a column depth of 5 feet, pH had increased to above 7.9 while the column effluent had a pH of 8.17. Oxygen in the column effluent appeared slightly supersaturated at 12 g O/m^3. Methane removal was near complete at the three-foot column level.

Increasing the air flow rate to 15 scfm, as would be expected, increased carbon dioxide removal and resulted in slightly higher pH at all column levels. However, since the incremental pH increase was marginal, the final column study employed a higher influent surface loading rate (40 gpm/sq. ft.) while the air flow rate was reduced to 9 scfm. The results were again acceptable with pH reaching 7.8 and oxygen exceeding 10 g O/m^3 at the five-foot level. Methane was reduced to 1 g CH_4/m^3 at the three-foot level.

Overall, the results of the pilot studies indicate that, with proper hydraulic loading and adjustment of the air flow rate, a tower aerator is initially capable of meeting the gas transfer goals of a water utility treating a methane-bearing ground water supply. Based on parallel observations of methane and carbon dioxide removal at Normal, it was also proposed that pH serve as the control (operational) parameter for continuously monitoring aerator efficiency to ensure effective methane removal.

Studies were conducted to determine column effluent pH as a function of air flow into the tower aerator. A pH of approximately 7.8 was obtained at an air flow rate of 10 scfm. This indicated degree of carbon dioxide removal should ensure effective methane removal and oxygen saturation.

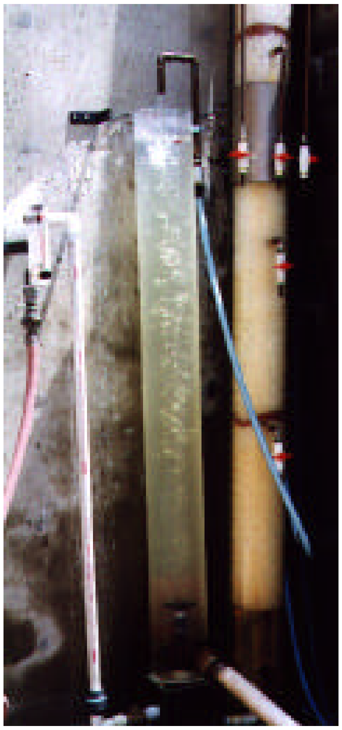
Effect of Air Flow Rate on pH

Air Flow, scfm	pH
0	7.18
5	7.36
10	7.78
15	7.86
20	7.88
40	7.92

Diffused Air Aeration

In addition to studies using plant influent water, the effluent from the lime softening clarifier (pH 11.2) was applied to the diffused air aeration column. This was part of an effort to determine the amount of ammonia (NH_3) which could be stripped form the lime-treated water at high pH. However, even under these favorable conditions, ammonia removals were marginal (≈ 5%).

Discussions of treatment plant configuration and operational aeration procedures indicated that diffused aeration might offer potential treatment advantages at Normal. Whereas tower aeration will significantly increase pumping head requirements, diffused air aeration entails little additional head loss. However, this advantage may be more than offset by the energy cost for compressing air to distribute to the diffusers. The cost of providing compressed air would depend strongly on the location and depth of submersion of the diffusers.



Diffused Air Column,

Air Diffuser and

Rising Bubbles

In addition, the amount of diffused air applied can be adjusted to meet predetermined gas transfer requirements, such as specific finished water oxygen concentrations or the removal of methane to less than 1 g CH_4/m^3. Specific goals may be achieved by either controlling the number of diffusers or the air flow rates. The quantity of air applied to the diffusers might also be adjusted to accommodate varying daily flow rates as well as the long-term, progressive annual increases in water demands.

Diffused air might also be used to augment the aeration presently provided by an existing, undersized tray aerator. At Normal, diffusers could be placed in the post aeration flume or at any location and depth in the recarbonation basin.

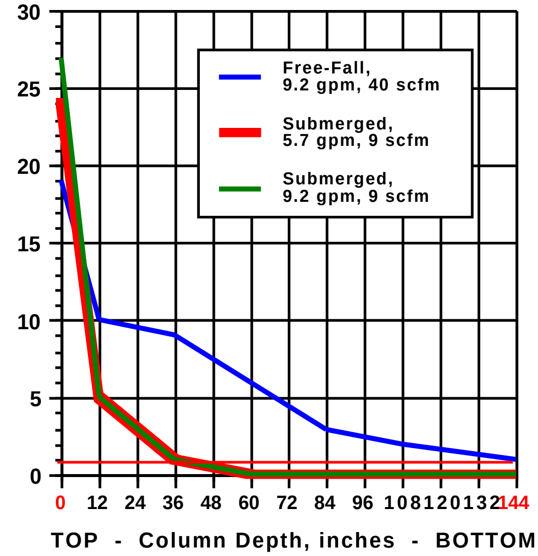
Finally, if biological treatment for methane oxidation and nitrification were found to be feasible and could be incorporated into Normal's existing treatment process, diffused air might subsequently be employed in the recarbonation basin to replace the oxygen consumed in the biological processes.

Methane Removal in Pilot Column Studies

Substantial methane removal was achieved in all the column studies (Figure 8). Under forced draft and 'free-fall' (unsubmerged) conditions, the full (12 ft.) column depth was required to reduce methane to 1 g CH_4/m^3.

With the contact media submerged (diffused air), methane removal was more complete. A performance goal of less than 1 g CH_4/m^3 was achieved at a column depth of three feet. These column studies indicate that, with proper surface loading and air flow, even a shallow aerator should achieve effective methane removal.

Figure 8. Methane Removal in Column Studies

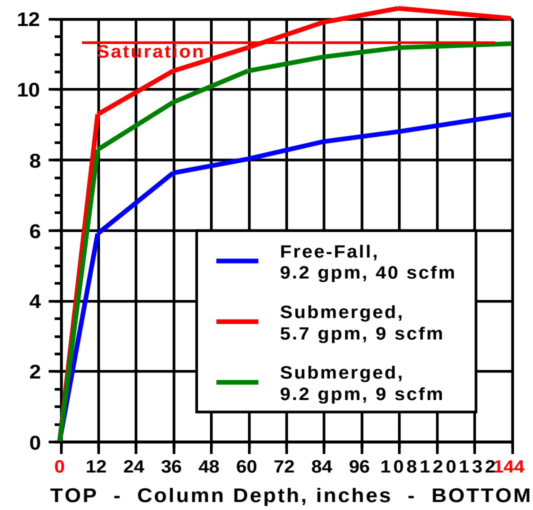


Oxygen Absorption during Aeration

Oxygen absorption from the anoxic well water was rapid. Again, in the free-fall, forced draft (simulated tower) aerator, oxygen transfer was not as complete as when the column media were submerged (Figure 9). Approximately, 80% saturation was achieved in a 12-foot free-fall cascade over the media.

Bubbling air into the submerged media yielded complete oxygen saturation. This appeared consistent with complete methane removal. In fact, at the lower hydraulic loading tested, oxygen in the tower effluent appeared to be saturated at the 5-foot level and marginally supersaturated thereafter.

Figure 9. Oxygen Absorption during Aeration



Carbon Dioxide Removal by Aeration

Since pH is readily measured and recorded, it may serve, not only as a measure of carbon dioxide, but as an operational surrogate for monitoring the efficiency of removal of methane and the introduction of oxygen. The current pilot study was conducted, in part, to determine the operational pH at Normal which would indicate methane removal to levels below 1 g CH_4/m^3.

A comparison of Figures 8-10 indicates that pH exceeding 7.8 may indicate effective methane removal from Normal's well water. Still higher pH is desirable from the standpoint of reduced lime requirements.

Figure 10. Influence of Column Aeration on pH