Control of Water Quality Deterioration in Water Distribution Systems:

Part 2. Removal of Methane at Normal, Illinois

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Summary

Part 1 of this series detailed 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 reports on studies of methane removal at the Normal, Illinois water treatment plant. These results indicate that, without adequate aeration, methane will penetrate into the distribution system.

Methane and Organic Carbon in the Normal, Illinois Well Water Supply

Beginning with Well #1 in 1917, sixteen wells have been developed over the past 72 years to supply drinking water for the Town of Normal, Illinois. Only water from the earliest wells were initially analyzed for methane. Well #2 (drilled to 215 feet in 1921) and Well #3 (drilled to 210 feet in 1931) were found to contain 4.5 and 6.0 cubic feet of methane per 1,000 gallons, respectively.

However, because of microbial slime growth in the Normal, Illinois, water system, an analysis (Neff, 1978) was conducted for methane in Well 101, the Town's fourteenth water supply well which was drilled into a newer and deeper (353 feet) well field. Methane in Well #101 was determined to be 8.2 cubic feet per 1,000 gallons while ammonium ion was found to be 5.6 g N/m^3.

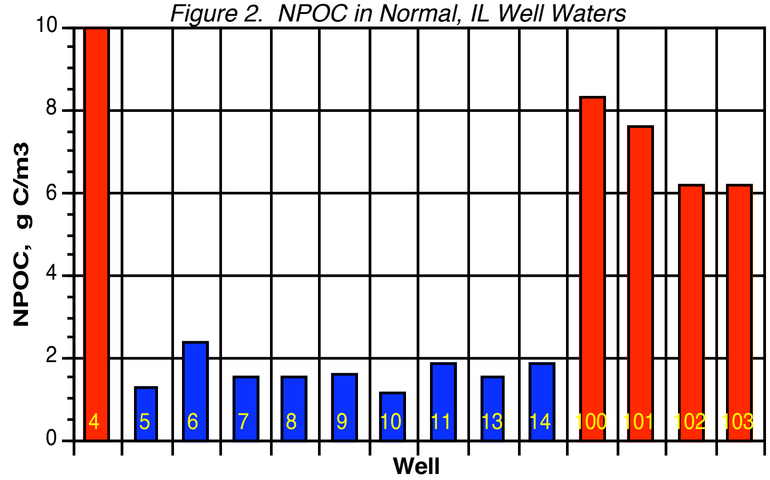
The newer, deeper, 100 series wells were found to sustain higher specific yields and were lower in hardness. Their use markedly reduced chemical costs for softening. As a result, a steadily increasing percentage of Normal's water supply was derived from this nutrient-rich aquifer.

In the current study, methane in the Normal plant blended influent was initially found to range from 8.8 to 9.5 g CH_4/m^3 ± 10%. With the plant aerator out of operation (bypassed), the plant finished water contained an average of 3.4 mg CH_4/m^3. This 63% reduction in methane concentration was accompanied by a 50% increase in dissolved oxygen (from 0.0 to 5.2 g O/m^3 at 13 °C) in the finished water. Most of the gas transfer appears to have occurred in the influent flume and mixing chamber of the softening unit.

Non-Purgeable Organic Carbon

Because measurements had not been made previously of the organic content of the well waters, a series of samples were collected as part of the present study. The results for each individual well demonstrate that water drawn from the five deeper wells is far richer in organic matter than water from the strata serving the shallower wells. The pattern of results is similar to that obtained for ammonium ion, indicating that there might be a relationship between the dissolved organic carbon and ammonium ion concentrations of well waters in this region.

Figure 2. NPOC in Normal, IL Well Waters



The results are expressed as non-purgeable organic carbon (NPOC) because the analytical procedure used involved the purging of gases from the water samples. Any volatile organic matter, such as methane, is stripped by this procedure. As a result, it is only the non-purgeable portion of the organic carbon (e.g., humic and fulvic substances) which are generally measured and reported. NPOC may erroneously be taken as total organic carbon (TOC).

A plot of the data pairs for NPOC and ammonium ion in the 14 Normal well waters indicates that there may be a direct, linear relationship between the two parameters.

NPOC is approximately 2 g C/m^3 for each 1 g N/m^3 of ammonium ion. While this relationship may apply only to Normal's well waters, the simple measurement of ammonium ion in the blended water treatment plant influent may serve as an

Figure 3. Relation between NPOC and Ammonium Ion

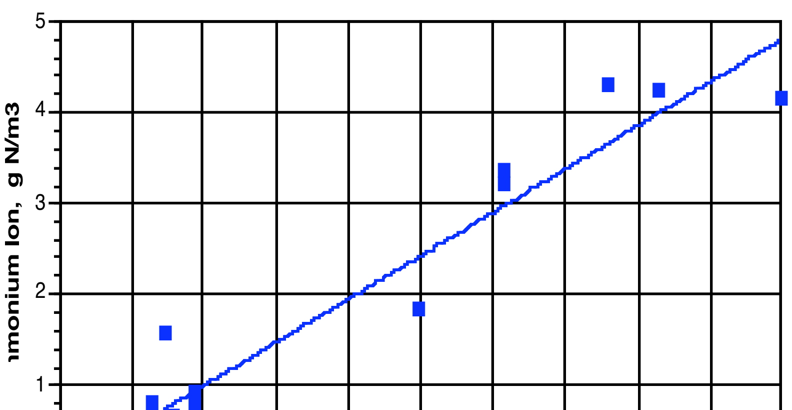
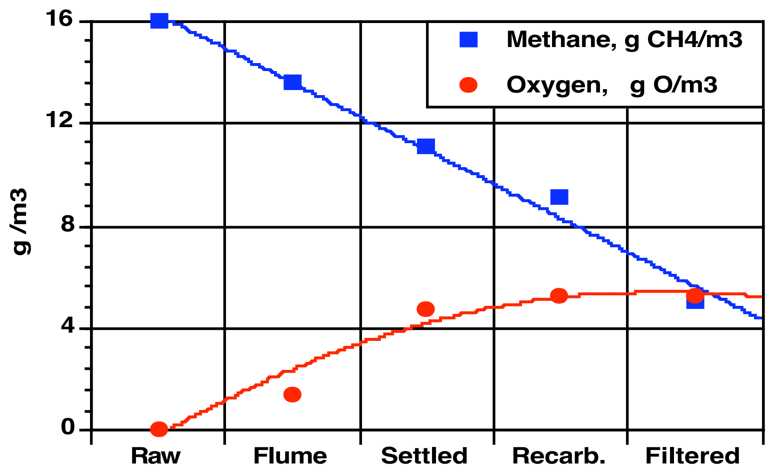


Figure 4. Methane Removal and Oxygen Absorption

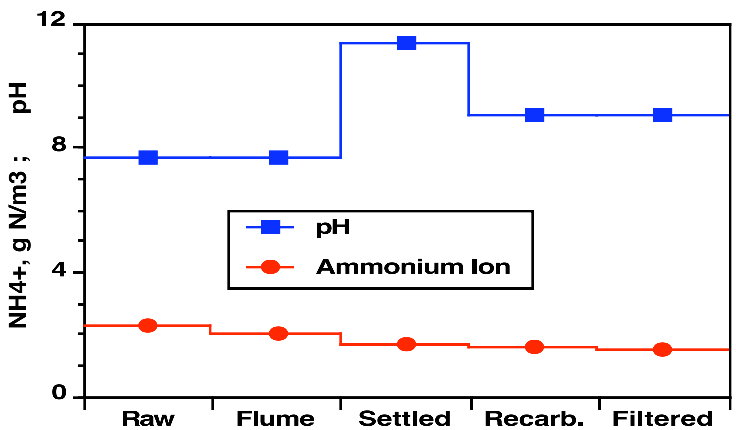


Effects of Bypassing of Aerator

During a short period when the Normal plant aerator was bypassed, profiles of methane and oxygen (Figure 4) were obtained following each plant process.

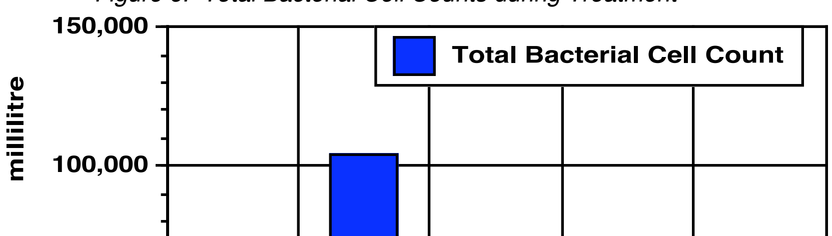
The results indicate that, even in the absence of aeration, methane is lost and oxygen is absorbed by exposing the water to the atmosphere. About two-thirds of the methane was removed while oxygen reached one-half saturation at 13 °C.

Figure 5. Ammonium Ion Reduction during Treatment



A progressive decline in the ammonium ion concentration, from 2.22 to 1.47 mg N/l (34%), was observed as water passed through the plant. The incremental reductions may have resulted from the activity of nitrifying organisms, the oxidation of ammonium ion by chlorine or the escape of ammonia following the addition of lime. However, efforts to purge ammonia by aeration of the settled water were only marginally successful with 12% removed by intensive air sparging.

Figure 6. Total Bacterial Cell Counts during Treatment



Bacterial cell counts were made using epifluorescence microscopy to observe changes in organism characteristics during treatment. Initially low in the well water, populations declined markedly during softening and, while increasing during recarbonation, remained low in the filtered

Table 2. Summary of Gas Analyses at Normal, Illinois, Water Treatment Plant During Aerator Bypass

Normal, Illinois	pH 7.3	pH 7.6	pH 9.0	Atmospheric	Henry's Law Constant,
Gas Concentration @ 12 °C.	**Influent**	**Aerated**	**Filtered**	Equilibrium	atm / mol fraction
Methane, g CH4 /m3	9	bypassed	3.4	0	29,700
Nitrogen, g N / m3	-	bypassed	-	13	66,800
Carbon Dioxide, g CO2 / m3	45	bypassed	0	1	1,040
Oxygen, g O / m3	0	bypassed	5.2	11	32,700
Hydrogen Sulfide, mg H2S / m3	160	bypassed	10	0	367

Methane in the Normal Water Distribution System

During the period the aerator was out of service, there was an opportunity to observe both the unaided reduction of methane within the plant and its penetration into the distribution system.

As shown in Figure 7, while methane averaged 15 g CH_4/m^3 at the three wells supplying 70% of the plant influent, 25 g CH_4/m^3 was found following transmission to the plant.

Even with the aerator out of service, three-quarters of the methane in the influent was released to the atmosphere or microbially oxidized as water passed through the plant processes. The remainder entered the distribution system.

Methane declined progressively from 7 to 0 g CH_4/m^3 as the water passed through the distribution system. This may have been to microbial activity or transients in concentrations during distribution.

Figure 7. Methane in Well, Finished and Distributed Water

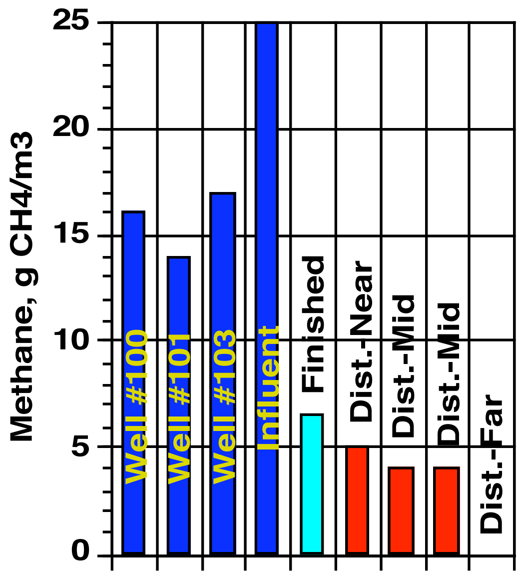


Table 3. Gas and Ammonium Ion Analyses following Modification of Aerator (Enclosed, Forced Draft)

Normal, Illinois	pH 7.37	pH 7.58	pH 7.62	pH 9.0
Gas Concentration @ 12 °C.	**Influent**	**Aerated**	**Flume**	**Filtered**
Methane, g CH4 / m3	18	4	-	2
Carbon Dioxide, g CO2 /m3	45	27	25	0
Oxygen, g O /m3	0	7.6	9.2	9.0
Hydrogen Sulfide, mg H2S /m3	3	2	-	0
Ammonium Ion, g N/m3	2.54	-	2.38	1.65

Even after the modification of the aerator and its return to service, 2 g CH_4/m^3 methane was found in the finished water (Table 3). In addition, as indicated by pH, carbon dioxide removals by aeration remained marginal.

Pilot Plant Aeration Studies

Part 3 of this series details 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. A 12-foot tall tower aerator was constructed and operated with and without internal packing. The tower aerator was operated under both submerged and free-fall conditions.