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Evaluating the Impact of Disinfectants on PE Pipe

Results from a study conducted to determine the potential effects of disinfectants on potable water supply polyethylene (PE) pipe are now available in the report, "Impact of Water Disinfectants on PE Pipe" (www.janalab.com/pdf/disinfection.pdf). Commissioned by the Plastics Pipe Institute (PPI) and the Alliance for PE Pipe, the study was conducted by Jana Laboratories. Designed to help the water industry understand the effects of potable water disinfectants on PE pipe, the project examined the key end-use factors affecting durability, including chlorination, oxidative aggressiveness, temperature, and pressure/stress. "Polyethylene pipe materials have been used in drinking water applications for more than 50 years and enjoy a consistently high satisfaction rating from water utilities," stated Tony Radoszewski, executive director of PPI. "During this time, PE resins have continued to evolve and improve. To demonstrate and validate the long-term performance of these resins, the industry has been developing accelerated test and analytical methodologies that will help project long-term performance in specific end-use environments. Current models project that high-performance PE piping materials can, conservatively, provide more than 100 years of resistance to chlorine- and chloramine-treated drinking water in the vast majority of potable water systems when properly designed and installed."

RESEARCH REFINES LONG-TERM PERFORMANCE FORECASTING

The mechanical aging mechanisms that form the basis of system design have been well-characterized, and methodologies for characterizing performance for these mechanisms are well-established. Considerable research has also been conducted to characterize the long-term aging mechanisms resulting from chemical factors, such as the effect of disinfectants on long-term performance.

"This research provides the crucial metrics for truly being able to design systems that fully account for what can happen in the field, giving design engineers and pipeline operators much greater ability to design and install systems knowing they will stand the test of time," said Ken Oliphant, executive vice-president of Jana Laboratories.

To project field performance based on accelerated laboratory testing, three key criteria needed to be met. First, the mechanisms observed in laboratory testing must be the same as those anticipated/observed in the field. Second, laboratory testing must be achievable in a practical timeframe.

TABLE 1 Summary of standard operating conditions and projected performance by utility

Operating Variable	Utility Location			
	Indiana	Florida	North Carolina	California
Average disinfectant residual—*mg/L*	1.6	1.4	0.9	1.9
Average pH	7.7	9.3	8.6	9.0
Estimated ORP—*mV**	650	650	680	650
Average water temperature—*°F (°C)*	57 (14†)	79 (26)	68 (20‡)	61 (16)
Average operating pressure—*psig*	70	70	70	65
Projected performance in the brittle oxidative regime—*years*	> 100	> 100	> 100	> 100

*Estimated value based on disinfectant residual, pH, and disinfectant type
†Average value; water temperature range 1–29°C
‡Average value; water temperature range 13–28°C

ORP—oxidation–reduction potential

TABLE 2 Summary of standard operating conditions for average and aggressive water conditions at US utilities

Operating Variable	Average US Utility	Aggressive US Utility
Average disinfectant residual—*mg/L*		
Average pH		
Estimated ORP—*mV**	650	825
Average water temperature—*°F (°C)*	57 (14†)	73 (23)
Average operating pressure—*psig*	70	70
Projected performance in the brittle oxidative regime—*years*	> 100	> 50

*Estimated value based on disinfectant residual, pH, and disinfectant type
†Average value; water temperature range 3–29°C

ORP—oxidation–reduction potential

Third, the approach must provide the ability for predictive extrapolations to end-use conditions.

The basis for the testing conducted during the study was ASTM F2263, "Standard Test Method for Evaluating the Oxidative Resistance of Polyethylene (PE) Pipe to Chlorinated Water." Conducting ASTM F2263 testing at multiple water qualities and modeling the effect of water quality allowed the development of a model capable of predicting long-term performance of a PE pipe compound as a function of water quality, temperature, and stress. The effect of water quality is modeled on the basis of the oxidation–reduction potential (ORP). A linear relationship between log (failure time) and ORP was used for the model. In addition to projecting the long-term chemical aging mechanism under standard operating conditions, the model also projects performance at the extremes of end-use operating conditions consistent with performance observed in the field.

DATA FROM CASE STUDIES HELP TO PROJECT PERFORMANCE

General operating data were obtained from four water utilities in Indiana, Florida, North Carolina, and California (Table 1). These data were used along with the models to project performance under actual operating conditions. Because the projections are specific to the operating conditions of these utilities, an analysis was also conducted for "average" water quality and "aggressive" (i.e., low mineral content and corrosive) water quality (Table 2).

Average water quality. The City of Palo Alto Utilities serves 60,000 people in the Palo Alto, Calif., area. Performance projections from the data collected show that PE pipe will provide service for more than 100 years. On the basis of an analysis of information from AWWA's Water:\Stats database, the literature, and Internet resources, operating conditions representative of an average US utility were identified (Table 2). Performance projections for the long-term chemical aging mechanism are in the 100-year life span, indicating that at average water quality conditions, high-performance PE piping systems are projected to provide excellent service.

Aggressive water quality. A model utility with a water quality of 825 mV was selected to represent worst-case water quality conditions for a chlorinated US system. Once again, however, life-span projections showed that for higher-performing current-generation materials, a life expectancy in excess of 50 years can be anticipated. It has been reported that the Las Vegas, Nev., Valley Water District (LVVWD) experienced failures in its PE water service lines, which were installed in the 1970s and 1980s; statistical Weibull analysis predicted a performance life between 23 and 29 years. The LVVWD environment represents an aggressive application, because of both high temperatures and an aggressive water quality. Using the rate process method (the mathematical extrapolation calculation for lifetime forecasting used by the plastics industry) in conjuncton with this new Jana Labs research methodology on test data from older-generation PE materials (i.e., those installed during the 1970s and 1980s), the projected mean lifetime for the long-term chemical aging mechanism was 24 years. This result shows excellent correlation of the model with observed field performance and further validates the methodology. The model calculations predict that even in this very aggressive end-use environment, higher-performing current-generation materials will provide more than 50 years of service.

CONCLUSION

The methodology developed to project PE pipe performance shows that higher-performing current-generation materials are expected to have excellent longevity across the majority of end-use applications and good performance—even in very aggressive end-use environments. The model is also able to characterize performance for older installed PE piping materials and to provide projections in line with observed field performance, providing a tool for understanding and characterizing those systems at the extremes of the end-use operating window.

According to Steve Shur, executive director of the Alliance for PE Pipe, "The Jana study is informative and gives us a road map of where we are and where we're going. It provides scientific evidence of what we've been saying: High-performance current-generation PE materials have an expected life span of 50 to 100 years. This [study] provides third-party scientific backup for that claim."

The report provides a summary of the efforts, details the mechanisms of long-term aging of PE materials in potable water applications, examines the primary end-use product factors affecting the long-term aging mechanisms, reports on the methodology to project long-term performance of PE piping materials in drinking water applications, validates the methodology, and provides the resulting performance projections on the basis of currently available data. Wayne Bryce, president of Jana Laboratories, noted that "the study covers a lot of ground and represents the culmination of more than a decade of research. It presents a detailed characterization of the long-term aging mechanisms of PE pipe, a methodology for forecasting and validating performance, and specific performance projections for high-performing current-generation materials. Plans are to turn the data into a support aid [for] design engineers so they can use it to gain full confidence that their PE systems will perform well into the future."

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