Distribution-Wide Water Quality Intelligence

Continuous, spatially distributed sensing of disinfectant chemistry and pressure, and its integration with hydraulic network models

A technical overview of the Halogen MP5 and MP-TOTAL sensor platform for drinking-water distribution systems

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1. Executive summary

Water utilities monitor distribution-system water quality today largely through periodic manual grab samples supplemented by a small number of online analyzers at treatment plants and pump stations. This approach captures sparse snapshots of free chlorine but is structurally blind to the intermittent, localized events (residual sags, nitrification onset, pathogen-favorable low-residual zones, intrusion, and pressure transients) that most threaten water quality and public health.

The Halogen sensor platform closes this gap. Reagent-free, self-cleaning amperometric sensors measure **free chlorine and monochloramine directly** - along with ORP, pH, conductivity, temperature and, in the MP5, **line pressure** - and stream the data to the cloud. Because the sensors are battery-powered, NSF/ANSI 61 certified, and require no reagents, they can be deployed densely across a network, including locations that conventional online analyzers cannot reach.

Individually, each sensor provides continuous multi-parameter measurement and a site-specific nitrification risk index. Deployed as a distributed field and coupled with a hydraulic and water-quality network model (EPANET / EPANET-MSX), the same data becomes a live, spatially resolved picture of both the disinfectant chemistry and the pressure regime - a capability utilities do not have today, and increasingly one that new state minimum-residual laws will require them to demonstrate.

2. The measurement gap in distribution

Distribution water-quality practice rests on three tools, each with structural limits:

- **Manual grab sampling.** Labor-intensive and sparse (often monthly per site), with lab turnaround. A weekly sample documents under 0.1 percent of operating hours and cannot see an event that starts and resolves between visits.
- **Plant / pump-station online analyzers.** Accurate but expensive, power- and often reagent-dependent, and located where infrastructure exists, not out in the network where problems develop.
- **SCADA pressure at limited points.** Useful hydraulically but rarely correlated with water-quality measurement at the same location.

Two chemistry gaps compound this. **Monochloramine - the active disinfectant in chloraminated systems - is rarely measured online in distribution at all**; utilities instead infer nitrification risk after the fact from grab samples. And free chlorine alone does not distinguish between ordinary decay, nitrification, and contamination.

3. The Halogen sensor platform

Each sensor node combines electrochemical measurement, on-board compensation, and cloud telemetry:

- **Direct free chlorine and monochloramine.** Dual electrically isolated potentiostats drive separate gold working electrodes for simultaneous amperometric measurement; monochloramine is determined by subtraction.
- **Supporting parameters.** Continuous ORP, pH, conductivity and temperature from the same assembly - the set required to distinguish causes of a water-quality change.

- **Line pressure (MP5).** Co-located pressure measurement links hydraulic events to water-quality events at the same point in the network.
- **Reagent-free, self-cleaning and self-diagnosing.** The patented SensiCLENE cleaning system holds calibration for six to twelve months; on-board EIS detects electrode fouling; the reference architecture compensates for potential shift in low-conductivity water.
- **Flow-independent and NSF-61 certified.** A HiRes impeller keeps readings accurate at zero bulk flow - dead ends, clearwells, tanks - and every sensor is NSF/ANSI 61 certified, installing by wet-tap into live pressurized main.
- **Battery power and two field variants.** No mains power or wired comms required. MP5 (free chlorine) and MP-TOTAL (monochloramine / total chlorine) cover free-chlorine and chloramine distribution systems.

4. From point measurement to network intelligence

EPANET, the U.S. EPA hydraulic and water-quality model, solves flows and pressures, computes water age, performs source tracing, and simulates reactive transport of a *single* constituent such as chlorine.[1] Its multi-species extension, EPANET-MSX, models the coupled chloramine / ammonia chemistry - chloramine auto-decomposition, nitrification, DBP formation and biofilm regrowth - rather than a single lumped decay rate.[2]

A model, however, is only as good as its boundary conditions and calibration data. A dense field of Halogen nodes supplies exactly that, enabling four classes of analysis:

[1] U.S. EPA, EPANET 2.2 - hydraulic and single-species water-quality simulation for pressurized pipe networks. epa.gov/water-research/epanet
[2] U.S. EPA, EPANET Multi-Species Extension (MSX) - models multiple interacting species including chloramine auto-decomposition, nitrification, DBP formation and biofilm regrowth.

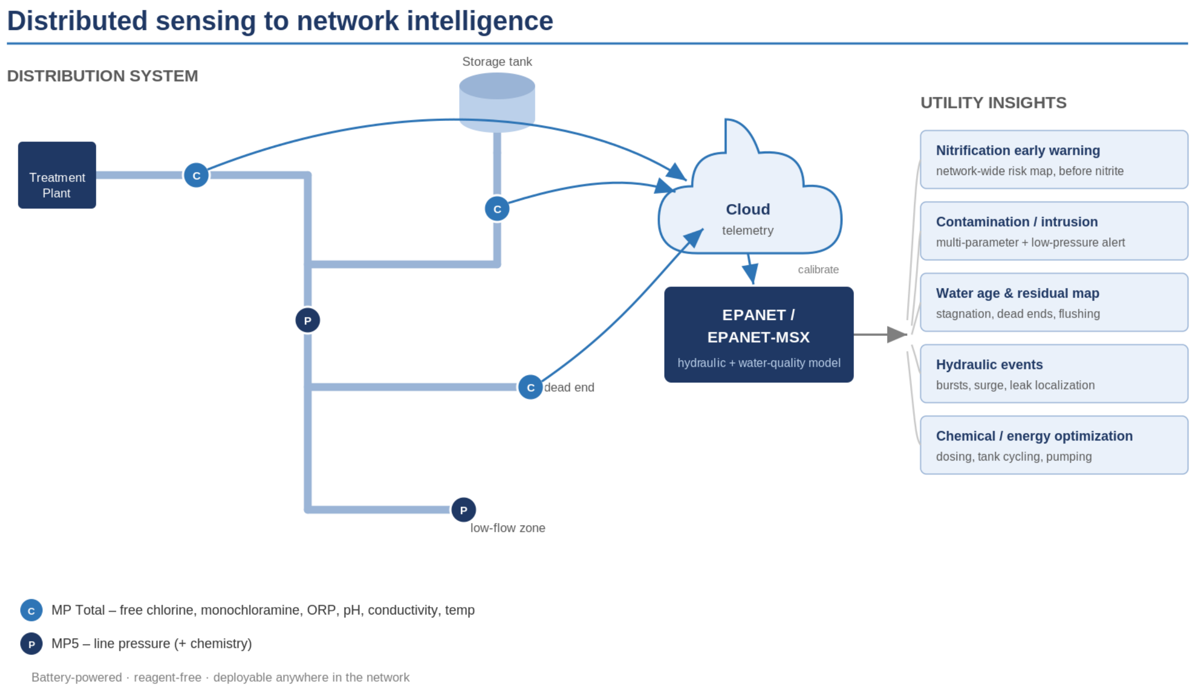

Figure 1. Distributed MP5 / MP-TOTAL nodes stream to the cloud; a calibrated EPANET / EPANET-MSX model turns the data into network-wide insights.

4.1 Model calibration and a live digital twin

MP5 pressures calibrate the hydraulic model (pipe roughness, demand allocation, valve and pump states); MP-TOTAL residuals calibrate the chloramine decay kinetics. Streaming both into EPANET / EPANET-MSX converts a static planning file into a continuously updated model of the running system.

4.2 Water-age and residual mapping

Water age is the strongest hydraulic predictor of nitrification and of low-residual zones where opportunistic pathogens establish. Distributed residual measurements validate the modeled age surface, confirm dead zones and poor tank turnover, and reveal where residual falls below the required threshold - informing rechloramination placement and targeted flushing.

4.3 Network-wide nitrification prediction

The platform's nitrification early-warning method combines monochloramine with two or more of free chlorine, ORP, pH, conductivity and temperature into a risk index that alerts before nitrite becomes elevated. With EPANET-MSX simulating chloramine loss everywhere and distributed sensors anchoring it, risk can be mapped across the whole system and its emergence predicted.

4.4 Contamination detection and source tracing

A multi-parameter anomaly - particularly one coincident with an MP5 low- or negative-pressure event, the mechanism for ingress - can be back-traced through EPANET source tracing to localize the origin and identify the zones to isolate.

5. Insights derived from a distributed deployment

The following capabilities emerge once continuous multi-parameter data exists at many points and is aggregated in the cloud:

Insight	What is measured / modeled	Operational value
Residual continuity	Continuous free-chlorine and monochloramine at many points across the network	Detects transient residual sags that begin and recover between monthly grab samples
Water-age validation	Measured residual decay compared against EPANET-computed water age	Confirms stagnation zones, dead ends, and poor tank turnover in the real network
Nitrification onset	Concurrent trending of monochloramine, ORP, pH, temperature (risk index)	Early warning before nitrite becomes elevated, days ahead of lab confirmation
Intrusion / contamination	Coordinated shift in ORP, pH, conductivity and residual, plus MP5 low/negative pressure	Flags probable ingress or backflow events in near real time
Hydraulic events	MP5 pressure transients coincident with water-quality disturbance	Locates main breaks, surge and burst events; supports leak / non-revenue-water work
Corrosion control	Distributed, continuous pH, ORP and conductivity throughout the network	Verifies corrosion-control stability system-wide (relevant to Lead & Copper)
Electrode fouling state	In-situ electrochemical impedance spectroscopy (EIS) on the electrode	Proxy for electrode fouling and a self-diagnostic for data quality
Operational optimization	Actual residual profile fed to dosing, tank cycling and pump scheduling	Trims rechloramination chemical use while still holding minimum residual

6. Regulatory drivers: distribution residual and pathogen control

Opportunistic pathogens, including Legionella, establish where the disinfectant residual is low and water is stagnant - the dead-end, low-flow and storage conditions in the cold-water distribution system that distributed sensing is built to watch. Maintaining a protective residual across the distribution system is the utility’s primary control, and *documenting* it continuously is shifting from best practice to a legal requirement.

6.1 New Jersey S2188

New Jersey's S2188 requires public water systems to maintain a minimum disinfectant residual - at least 0.3 mg/L free chlorine, or 1.0 mg/L monochloramine for chloramine systems - throughout the distribution system, demonstrated continuously rather than by periodic grab sample.[3] The residual requirement carries a compliance deadline of August 1, 2026, with NJDEP directed to publish best-management practices for community water systems in 2025. It marks a shift from sampling a residual periodically to continuously demonstrating that one is held everywhere in the distribution system.

Parameter	Minimum level	Monitoring
Free chlorine	0.3 mg/L or greater	Continuous, all points in the system
Monochloramine	1.0 mg/L or greater	Continuous, chloramine systems

6.2 A national trend

New Jersey is widely regarded as a model for distribution-residual mandates, and other states are weighing similar measures. The direction reinforces long-standing federal rules: EPA's Surface Water Treatment Rule and Revised Total Coliform Rule already require a detectable disinfectant residual to be maintained throughout the distribution system.[4] What is changing is the expectation that utilities demonstrate that residual continuously and system-wide, rather than through a handful of periodic grab samples.

6.3 Why continuous monitoring is the compliance answer

A weekly DPD grab sample documents less than 0.1 percent of operating hours; a residual can fall below the mandated threshold and recover before anyone takes a reading. Continuous in-pipe measurement produces the 24/7 record these rules increasingly demand. The Halogen platform maps directly onto the requirements: the MP5 verifies free-chlorine residual and the MP-TOTAL verifies monochloramine across the distribution system. Both are NSF/ANSI 61 certified, install by wet-tap into live pressurized pipe, read accurately at zero flow even in dead ends and storage, and stream to SCADA, AMI networks, or the Halogen cloud. See halogensys.com for the S2188 application details.

7. District monitoring to contain and shorten boil-water advisories

Boil-water advisories are triggered by loss of positive pressure - commonly a drop below 20 psi, which invites intrusion and backflow - and by main breaks, treatment upsets, or loss of disinfectant residual.[5] Because a utility often cannot prove which areas were actually affected, or for how long, advisories are frequently issued system-wide and lifted only after multiple rounds of clearing samples - a costly, trust-eroding, days-long event.

[3]New Jersey S2188 (2024-2025 session). Statute: pub.njleg.gov/Bills/2024/S2500/2188_I1.HTM. Residual-compliance deadline August 1, 2026.
[4]U.S. EPA National Primary Drinking Water Regulations - Surface Water Treatment Rule and Revised Total Coliform Rule require maintaining a detectable disinfectant residual throughout the distribution system. epa.gov.
[5]State primacy-agency guidance commonly triggers a precautionary boil-water advisory when distribution pressure falls below 20 psi, and elevates residual to at least 1.0 mg/L free chlorine as a precaution (e.g., FL DOH, MI EGLE, IN IDEM guidance).

Distributed district-level monitoring changes the calculus in three ways:

- **Contain the footprint.** MP5 pressure nodes at pressure-zone boundaries pinpoint which district dropped below 20 psi and for how long, so the advisory can be scoped to the affected district-metered area (DMA) rather than the whole system. Primacy agencies base the decision on all available data - the extent of the problem, the duration of the low-pressure condition, and the possibility of infiltration - which continuous monitoring supplies.
- **Avoid unnecessary notices.** Continuous pressure and residual records in unaffected zones document that system integrity and disinfectant residual were maintained there, supporting a narrower, evidence-based advisory instead of a precautionary system-wide one.
- **Lift faster.** Once mains are repaired and flushed, the same sensors confirm in real time that pressure is restored and residual has recovered above threshold - shortening the advisory and reducing the rounds of grab samples needed to rescind it.

The net effect is fewer, smaller, and shorter boil-water advisories, with a defensible data record for the primacy agency and the public.

8. What utilities gain that they do not have today

Three structural gaps in current practice are closed:

- **Direct, continuous monochloramine in distribution.** Chloraminated systems currently infer nitrification risk after the fact from grabs. Continuously measuring the actual disinfectant species is effectively unavailable in the field today.
- **Spatial and temporal density.** Battery power, cloud telemetry and reagent-free measurement make it economical to deploy many nodes where SCADA and reagent analyzers cannot go.
- **A shift from reactive compliance to predictive operation.** The multi-parameter fingerprint lets a utility distinguish nitrification from decay from intrusion, act early, and produce the continuous record new Legionella and residual mandates demand.

In short, utilities move from sparse snapshots of free chlorine to a live, spatially resolved, cause-aware view of both water-quality chemistry and the pressure regime together - the foundation that makes early warning, contamination detection, regulatory documentation, and model-based optimization possible.

9. Conclusion

Distributed Halogen sensing does not merely add data points; it changes the class of question a utility can answer. A distributed, cloud-aggregated field, coupled to a calibrated EPANET / EPANET-MSX model, supports network-wide nitrification early warning, minimum-residual and pathogen-control compliance, contamination and intrusion detection, corrosion-control verification, containment of boil-water advisories, hydraulic-event localization, and chemical and energy optimization - capabilities the prevailing grab-sample-plus-plant-analyzer paradigm cannot deliver.

10. References

[1] U.S. Environmental Protection Agency. EPANET 2.2 - Application for Modeling Drinking Water Distribution Systems. epa.gov/water-research/epanet.

[2] U.S. Environmental Protection Agency. EPANET Multi-Species Extension (MSX) User's Manual (EPA/600/S-07/021).

[3] U.S. Environmental Protection Agency. National Primary Drinking Water Regulations - Surface Water Treatment Rule and Revised Total Coliform Rule. epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations.

[4] State of New Jersey. Senate Bill S2188, 2024-2025 Regular Session. pub.njleg.gov/Bills/2024/S2500/2188_I1.HTM.

[5] Florida Department of Health. Guidelines for Issuing Precautionary Boil Water Notices. floridahealth.gov.

[6] Michigan Department of Environment, Great Lakes, and Energy (EGLE). Guidelines for Issuing Boil Water Advisories, DWEHD-399-022. michigan.gov/egle.

[7] Indiana Department of Environmental Management (IDEM). Boil Water Procedure Guidance. in.gov/idem.

[8] American Water Works Association (AWWA). Water Quality in Distribution Systems - resources and guidance. awwa.org.

[9] Halogen Systems Inc. MP5 and MP-TOTAL sensor documentation and NJ S2188 distribution application. halogensys.com.