

EMERALD NEXUS

Industrial Symbiosis Platform for Thermally-Accelerated Water Treatment

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1. The Thermal Coupling Concept

Biological denitrification is temperature-dependent, following Arrhenius kinetics. Reaction rates at 5°C are roughly one-ninth of rates at 35°C. In cold climates, standalone treatment systems are seasonal — effective in summer, marginal in winter. This makes year-round operation of biological water treatment in the Pacific Northwest a fundamental engineering challenge.

EMERALD NEXUS solves this by coupling PAWD modular reactors to industrial waste heat sources — primarily data centers, which generate enormous thermal loads they currently pay to reject through evaporative cooling. This creates an industrial symbiosis: one facility's cooling liability becomes the thermal energy that drives biological water treatment for surrounding communities.

The result is digital-to-analog energy conversion: computational waste heat becomes the kinetic accelerant that enables year-round, high-velocity remediation of contaminated groundwater at concentrations (63–75.5 mg/L NO₃-N) that would overwhelm ambient-temperature systems.

2. Thermal Performance Impact

The following table shows simulated batch cycle times for PAWD v1 treating 25 mg/L NO₃-N influent to ≤5 mg/L qualification, using AnoxKaldnes K5 Micro carriers at 55% fill fraction. Times are derived from ASM1-lite kinetics with published Arrhenius coefficients for MBBR heterotrophic denitrification (Ødegaard, Rusten, Hem).

Reactor Temperature	Batch Cycle Time (25 mg/L → ≤5 mg/L)
5°C (winter ambient)	13.2 hours
10°C	9.4 hours
15°C (summer ambient)	6.8 hours
20°C (design reference)	5.2 hours
25°C	3.6 hours
30°C (waste heat coupled)	2.8 hours
35°C (optimal waste heat)	2.3 hours

At 30–35°C with waste heat coupling, treatment velocity is 3–5× faster than ambient winter conditions.

This is the core value proposition of EMERALD NEXUS: converting a thermal waste stream into treatment speed that makes high-concentration remediation economically viable.

Simulation-derived from published MBBR kinetics. Field validation pending pilot deployment (target Q2 2026).

3. Data Center Integration Architecture

The Columbia Basin — where the LUBGWMA nitrate crisis is located — hosts major data center operations from multiple hyperscale operators. These facilities reject tens of megawatts of thermal energy through cooling towers and evaporative systems. EMERALD NEXUS captures a fraction of this rejected heat through a simple hot water loop connection.

3.1 Thermal Interface

The PAWD reactor contains an immersed heat exchanger (316 SS coil or plate) connected to the data center's cooling reject loop. Hot water at 40–60°C from the data center flows through the heat exchanger, maintaining reactor temperature at 30–35°C. The PAWD system requires 25–50 kW peak thermal input for batch reheat and 5–15 kW steady-state to offset insulated vessel losses — a negligible fraction of data center thermal output.

3.2 Mutual Benefit

- Data center receives supplemental cooling capacity and water treatment services for its own process water (cooling tower blowdown, cycles-of-concentration management)
- PAWD receives year-round thermal energy maintaining optimal biological treatment velocity regardless of ambient conditions
- Surrounding agricultural community receives safe drinking water from remediated groundwater
- Columbia River watershed receives reduced nitrogen loading from diverted agricultural contamination

3.3 Built-to-Fit Deployment

EMERALD NEXUS is not a retrofit. Each deployment is engineered to integrate with the specific facility's cooling infrastructure, water chemistry, and thermal profile. The PAWD containerized form factor (40-ft modified shipping container) allows deployment adjacent to data center facilities with minimal site preparation. Multiple units can be deployed in parallel, scaling treatment capacity with the facility's thermal output.

4. Dual-Architecture Platform

Configuration	Description
PAWD v1: High-Velocity Volume	Full 40-ft container as reactor. Operates at 30–35°C for peak biological activity. Thermally unregulated warm discharge. Optimized for industrial reuse, blowdown cleanup, agricultural applications where discharge temperature is not regulated.
PAWD v2: Precision Environmental Discharge	2/3 reactor + 1/3 integrated chiller/holding tank. Discharge thermally locked below 18°C for salmon-safe surface water compliance. Counter-flow heat recovery pre-warms intake while cooling discharge. DEQ/EPA thermal compliance.

Both variants use the same core components: AnoxKaldnes K-series biofilm media, Xylem/YSI IQ SensorNet instrumentation, and the sensor-verified Fail-Closed discharge protocol. The v2 chiller extension adds thermal qualification as a second gate — no water discharges unless both chemical AND thermal criteria are met.

5. Optional Energy Recovery

In deployments where the thermal differential between reactor operating temperature and required discharge temperature is sufficient, the discharge thermal conditioning path can incorporate energy recovery systems. Patent claims cover integration of Organic Rankine Cycle (ORC) engines, thermoacoustic Stirling engines, Kalina cycle systems, and thermoelectric generators (TEG) to convert discharge cooling into auxiliary electrical power for sensors, control electronics, and data systems.

Energy recovery is a v2+ enhancement. It does not affect the core treatment or safety architecture.

6. Extended Product Integration

The EMERALD NEXUS platform extends beyond water treatment. The same thermal coupling infrastructure can support controlled-environment agriculture (CEA), anaerobic digestion, and other thermally-dependent biological processes. The Xylem/YSI instrumentation platform spans all product lines, providing consistent monitoring across water treatment, agricultural, and industrial applications from a single sensor network.

7. Intellectual Property

Three provisional patent applications were filed February 10–12, 2026, covering the PAWD modular MBBR system, the EMERALD NEXUS industrial symbiosis platform, and integration architectures connecting the two. Claims include thermal conditioning subsystems, counter-flow heat recovery, energy recovery from discharge cooling, and the sensor-verified fail-closed discharge protocol.

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