374WATER°

Super**C**ritical **W**ater **O**xidation

— pioneering a new era in sustainable waste management

INTRODUCTION

374Water's offers a proprietary sustainable waste management technology (AirSCWO™). AirSCWO™ transforms the simplest and most complex wastes such as wastewater sludges, biosolids, food and gardening waste (FOGO), agricultural and dairy wastes, and organic chemical wastes, including harmful contaminants (e.g., PFAS, drugs, microplastics), into reusable water, energy, and minerals.

AirSCWO™ is a transformative technology that harnesses the process of supercritical water oxidation (SCWO). SCWO utilizes the unique properties of water above its critical point (374°C and 221 Bar). Figure 1 shows the supercritical phase of water.

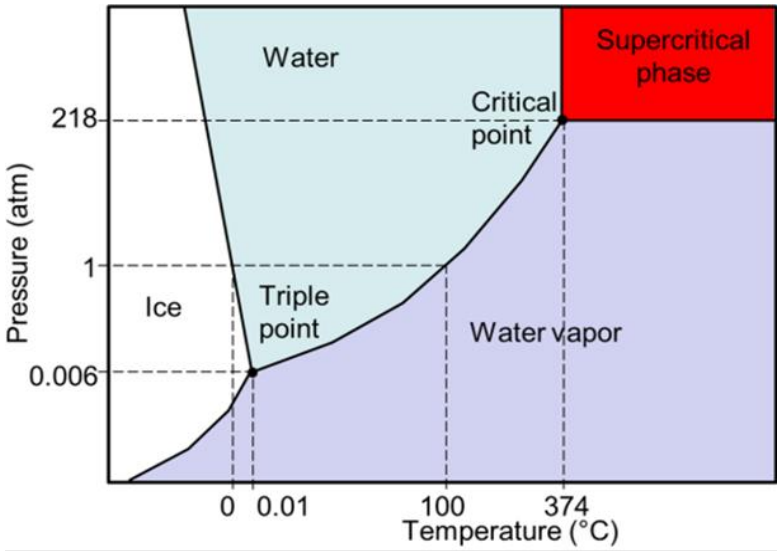

Figure 1. Supercritical water

At supercritical conditions, in the presence of oxygen, organics are rapidly converted to water, inert solids and gases, and reusable heat with >99.9% reduction in volatile solids volume. The reaction is illustrated as shown in Figure 2.

Figure 2. Supercritical water oxidation with AirSCWO™

AirSCWO™ is a continuously operating, auto-thermal process that utilizes the energy embedded in the waste for power. After a short heat-up period of 2-3 hours, an AirSCWO™ system is self-sufficient requiring little or no external energy to operate (large units are net energy positive). The process is illustrated in Figure 2 below. An AirSCWO™ system is automated using sensors connected to a SCADA system and historian PI for real-time analysis of trends, key process indicators (KPIs) and performance measurements.

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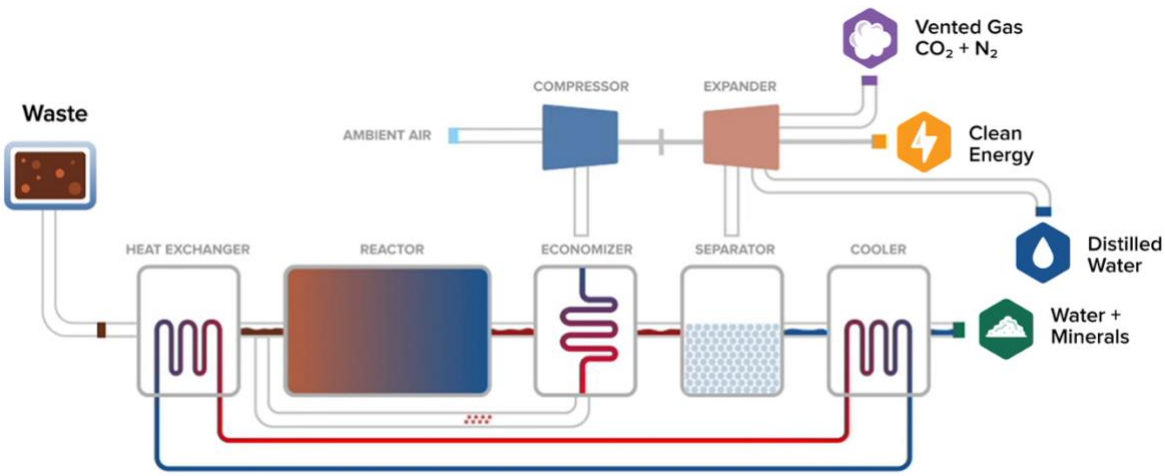

Figure 2. 374Water AirSCWO process flow diagram.

- **Heating and Pressurization:** Incoming organic waste and atmospheric air are heated and pressurized towards supercritical conditions (> 374°C and 22.1 MPa).
- **Reaction:** Hot pressurized organic waste is injected into a plug flow reactor alongside the pre-heated and pressurized air (oxidant). A rapid oxidation of the waste's organic compounds converts almost all the calories (or chemical oxygen demand) in the waste into heat (supercritical mass).
- **Heat Recovery:** Supercritical water leaves the reactor and is split into gaseous and liquid streams; heat is recovered at various stages using a combination of heat exchangers and solid/liquid/gas phase separation vessels.
- **Superheated Steam**: Sent to a built-in expander to generate electricity that could be used onsite. Post expansion this waste stream will become vent gas and distilled quality water.
- **Energy Recovery:** An energy recovery unit converts superheated steam into electricity for the system to heat and pressurize the incoming waste and oxidant.
- **Air emissions:** The gases emitted from the system are CO_2 and N_2. AirSCWO™ does not produce detectable levels of NO_x, SO_x, acid gases, or hazardous and volatile organics.
- **Distilled water:** Approximately two-thirds of the feedstock by weight, is condensed water vapor removed from the gaseous stream after the separator.
- **Effluent water**: Approximately one-third of the feedstock by weight, leaves the system in the form of a liquid mineral stream. The makeup of the mineral stream will determine the potential post-treatment needs.

AirSCWO™ systems achieve new heights of operational performance and resource recovery shifting waste management paradigm from conventional treatment and disposal to innovation pollution elimination and resource recovery.

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374WATER IS PIONEERING A NEW ERA OF SCWO

AirSCWO™ addresses waste management challenges plaguing communities across the globe and tackles prior hurdles which prevented SCWO technology from widespread adoption and commercialization. Since its introduction, commercial development of SCWO has been slow due to technical challenges inherent to the approach. The complex nature of a high-pressure, high-temperature process can lead to corrosion, plugging and fouling. These logistical issues have driven a need for change to critical design elements of SCWO processors - including experimenting with changes to the reactor material, shape, and size. What's more, the pure oxygen used in older generation SCWO processes must be handled and stored safely, creating a need for expensive safety design and control processes to avoid hazards.

With energy being a byproduct of the SCWO process, early attempts to commercialize SCWO were also sidelined by unrealistic expectations that SCWO could produce power at a competitive retail electricity rate (approximately $0.03-0.05 per kWh). This goal proved to be unreachable, making SCWO adoption and commercialization that much more difficult.

Using technology invented and patented by engineers at Duke University in Durham, NC, U.S.A., 374Water developed the AirSCWO™ technology as the world's first self-sustaining, continuous flow SCWO omniprocessor. AirSCWO™ was labeled "the third generation of SCWO" during recent PFAS elimination work performed by the U.S. EPA PFAS Innovation Technology Team (PITT). The technology is in commercial production and has the potential to shift the wastewater paradigm from the traditional centralized, end-of-pipe treatment to innovative, decentralized resource recovery.

AirSCWO™ addresses prior hurdles by incorporating moderate preheating of the waste slurry, followed by mixing with supercritical water and air. Air serves as the oxidant which is much safer to use than pure oxygen. The internal mixing rapidly brings the waste undergoing treatment to supercritical conditions thereby minimizing corrosion and the risks of waste charring and plugging. All organics in the residuals are rapidly oxidized to CO_2, while the heat of oxidation is recovered to heat the influent waste, and water and minerals are recovered for reuse. The other critical innovations instrumental in overcoming corrosion, plugging and energy efficiency challenges is a multi-stream tubular reactor configuration that enables efficient and sustainable treatment. These unique design elements differentiate 374Water's AirSCWO technology from other SCWO technology providers.

374Water has several pending U.S. patents that allow the system to preheat waste slurry more moderately before mixing with supercritical water and air. This allows air to serve as the oxidant, a much safer alternative than pure oxygen and chemicals. Further, internal mixing brings waste to supercritical conditions rapidly, minimizing corrosion and risks of waste charring and plugging. With AirSCWO™, all organics found in the feedstock mineralize to H_2O, CO_2, and inorganics with the heat of the oxidation process recovered to heat influent waste. The system also features a multi-stream tubular reactor configuration, which enables efficient and sustainable treatment while helping overcome corrosion and plugging.

By harnessing energy embedded in the waste stream undergoing treatment and simultaneously enabling recovery of clean water and minerals from numerous sludges and biosolid sources, AirSCWO™ is paving the way for a new era in sustainable waste management and resource recovery.

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The process is fast, clean and the units serve as net energy producers leveraging a unique, proprietary energy recovery unit ("Expander").

EXAMPLES OF WASTE TREATMENT USING AirSCWO™

374Water's AirSCWO™ has successfully treated numerous waste streams. Tables 1 and 2 present results from two different waste streams. Table 1 is wastewater sludge from a municipal wastewater treatment plant in North Carolina, USA. Table 2 is spent ion exchange resin contaminated with PFAS. The resin was used to remove PFAS from groundwater at a confidential US defense installation.

Table 1. Wastewater sludge before and after AirSCWO treatment.

Parameter	Feedstock	Effluent
COD (mg/L)	160,000 - 220,000	50-200
VSS	10-18%	0%
Total N (mg-N/L)	2000-15,000	20-500
NH_3 (mg-N/L)	300-600	5-100
NO_2^- (mg-N/L)	0-20	<5
NO_3^- (mg-N/L)	100-300	<10
PO_4^{3-} (mg-P/L)	2000-6000	20-150
pH	6-8	6-7
Conductivity (µS/cm)	3000-5000	100-300

Table 2. Spent ion exchange resin with PFAS before and after AirSCWO treatment.

PFAS	Input Range (ng/kg_{IX})	Percent Elimination
Total PFCA	240,000 - 280,000	99.97%
Total PFSA	900,000 - 1,200,000	99.56%
Precursors	30,000 - 36,000	98.85%
Short chain (C<6)	700,000 - 790,0000	99.91%
TOTAL	1,000,000 - 1,500,000	99.59%

COMMERCIAL AirSCWO™ SYSTEMS

AirSCWO™ systems are prefabricated, compact and efficient, capable of converting organic waste into clean water within seconds. AirSCWO™ systems are designed for continuous, 24x7 operation and containerized in shipping containers that can be stacked and scaled based on the needs of the installation site.

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Figure 3. AirSCWO 6 at 374Water's assembly plant in Kokomo, IN, U.S.A.

Table 2 presents the models, capacity, flow rate, energy requirements and size of the units.

Table 3. AirSCWO™ commercial systems offered by 374Water.

Model	Daily Capacity	Flow Rate	Energy	Unit Size
	Wet ton / day @ 15% TS	gpm	kW-h / day	
AirSCWO™ 6	6.6	1.1	-300	40-ft
AirSCWO™ 30	33	5.5	+300	3 x 40-ft
AirSCWO™ 200	220	36.7	+4000	Bespoke

The following equipment are provided with a system:

SCWO reactor	Air-to-water heat exchanger
Water-to-water heat exchangers	Slurry heat exchangers
Low- and high-pressure air compressors	Gas analyzers
Water pumps	Co-fuel pumps
Slurry pumps	Liquid/gas/solid phase separators
Expander (energy recovery unit)	Remote access PLC
Automated valves	Pressure relief valves
Rupture discs	Co-fuel storage
Cooling tower	

The systems require the following utilities:

Utility	Description
Water	Process water (for AirSCWO system): Very little water is required for day-to-day operation. A hose or tap water connection is required for initial filling of the system.

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Electricity	400/480 3 Phase, 200 Amps max draw during start-up for the AirSCWO 6 system. Pre or post processing equipment is not included in this estimate.
Co-Fuel	A tank for onsite storage of ~50 gallons of diesel for start-ups
Drain	Capability to discharge or store distilled water
Effluent Handling	Capability to discharge effluent water to plant headworks or centrate lines.

AirSCWO™ systems operate at high pressures and temperatures. Process safety has been designed into the systems.

- The system operates with ambient air; this significantly reduces risk compared to other SCWO systems that operate with pure oxygen.
- The SCADA system is programmed to continually monitor the system with interlocks and alarms that minimize the risk of process failure.
- The system includes physical safety elements (pressure safety valves, rupture disks, and more) that will release excess pressure from the system and divert it to a safe location if the system pressure regulation malfunctions.
- All high-pressure equipment is located inside a steel frame (container). The total reactor volume is very small.

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