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Desiccant vs. Refrigerant Dehumidifiers

—And Why Hydrogel Technology Is the Next Leap Forward

Controlling humidity is essential for comfort, product quality, and energy efficiency in residential, commercial, and industrial environments. Today the market relies on **two legacy technologies**—refrigerant (compressor-based) and desiccant (rotary-wheel) dehumidifiers.

Each excels under certain conditions yet carries intrinsic drawbacks that limit operating range, energy efficiency, or cost-effectiveness.

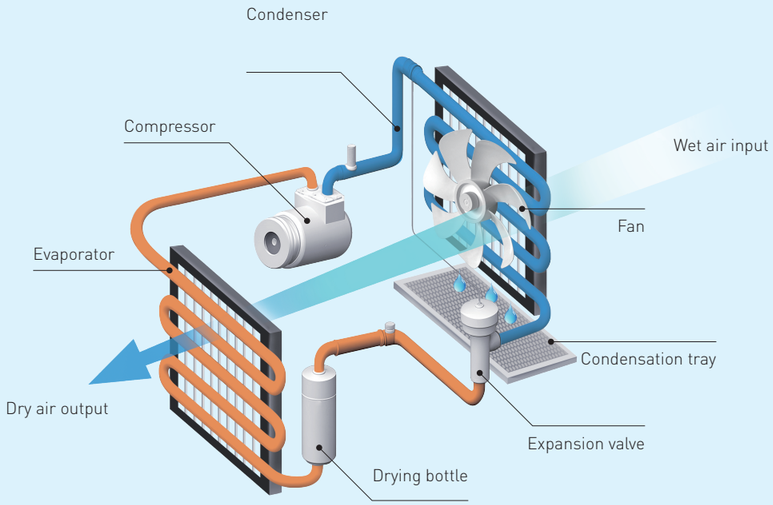
AIQUA-A1

Our next-generation hydrogel dehumidifier, was engineered to eliminate those compromises: it couples record-setting water uptake with heat-free mechanical regeneration.

The sections below:

- Explain how existing systems work and where they fall short.
- Introduce our 3-D-printed hydrogel breakthrough.
- Compare all three approaches side-by-side.

Refrigerant (Condensation) Dehumidifiers



Operating principle

A refrigerant dehumidifier pulls humid air across cold evaporator coils, condensing water vapor into liquid that drains away. The dried air then crosses a warm condenser coil and returns to the space slightly reheated, preventing over-cooling.

Because it exploits latent heat of condensation, the cycle is **highly efficient in warm, humid climates** (≈ 27–30 °C, 60–80 % RH). Modern Energy-Star units reach ≈ **2.35 L water · kWh-¹** at those conditions.

Key drawbacks

Capacity and efficiency collapse below ≈ 10–15 °C or RH < 40 % as frost forms and condensation slows. Case data show energy use rising to ≈ 3.1 kWh · L-¹ at 20 °C/48 % RH—five times worse than at rating conditions.

Cannot reach ultra-low RH: achieving < 40 % RH would require over-cooling and costly reheating.

Rated performance at 30 °C/80 % RH often overstates real-world delivery by a factor of two to three in cooler, drier environments.

Conventional Technologies on the Market

Operating principle

A desiccant dehumidifier uses a slowly rotating wheel coated with hygroscopic media (silica gel, molecular sieves). Process air dries as it passes through one sector; the saturated sector is simultaneously heated (≈ 100–140 °C) by a **regeneration airstream** that vents hot, moist exhaust outside.

Because no coils can freeze, desiccant units maintain **stable drying in cold or very dry air**, easily achieving RH < 20 %.

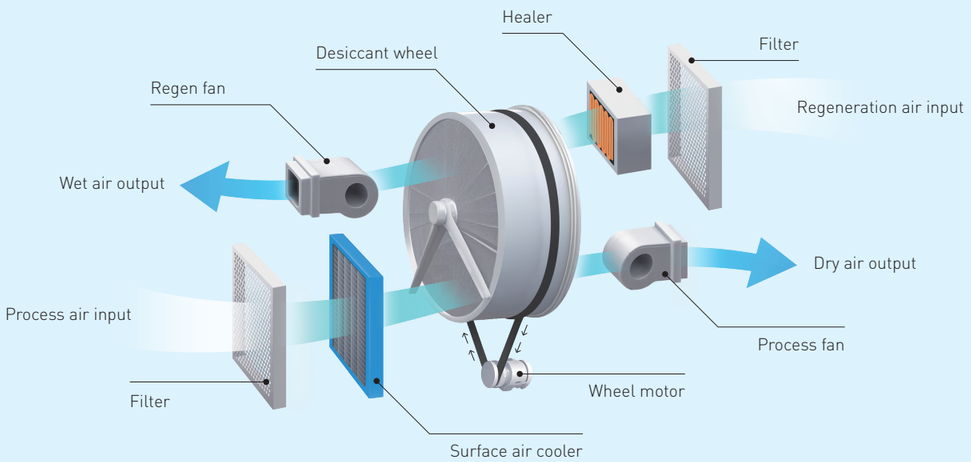
Key drawbacks

Thermal regeneration is energy-intensive; full-cycle specific moisture extraction rate (SMER) is usually **0.5–1.0 kg · kWh-¹**—one-half to one-third the efficiency of a warm-climate refrigerant unit.

Requires bulky heaters and dedicated exhaust ducting; adds CAPEX and maintenance (wheel replacement).

All electrical input ultimately appears as heat, acting like a space heater that may be undesirable in conditioned rooms.

Desiccant (Rotary-Wheel) Dehumidifiers



Our Next Generation Dehumidifier

No Heating and Condensation Unit

- Effective dehumidification down to **10%** RH
- **10x** lower energy compared to existing solutions
- Precision humidity control

Model	AIQUA-A1
Dehumidification Capacity	12 kg/h
Voltage / Frequency	220V / 230V, 50Hz
Power Consumption	800 W
Humidity Control Range	10% – 98% RH
Humidity Control Accuracy	±0.03% RH
Air Circulation Volume	High-flow circulation with low-resistance duct design
Noise Level	⩽ 58 dB(A) @ 1 meter
Vibration Level	⩽ 1.2 mm/s RMS (measured at chassis base)
Air Filtration System	- Built-in primary dust filter (standard) - Optional HEPA H13 kit (⩾99.95% efficiency for particles ⩾0.3 μm) - Optional activated carbon module for odor and VOC removal
Protection Rating	IP21 (suitable for indoor industrial environments)
Coverage Area	300–380 m² (with ceiling height of approx. 3 meters)
Dimensions (W × D × H)	763 × 472 × 1680 mm
Base Support	Powder-coated steel frame with industrial-grade casters
Optional Features	HEPA/Carbon air filtration kits, RS485/Modbus interface, mobile base frame

Hydrogel Breakthrough — AIQUA-A1

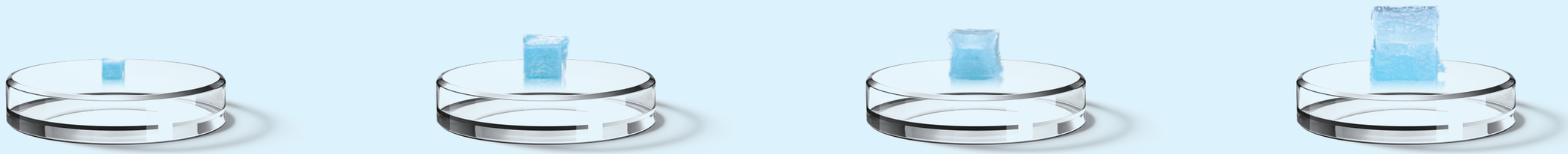


Figure:Time-Lapse Swelling of 3-D-Printed HEA Hydrogel

Through advanced material design and structural innovation, we pioneered a **layer-by-layer photopolymer 3-D-printing process** to fabricate hydroxyethyl acrylate (HEA) lattice hydrogels.

These lattices swell rapidly in ambient air, breaking the adsorption limit of traditional sorbents. Their distinctive architecture yields both extraordinary capacity and ultrafast kinetics.

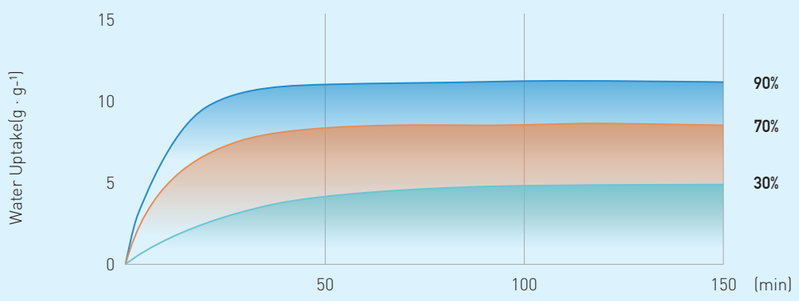


Figure:Water Uptake vs Time under 30 %, 70 %, 90 % RH

Unmatched adsorption performance

3 **Times Absorption**

7.8 g water · g^{-1} gel at 70 % RH (≈ three times the best literature value).

15 **Times Faster**

5 g · g^{-1} absorbed in the first 20 minutes—roughly fifteen-fold faster than leading research materials.

10% **RH Low humidity**

Maintains uptake below 10 % RH, enabling water capture in extremely arid regions.

Heat-Free Mechanical Regeneration

Instead of heating, AIQUA-A1 **mechanically extrudes** the swollen gel—literally "wringing" out liquid water. The required pressure converts to ≈ **1 % of the energy demanded by thermal desorption**, eliminating hot exhaust and slashing operating cost. Resulting **SMER = 8.8–32.6 kg · kWh-1**, an order of magnitude above legacy systems.

Usage Scenario

- Data Center Humidity Control
- Pharmaceutical Storage Warehouse
- Food Processing & Packaging Facility
- Museum & Archival Preservation Room
- Electronics Manufacturing Cleanroom
- Underground Parking Garage Moisture Management
- Textile Mill Drying Area

Side-by-Side Technology Matrix

Feature / Technology	Refrigerant (Condensation)	Desiccant (Rotary Wheel)	Hydrogel (AIQUA-A1)
Operating Principle	Air cooled below dew point → condensate drips → reheated	Rotating sorbent wheel → moisture adsorbed → sector heated and vented	Air contacts super-absorbent hydrogel → moisture captured → mechanical extrusion removes liquid
Effective Range	⩾ 10 °C, RH 40–100 %	Down to < 0 °C, RH 10–100 %	Full temperature & humidity range (0–100 % RH)
Energy Efficiency (SMER)	1.5–2.5 kg · kWh-1 at 27–30 °C, high RH	0.33–1 kg · kWh-1 (full-cycle)	**8.8–32.6 kg · kWh-1**
Regeneration Method	Continuous refrigeration (no separate step)	Thermal (100–140 °C hot air)	**Mechanical extrusion (no heat)**
Key Advantages	High warm-climate efficiency; compact; low CAPEX	Performs in cold & low RH; no frost; deep-dry capability	Ultra-fast uptake; minimal energy; silent; no exhaust duct
Primary	Frost & poor	High heating cost	Emerging tech; higher
Drawbacks	efficiency below 10 °C; cannot reach ultra-low RH	bulky; exhaust duct needed	unit cost (offset by rapid ROI)
Exhaust / Ducting	None	Dedicated regen-air duct	None
Maintenance	Clean coils & filters	Inspect rotor & heater; replace wheel	Inspect extrusion mechanism & drain
Typical Applications	Homes, offices, workshops, basements	Pharma, electronics dry rooms, cold storage, museums	High-efficiency full-range drying; large-scale water harvesting

Benchmarking Against the Latest Hygroscopic Materials

Latest Progress in Hygroscopic Materials

Reference	Uptake ($g \cdot g^{-1}$, 70 % RH)	Rate ($g \cdot min^{-1}$, 70 % RH)	Cycle Life	Minimum RH for Uptake
Xu et al. 2020 [1]	1.9	0.06	48 h	30 %
Teo et al. 2017 [2]	0.21	0.03	30 cycles	20 %
Zhao et al. 2024 [3]	0.97	0.05	20 h	20 %
Duan et al. 2024 [4]	2.42	0.02	10 cycles	25 %
Liu et al. 2021 [5]	2.11	0.06	60 h	30 %
Guo et al. 2022 [6]	2.53	0.03	24 h	25 %
Guan et al. 2022 [7]	2.42	0.02	30 cycles	20 %
Zhang et al. 2023 [8]	2.90	0.02	12 cycles	20 %
Min et al. 2023 [9]	1.50	0.05	30 h	25 %
Duan et al. 2024 [10]	2.60	0.04	50 h	30 %
Zhang et al. 2024 [11]	2.87	0.06	10 cycles	30 %
AIQUA-A1 (This Work)	**7.8**	**0.94**	**> 180 days**	**10 %**

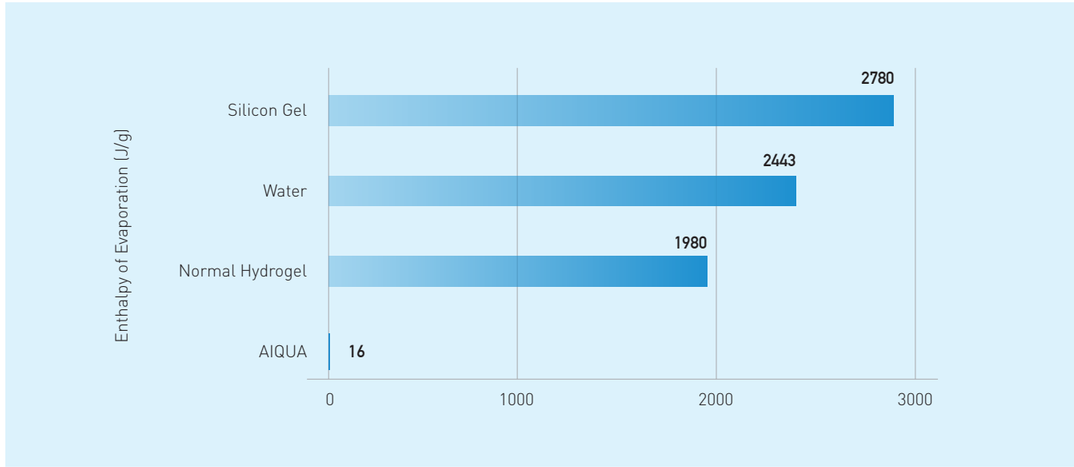


Figure:Evaporation Enthalpy vs Extrusion Energy for Silica Gel, Standard Hydrogel, AIQUA Hydrogel

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[7] W. Guan, C. Lei,Y. Guo, W. Shi, G. Yu, Adv. Mater. 2022, 2207786.

[8] H. Zhang, Z. Zhou, J. Du, X. Pei, L. Zhou, J. Clean. Prod. 2023, 416, 137897.

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[10] Y. Duan,Y. Gao, Z. Ren,Y. Li, Z. Si, H. Du,Y. He, D. Zhou, W. Lv, F. Kang, Appl. Surf. Sci. 2024, 159884.

[11] M. Zhang, Q. Fu, H. Deng, Chem. Eng. J. 2024, 150307.

[Highlights] AIQUA-A1 provides roughly **3 × the maximum uptake**, **15 × the adsorption rate**, and a **far longer service life** than the best published sorbents. Because regeneration is purely mechanical, the energy required is about **1 % of that for conventional desiccants**, laying the foundation for truly high-efficiency dehumidification and atmospheric water harvesting.

Our Solution

Example : Plastic Manufacturing Facility

In a 3,000 m² plastic extrusion workshop with high ambient humidity, maintaining a stable 45 %±2 %RH is critical to prevent raw polymer pellets from absorbing moisture and affecting product quality.

Traditional Solution

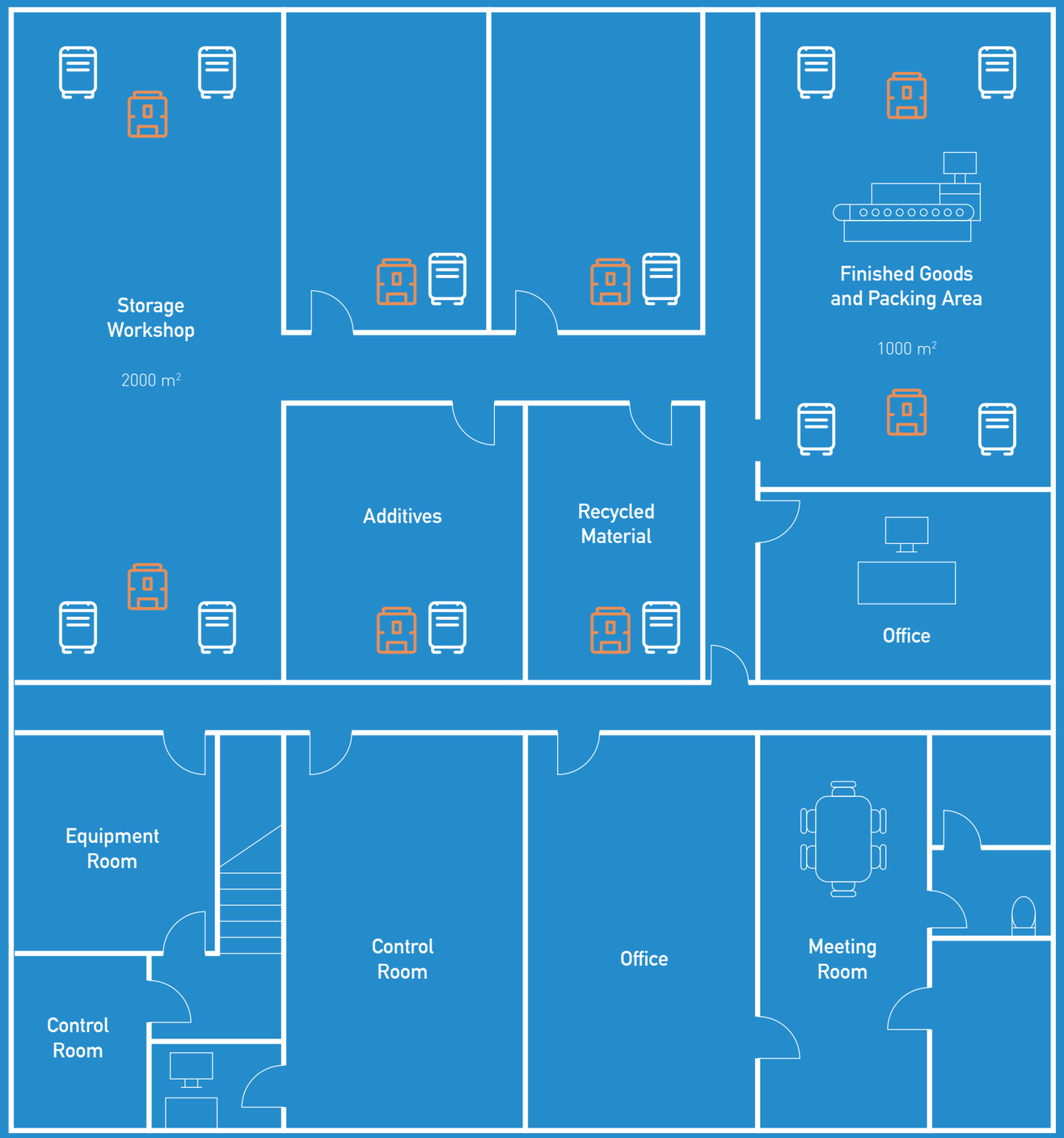
- **Equipment:** 12 × 30 kW cold-condensing dehumidifiers
- **Annual Energy Consumption:** 3,000 MWh
- **Annual Operating Cost:** SGD 480,000

AIQUA-A1 Solution

- **Equipment:** 8 × 800W 120 L/day AIQUA-A1 units
- **Annual Energy Consumption:** 30MWh

Current Machine

Our Solution



Product & After-Sales Q&A

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Can I discuss technical details with your engineers?

Absolutely. We welcome industry peers for in-depth technical exchanges and joint problem-solving sessions.

Do you support applications outside plastics?

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What after-sales services do you offer?

24/7 Hotline Support: Immediate troubleshooting via our unique hotline.

On-Site Maintenance: Annual preventive maintenance visits included in your service plan.

Spare Parts & Consumables: Fast delivery of replacement modules—typical lead time ⩽ 3 days.

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Market reality

Refrigerant and desiccant dehumidifiers each address only half the humidity-control challenge: one fails in cold/dry air, the other burns excessive energy in warm climates.

Our solution

By leveraging a 3-D-printed hydrogel with **record-breaking capacity** (7.8 g · g-¹), **ultrafast kinetics** (0.94 g · min-¹), and heat-free mechanical regeneration, **AIQUA-A1** delivers high-efficiency dehumidification across the **entire humidity spectrum** while virtually eliminating waste heat and ducting requirements.

Outcome

A commercially scalable platform that achieves **8.8–32.6 kg water · kWh-¹**, redefines operating cost, and opens new horizons for indoor climate control and atmospheric water extraction—anywhere precise humidity management must be achieved with maximum efficiency and minimum hassle.

Bottom Line