

# Hawaii (Kona/Hilo) – Infrastructure & Ecological Innovation Opportunities.

**Project:** Search for the R2R Deterministic Nanostructured Membrane opportunities to shape the design of our new deterministic precision engineer R2R machine. [11]

**Locations:** Kailua-Kona, Kahaluu Bay, Kona (NELHA/HOST Park), Hilo (County Wastewater).

**Strategic Goal:** To learn from as many real-life applications as possible on the Kohala Coast of water membrane requirements, as one of the most tested locations in the US given their challenging environment.

**Highest Opportunity identified:** Cindi Punihaole from The Kahala Center would like us to explore R2R low-cost, tertiary "Beyond R1" Direct Nanofiltration (dNF) mechanical filter to intercept CECs (Contaminants of Emerging Concern) threatening coral reef ecosystems.

---

## I. KEY STAKEHOLDER LOG & STRATEGIC INSIGHTS

- **Larry Visocky ([Deep Water Desal](#) / Chief Plant Officer Koyo USA Corp):** Larry provided a great tour of their RO deep water desalination process as well as the critical "Golden Ticket"—an introductory email to Alex at NELHA. He confirmed that while their 1km-deep water is pristine, industrial infrastructure requires **armored robustness**. He validated that high-pressure systems use backwash.
- **Alex Leonard (Chief Projects Officer, [NELHA](#)):** Acted as the primary strategic facilitator. He leveraged his position at HOST Park to secure critical technical consultations for our team with Bill Morton (Pacific Filtration) and John Webley (Trevi Systems), allowing us to align our membrane specs with current industrial requirements.
- **Cindi Punihaole [14] ([The Kohala Center](#)):** Defined the "**Beyond R1 to Direct Nanofiltration (dNF)**" requirements. She noted that current R1 standards fail to stop pharmaceuticals and other toxins that bleach the coral reef.
- **Stephen Holmes (The Kahala Center advisor and board member):** Provided the "Stay in the Science Lane" strategy to keep the research politically neutral. This protects the project from being slowed down by local politics or bureaucratic friction.
- **Christopher Laude, P.E. (County Wastewater Chief):** Provided a critical assessment of "Island Hardiness." He noted that standard Membrane Bioreactors (MBR) often fail in the local environment, leading to a preference for more robust systems like Moving Bed Biofilm Reactors (MBBR).
- **John Webley ([Trevi Systems](#)):** Highlighted the need for thermal stability 70 deg C to survive their FO thermolytic draw solution cycles.

## II. TECHNICAL PIVOT: THE "DETERMINISTIC REEF-SHIELD"

Of the many challenges we saw during the trip, it seems like Cindi's "Reef-Safe" provides us with an opportunity, our research target should shift from 40nm to a **20nm minor axis**.

### 1. Why 20nm? (The Molecular Sieve)

Most pharmaceuticals bind to Natural Organic Matter (NOM). A 20nm minor axis acts as a physical barrier for these bound clusters, nano plastics, and viruses, far exceeding R1 standards. According to Werber et al. (2016) [4], next-generation water purification requires molecular-level design to overcome the limitations of current materials. If we develop the 20nm deterministic oval utilizes the principle of isoporous size-selective transport to intercept micropollutants and viruses while ensuring that life-sustaining minerals—which are an order of magnitude smaller—remain in the waste stream. While typical tertiary treatment relies on Chlorine or UV disinfection, these methods are ineffective against nano plastics and pharmaceutical chains and are often unreliable in the high-turbidity conditions of the Kohala Coast. Our deterministic mechanical sieve provides a robust, chemical-free alternative [5].

### 2. Why "Upward" Micro-Volcanoes? (Passive Scouring)

Such a design should utilize **Vertical SU-8 Volcanoes** sticking *up* into the flow.

**Vortex Generation:** These cones create tiny whirlpools (vortices) that physically "scour" the surface at low pressure, keeping particles from settling into the 20nm slits on the floor [2, 7].

**Shadow Protection:** They act as bumpers against the volcanic grit Larry identified, shielding the 20nm "gates" from physical abrasion.

### 3. The "Stick-and-Sieve" Mechanism

Contaminant	Size	Removal Mechanism
Nano plastics	20nm	<b>Absolute Physical Rejection</b> via 20nm gate.
Bound Pharma	50-100nm	<b>Steric Hindrance:</b> Molecules are blocked by the slit.
Free PFAS/Drugs	1-5nm	<b>Adsorption:</b> High-surface-area SU-8 walls attract molecules.

### III. LOW-COST NANO-MANUFACTURING INNOVATION:

Operational feedback from Christopher Laude (County Wastewater) highlighted that traditional membranes lack the 'island hardiness' required for Hawaii County, often losing out to more rugged moving-bed systems. Our modified design bridges this gap by incorporating Upward Volcanoes that mimic the scouring physics of moving-bed media at the nanoscale [7]. This allows us to maintain the extreme durability required by local operators while achieving the 20nm low pressure 'Direct Nanofiltration' selectivity defined by Werber et al. (2016) as the next-generation standard for protecting aquatic environments from micropollutants [4]. To ensure these features are rugged, we could combine **R2R-holographic or phase mask Lithography** with a **Vacuum-Assisted Infrared Cure Micro Molding**.

1. **Oval axis slits:** Using R2R-holographic Lithography is currently being developed by our team of researchers which helps reduce fouling and improve flow. The design uses different wavelengths to cure the edges to offer higher hardness and minimize potential tears on the nano oval [10]. In addition, the oval shape is antifouling so nanoparticles will not stick well and will be pushed out by inwards and downstream flows.
2. **The Vacuum:** During curing, a vacuum pulls the web into the micro-mold, ensuring the "Volcanoes" are structurally reinforced and the 20nm ovals are perfectly hollowed out, using either vacuum or capillary forces [6, 9].
3. **The Resist** utilizing the wavelength-selective kinetics proved in recent UT Austin studies [10], the 365nm exposure will selectively target the epoxy-rich domains to define the high-modulus rings of the 20nm ovals. Simultaneously, the 405nm exposure will trigger the epoxy-acrylate segments to form a compliant, high-damping matrix. For the Kahola coast and John's application these material properties need further investigation that could potentially be solved using tri-hybrid resin with silicones [12,13]

### IV. CONCLUSIONS

**Low-cost chemical-free Nanofiltration** is ecologically imperative for the reef that we would like to call the **Punihaole Filter**. Its implications would improve RO home use. If we can prove this deterministic membrane that survives the Kohala Coast—with its volcanic grit that acts like high velocity sandpaper, high organics, and pharmaceutical traces—we have a solution for every home, from large American cities to remote global villages. This 20nm filter catches the organic-bound PFAS chains and microplastics currently showing up in municipal tap water everywhere. However, the "20nm Magic" is that the minerals we need for health ( $Mg^{2+}$ ,  $Ca^{2+}$ ,  $K^+$ ) sail right through the filter effortlessly, preserving the nutritional value of the water without the energy cost of Reverse Osmosis [8].

## IV. REFERENCES & CITATIONS

1. **Hutfles, J., et al. (2018).** "Roll-to-roll nanoimprint lithography of ultrafiltration membrane." *J. Appl. Polym. Sci.* — **Validates R2R scalability and structural stability.**
2. **Jin, P., et al. (2025).** "Nanoimprinted polyamide membranes for ultrafast and precise molecular sieving with low fouling." *Nature Communications.* — **Proves "Upward" cone topographies create anti-fouling vortices.**
3. **Lorenz, H., et al. (2015).** "SU-8: A Photoresist for High-Aspect-Ratio Lithography." *MDPI Micromachines.* — **Validates thermal/chemical stability of SU-8 over standard polymers.**
4. **Werber, J. R., et al. (2016).** "Materials for next-generation desalination and water purification membranes" *Department of Chemical and Environmental Engineering, Yale University, New Haven, Connecticut 06520-8286, USA..* — **Justifies the 20nm gate for molecular sieving.**
5. **Enfrin, M., et al. (2018).** "Nano/microplastics in water and wastewater treatment plants." *J. Hazard. Mater.* — **Proves size-exclusion requirements for nanoplastics.**
6. **Kim, E., Xia, et al. (1997).** "Solvent-Assisted Microcontact Molding: A Convenient Method for Fabricating Three-Dimensional Structures on Surfaces of Polymers." *Advanced Materials*, 9(8), 651-654.
7. **Won, Y. J., et al. (2012).** "Hierarchical patterning... for biofouling control." *Scientific Reports.* — **Validates that protruding (Upward) patterns reduce bio-fouling by 45%.**
8. **NX Filtration.** "Direct Nanofiltration (dNF) Benchmarks." — **Commercial baseline for chemical-free nanofiltration.**
9. **Kim, E., Xia, Y., & Whitesides, G. M. (1995).** "Polymer microstructures formed by moulding in capillaries." *Nature*, 376(6541), 581-584.
10. Kim, JW., Allen, M.J., Recker, E.A. et al. Hybrid epoxy-acrylate resins for wavelength-selective multimaterial 3D printing. *Nat. Mater.* 24, 1116-1125 (2025). <https://doi.org/10.1038/s41563-025-02249-z>
11. **NSF #2227702 future manufacturing: RM3L: Cyber-Enabled High-Throughput Manufacturing of 3D Nanostructures.** This grant is currently providing funding for our R2R prototype.
12. **Chruściel, J. J., & Leśniak, E. (2015).** "Modification of epoxy resins with functional silanes, polysiloxanes, silsesquioxanes, silica and silicates." *Progress in Polymer Science*, 41, 67-121. [doi:10.1016/j.progpolymsci.2014.08.001].
13. [14] ACS Omega (2023). "Research on Properties of Silicone-Modified Epoxy Resin and 3D Printing Materials." 8, 23044-23050. Key Data: Confirms the transition from brittle to ductile fracture and a Tg increase via silicone-EA molar ratio optimization.
14. **P. Dobbyn, December 31, 2024,** "[Hawaiian Knowledge And Western Science: A Recipe For Reef Recovery?](#)"