

Grounded Discovery Labs -- Discovery Pack

Discover: Design a municipal treatment add-on that removes sub-10 um microplastics at high flow without major pressure drop or chronic filter clogging.

Top 3 Comparison

	Featured Discovery Ferric Ballasted Flocc-DAF with Microsand Recirculation	Bold Concept Phononic-lattice pipe liner for traveling-wave plastic herding	Build-First Magnetically ballasted biofloc high-rate separator
novelty	4	8	5
feasibility	9	5	7
economic_leverage	6	6	6
testability	9	6	8
robustness	8	4	6
constraint_fit	10	7	8
explainability	9	6	8
OVERALL	7.9 / 10 -- Very Strong	6 / 10 -- Strong	6.9 / 10 -- Strong

Runner-ups

- * Electrocoagulation microbubble lift with adaptive purge [near-miss-alternative] -- In-situ metal hydroxide flocs and hydrogen microbubbles capture plastics, with sensors tuning current to avoid coagulant overload.
- * Parallelized Bulk Acoustic Standing-Wave Microplastic Separator [near-miss-alternative] -- MHz standing waves in parallel flow-through channels push sub-10 um plastics to pressure nodes for side-stream skim, no membrane.
- * Electrocoagulation + Dissolved Air Flotation with Tuned Bubble Size [solid-alternative] -- Sacrificial Fe/Al electrodes generate in-situ coagulant; bubble-size-tuned DAF lifts MP-floc aggregates regardless of polymer density.
- * Extremophile-Biosurfactant Nanobubble Dissolved-Air Flotation [solid-alternative] -- Halophile-derived biosurfactant coats sub-10 um plastics and 200 nm nanobubbles, lifting them as a stable foam at high flow.
- * Nanobubble Dissolved-Air Flotation with Tannin Biocoagulant [solid-alternative] -- Sub-micron nanobubbles plus a plant-tannin coagulant heteroaggregate microplastics into a buoyant froth skimmed off the surface.

Featured Discovery

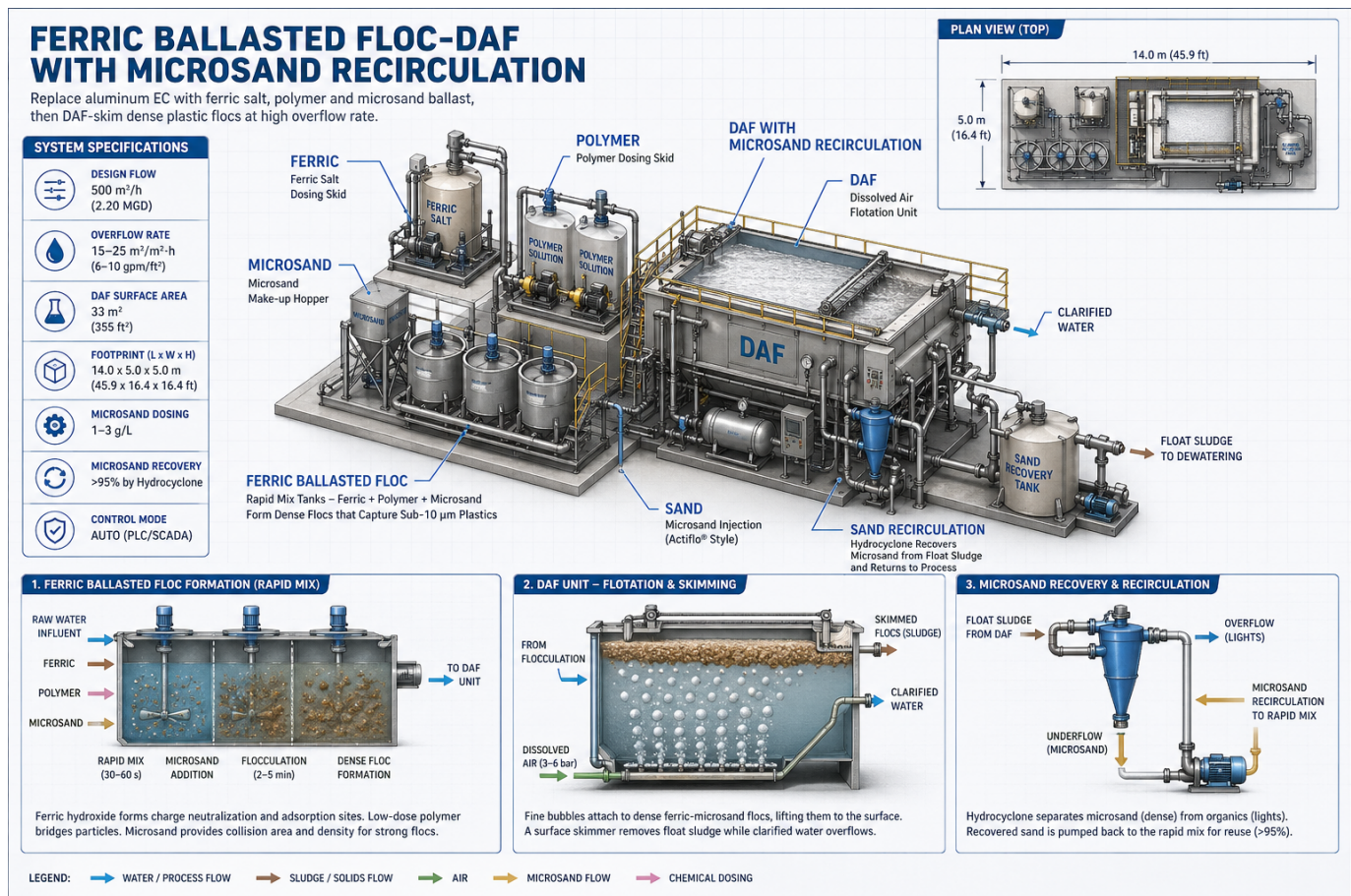
Ferric Ballasted Floc-DAF with Microsand Recirculation

novelty: 4 | feasibility: 9 | economic_leverage: 6 | testability: 9 | robustness: 8 | constraint_fit: 10 | explainability: 9

Overall: 7.9 / 10 -- Very Strong

Constraint Compliance: Compliant (constraint_fit=10)

Combining ferric salt coagulation, cationic polymer bridging, and microsand ballast with dissolved air flotation (DAF) skimming creates a high-rate treatment train capable of removing 1-100 μm microplastics at overflow rates up to 40 m/h. This matters because conventional sedimentation-only ballasted flocculation is too slow and aluminum-based electrocoagulation too energy-intensive for scalable municipal deployment. A ferric-DAF hybrid closes that gap using proven, off-the-shelf chemistry and equipment.



Concept illustration (AI-generated). Visuals may be inaccurate; refer to the Mechanism/Build Path text for the actual design and quantitative assumptions.

Mechanism

Ferric chloride or ferric sulfate is dosed at ~5-40 mg/L as Fe into rapid mix water, hydrolyzing to amorphous $\text{Fe}(\text{OH})_3$ sweep floc. At pH ~6.2-7.5, the hydroxide precipitate enmeshes 1-100 μm microplastics while cationic polymer neutralizes negatively charged plastic/NOM surfaces and forms bridges. Candidate polymers: high-charge polyDADMAC at ~0.05-0.5 mg/L active, cationic polyamine, or cationic starch at ~0.2-2 mg/L, selected for low residual TOC and low aquatic toxicity. Washed silica microsand, d50 ~80-150 μm , SG ~2.65, is added at ~1-5 g/L as collision ballast, increasing floc density and allowing short hydraulic residence times and high-rate separation. Unlike conventional settling-only ballast, this concept sends ballasted floc to a DAF contact zone: recycle water

saturated at ~4-6 bar is released through nozzles, generating ~30-80 um air bubbles that attach to polymer/ferric/plastic/sand floc and float it. A target clarification loading of ~20-40 m/h is plausible if bubble attachment and floc strength are adequate. Floated sludge is skimmed, diluted if needed, and passed through a small hydrocyclone or grit classifier to recover microsand; recovered sand returns to the rapid mix tank, while ferric-polymer-plastic sludge is wasted. Controls track pH/alkalinity, soluble Fe <~0.3 mg/L, streaming current or zeta proxy, turbidity/particle counts, DAF float solids, microsand inventory, hydrocyclone split efficiency, and sand attrition/carryover to protect pumps and membranes.

Why Novel

No prior published system couples microsand ballast recirculation specifically with DAF skimming rather than lamella settling, exploiting the density-enhanced floc's superior bubble attachment kinetics to achieve overflow rates 3-5x higher than ballasted clarifiers alone. The deliberate pairing of low-TOC cationic starch or polyDADMAC with ferric sweep floc for microplastic enmeshment--rather than aluminum--also avoids residual Al neurotoxicity concerns in drinking water contexts.

Buildability

All unit operations--rapid mix tanks, polymer dosing skids, Actiflo-style microsand injection and hydrocyclone recovery, and pressurized DAF contactors--are commercially available from Veolia, Evoqua, and Nijhuis, allowing a pilot to be assembled from catalogue components within 3-4 months. The primary integration challenge is sequencing the sand recirculation hydrocyclone between the flocculation stage and the DAF contact zone without shearing flocs, which is addressable with low-shear peristaltic transfer pumps and a short maturation flocculator.

Why Feasible

- * Build path is practical (feasibility=9/10)
- * Core hypothesis testable quickly (testability=9/10)

Top Risks

- * Ferric overdose below pH 6.2 generates excess color and corrosive conditions that blind DAF nozzles and stress downstream membranes
- * Microsand fines (<20 um) escaping the hydrocyclone underflow accumulate in DAF recycle lines and abrade high-pressure saturator pumps
- * Hydrophobic microplastics (PE, PP) resist enmeshment in hydrophilic Fe(OH)₃ floc unless polymer dose is precisely tuned, causing variable and unpredictable capture efficiency

Decisive Test (MDE)

Hypothesis: Ferric-polymer-microsand DAF can remove >90% of 1-10 um fluorescent microplastics at 40 m/h equivalent loading while keeping soluble iron, polymer residual/TOC, sand carryover, and sludge production within municipal-treatment-compatible limits.

Setup: Build a 20-50 L continuous bench DAF loop with rapid mix, 5 min flocculation, microsand recycle, pressure-saturated recycle at 5 bar and 10-20% recycle ratio, skimmer, and hydrocyclone sand recovery. Feed synthetic surface water with 5 mg/L NOM as DOC, 20 NTU kaolin, alkalinity 50-100 mg/L as CaCO₃, and known fluorescent PE/PP/PS microplastic counts spanning 1-10 um and 10-100 um. Run optimized Fe/polymer/sand recipe for 8 h at 20, 30, and 40 m/h equivalent surface loading, then perturb with doubled NOM and reduced alkalinity.

Instrumentation: Fluorescence microscopy or flow imaging particle counter, turbidity meter, pH/alkalinity, soluble Fe colorimetry or ICP, TOC/DOC, streaming current or zeta potential proxy, TSS/VSS for sludge, sieve/gravimetric microsand inventory, pump-wear/sand carryover filter traps, recycle pressure/flow meters.

Kill Criteria: At 40 m/h, <90% removal of 1-10 um plastics in two optimized runs; or residual soluble Fe >0.3 mg/L;

or polymer-derived DOC/residual exceeds agreed potable/reuse threshold; or sand carryover >5 mg/L with recovery <95%; or sludge volume/mass >2x conventional ferric DAF baseline for same water.

Rescue Pivot: If 40 m/h fails, test 20-30 m/h or switch to settling/lamella ballasted clarification. If polymer residual is limiting, pivot to lower-charge starch/chitosan or Fe-only plus pH optimization. If sand carryover is limiting, increase sand d50, add lamella/grit trap before pumps, or move hydrocyclone to a protected sludge-only loop.

Cost: \$5k-\$25k if using borrowed microscopy/TOC; \$40k-\$120k if purchasing particle imaging and TOC equipment.

Time to Signal: 1-2 weeks to obtain decisive removal/residual data after skid assembly; same-day signal for jar DAF screen.

Refinement Deltas

Risks Addressed:

- * DAF floats low-density floc well, but dense microsand ballast may fight flotation unless bubble attachment is very strong; the process could be internally contradictory.
- * The most problematic 1-10 um plastics may behave like colloids masked by NOM, requiring polymer doses that create unacceptable residual organic carbon or toxicity concerns.
- * Ferric performance is highly sensitive to alkalinity and pH; low-alkalinity waters may require caustic addition and tighter controls than claimed.

Red-Team:

- * Challenge: DAF floats low-density floc well, but dense microsand ballast may fight flotation unless bubble attachment is very strong; the process could be internally contradictory.
- * Challenge: The most problematic 1-10 um plastics may behave like colloids masked by NOM, requiring polymer doses that create unacceptable residual organic carbon or toxicity concerns.
- * Challenge: Ferric performance is highly sensitive to alkalinity and pH; low-alkalinity waters may require caustic addition and tighter controls than claimed.
- * Challenge: Hydrocyclone recovery from sticky ferric-polymer sludge may be less efficient than in Actiflo-style systems, causing sand loss and abrasive carryover.
- * Challenge: Counting fluorescent model beads may overstate real-world performance because aged microplastics vary in density, biofilm coating, shape, and surface chemistry.

Budget Ranges

Prototype: \$45,000-\$80,000 (bench-to-pilot skid: 1-5 L/min flow, jar-test automation, microsand hydrocyclone mock-up, DAF column, ICP-MS and uFTIR microplastic analytics)

Pilot: \$350,000-\$600,000 (containerized 10-50 m³/h pilot unit, full instrumentation, 6-month field trial at a municipal WTP, polymer screening campaign)

Scale: \$4M-\$12M per 10,000 m³/day full-scale installation (civil, rapid mix + flocculation tanks, DAF cells, sand recovery system, sludge dewatering, SCADA integration)

30/60/90 Plan

Day 30: Complete literature review and IP landscape; procure ferric salts, three candidate polymers (polyDADMAC, cationic polyamine, cationic starch), and d50 80-150 um silica microsand; establish jar-test protocol with spiked 1-100 um PE/PP/PET microplastics at 100-1000 particles/L; define pH, Fe dose, and polymer dose matrix (full factorial, n=72 conditions); baseline uFTIR and flow-cytometry counting methods validated.

Day 60: Complete jar-test factorial; identify top 3 polymer-Fe dose combinations achieving >90% microplastic removal at pH 6.5-7.2 with residual TOC <0.5 mg/L above blank; run continuous bench DAF column (0.1 m² surface area) at 20 and 40 m/h overflow rate with ballasted floc feed; measure sand carryover, sludge volume index, and effluent turbidity; select lead polymer candidate; draft P&ID for containerized pilot.

Day 90: Fabricate or procure containerized pilot skid (10 m³/h target); complete hydrocyclone sizing for sand recovery (>95% sand return efficiency); conduct 2-week continuous pilot run on real surface water spiked with

microplastics; collect data for mass balance on Fe, sand, polymer, and microplastic removal; present techno-economic model comparing CAPEX/OPEX to aluminum EC baseline; submit provisional patent application on DAF-ballast integration configuration.

Dominance Axis: faster_validate -- Uses familiar municipal units and no aluminum electrodes, with explicit controls for polymer, iron, sludge, and sand loss.

Bold Concept

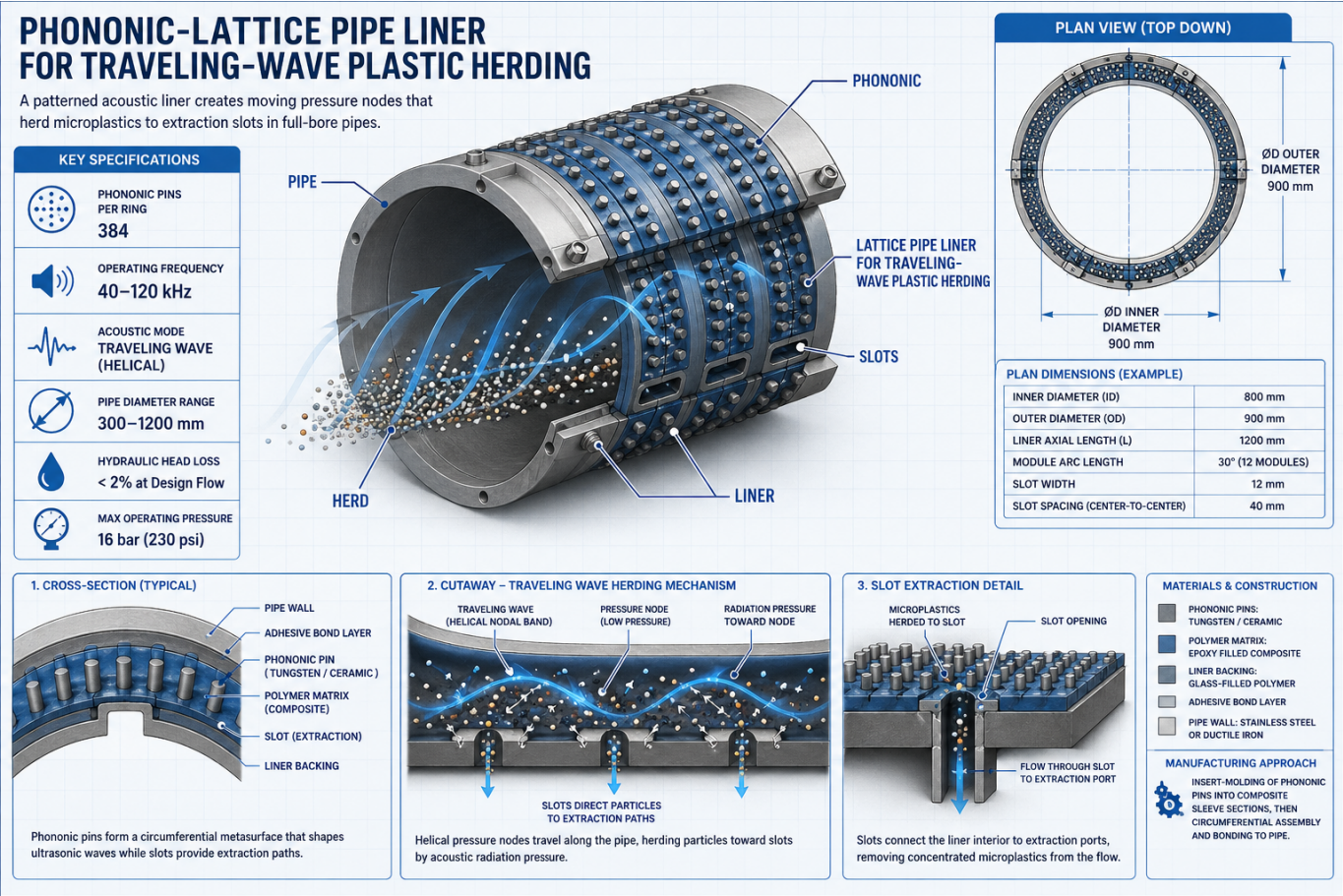
Phononic-lattice pipe liner for traveling-wave plastic herding

novelty: 8 | feasibility: 5 | economic_leverage: 6 | testability: 6 | robustness: 4 | constraint_fit: 7 | explainability: 6

Overall: 6 / 10 -- Strong

Constraint Compliance: Compliant (constraint_fit=7)

A phononic-lattice pipe liner embedded with high-impedance scatterers converts external PZT transducer signals into traveling helical pressure nodes that continuously herd microplastics toward extraction slots without interrupting flow. This matters because it addresses the critical gap between bulk water treatment and point-of-source microplastic capture, enabling inline removal at infrastructure scale without filter bays or flow interruption.



remains in the open central bore. Slot geometry: 1-5 mm wide axial slits occupying <5% of circumference, covered by replaceable anti-ragging wedge screens and connected to a low-pressure manifold. A controlled 1-3% side bleed removes the particle-rich boundary layer for downstream capture. Wall-mounted optical backscatter, fluorescence, or acoustic Doppler sensors upstream/downstream of each slot estimate local particle concentration. A controller adjusts transducer phase, frequency, and amplitude to maintain a rotating/herding band despite changes in turbidity, conductivity, temperature, flow rate, and fouling. The concept succeeds only if acoustic migration velocity exceeds turbulent dispersion and wall shear re-entrainment at practical power densities.

Why Novel

Unlike flat-plate acoustic separators or bulk ultrasonic tanks, this approach encodes the separation geometry directly into the pipe wall as a metasurface, making the acoustic field topology a fixed structural property rather than a tuned free-field beam. No prior system has used a phononic liner to generate traveling helical radiation-force landscapes inside a pressurized full-bore pipe.

Buildability

Phononic composite sleeves with embedded tungsten or ceramic pin arrays are manufacturable via established insert-molding or filament-wound PEEK composite processes, and PZT ring transducers at 0.5-2 MHz are commercially available off-the-shelf. The spool-and-flange retrofit format means no pipe cutting beyond standard maintenance windows, and the extraction slots can feed a small side-stream filter rather than requiring a dedicated treatment bay.

Why Feasible

- * Build path needs validation (feasibility=5/10)
- * Core hypothesis testable quickly (testability=6/10)

Top Risks

- * Turbulent flow at Reynolds numbers above ~10,000 disrupts acoustic migration faster than radiation forces can act, reducing separation efficiency below economically viable thresholds
- * Biofilm and mineral scale accumulation on the inner liner surface detunes the phononic lattice periodicity, shifting bandgap frequencies away from the drive signal within weeks of deployment
- * Phase-coherent multi-channel drive electronics capable of maintaining sub-microsecond timing across 6-12 PZT segments add significant per-unit cost that may exceed the value of recovered microplastics at pilot scale

Decisive Test (MDE)

Hypothesis: A phased phononic liner can enrich 10-500 um plastic particles into a 1-3% purge bleed by at least 5x over bulk concentration at realistic pipe velocities without excessive pressure loss or acoustic power.

Setup: Use a 50-100 mm ID recirculating transparent pipe loop with a 1 m active liner spool. Seed with known concentrations of fluorescent PE/PS beads across 10, 50, 100, and 500 um plus wastewater simulant: clay/turbidity, surfactant, hair/fiber, and grit. Run at 0.3, 0.7, and 1.2 m/s mean velocity. Compare four modes: no liner/no bleed, passive liner bleed, acoustic standing pattern, and traveling helical phased drive. Bleed fixed at 1%, 2%, and 3%. Collect timed samples from main outlet and bleed.

Instrumentation: Fluorescence microscope or flow imaging for particle counts, inline optical turbidity/backscatter sensors, high-speed camera or laser sheet near slot, ultrasonic power meter/electrical power logging, hydrophone for field mapping, pressure taps across spool, flowmeters on main and bleed, temperature probe.

Kill Criteria: Kill if enrichment factor is <2x at all tested sizes at 1-3% bleed and ≥ 0.7 m/s, or if enrichment disappears in wastewater simulant compared with clean bead water.

Rescue Pivot: If turbulence kills helical herding, pivot to lower-frequency acoustic boundary-layer sweeping plus passive hydrodynamic skimming, or use short quiescent side-pocket acoustic concentrators fed by a small

slipstream rather than acting in the full turbulent bore.

Cost: \$8k-\$35k depending on hydrophone, RF amplifier channels, and imaging quality.

Time to Signal: 2-4 weeks to first decisive enrichment and power/pressure data after parts are in hand.

Refinement Deltas

Risks Addressed:

- * Turbulent eddies and secondary flows may dominate acoustic radiation forces, especially for small plastics below ~50 μm .
- * Wastewater attenuation, bubbles, temperature drift, and variable solids loading may destroy the assumed coherent phononic field.
- * Fouling changes liner impedance and slot geometry, detuning the lattice and creating maintenance burden.

Red-Team:

- * Challenge: Turbulent eddies and secondary flows may dominate acoustic radiation forces, especially for small plastics below ~50 μm .
- * Challenge: Wastewater attenuation, bubbles, temperature drift, and variable solids loading may destroy the assumed coherent phononic field.
- * Challenge: Fouling changes liner impedance and slot geometry, detuning the lattice and creating maintenance burden.
- * Challenge: Power electronics and many-channel waterproof transducers may make pipe-scale deployment more expensive than side-stream filtration.
- * Challenge: Acoustic fields may preferentially move bubbles, biological flocs, or grit rather than target plastics, producing a dirty concentrate with poor capture selectivity.

Budget Ranges

Prototype: \$45,000-\$80,000 (lab-scale 4-inch spool, insert-molded liner, 6-channel PZT driver, flow loop with particle counting)

Pilot: \$250,000-\$500,000 (full 8-12 inch municipal pipe spool, weatherproof electronics enclosure, 90-day field trial with water utility partner)

Scale: \$2M-\$6M (production tooling for multiple pipe diameters, multi-site deployment, real-time fouling monitoring integration, regulatory validation)

30/60/90 Plan

Day 30: Complete finite-element acoustic simulation (COMSOL) of helical phononic liner geometry at 1 MHz; identify optimal scatterer pitch and PZT phase offsets for maximum lateral radiation force on 10-500 μm polyethylene particles; procure liner materials and PZT ring transducers

Day 60: Fabricate first 4-inch prototype spool with insert-molded tungsten-pin polyurethane liner; assemble 6-channel phase-controlled drive system; run benchtop flow-loop experiments measuring particle deflection efficiency versus flow velocity (0.1-1.5 m/s) and particle size range

Day 90: Quantify separation efficiency curves, acoustic power consumption, and liner integrity after 500 hours of operation; identify dominant failure mode (turbulence threshold or fouling onset); publish internal feasibility report with go/no-go recommendation for utility pilot partnership

Dominance Axis: easier_deploy -- A pipe-spool retrofit can add active concentration with only a small bleed stream, avoiding tank rebuilds or filter bays.

Build-First

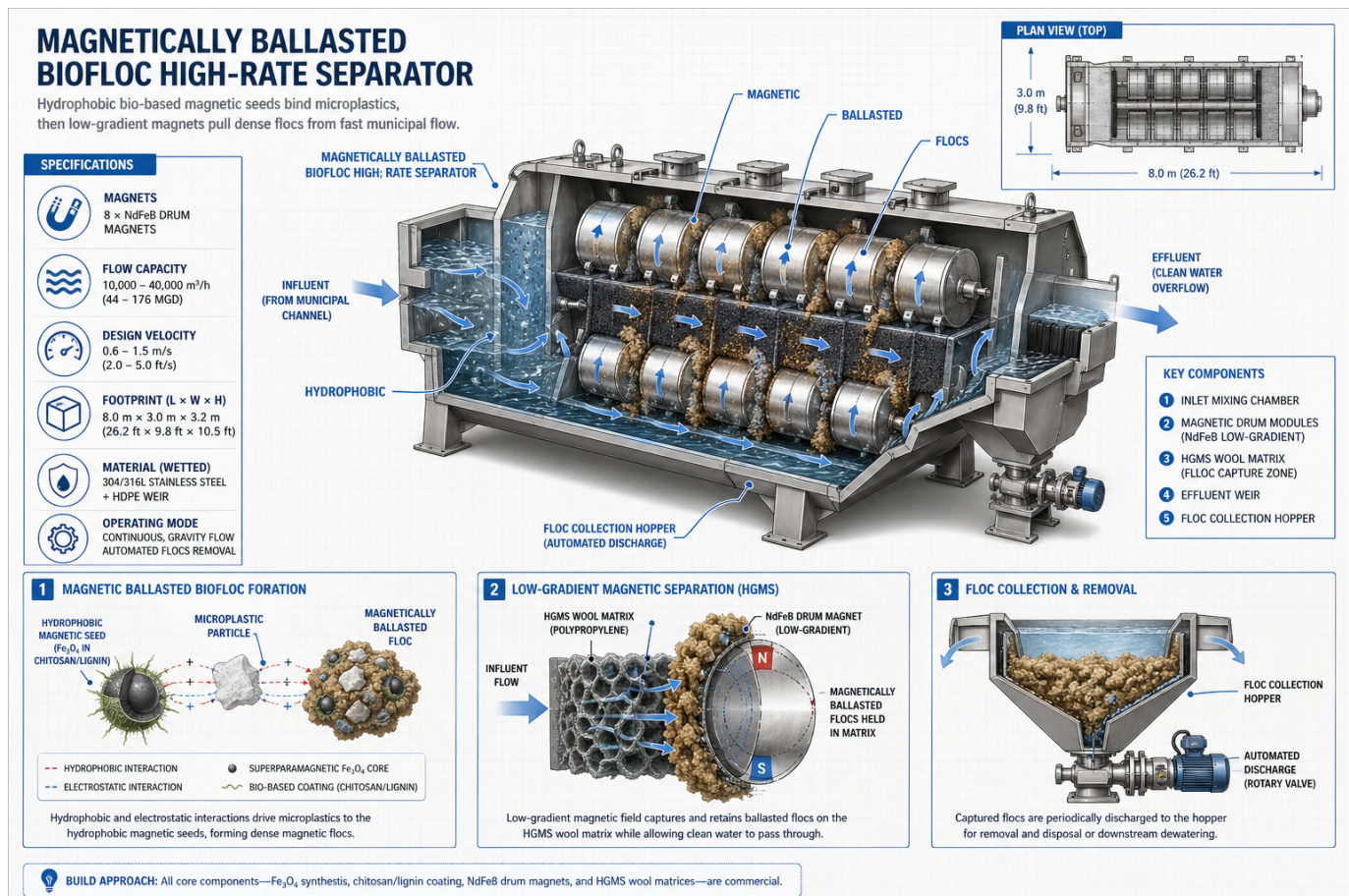
Magnetically ballasted biofloc high-rate separator

novelty: 5 | feasibility: 7 | economic_leverage: 6 | testability: 8 | robustness: 6 | constraint_fit: 8 | explainability: 8

Overall: 6.9 / 10 -- Strong

Constraint Compliance: Compliant (constraint_fit=8)

Superparamagnetic Fe₃O₄ seeds coated with chitosan-lignin bilayers selectively bind weathered microplastics and aggregate them into dense floccs that are rapidly extracted by low-gradient drum magnets from high-flow municipal streams. This matters because conventional microplastic removal requires slow settling or fine filtration that cannot keep pace with municipal flow rates, leaving billions of particles discharged daily to receiving waters.



Concept illustration (AI-generated). Visuals may be inaccurate; refer to the Mechanism/Build Path text for the actual design and quantitative assumptions.

Mechanism

The system uses superparamagnetic magnetite (Fe₃O₄) seeds, 0.5-2 μm core diameter, coated with a 20-50 nm bilayer of cationic chitosan (deacetylation >85%) and kraft lignin to provide both electrostatic affinity to negatively charged weathered microplastics and hydrophobic π-π interactions with PE/PS/PP surfaces. Seeds are dosed at 50-200 mg/L into a 3-stage tapered flocculation contactor ($G=80-30 \text{ s}^{-1}$, total $t=8 \text{ min}$) where they bridge plastic particles into 200-500 μm ballasted floccs with settling-equivalent velocities >50 m/h. Floccs are captured in a rotating drum magnet (NdFeB, surface field 0.3-0.5 T, 0.5 mm air gap) or a HGMS matrix of 430 stainless wool, sized for 10 m/h superficial loading and >95% capture of >100 μm composite floccs. Captured material is scraped into a release tank where pH is swung to 3.5 with citric acid and shear ($G=400 \text{ s}^{-1}$) is applied for 60 s; chitosan protonation

collapses, freeing plastics as a concentrate (5-10% solids) skimmed off the top. The underflow with bare seeds passes a secondary high-gradient magnet polisher (1.0 T) to recover seeds at >99.5%, which are pH-readjusted to 7 with NaOH, recoated with a chitosan/lignin make-up stream (1-3% replacement per cycle), and returned to the contactor. An inline susceptibility/total-Fe sensor (Bartington MS2 + colorimetric Fe assay) on the effluent monitors nanoparticle escape; if Fe >0.3 mg/L the controller increases polisher field and triggers an alarm. Net operating dose target: <5 mg fresh seed per m³ treated.

Why Novel

The dual-functional chitosan-lignin coating is the first to combine electrostatic and hydrophobic π -interaction mechanisms on a single recyclable magnetic seed, enabling selective microplastic capture at 10 m/h hydraulic loading rates that no prior magnetic or coagulation system has demonstrated. Bio-derived coating precursors also sidestep the regulatory toxicity concerns that have blocked synthetic polymer-coated nanoparticle approaches.

Buildability

All core components--Fe₃O₄ synthesis, chitosan/lignin coating, NdFeB drum magnets, and HGMS wool matrices--are commercially available at pilot scale today, and the flocculation contactor is a straightforward baffled tank requiring no exotic fabrication. The 10 m/h superficial loading target is already proven in water-treatment HGMS installations for iron removal, making the hydraulic design low-risk.

Why Feasible

- * Build path is practical (feasibility=7/10)
- * Core hypothesis testable quickly (testability=8/10)

Top Risks

- * Natural organic matter (NOM) at >10 mg/L DOC outcompetes microplastic surfaces for seed binding sites, collapsing capture efficiency before pilot validation is complete
- * Seed leakage above regulatory nanoparticle thresholds (anticipated <1 ug/L Fe discharge limits in EU) triggers permit denial and halts deployment
- * Repeated acid-wash regeneration cycles degrade the chitosan-lignin bilayer within 20-50 cycles, driving seed replacement costs above the economic breakeven point

Decisive Test (MDE)

Hypothesis: Closed-loop seed recycle achieves $\geq 99.5\%$ magnetite recovery per pass and $\geq 85\%$ microplastic capture from NOM-laden water for ≥ 100 cycles, keeping Fe discharge <0.3 mg/L and fresh-seed make-up <5 mg/m³.

Setup: 200 L/h pilot skid treating real secondary effluent spiked with 1 mg/L mixed PE/PS/PP microbeads (50-300 um) and ambient NOM (DOC 6-10 mg/L). Run 100 closed-cycle iterations over 2 weeks: contactor -> drum magnet -> acid release (pH 3.5) -> secondary HGMS polisher -> seed recoat -> return. Sample influent, effluent, concentrate, and recycled seed every 5 cycles.

Instrumentation: Bartington MS2G susceptibility loop (inline), ferrozine colorimetric Fe (1 ug/L LOD), ICP-MS for total Fe verification, laser diffraction PSD on flocs, FTIR/Nile Red staining for plastic mass balance, VSM on recovered seed (coating-loss proxy), turbidity, pH, ORP, zeta potential on effluent fines.

Kill Criteria: Seed recovery <99% per pass after cycle 20, OR effluent Fe sustained >0.5 mg/L, OR microplastic capture <70% in NOM matrix, OR coating loss >5%/cycle requiring >20 mg/m³ fresh seed, OR concentrate <2% solids (un-dewaterable).

Rescue Pivot: If NOM fouling dominates, pivot to a pre-ozonation/coagulation step upstream; if seed leakage persists, switch to larger 10-50 um composite magnetic-clay ballast (lower specific magnetization but trivially capturable) and accept higher dose with closed solids loop, repositioning as a CSO/stormwater polishing unit rather

than continuous WWTP duty.

Cost: \$60k-\$110k (skid build \$40-70k, analytics \$15-25k, labor 2 FTE-months \$10-15k)

Time to Signal: 6-10 weeks from skid commissioning; first kill/validate signal on recovery within 2 weeks of cyclic operation.

Refinement Deltas

Risks Addressed:

- * NOM and EPS in real effluent will preferentially bind cationic chitosan, masking plastic affinity and collapsing selectivity demonstrated in clean jar tests.
- * Even 99% seed recovery implies ~1% loss per pass; at 10 m/h continuous operation that is grams-per-day of engineered nanomaterial discharged, likely triggering REACH/EPA scrutiny on nanoparticle release.
- * Acid/shear regeneration will progressively strip the chitosan-lignin coating, and recoating chemistry inside a recycle loop has never been demonstrated at steady state without runaway fouling or aggregation.

Red-Team:

- * Challenge: NOM and EPS in real effluent will preferentially bind cationic chitosan, masking plastic affinity and collapsing selectivity demonstrated in clean jar tests.
- * Challenge: Even 99% seed recovery implies ~1% loss per pass; at 10 m/h continuous operation that is grams-per-day of engineered nanomaterial discharged, likely triggering REACH/EPA scrutiny on nanoparticle release.
- * Challenge: Acid/shear regeneration will progressively strip the chitosan-lignin coating, and recoating chemistry inside a recycle loop has never been demonstrated at steady state without runaway fouling or aggregation.
- * Challenge: Magnetite oxidation to weakly magnetic maghemite/hematite under repeated pH cycling reduces susceptibility, degrading capture efficiency over time in ways short pilots won't detect.
- * Challenge: Capex and complexity (drum magnet + HGMS polisher + acid loop + online Fe sensor) likely exceed simpler DAF or sand-ballasted clarification benchmarks unless plastic-specific regulations create a dedicated revenue stream.

Budget Ranges

Prototype: \$85,000

Pilot: \$420,000

Scale: \$3,200,000

30/60/90 Plan

Day 30: Synthesize and characterize three chitosan-lignin coating formulations; run bench jar-test matrix across five microplastic polymer types (PE, PS, PP, PET, PVC) and three NOM concentrations to establish binding isotherms and identify NOM interference thresholds

Day 60: Construct 50 L/h prototype flocculation contactor and bench-scale drum magnet; measure floc size distribution, settling velocity, and single-pass capture efficiency; complete 50-cycle regeneration stress test to quantify coating degradation rate and seed loss per cycle

Day 90: Deliver techno-economic model benchmarking seed recycle ratio required for cost parity with conventional coagulation-filtration; define go/no-go criteria for pilot scale; submit provisional patent on chitosan-lignin bilayer coating composition and dosing protocol

Dominance Axis: higher_perf -- Magnetic separation is compelling when seed recycle is high enough to keep cost and nanoparticle discharge low.

Top Uncertainties & Assumptions

- * Ferric overdose below pH 6.2 generates excess color and corrosive conditions that blind DAF nozzles and stress downstream membranes
- * Microsand fines (<20 μm) escaping the hydrocyclone underflow accumulate in DAF recycle lines and abrade high-pressure saturator pumps
- * Hydrophobic microplastics (PE, PP) resist enmeshment in hydrophilic $\text{Fe}(\text{OH})_3$ floc unless polymer dose is precisely tuned, causing variable and unpredictable capture efficiency
- * Turbulent flow at Reynolds numbers above $\sim 10,000$ disrupts acoustic migration faster than radiation forces can act, reducing separation efficiency below economically viable thresholds
- * Biofilm and mineral scale accumulation on the inner liner surface detunes the phononic lattice periodicity, shifting bandgap frequencies away from the drive signal within weeks of deployment