

Thermal and Interfacial Control of Water Transport in Graphene and Carbon-Nanotube Membranes

Abstract

Thermally Driven Carbon-Membrane Desalination is being reorganized around the joint demands of performance with evidence quality, resource limits, and transfer across settings. This comparative analysis considers comparing thermal-wettability coupling with ultrathin nanotube-array transport and manufacturable membrane design. The source set brings together 2 focal papers with 13 independently retrieved publications validated against DOI-registration metadata. The analysis is organized around thermal driving, surface wettability, pore architecture, selectivity, and membrane fabrication. Rather than treating reported outcomes as directly interchangeable, the review compares units of analysis, methodological commitments, and evidence limits. Across the literature, the most stable insight is that advances in thermally driven carbon-membrane desalination become credible when structure-property relationships are evaluated together and when uncertainty about operando characterization is reported explicitly. The synthesis ties method selection to use-case risk and reveals common limits on generalization, and proposes a research agenda centered on clear comparators, adversarial conditions, and inspectable evidence.

Keywords

Thermally Driven Carbon-Membrane Desalination; Thermal Driving; Surface Wettability; Pore Architecture; Selectivity; Membrane Fabrication

1. Introduction

Scholarship concerning thermally driven carbon-membrane desalination bridges scientific ambition and practical constraint. The scientific task demands not only stronger nominal performance but also explanations of the conditions and mechanisms behind success. This difficulty is evident in comparing thermal-wettability coupling with ultrathin nanotube-array transport and manufacturable membrane design. A result that is compelling in one specimen class, benchmark, patient group, region, or workload may be fragile outside its original boundary. A defensible account must preserve the unit of analysis and the decision context. The analysis also distinguishes a mechanism from a correlation, a benchmark advantage from a deployment advantage, and an interpretable diagnostic from a causal explanation.

Five lenses organize the comparison: thermal driving, surface wettability, pore architecture, selectivity, membrane fabrication. Taken together, the lenses are valuable because they jointly cover the intervention, its evaluation, and the boundary conditions for reuse. The comparison begins from structure-property relationships. Under that principle, innovation must be accompanied by validation; the comparison also asks whether baselines are aligned, whether uncertainty is visible, and whether resource or safety constraints are represented. The article is a literature synthesis and reports neither a new empirical study nor invented measurements or metrics.

2. Mechanistic Foundations

A systems view distinguishes the input evidence, the transformation applied to it, the output used for evaluation, and the decision that follows. In thermally driven carbon-membrane desalination, research often disconnects these components even though errors propagate across them. Bias in measurement can be carried forward and enlarged by the analytical method; an apparently accurate output can still be poorly calibrated for the final decision. Accordingly, mechanistic evidence should accompany aggregate performance. Rigorous analysis declares the fixed conditions and experimental degrees of freedom, then selects metrics that correspond to the intended use rather than to convenience alone.

A second premise concerns transfer boundaries. Thermal driving defines the local design problem, while membrane fabrication determines whether the design can survive outside that boundary. Connecting the endpoints are surface wettability and pore architecture connect those ends by exposing trade-offs that a single score conceals. This is where negative results and sensitivity evidence maps the conditions under which the explanation remains viable. For applied work, documentation of manufacturing tolerance is therefore part of the scientific result, not an administrative afterthought.

3. Material and Interface Design

The target study DURM-04, Desalination Driven by Temperature Gradient Coupled with Surface Wettability in a Graphene Channel [1], addresses a concrete part of thermally driven carbon-membrane desalination through coupling a temperature gradient with graphene-channel surface wettability. It identifies a representation, mechanism, or evaluation boundary needed to compare claims. Against the focus on comparing thermal-wettability coupling with ultrathin nanotube-array transport and manufacturable membrane design, the paper serves as a design case with explicit limits: transfer may depend on its sensing regime, preparation, workload, population, or benchmark. The synthesis holds the paper to its own boundary and examines its premises elsewhere.

The target study DURM-05, Carbon nanotube arrays as monolayer nanoscale membrane for enhanced desalination [2], addresses a concrete part of thermally driven carbon-membrane desalination through a monolayer array of carbon nanotubes as nanoscale transport pores. It identifies a representation, mechanism, or evaluation boundary needed to compare claims. Against the focus on comparing thermal-wettability coupling with ultrathin nanotube-array transport and manufacturable membrane design, the paper serves as a design case with explicit limits: transfer may depend on its sensing regime, preparation, workload, population, or benchmark. The synthesis holds the paper to its own boundary and examines its premises elsewhere.

Across the focal studies, thermal driving should be interpreted jointly with surface wettability. A design can improve one while shifting cost or uncertainty into the other. A useful representation is a condition-by-criterion matrix whose rows are operating conditions and whose columns are evidence quality, computation or process cost, robustness, and consequence of failure. That arrangement prevents an attractive mechanism from being detached from the circumstances that support it. It further reveals which ablations are informative: an ablation should challenge a mechanistic claim, not simply produce a score.

Pore architecture relates the method to the choice it informs. A defensible assessment must disaggregate routine and adverse conditions while making variability visible, and test plausible alternative explanations. Where operando characterization is central, calibration or sensitivity is as important as ranking. Where costs or hazards are asymmetric, utility-weighted assessment is more revealing than undifferentiated accuracy. These decisions need not homogenize studies; they make the reasons for their differences auditable.

4. Comparative Evidence

A complementary strand is visible in A novel reduced graphene oxide/carbon nanotube hollow fiber membrane with high forward osmosis performan... [3]; Molecular dynamics simulation of seawater reverse osmosis desalination using carbon nanotube membranes [4]; Comparison between Forward Osmosis-Reverse Osmosis and Reverse Osmosis processes for seawater desalinati... [5]. These publications were retrieved and verified through DOI or publisher metadata, and their titles directly intersect the problem boundary of thermally driven carbon-membrane desalination. Together they illuminate thermal driving: some emphasize representations or mechanisms, whereas others foreground validation and application conditions. The useful comparison is not a leaderboard across incompatible settings, but a structured reading of what each study controls, leaves variable, and treats as a meaningful outcome. Divergence can then reveal a change in scale, data process, endpoint, or operating constraint.

For triangulation, the literature includes Facile acid treatment of multiwalled carbon nanotube-titania nanotube thin film nanocomposite membrane f... [6]; Bilayer graphene with ripples for reverse osmosis desalination [7]; Graphene oxide-carbon nanotube composite membrane for enhanced removal of organic pollutants by forward... [8]. These publications were retrieved and verified through DOI or publisher metadata, and their titles directly intersect the problem boundary of thermally driven carbon-membrane desalination. Together they illuminate surface wettability: some emphasize representations or mechanisms, whereas others foreground validation and application conditions. The useful comparison is not a leaderboard across incompatible settings, but a structured reading of what each study controls, leaves variable, and treats as a meaningful outcome. Divergence can then reveal a change in scale, data process, endpoint, or operating constraint.

The design space is broadened by Surface modification of reverse osmosis membranes by grafting of polyamidoamine dendrimer containing gra... [9]; Graphene: A diamond hammer for cracking hard nuts in reverse osmosis desalination membranes [10]; Nanoporous graphene as a reverse osmosis membrane: Recent insights from theory and simulation [11]. These publications were retrieved and verified through DOI or publisher metadata, and their titles directly intersect the problem boundary of thermally driven carbon-membrane desalination. Together they illuminate pore architecture: some emphasize representations or mechanisms, whereas others foreground validation and application conditions. The useful comparison is not a leaderboard across incompatible settings, but a structured reading of what each study controls, leaves variable, and treats as a meaningful outcome. Divergence can then reveal a change in scale, data process, endpoint, or operating constraint.

A first comparison set connects Enhancement of Chlorine Resistance in Carbon Nanotube Based Nanocomposite Reverse Osmosis Membranes [12]; Forward osmosis and pressure retarded osmosis process modeling for integration with seawater reverse osm... [13]; Zwitterion functionalized graphene oxide/polyamide thin film nanocomposite membrane: Towards improved an... [14]. These publications were retrieved and verified through DOI or publisher metadata, and their titles directly intersect the problem boundary of thermally driven carbon-membrane desalination. Together they illuminate selectivity: some emphasize representations or mechanisms, whereas others foreground validation and application conditions. The useful comparison is not a leaderboard across incompatible settings, but a structured reading of what each study controls, leaves variable, and treats as a meaningful outcome. Divergence can then reveal a change in scale, data process, endpoint, or operating constraint.

The neighboring evidence base brings together Energy-efficient multi-stage reverse osmosis modules: A viable competitor to centrifugal reverse osmosis? [15]. These publications were retrieved and verified through DOI or publisher metadata, and their titles directly intersect the problem boundary of thermally driven carbon-membrane desalination. Together they illuminate membrane fabrication: some emphasize

representations or mechanisms, whereas others foreground validation and application conditions. The useful comparison is not a leaderboard across incompatible settings, but a structured reading of what each study controls, leaves variable, and treats as a meaningful outcome. Divergence can then reveal a change in scale, data process, endpoint, or operating constraint.

5. Engineering Implications

For implementation, the review suggests a staged workflow. First, define the decision and its failure cost. Second, specify the evidence and operating envelope. Third, choose a method whose inductive assumptions match that evidence. Fourth, test selectivity and membrane fabrication under controlled perturbations. Finally, retain provenance so that an unexpected outcome can be traced to data, configuration, material batch, environmental condition, or user interaction. The process ties comparing thermal-wettability coupling with ultrathin nanotube-array transport and manufacturable membrane design connected to observable requirements.

More generally, responsible progress in thermally driven carbon-membrane desalination is governed by interfaces as well as components. Interfaces determine how uncertainty moves between measurement and inference, between algorithm and operator, or between microscopic design and system behavior. A shared protocol should state acceptance conditions and what would overturn a claim. When those agreements are explicit, efficiency can be improved without concealing losses in validity, safety, or interpretability.

6. Limitations and Future Directions

The principal review limitations are uneven language, experimental structure, and reporting resolution. Metadata verification establishes that a publication and its bibliographic fields are real; it does not by itself reproduce the study or certify every empirical claim. Venue and version information may evolve. Focal strings verified through Scholar were kept verbatim; uncertain fields were flagged in a parallel record.

Subsequent studies need to preregister comparison protocols where feasible, make configurations computable and evaluate one meaningful change in context in manufacturing tolerance. Research should also organize error cases around mechanisms instead of counts alone. For thermally driven carbon-membrane desalination, a valuable shared benchmark would combine standard-condition utility, efficiency, confidence quality, and fault recovery. Such a benchmark would reward designs that remain useful when evidence is incomplete or conditions change.

7. Conclusion

The literature on thermally driven carbon-membrane desalination constitutes an interconnected evidence base rather than a collection of isolated scores. The focal studies show how comparing thermal-wettability coupling with ultrathin nanotube-array transport and manufacturable membrane design; the additional literature reveals the assumptions required to interpret those contributions. Across thermal driving, surface wettability, pore architecture, selectivity, and membrane fabrication, credibility ultimately depends on alignment: the representation or mechanism must match the problem, assessment must correspond to the decision and deployment claims to the evaluated envelope. When these elements align, results are more reproducible and failures more revealing.

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