

Laboratory Validation Summary

Biological & Fouling Trends

Produced-Water Systems – Interfacial Conditioning Context

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1. Purpose & Scope

This summary evaluates biological activity and fouling behavior observed across controlled laboratory datasets, with supporting field-conditioned evidence, to distinguish effects attributable to Ultra-Fine Bubbles (UFB) alone, sub-nanometer interfacial chemistry alone, and the coupled UFB + chemistry system.

2. Laboratory Observations – Biological Response

Across treated laboratory streams, ATP levels are consistently and materially suppressed relative to untreated comparators. Suppression is persistent, with no rapid rebound, indicating loss of attachment niches rather than transient planktonic shock.

3. Attribution by Treatment Mode

UFBs enhance interfacial access but are insufficient alone. Chemistry restructures ultra-thin water films but is delivery-limited. The coupled system produces the most durable biological suppression and stability.

4. Supporting Evidence – N. Cowden Dataset

Independent N. Cowden produced-water data corroborate persistence and rebound resistance observed in laboratory analyses. This dataset confirms real-world durability but is not used to establish primary mechanism.

5. Conclusions

The data validate applied interfacial conditioning: system behavior modification that suppresses fouling persistence and reduces downstream treatment burden without reliance on aggressive bulk chemistries.

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