



ORGANIC VS INORGANIC COAGULANTS FOR WASTEWATER APPLICATIONS

Performance, Cost and Operational Impacts Compared with
Ferric Sulphate

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Introduction

Coagulants play a central role in water and wastewater treatment helping to remove fine suspended particles, colloids and other materials that do not readily settle on their own. Through charge neutralisation, floc formation or sweep coagulation, coagulants bring small particles together into larger aggregates that can be separated more effectively by settlement, flotation or filtration. In municipal wastewater treatment, this supports primary clarification, reduces suspended solids loading, improves downstream biological performance and helps treatment plants meet discharge requirements.

The selection of coagulant chemistry has a direct influence on treatment performance, pH control, sludge production, phosphorus removal, storage requirements and whole-life operating cost.

Inorganic coagulants, such as ferric sulphate, are widely used within the industry as they are cost-effective, stable and well understood across a broad range of treatment conditions. Organic coagulants, including tannin-based products, starch-based biopolymers and synthetic polymer systems, are increasingly being considered where near-neutral pH behaviour, simplified dosing or specific sustainability objectives are important.

Organic coagulants based on plant extracts as well as alternative coagulant chemistries, have received increasing attention for wastewater treatment, because they can simplify dosing and pH management and are generally less sensitive to pH variations than traditional inorganic coagulants.

When considering sustainability, the carbon footprint of the products themselves is not the only factor to consider. Some of these naturally derived products, such as those based on plant extracts can have a higher carbon footprint per tonne of manufactured product than inorganic coagulants. A more meaningful comparison considers the carbon footprint of the overall process including chemical dose, sludge production, sludge handling and disposal.

The following sections present a comparative technical evaluation of selected coagulant classes using suspended solids reduction, dose efficiency, and operational implications as the basis for discussion. Organic coagulants can originate from several sources, such as tannin extract (Figure 1), synthetic organic polymer and plant starch. The base material is then chemically modified to form the final coagulant.

Suspended solids (SS) removal is a core objective of municipal and industrial effluent and wastewater treatment, governing primary clarification efficiency, downstream biological performance, sludge production, regulatory compliance, and whole-life operating cost. Ferric sulphate has historically been adopted as the reference coagulant for this duty due to its low cost, availability, stability and predictable behaviour across a wide range of operating conditions.



Figure 1- Organic Coagulants may be derived from Tannin extract

Coagulant Evaluation and Performance

Chemifloc performed bench-scale testing using raw wastewater from a coastal municipal site in the West of Ireland. Comparing both inorganic and organic coagulants, all products reduced the suspended solids at low dose rates. Table 1 compares dose, performance, and operating costs for each coagulant. Please note that these results provide indicative comparison for selected coagulants. As with all coagulant applications, final product selection and dose optimisation should be confirmed through site-specific jar testing or plant trials.

Table 1 - Performance versus Cost

Coagulant class	Site daily throughput m3	Dose (mg/L)	SS reduction	Relative cost per day
Ferric Sulphate (inorganic)	1,000	50	89%	€
Plant-derived Tannin-based Coagulant	1,000	50	75%	€€€€
Synthetic Organic Polymer	1,000	50	75%	€€€€
Starch-based Biopolymer	1,000	50	75%	€€€

Relative cost is based on stated dose and does not include potential cost impacts associated with sludge handling, storage, pH correction.

Interpretation of Comparative Performance

Organic coagulant systems achieve comparable suspended solids reductions at lower mass dose through charge-driven mechanisms. Plant-derived tannin systems and starch-based biopolymer coagulation mechanisms combine charge interaction and polymer bridging, whereas the synthetic organic systems based on polymer salts rely on high charge density and rapid destabilisation of colloidal material. They all exhibit near-neutral pH behaviour, so post-coagulation pH adjustment is not necessary. They all carry a higher relative operating cost, and the storage IBCs need to be emptied regularly because of the 6-month shelf-life.

Ferric sulphate remains the baseline against which alternative chemistries are assessed. When applied at higher doses, ferric coagulation produces dense sweep flocs and consistently high suspended solids removal at the lowest relative operating cost. This performance is partially offset by acidic behaviour and the potential requirement for pH management depending on site conditions.

Table 2 - Operational Characteristics

Coagulant class	Key advantages	Key limitations	Phosphate interaction
Ferric Sulphate (inorganic)	Stable, well understood; lowest cost; indefinite shelf life; strong sludge aggregation	Acidic; may require alkalinity correction; higher sludge metal content	Strong co-precipitation of orthophosphate
Plant-derived Tannin-based Coagulant	Renewable feedstock; neutral pH; reduced chemical interfaces; good floc structure	Higher cost; finite shelf life; storage temperature sensitivity	Limited direct phosphate removal
Synthetic Organic Polymer	High charge efficiency; low dose requirement; simple single-product operation	Synthetic petrochemical origin; higher carbon intensity; overdosing sensitivity	Minimal direct phosphate removal
Starch-based Biopolymer	Biobased; very low dose; mild process chemistry	Performance variability; weaker floc strength in some matrices	Negligible phosphate removal

Cost, Operational and Sustainability Considerations

From a whole-life operational perspective, ferric sulphate continues to offer the lowest relative cost envelope coupled with long-term storage stability and a well-understood carbon footprint of 118-132 kg CO_{2e} per tonne of product (Source 1).

Organic and bio-based alternatives, can provide operational benefits linked to pH stability and simplified dosing. However they can also entail higher costs and, in some cases, increased sensitivity to storage and handling. The carbon footprint for these products can also be higher than that of ferric sulphate when taking the full process into account. Sustainability comparisons should therefore be made at process level rather than product level alone. A coagulant with a higher carbon footprint per tonne of manufactured product may still reduce overall treatment impact if it lowers dose, reduces pH correction, changes sludge production, improves sludge handling or reduces downstream process demand. Equally, a lower-impact product does not automatically result in a lower-carbon treatment process. The overall outcome should be assessed on a site-by-site basis.

Phosphate removal capability is an additional differentiator. Iron-based systems provide inherent chemical phosphorus removal via precipitation, whereas organic and polymer-based coagulants primarily remove particulate phosphorus bound within suspended solids.

Conclusion

Organic and alternative coagulant systems represent credible technical options for water treatment applications where pH stability, simplified operation, or sustainability considerations justify higher operating costs. Their near-neutral behaviour can offer operational advantages, particularly on sites where pH correction is a key consideration.

Ferric sulphate remains the preferred solution for primary suspended solids and phosphate removal, where low chemical cost and operational stability are the primary drivers.



Organic coagulants offer clear operational benefits in certain wastewater applications, particularly where pH stability and simplified dosing are important. However, our testing shows that ferric sulphate remains a highly effective and economical benchmark, so the best choice should always be based on site-specific performance, whole-life cost and treatment objectives

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The optimum coagulant choice should therefore be based on whole-process performance rather than product chemistry alone. Dose efficiency, SS removal, phosphorus limits, pH impact, sludge production, storage life, handling requirements and whole-life cost should all be considered before selecting an organic, inorganic or blended treatment approach.

We understand that every wastewater network is unique. Our scientists and engineers are available to discuss how coagulants can be applied to optimise performance in your facility. Get in touch to arrange a technical consultation info@csq-corporate.com

Sources

- Source 1: https://www.incopa.org/wp-content/uploads/2024/10/INCOPA-ExecutiveSummary_A4-Booklet-30102023.pdf