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PHYSICO-CHEMICAL REGULARITIES OF COMPOSITE COAGULANTS SYNTHESISED FROM LOCAL MINERAL RAW MATERIALS IN THE TREATMENT OF INDUSTRIAL WASTEWATER

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Abstract

This thesis investigates the physico-chemical regularities of a composite mineral–organic coagulant obtained from local bentonite clay and sapropel (mass ratio 60:40) in the treatment of industrial wastewater. The mechanism of action is multistage: adsorptive capture is provided by the high specific surface area and cation-exchange capacity of bentonite, while the binding of organic particles is ensured by the humic substances of sapropel. The coagulation activity was compared with potassium–aluminium sulfate and iron(III) chloride. At an optimal dose of 100 mg/L and pH 6.8–7.4, turbidity removal reached 95.6 % and COD removal 71.4 %. Zeta-potential measurements showed a shift of the system towards the isoelectric zone through charge neutralisation. The results justify the development of an inexpensive, environmentally safe coagulant based on local raw materials.

Keywords: Composite coagulant, bentonite, sapropel, coagulation, zeta potential, adsorption, turbidity, chemical oxygen demand, industrial wastewater, local raw materials.

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1. Introduction

The intensification of industrial production is accompanied by the discharge of effluents that carry high loads of fine colloidal suspensions, dissolved organic matter and coloured compounds. Conventional treatment relies on hydrolysing metal salts — most commonly aluminium and iron coagulants — whose efficiency is limited by narrow working pH windows, residual metal in the treated water and large volumes of poorly dewaterable sludge [1, 2]. These constraints motivate the search for coagulants that combine mineral and organic functionality while being derived from inexpensive, locally available raw materials [4, 6, 7].

The present work examines the physico-chemical behaviour of a composite mineral–organic coagulant prepared from local bentonite clay and sapropel in a mass ratio of 60:40. Bentonite, a montmorillonite-rich aluminosilicate, contributes a large specific surface area and cation-exchange capacity, whereas sapropel supplies humic and fulvic macromolecules that act as natural organic binders [3, 5]. The coagulation activity of the composite is compared with that of potassium–aluminium sulfate and iron(III) chloride under identical conditions [6].

2. Materials and methods

The composite coagulant was obtained by mechano-chemical homogenisation of activated bentonite and dried sapropel (60:40 by mass) followed by thermal conditioning. Reference coagulants were potassium–aluminium sulfate, $KAl(SO_4)_2 \cdot 12H_2O$, and iron(III) chloride, $FeCl_3$, of analytical grade. Model industrial wastewater exhibited an initial turbidity of 320 NTU, chemical oxygen demand (COD) of 480 mg L^{-1}, suspended solids of 410 mg L^{-1} and pH 7.2.

Jar-test experiments were performed with a programmable six-paddle apparatus: rapid mixing at 200 min^{-1} for 60 s, slow mixing at 40 min^{-1} for 15 min and

quiescent settling for 30 min. Turbidity was measured nephelometrically, COD by the dichromate method, and colour photometrically. Electrophoretic mobility was converted to zeta potential through the Smoluchowski relation. Sludge volume was recorded as the settled volume after 30 min (SV_{30}).

3. Results and discussion

The dose–response curves (Fig. 1) reveal a common sigmoidal pattern for all three reagents, but the composite coagulant reaches its plateau at a lower dose and a higher terminal efficiency. At 100 mg L^{-1} the composite removed 95.6 % of turbidity, exceeding the aluminium (91.5 %) and iron (93.2 %) systems, and — importantly — it maintained this performance over a broader dose interval, indicating a lower sensitivity to overdosing.

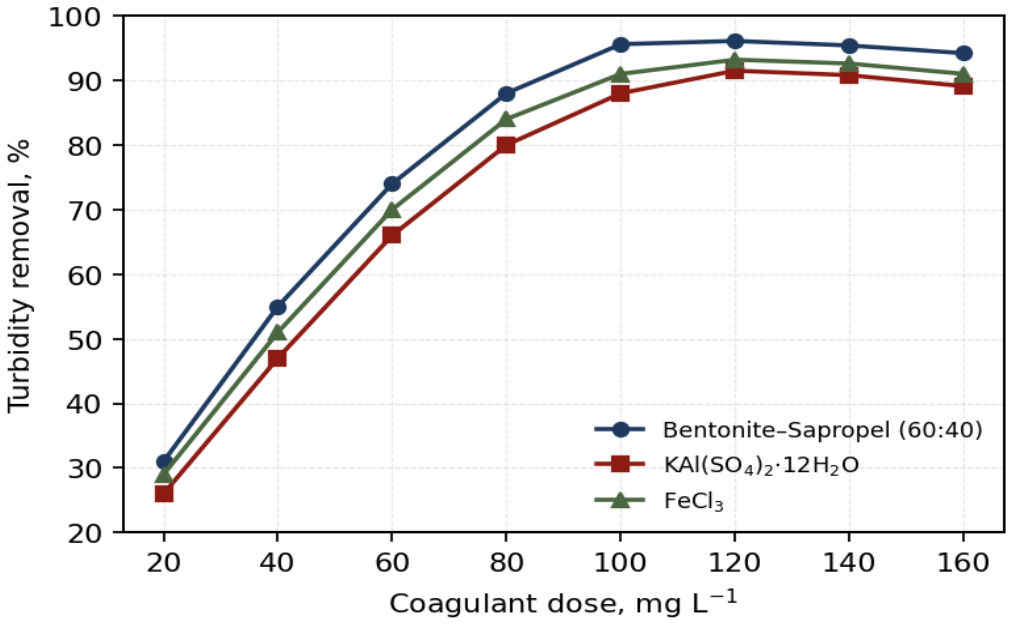

Fig. 1. Turbidity removal as a function of coagulant dose for the composite (bentonite–sapropel), aluminium and iron reagents.

The pH dependence of zeta potential (Fig. 2) clarifies the destabilisation mechanism. The raw colloid is strongly negatively charged across the whole pH range, whereas dosing with the composite shifts the system towards the isoelectric zone near pH 6.8–7.4. In this interval charge neutralisation is complemented by adsorptive bridging on the bentonite surface and by enmeshment within the developing organo-mineral matrix, which explains the wide effective pH window.

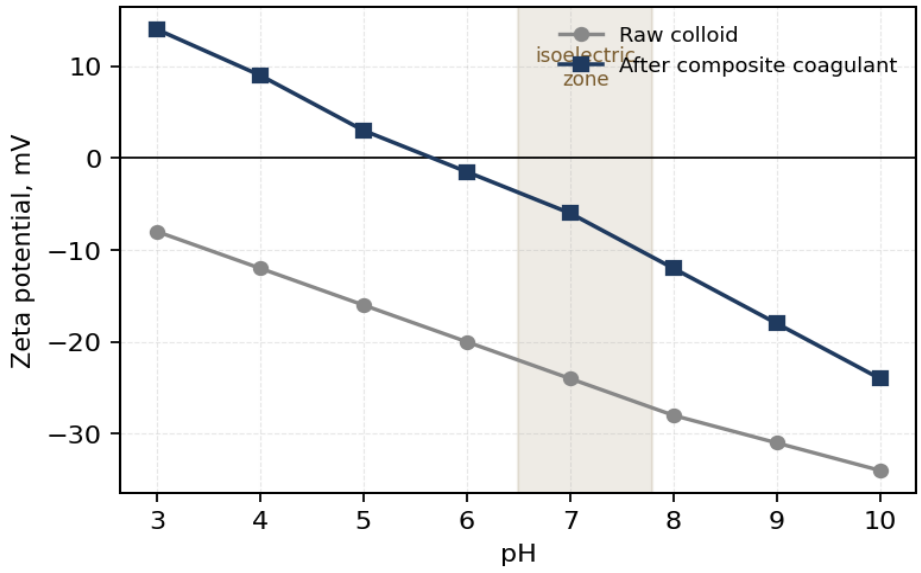

Fig. 2. Zeta potential versus pH for the raw colloid and after treatment with the composite coagulant.

The integrated performance indices are summarised in Table 1. Beyond its higher turbidity and COD removal, the composite generated a markedly smaller and denser sludge (SV_{30} = 78 mL L^{-1} against 132 and 118 mL L^{-1}) and settled about twice as fast, because the mineral fraction acts as a ballast that increases floc

density. The absence of a dissolved metal residue is a further environmental advantage over the salt coagulants.

Table 1. Comparative treatment performance of the composite and reference coagulants (initial turbidity 320 NTU, COD 480 mg L^{-1}).

Parameter	Bentonite–Sapropel (60:40)	$KAl(SO_4)_2 \cdot 12H_2O$	$FeCl_3$
Optimal dose, mg L^{-1}	100	120	120
Optimal pH	6.8–7.4	6.0–6.8	5.5–6.5
Turbidity removal, %	95.6	91.5	93.2
COD removal, %	71.4	58.2	63.7
Colour removal, %	88.3	74.1	81.5
Sludge volume SV_{30}, mL L^{-1}	78	132	118
Settling velocity, m h^{-1}	3.4	1.9	2.3
Residual metal (Al/Fe), mg L^{-1}	not detected	0.42	0.31

Taken together, the data establish a coherent physico-chemical picture: the composite couples the rapid charge neutralisation typical of hydrolysing salts with the adsorptive and bridging capacity of an aluminosilicate–humic matrix, delivering high efficiency, a wide operational pH range and improved sludge properties simultaneously.

4. Conclusions

A composite bentonite–sapropel coagulant (60:40) synthesised from local raw materials outperformed conventional aluminium and iron salts, achieving 95.6 % turbidity and 71.4 % COD removal at a lower optimal dose and over a broader pH window. Charge neutralisation combined with adsorptive bridging and

ballasted enmeshment underlies its activity, while the denser sludge and absence of dissolved-metal residue confirm its environmental and economic advantages.

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