IOCXe 2026 Conference
The 1st International Online Conference on Xenobiotics
22–23 June 2026 | Online
MDPI

Flocculation as a Control Strategy for Plastic Removal in Wastewater Treatment Plants

Cristina Cremonesi[1], Giada Caorsi[1], Stefano Magni[1], Camilla Della Torre[1], Andrea Binelli[1]
1 Department of Biosciences, University of Milan, Via Celoria 26, 20133 Milan, Italy
e-mail contact: cristina.cremonesi@unimi.it

INTRODUCTION

Wastewater treatment plants (WWTPs) have been identified as a major source of plastics entering aquatic environments. Although several studies have demonstrated the effectiveness of certain flocculants in removing plastics under laboratory conditions, their performance in WWTP settings remains largely unexplored. Moreover, many commercially available polymer-based flocculants have not yet been tested. To address this gap, the aim of this project is to evaluate the effectiveness of different commercial polymer-based flocculants, both synthetic and bio-based, in reducing plastics in wastewater. In parallel, key chemical parameters (chemical oxygen demand (COD), total suspended solids (TSS), total nitrogen (N), ammonium (NH_4^+), nitrate nitrogen (NO_3^-–N), ionic and non-ionic surfactants, phosphorus (P), and aluminum (Al). were monitored to assess compliance with regulatory standards, including those defined by the European Directive (EU) 2024/3019.

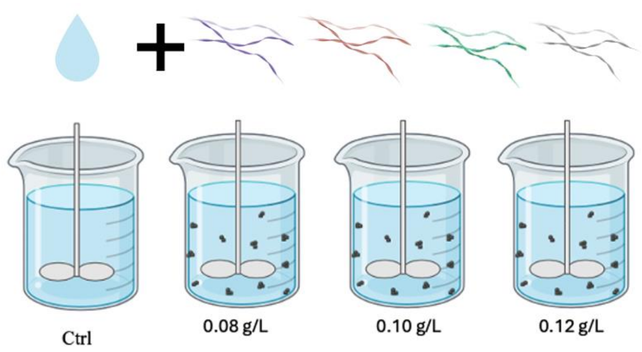
METHOD

Experimental plan

Flocculation tests were performed using a standard jar test procedure with 1 L beakers and a professional flocculation system. Each beaker contained 40 fibers for each polymer type (PA, PEST, PP, PET), equally distributed among micro-, large micro-, and macroplastics. The protocol included rapid mixing (300 rpm, 1 min), followed by slow mixing (100 rpm, 15 min) and a settling phase (30 min). The supernatant was then filtered, and remaining fibers were quantified and characterized. Tests were conducted separately for each commercial flocculant at three concentrations near those typically used in WWTPs for suspended solids removal. Chemicals parameter were analyzed used spectrophotometer and commercially available cuvette test kits (Hach Lange GmbH, Germany).

Synthetic flocculants	Bio-based flocculants
POLYACRYLAMIDE MIXTURE	TANNIN BASED
POLYACRYLAMIDE	STARCH

Wastewater collected directly from a wastewater treatment plant



RESULTS & DISCUSSION

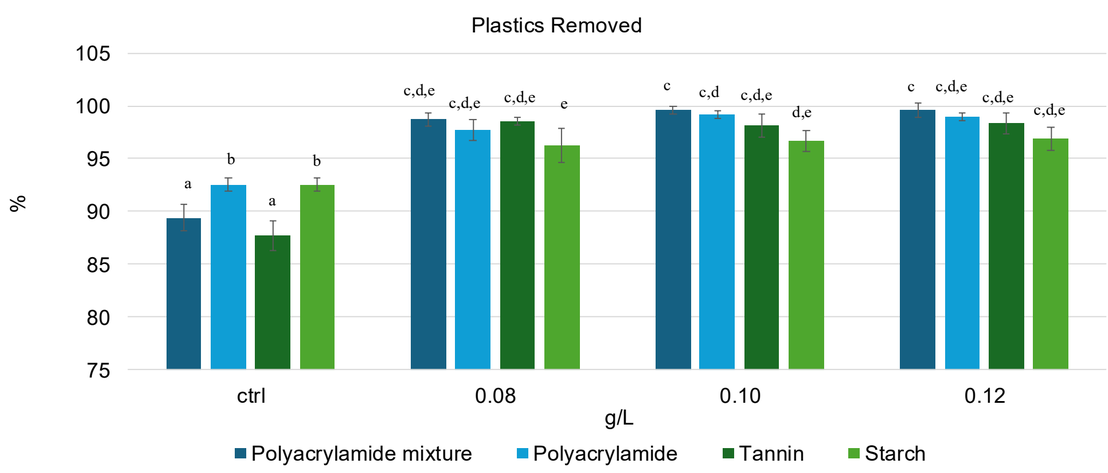
Chemical results

	Concentration	COD (O_2) mg/L
CTRL		262
POLYACRYLAMIDE MIXTURE	0.08g/L	169
	0.10g/L	165
	0.12g/L	162
POLYACRYLAMIDE	0.08g/L	205
	0.10g/L	197
	0.12g/L	180
TANNIN	0.08g/L	273
	0.10g/L	257
	0.12g/L	250
STARCH	0.08g/L	255
	0.10g/L	257
	0.12g/L	276

Red numbers indicate values above regulatory limits of 160 mg/L (D.Lgs. 152/2006, Annex 5, Table 3, developed in accordance with European Directives 91/271/EEC and 2000/60/EC).

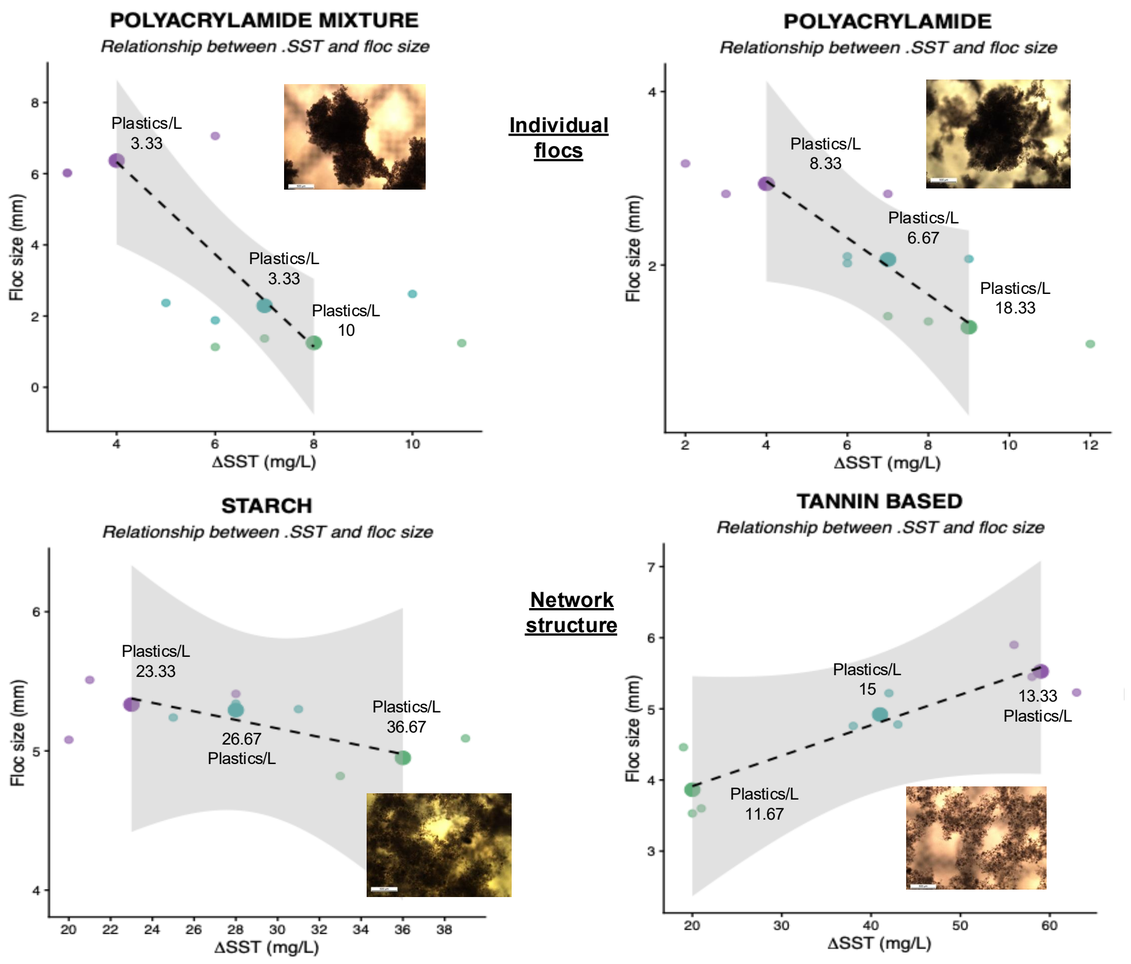
The chemical analyses demonstrated that the use of coagulants is necessary to meet the regulatory discharge limit.
In particular, the addition of Poly-Aluminum Chloride (PAC) at 0.08g/L allowed Chemical oxygen Demand (COD) value to decrease below the regulatory limit (160 mg/L) for all the flocculants tested at all the concentrations investigated.

Plastic removal efficiency



Significant differences in residual plastic levels were observed depending on both: the type of flocculant and its concentration.
Higher concentrations led to a marked reduction in plastic residues for Polyacrylamide mixture, Polyacrylamide ed Strach, whereas tannin showed greater removal efficiency at lower concentrations.

Flocs characterization



Synthetic polyacrylamides promoted the formation of distinct and compact flocs, whose size increased with dosage, enhancing system stability and improving the removal of suspended solids and plastic particles.
In contrast, natural-based flocculants formed network-like aggregates. Although size increased with concentration, tannin-based flocculants showed reduced system stability and lower plastic particle removal efficiency

CONCLUSION

Based on the obtained results, the addition of PAC is necessary to ensure compliance with regulatory discharge limits and support the applicability of these products in WWTPs. Flocculants combined with PAC showed very high removal efficiencies up to 96.25% for bio-based polymers and 99.58% for polyacrylamide-based flocculants. The results also showed that different flocculants operate through different mechanisms. From an applied perspective, these findings suggest that the use of these products for plastic removal in wastewater treatment plants is realistically achievable, provided that the most suitable product is selected according to wastewater composition through preliminary tests.