International Journal of Materials and Chemistry 2025, 15(1): 5-8
DOI: 10.5923/j.ijmc.20251501.02

Processing of Wastewater Treatment in Gas Industry Enterprises Using Flocculant Composition

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Abstract One of the most important methods for treating wastewater from soluble organic impurities is chemical water treatment, in which synthetic water–soluble organic polymers are used as flocculants. It is known that flocculants chemically interact with various impurities in wastewater, forming insoluble compounds. Effective polymers of this type include substances containing anionic and cationic surfactants, humic and fulvic acids, various dyes, high–molecular–weight acids, as well as mineral acids and their salts. These substances are present in the wastewater of gas processing enterprises. This article presents the results of a study on the potential application of new compositions of synthetic water–soluble and highly absorbent polymeric flocculants in wastewater treatment processes at gas processing enterprises.

Keywords Wastewater treatment, Flocculants, Synthetic water–soluble polymers, Chemical oxygen demand (COD), Coagulants, Sorption and desorption processes

1. Introduction

Experimental and analytical methods have been used to study their effect on the removal of various pollutants from wastewater. The research is aimed at ensuring an innovative approach to solving environmental problems.

Since synthetic water–soluble polymers have an organic nature, their macromolecules facilitate the accelerated settling of coagulated impurities in wastewater, thereby increasing the efficiency of removing various substances and fine–dispersed mechanical impurities. The removal of these impurities using traditional mechanical methods such as sedimentation, flotation, and filtration is not feasible [1, p. 47; 2, p. 50–53].

This study examines the effect of new compositions of synthetic water–soluble and highly absorbent polymeric flocculants on the wastewater treatment of gas processing enterprises.

The composition of flocculant mixtures, including sodium carboxymethyl cellulose (Na–CMC), polyacrylamide (PAA), and hydrolyzed polyacrylonitrile (HPAN) in a mass ratio of 1.0:0.5:0.5, demonstrated high efficiency. During the experiments, various flocculant concentrations in the range of 0.15–0.30 mg/L were studied. The resulting suspension was allowed to settle for 10–15 minutes until complete sedimentation of the formed flocs, ensuring water clarity.

A comprehensive study was conducted on the relationship between the reduction in flocculant dosage and treatment efficiency. The experimental results help determine the optimal flocculant dose to ensure both economic and environmental safety [3, p. 3026].

An experimental analysis of the relationship between the compositional characteristics of various pollutants and the effect of flocculants on their removal was also evaluated, which has practical significance for improving wastewater treatment technologies [4, p. 757; 5, p. 892].

Received: Feb. 27, 2025; Accepted: Mar. 13, 2025; Published: Mar. 15, 2025
Published online at http://journal.sapub.org/ijmc

2. Materials and Methods

Wastewater samples were characterized based on key parameters: turbidity, suspended solids content, and chemical oxygen demand (COD). The flocculant composition was prepared by sequentially adding synthetic water–soluble polymers (sodium carboxymethyl cellulose (Na–CMC), polyacrylamide (PAA), and hydrolyzed polyacrylonitrile (HPAN)) in a specific proportion. The composition optimization was carried out experimentally. The resulting suspension was allowed to settle for 10–15 minutes until complete sedimentation of the formed flocs.

Wastewater samples were treated with the prepared flocculant composition under varying pH levels and temperatures. The mixture was stirred to ensure the interaction of reagents with contaminants. After treatment, sedimentation was performed to separate the sludge.

The treatment efficiency was evaluated based on the reduction in turbidity, suspended solids concentration, and COD levels. Analyses were conducted using spectrophotometry and titrimetric methods.

A flocculant in the form of water–soluble polymers Na–CMC, PAA and HPAN in a weight ratio of 1.0:0.5:0.5, prepared in advance, demonstrates its high efficiency. During the experiments, various amounts of flocculants were studied at a total concentration of 0.15–0.30 mg/l. In this process, the resulting suspension was maintained for 10–15 minutes until the flocculated sediment was completely deposited, i.e. until the water became transparent. Depending on the nature of the curve of the dependence of dispersed turbidity on temperature, all the studied flocculants can be divided into three groups (Figure 1).

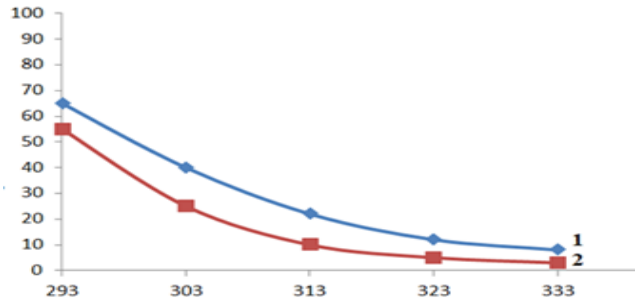

Figure 1. The ratio of flocculants Na–CMC, PAA and HPAN depending on the dispersion of wastewater turbidity and temperature. The ratio of flocculants is 1.0:1.0:1.0 (1) and 1.0:0.5:0.5 (2), respectively, t=20 minutes

For each water sample, based on the turbidity, color and pH level of the wastewater, suitable light filters and 10 mm thick cuvettes were selected. Distilled water was used as a control solution. The results showed that in the temperature range of 293–303 K, the sedimentation rate of dispersed particles increases with increasing concentration of coagulant and flocculants, reaching the maximum sedimentation rate at a temperature of 313–323 K.

Thus, when using Na–CMC, PAA and HPAN polymers as flocculants, a high degree of purification of wastewater from pollutants was achieved, which allows them to be recommended for use in wastewater treatment processes at gas processing plants.

3. Results and Discussion

The ratio of flocculants Na–CMC, PAA and HPAN 1.0:0.5:0.5 provided a transparency level of 95–97%. The total concentration of polymers was 0.15–0.20 mg/l. To achieve consistent interaction of reagents (coagulant and flocculant) with purified water, the dispersion level of coagulant particles should be within 0.006–0.016 μm–1, flocculant–0.003 μm–1, sorbent–0.02–0.05 μm–1.

Considering the dependence of the rate of sorption and desorption processes on the concentration of substances on the adsorbent surface and in the solution, various coagulant dosages were studied to reduce the chemical oxygen demand (COD) of wastewater. Table 1 presents the changes in COD values depending on the flocculant dosage.

It is impossible to achieve high efficiency of wastewater treatment using only a coagulant or flocculant [6, p.10; 7, p. 26]. Therefore, they are used together.

Experimental results have proven that the coagulant to flocculant ratio of 2:1 ensures high efficiency of wastewater treatment at gas processing plants.

Optimal dosages of coagulants: for aluminum sulfate–0.5 mg/l, for iron chloride–0.75 mg/l, and for flocculants Na–CMC: PAA = 1.0:0.5–20 mg/l.

Table 1. Change in the efficiency of wastewater treatment at the Mubarek gas processing plant from various pollutants depending on the dosage of flocculants

Wastewater taken at different times	Flocculant		pH			Cleaning efficiency, %	Volume of sludge in relation to the volume of wastewater, %
COD, mg O_2/l	Name of flocculant	Dose, mg/l	Before cleaning	After cleaning	By COD indicator, mg O_2/l		
220	PAA	0,25	8,14	7,20	44,1	87,2	3,72
220	Na–CMC	0,25	8,14	7,34	41,2	90,1	4,16
250	HPAN	0,25	7,85	6,56	63,2	85,1	3,40
250	Uniflok	0,25	7,85	6,92	61,3	88,4	3,60
195	PAA+Na–CMC	0,20	7,94	6,81	32,1	93,6	4,70
195	PAA+HPAN	0,20	7,94	6,82	33,1	95,1	5,76
230	PAA+Uniflok	0,20	7,94	6,78	48,2	89,3	3,83
230	Na–CMC+HPAN	0,20	7,94	6,70	46,4	94,9	4,36
170	HPAN+Uniflok	0,20	7,94	7,16	25,3	95,1	3,53
170	Na–CMC+ Uniflok	0,20	7,94	6,88	21,7	96,2	3,76
270	PAA+Na–CMC+ HPAN	0,15	7,65	7,25	45,4	83,1	3,32
270	PAA+Na–CMC+ Uniflok	0,15	7,65	7,02	42,6	85,2	4,10
180	HPAN+Na–CMC+Uniflok	0,15	7,65	7,10	28,2	92,1	4,67

In these concentration ranges, the purification efficiency in terms of COD reaches 83–92%, and in terms of color intensity–95–97%.

In order to determine the optimal amount of coagulants, the conducted studies demonstrated that exceeding the dosage of coagulants above 0.5–0.6 mg/l has a negative impact on the efficiency of wastewater treatment, leading to its reduction.

This is due to oversaturation of the system with coagulants, which can lead to the formation of undesirable side effects, such as deterioration of precipitation or oversaturation with reagent residues.

To evaluate the flocculation capacity of polyelectrolytes, the polymers PAA, Na–CMC, HPAN and Uniflok were used in the experiments. Despite their relatively higher cost compared to inorganic coagulants, these polymers have a number of significant advantages. The key advantages are higher efficiency of pollutant removal, reduced required reagent dosage compared to traditional coagulants, prevention of corrosive effects on equipment, reduced volume of sediment formed and absence of additional contaminants in purified process water [8, p. 243; 9, p. 536; 10, p. 21]. These aspects make polymer flocculants economically and environmentally attractive for use.

Thus, the use of the proposed flocculant composition contributes to a significant increase in the efficiency of wastewater treatment from various impurities, including organic and inorganic contaminants. The study of the effect of the dosage of water–soluble synthetic polymer flocculants, such as PAA, Na–CMC, HPAN and Uniflok, on the wastewater treatment process is an important stage in the development of innovative technologies. It is important to note that the chemical environment of wastewater plays a decisive role in ensuring the maximum degree of purification from all ionic and suspended substances. The optimal pH range for the flocculation process was determined to be within 6.0–8.0, which is consistent with the physicochemical properties of the flocculants used.

Based on the obtained experimental data, it was established that the highest efficiency of wastewater treatment using PAA and Na–CMC as flocculants is achieved at a pH level of 7.5 to 8.5 [11, p. 1–6]. This is due to the optimal conditions for the aggregation and sedimentation of dispersed particles, which allows for a significant reduction in the concentration of residual pollutants and ensures process stability. The developed recommendations are of high practical importance for industrial wastewater treatment, especially at enterprises with high levels of pollution, such as gas processing facilities [12, p. 312–331].

4. Conclusions

Thus, as a result of the conducted research, an innovative composition of reagents for highly effective wastewater treatment was developed. This composition includes powdered coagulants, such as aluminum sulfate and iron chloride, which provide primary sedimentation of pollutants. In addition, it contains water–soluble polymer flocculants (PAA, HPAN, Na–CMC), which have high adsorption capacity and promote the aggregation of dispersed particles, which significantly increases the degree of purification.

The developed reagent composition provides improved efficiency of coagulation and flocculation processes, which is confirmed by experimental data. The use of this composition allows not only to minimize the concentration of residual pollutants in purified water, but also reduces the volume of sediment formed, which is an important factor for optimizing the operation of treatment facilities. Moreover, the use of these reagents helps to reduce the corrosive effect on equipment, which increases its service life and reduces operating costs. These results demonstrate the practical importance of using the proposed reagent composition in industrial wastewater treatment, especially at gas processing plants, where effective removal of complex organic and mineral contaminants is required.

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