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Biochemical Treatment of Wastewater Containing Partially Hydrolyzed Polyacrylamide

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Partially hydrolyzed polyacrylamide (HPAM) in production water after polymer flooding in oil filed causes environmental problems, such as increases the difficulty in oil-water separation, degrades naturally to produce toxic acrylamide and endanger local ecosystem. Two hydrolyzed polyacrylamide-degrading bacterial strains, named P-1 and P-2, were isolated from the produced water of polymer flooding. The influence factors on mixed bacteria to degrade hydrolyzed polyacrylamide-containing wastewater were optimized. The optimum process conditions were as follows: polyacrylamide (*i.e.*, hydrolyzed polyacrylamide) which comes from waste water could serve as nitrogen source, K_2HPO_4 serve as phosphorus source, the microorganisms activation times was 2 h, incubation time was 3 d, initial pH was 7, the inoculum size was 5 % (v/v), incubation temperature was 35 ºC, the mineralization degree was 4000 mg L^{-1}. The main factors affecting degradation rate were nitrogen source, time, pH, activation times, inoculum size and mineralization degree.

Key Words: Biochemical treatment, Wastewater, Hydrolyzed polyacrylamide, Orthogonal experiments.

INTRODUCTION

Partially hydrolyzed polyacrylamide (HPAM) have recently been widely used to enhance oil recovery in the east oilfields of China. However, partially hydrolyzed polyacrylamide (HPAM) present inproduction water causes some problems[1]. The residual HPAM in the wastewater can slowly degrade into the toxic acrylamide monomer naturally. The toxicity of acrylamide monomer has been studied by numerous researchers all over the world[2]. The acrylamide monomers degraded by HPAM harm human and animals[3]. A large quantity of HPAM will be taken out with produced water when oil is extracted[4]. Since HPAM could remain in surface water and groundwater for a long period of time, it may endanger human health. It is reported that soil microorganisms could utilize water-soluble HPAM as a sole N-source, suggesting that the microbes could hydrolyze the amide group but were incapable of cleaving the main C-chain backbone[5,6]. Microbiological degradation will be effective method with innocent treatment to solve the problem which related to the potentially toxic of environment pollution caused by HPAM. Biodegradation is an efficient treatment to deal with environmental pollutant, which has many advantages, such as non secondary pollution and low-cost operation expense. It will become effective measure to solve the problem of HPAM potential toxicity.

The aim of this work was to discuss the biochemical treatment of HPAM-containing wastewater. Based on explored HPAM degradation influence factors, HPAM determination methods are optimized, polymer-degrading bacteria are screened and degradation conditions are optimized.

EXPERIMENTAL

Two HPAM-degrading bacterial strains, named P-1 and P-2, were isolated from the produced water of polymer flooding in Daqing oilfield, China. The amide group of HPAM could serve as nitrogen source for the two microorganisms, the carbon backbone of these polymers could be partly utilized by microorganisms. The concentration of HPAM is measured by starch-cadmium iodine method. The HPAM removal efficiency was calculated by the difference of the concentration value between the control and biodegraded sample divided by the concentration value of the control.

RESULTS AND DISCUSSION

Effects of microbial degradation of HPAM determination of main parameters. Two HPAM-degrading bacteria were

isolated from production water after polymer flooding. Strains P-1 and P-2 showed a strong ability to degrade HPAM.

Activation times, inoculation quantity, temperature, salinity, pH, degradation time that could influence HPAM degradation rate were studied. The results are shown in Figs. 1-6. When the activation time was 4 h, HPAM degradation rate was basically stable (Fig. 1). Similarly, when the mixed bacteria inoculum size was 3 % (v/v), HPAM degradation rate reached a steady value (Fig. 2). The HPAM degradation rate was higher when the temperature was in the range of 30-40 ºC (Fig. 3). It can be seen that mineralization rate in 3000-5000 mg L^{-1}, HPAM degradation effect is better (Fig. 4). The initial pH 6.5 to 7.5 was suitable for the growth of strains (Fig. 5). HPAM degradation rate of mixed bacteria in 3 days was stable in principle (Fig. 6).

Orthogonal experimental optimization for microbial degradation of HPAM conditions. This study selected nitrogen source, phosphorus source, time, inoculation amount, temperature, mineralization rate, initial pH and activation time as 8 factors

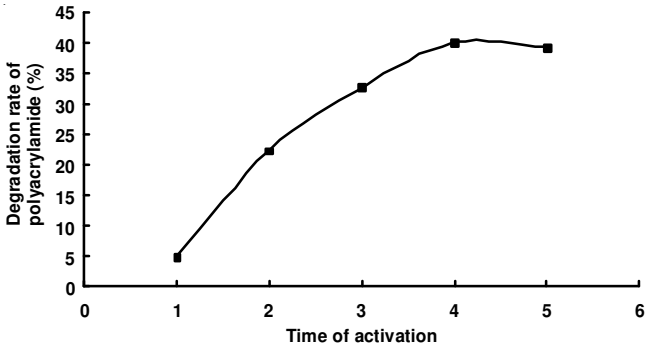

Fig. 1. Effect of activation times on HPAM degradation

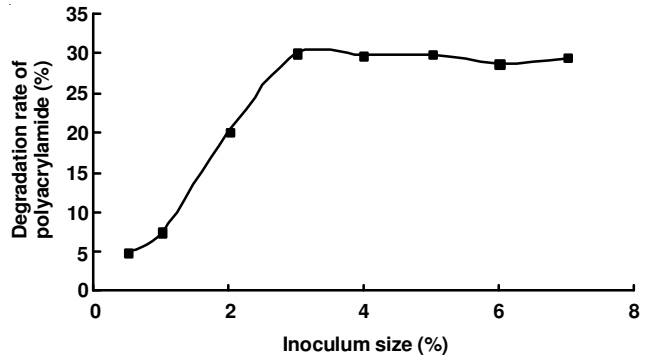

Fig. 2. Effect of inoculum size on HPAM degradation

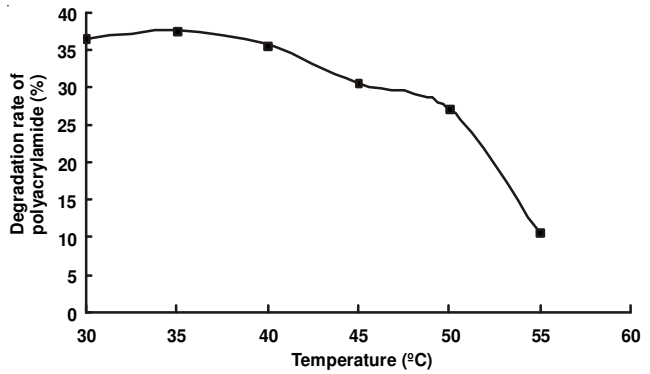

Fig. 3. Effect of temperature on HPAM degradation

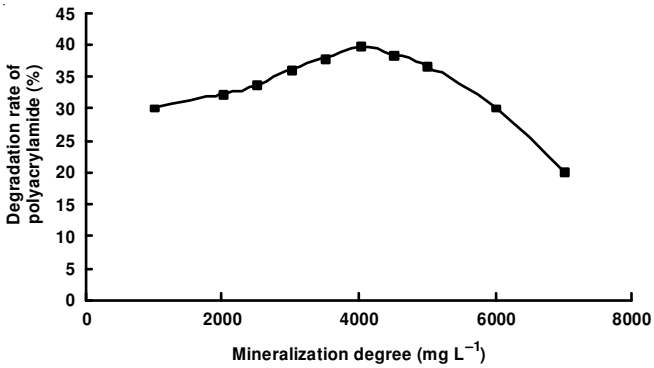

Fig. 4. Effect of mineralization rate on HPAM degradation

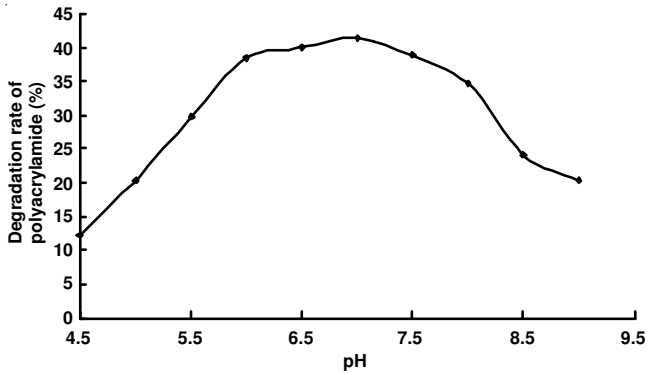

Fig. 5. Effect of initial pH on HPAM degradation

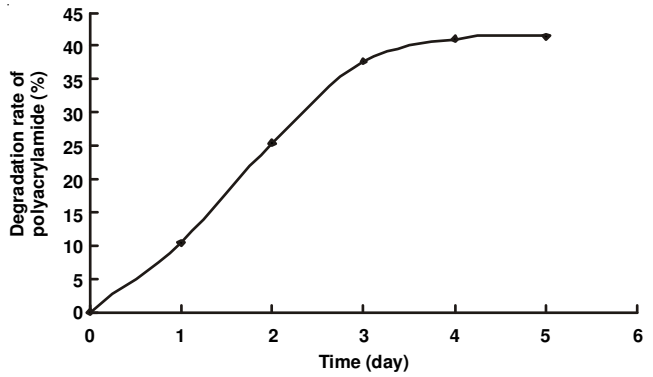

Fig. 6. Effect of time on HPAM degradation

of the orthogonal experiment. Each of the factors was chosen 3 levels, as shown in Table-1. Orthogonal table L_{27} (3^{13}) of orthogonal experiment was used in the 8 factors and 3 levels. Orthogonal experiments and analysis results were shown in Table-2.

As shown in Tables 1 and 2, impact factors in descending order was nitrogen source > degradation time > pH > activation times > inoculum size > mineralization rate > temperature > phosphorus source. Nitrogen source, degradation time, pH, activation times, inoculum size, degree of mineralization on affecting HPAM degradation rate were remarkable affecting factors. It was the best conditions for mixed bacteria to degrade HPAM that K_2HPO_4 served as phosphorus source, activated 2 times, degradation time was 3 d, pH was 7, the inoculum size was 5 % (v/v), culture temperature was 35 ºC, mineralization rate was 4000 mg L^{-1}. Table-2 showed the range for maximum and minimum difference in the average values of experimental index level of influenced by the same factors.

TABLE-1
LEVELS AND FACTORS OF ORTHOGONAL EXPERIMENT

Level	Factor							
	A	B	C	D	E	F	G	H
	Nitrogen source	Phosphorus source	Activation time (h)	Degradation time (h)	Inoculum size, % (v/v)	Temperature (ºC)	Mineralization rate (mg L^{-1})	pH
1	–	K_2HPO_4-KH_2PO_4	4	72	1	20	1000	5
2	NH_4Cl	K_2HPO_4	2	36	3	35	4000	7
3	$NaNO_3$	KH_2PO_4	0	6	5	50	7000	9

TABLE-2
$L_{27}(3^{13})$ ORTHOGONAL EXPERIMENT RESULTS

No.	A	B	C	D	E	F	G	H	Empty column	Empty column	Empty column	Empty column	Empty column	Degradation rate (%)
1	1	1	1	1	1	1	1	1	1	1	1	1	1	35.5
2	1	1	1	1	2	2	2	2	2	2	2	2	2	55.6
3	1	1	1	1	3	3	3	3	3	3	3	3	3	50.4
4	1	2	2	2	1	1	1	2	2	2	3	3	3	42.4
5	1	2	2	2	2	2	2	3	3	3	1	1	1	39.1
6	1	2	2	2	3	3	3	1	1	1	2	2	2	34.4
7	1	3	3	3	1	1	1	3	3	3	2	2	2	41.9
8	1	3	3	3	2	2	2	1	1	1	3	3	3	38.8
9	1	3	3	3	3	3	3	2	2	2	1	1	1	39.8
10	2	1	2	3	1	2	3	1	2	3	1	2	3	19.8
11	2	1	2	3	2	3	1	2	3	1	2	3	1	31.7
12	2	1	2	3	3	1	2	3	1	2	3	1	2	45.5
13	2	2	3	1	1	2	3	2	3	1	3	1	2	20.7
14	2	2	3	1	2	3	1	3	1	2	1	2	3	30.6
15	2	2	3	1	3	1	2	1	2	3	2	3	1	29.9
16	2	3	1	2	1	2	3	3	1	2	2	3	1	15.4
17	2	3	1	2	2	3	1	1	2	3	3	1	2	12.7
18	2	3	1	2	3	1	2	2	3	1	1	2	3	24.5
19	3	1	3	2	1	3	2	1	3	2	1	3	2	18.4
20	3	1	3	2	2	1	3	2	1	3	2	1	3	10.3
21	3	1	3	2	3	2	1	3	2	1	3	2	1	32.5
22	3	2	1	3	1	3	2	2	1	3	3	2	1	30.3
23	3	2	1	3	2	1	3	3	2	1	1	3	2	35.1
24	3	2	1	3	3	2	1	1	3	2	2	1	3	33.1
25	3	3	2	1	1	3	2	3	2	1	2	1	3	46.3
26	3	3	2	1	2	1	3	1	3	2	3	2	1	33.9
27	3	3	2	1	3	2	1	2	1	3	1	2	3	49.6
K1	41.9	33.3	32.5	39.1	30.1	33.2	34.4	28.5	32.3	33.2	32.5	31.4	32.0	–
K2	25.6	32.8	38.1	25.5	31.9	33.8	36.4	37.8	34.9	34.9	33.2	39.2	29.4	–
K3	32.2	33.6	29.2	35.1	37.7	32.7	28.9	33.4	32.6	31.5	34.1	29.1	38.4	–
R	16.3	0.8	8.9	13.6	7.6	1.1	7.5	8.9	2.6	3.4	7.1	10.1	9.0	–

TABLE-3
VARIANCE ANALYSIS

Source	SS	DF	MS	F	P
A	1218.469	2	609.234	32.319	0.000
B	2.976	2	1.488	0.079	0.925
C	361.487	2	180.743	9.588	0.005
D	883.696	2	441.848	23.439	0.000
E	286.927	2	143.463	7.611	0.010
F	5.582	2	2.791	0.148	0.864
G	280.169	2	140.084	7.431	0.011
H	363.269	2	181.634	9.635	0.005
Error	188.507	10	18.851	–	–

Orthogonal experiment and variance analysis were shown in Table-3. By the analysis of variance results as shown in Table-3, when phosphorus degree was below 0.05, it was considered that the factors had significant influence on experimental results.

Conclusion

In this study, two isolates that can effectively degrade HPAM were isolated. The results showed that bacteria could partly utilize HPAM as carbon source and nitrogen source. The optimum process parameters were concluded that nitrogen source, degradation time, pH, activation times, inoculation quantity, mineralization rate on HPAM degradation rate were significant factors.

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