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WATER FILTRATION RESEARCH PART IV.
AN EVALUATION OF SELECTED
POLYELECTROLYTES AS FILTER BED
CONDITIONERS IN WATER TREATMENT

D. E. Olesen
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C. J. Touhill

May 1968

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AN EVALUATION OF SELECTED POLYELECTROLYTES
AS FILTER BED CONDITIONERS IN WATER TREATMENT

By

D. E. Olesen, R. L. Schmidt, and C. J. Touhill

Water and Waste Management
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May 1968

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ABSTRACT

This research has shown five polyelectrolytes to be as effective as those presently used as filter bed conditioners at the Hanford water treatment plants. Cost comparisons are presented for the polyelectrolytes studied. Laboratory filtration data is included for twenty-two polyelectrolytes.

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INTRODUCTION

The water treatment plants operated by Douglas United Nuclear at the Hanford production reactors are among the most advanced in existence. They are characterized by two distinctive features: 1) high filtration rates, and 2) very low effluent water turbidity. Use of dual media filters and organic polyelectrolytes have made it possible to employ filtration rates well above those found in most municipal and industrial water treatment systems. The dual media filters are comprised of a 27 in. layer of anthracite over a 3 in. layer of sand, and both are supported by a gravel layer. Grain size of the anthracite is larger than that of the sand, but the specific gravity of the anthracite is lower so that stratification can be maintained during backwashing. Dual media beds are used in order to have an upper layer media of large enough grain size to encourage penetration of floc particles into the filter bed. Hence, it is possible to take advantage of all of the void spaces within the bed for floc storage. The sand layer acts as a final polishing step, retaining the small amount of floc which passes through the upper anthracite layer.

After a period of operation at high filtration rates, floc will begin to breakthrough the filter. Organic polyelectrolytes have been very effective in retarding this floc breakthrough. The polyelectrolytes are added in very low concentrations to the chemically coagulated water just prior to filtration.

In recent years a variety of polyelectrolytes has appeared on the market but evaluation for water treatment applications has

not kept pace with the rapid development of improved polyelectrolytes because of the difficulties in testing these materials on a plant scale. Many polyelectrolytes could be evaluated for use at the Hanford water treatment plants. Even though polyelectrolytes are used at very low concentrations, they represent a considerable expense at Hanford because of the volume of water treated. In addition to possible financial savings there is an opportunity to improve the efficiency of treatment. In this research a selected number of polyelectrolytes were evaluated to determine their potential as filter bed conditioners at the Hanford water treatment plants. Each of the polyelectrolytes studied is referred to by a coded number. A supplement containing the code number key for polyelectrolyte identification will be issued for limited distribution.

SUMMARY AND CONCLUSIONS

This research was undertaken to evaluate 51 polyelectrolytes as filter bed conditioners in water treatment. The polyelectrolytes were initially screened by a unique coagulation jar test to determine visually their effect on alum flocculated water. Twenty-two were found to significantly increase flocculation. Laboratory filtration studies compared the 22 polyelectrolytes with Magnifloc 990N as filter bed conditioners. Magnifloc 990N was used as the standard index because of its demonstrated effectiveness at Hanford water treatment plants. The 5 polyelectrolytes which proved as effective as Magnifloc 990N in retarding turbidity breakthrough are: K-1, D-1, A-2, A-3, and A-4.

Cost figures for the 22 polyelectrolytes are furnished. It is recommended that the 5 effective polyelectrolytes listed be further tested at the Hanford water treatment plants to establish whether or not they can be used on a routine basis. Studies should continue to evaluate new polyelectrolytes as they become available. The procedure developed for coagulation jar tests can serve as a valuable screening method in the initial evaluation of polyelectrolytes.

DISCUSSION

THEORY AND PRACTICE

Organic polyelectrolytes have been shown to be of value in improving the performance of various unit operations in water treatment. Oulman, Burns, and Bauman⁽¹⁾ found certain cationic polyelectrolytes to be superior to alum as a diatomite filter coating. The coating made the media more adsorptive by inducing a positive zeta potential in certain pH ranges. The Gouverneur, New York, water treatment plant uses alum and a medium chain length polyelectrolyte to control zeta potential and to produce a rapid settling floc.⁽²⁾ Robeck, Dostal, and Woodward⁽³⁾ observed that adequate floc strength was more important than settleability in producing low turbidity effluents with coarse media and high filtration rates. Polyelectrolytes were valuable in attaining the required floc strength. At the Hanford reactor water treatment plants, Conley and Pitman^(4,5) found certain polyelectrolytes to be very effective in retarding turbidity breakthrough at high filtration rates and high alum concentrations.

A mechanism for polymer-floc interaction has been postulated.⁽⁶⁾ The polymer is adsorbed at one or more points on the floc particle with much of the polymer chain length extending free into the surrounding medium. This free end may attach to more floc particles or to another polymer chain. In this fashion, a bridging effect occurs between floc particles, thus increasing the floc particle size. Low polymer concentrations produce weak bridging, while high concentrations retard bridging by covering all particle adsorption sites.

When used as a filter bed conditioner, the polyelectrolyte should function in two ways to aid filtration: 1) by increasing floc particle size, potential for removal in a filter is enhanced, and 2) by attaching to the filter media, the polymer offers added points of contact within the filter to hold up floc particles.

At the Hanford water treatment plants operated by Douglas United Nuclear, two polyelectrolytes are in routine use as filter bed conditioners - 1) Separan NP10* and 2) Magnifloc 990N.** These are both high molecular weight nonionic polyacrylamides. They are added continuously in very low concentrations to the chemically coagulated water just prior to filtration. Since the time that these polyelectrolytes were selected for use, a large number of new materials have become available, but only a few of these have been evaluated.⁽⁷⁾ Even though the polyelectrolytes are used in low concentrations, the volume of water treated results in a considerable cost for these materials. Since the polyelectrolytes are purchased competitively, it would be economically attractive to have a greater number from which to choose.

EXPERIMENTAL METHODS

A unique jar test was developed for preliminary screening of the 52 polyelectrolytes. First, 18 ppm alum was added during rapid mixing of raw water samples, and then the solution was mixed slowly to promote flocculation. After 10 min of flocculation, 10 ppm of a polyelectrolyte was added during rapid mixing. Flocculation then followed for 10 more minutes after which the floc was evaluated visually. Judgment of the polyelectrolytes was based on their effect upon the alum floc. Polyelectrolytes which coagulated and settled rapidly were selected for further testing. An additional index was the clarity of the coagulated water.

Filtration tests of the selected polyelectrolytes were run, utilizing the water filtration pilot facility at Pacific Northwest Laboratory. Alum was added at 18 ppm to the raw water

* Product of Dow Chemical Company

** Product of American Cyanamid Company

in the rapid mix tank, from which the water flowed by gravity to the filters. Sulfuric acid was added at the rapid mix tank to maintain a pH of 6.6. Polyelectrolytes were added just prior to the filtration. All tests used a filtration rate of 8.0 gal/min/ft². Filter headloss and effluent turbidity were monitored on all runs. Filters were thoroughly backwashed at 16 gal/min/ft² between runs. Surface washing just prior to backwashing was employed to insure thorough bed cleaning. Filter beds were of the dual media type, a 27 in. layer of anthracite over a 3 in. layer of sand.

RESULTS

Jar test screening of the 51 polyelectrolytes produced 23 which significantly changed the floc characteristics (Table 1). Basically, two visual results were evident from the jar testing: 1) drastic increase in floc particle sizes, 2) no discernible change in floc appearance. This method, employed to screen the initial group of polyelectrolytes, was considered satisfactory, since to be effective the polyelectrolytes must be adsorbed onto the floc particles. Hence, by adding concentrations of polyelectrolytes which will produce visually large particles, the polyelectrolytes can be separated into two categories: those that are effective to some extent, and those which produce no change. Both Separan NP10 and Magnifloc 990N were visually observed to be effective in increasing floc particle sizes.

Results of filtration studies on the 22 polyelectrolytes are presented in Figures 1 through 22 (All figures appear at end of report). Figure 23 compares use of alum alone with use of Magnifloc 990N in conjunction with alum. It is evident from the data that both the rate of headloss and effluent turbidity are effective in evaluating filter bed conditioners. Headloss is greater with the more effective polyelectrolytes, and this is in accord with the bridging mechanism theory for

Table 1. Characteristics of Tested Polyelectrolytes

Designation	Ionic Character	Chemical Nature	Molecular Weight
A-1	anionic	polyacrylamide	$2-3 \times 10^6$
A-2*	non-ionic	polyacrylamide	$2-3 \times 10^6$
A-3*	non-ionic	polyacrylamide	$10-12 \times 10^6$
A-4*	non-ionic	polyacrylamide	$10-12 \times 10^6$
A-5*	non-ionic	polyacrylamide	
B-1	non-ionic	guar seed extract	330,000
C-1*	non-ionic	--	--
C-2	non-ionic	--	--
C-3	anionic	--	--
C-4*	non-ionic	polyacrylamide	$4-10 \times 10^6$
C-5	cationic	--	--
C-6	cationic	--	--
C-7*	non-ionic	polyacrylamide	$4-10 \times 10^6$
C-8	anionic	polyacrylamide	$4-10 \times 10^6$
D-1*	non-ionic	acrylamide	$>2 \times 10^6$
D-2*	non-ionic	acrylamide	$>1 \times 10^6$
D-3*	anionic	sodium polystyrene sulfonate	$>5 \times 10^6$
D-4*	anionic	acrylamide	$>1 \times 10^6$
D-5*	anionic	acrylamide	$>2 \times 10^6$
D-6	cationic	polyamiene	$<1 \times 10^5$
E-1*	anionic	--	--
E-2	cationic	--	--
F-1*	--	--	--
G-1	--	sodium cellulose sulfate	3×10^5
G-2	--	sodium alginate	$1.5-1.75 \times 10^5$
G-3	--	potassium salt of polyceronide	$>1 \times 10^6$
G-4	--	sodium alginate	$1.5-1.75 \times 10^5$
H-1	cationic	poly-methyl vinyl ether (monomer)	188
H-2	cationic	aluminum tri hydrate + starch	85
I-1	non-ionic	--	--
I-2	cationic	--	--
I-3	cationic	--	--
I-4	cationic	--	--
I-5	--	sodium aluminate + nucleating agent	--
I-6	--	montmorillonite clay	--
I-7*	non-ionic	--	--
I-8*	anionic	--	--
I-9*	anionic	--	--
I-10*	anionic	--	--
I-11*	anionic	--	--
J-1	cationic	aluminate	low
J-2*	cationic	aluminate-carbohydrate adduct	$1-5 \times 10^4$
J-3	non-ionic	acrylic	1×10^6
J-4	cationic	aluminate-carbohydrate adduct	$1-5 \times 10^4$
J-5	non-ionic	acrylic	1×10^6
J-6	anionic	acrylic	3×10^6
K-1*	non-ionic	polyacrylamide	4×10^6
K-2*	non-ionic	polyacrylamide	$4-5 \times 10^6$
K-3*	anionic	polyacrylamide	5×10^6
K-4	non-ionic	guar gum derivative	2×10^5
K-5	cationic	guar gum derivative	2×10^5

*Those polyelectrolytes judged effective enough to be studied by filtration testing.

polymer-floc interaction. When the polymer-floc matrices become trapped in the filter bed, the restriction of flow through the bed should be greater than for individual floc particles trapped within the filter bed. The data show how effective the correct polyelectrolyte can be in insuring low effluent turbidity for the duration of a filtration run.

Following is a list of the polyelectrolytes which were found to be as effective as Magnifloc 990N when used as filter bed conditioners:

- K-1, Figure 12
- D-1, Figure 8
- A-2, Figure 20
- A-3, Figure 21
- A-4, Figure 22

Cost figures for the 22 polyelectrolytes studied and Magnifloc 990N are given in Table 2. From the cost information, an economic incentive to test these five materials on a plant scale is apparent. Four of the five polyelectrolytes are less expensive than those presently in use. In the case of K-1, the price difference is substantial.

In a study by Wells and Pitman⁽⁷⁾, K-1 was rejected for use at the Hanford water treatment plants. It is recommended that this material be subjected to further plant scale tests, based upon the results of this study and because of the very favorable cost picture.

A-2 and A-3 are industrial grade polyelectrolytes and, as such, the amounts of impurities will be higher, but because the polyelectrolytes are used in such low concentrations it is very probable that no adverse effects would occur from their use.

The study results for K-1 and D-1 indicate these materials result in lower rates of headloss buildup than does Magnifloc 990N, while maintaining acceptable effluent turbidity. This

would be an important consideration in allowing longer filter runs before headloss necessitated backwashing; thus increased plant output should be evident. A-3 and A-4 resulted in greater rates of headloss than Magnifloc 990N, which indicates these materials could be used in concentrations less than Magnifloc 990N and still produce acceptable water. In the case of A-4, the possibility of using lower concentrations dictates further testing even though its price is greater than that of Magnifloc 990N.

TABLE 2. *Selected Polyelectrolyte Prices*

<u>Polyelectrolyte</u>	<u>Cost/lb*</u>
I-8	\$1.70
I-7	1.80
I-9	1.50
I-10	1.70
I-11	1.50
E-1	1.27
D-4	1.15
D-1	0.95
D-2	1.40
D-3	1.00
D-5	1.35
K-1	0.76
K-2	0.91
K-3	1.36
J-2	0.25
F-1	0.20
C-4	1.35
C-7	1.02
C-1	1.35
A-2	1.10
A-3	1.35
A-4	1.65
Magnifloc 990N	1.40

*Truckload lots, 24,000 lb

Following is a list of polyelectrolytes that were not as effective as Magnifloc 990N but were more effective than use of

alum with no polyelectrolyte.

- C-1, Figure 19
- C-4, Figure 17
- D-2, Figure 9
- I-7, Figure 2
- I-8, Figure 1
- I-11, Figure 5
- K-2, Figure 13

Table 1 shows that the 12 effective or partially effective polyelectrolytes (Listed on page 7 and above) were acrylamides or polyacrylamides to the extent that descriptions of chemical nature were available. Of the 12 polyelectrolytes, all but one are non-ionics, the exception, I-8 is anionic. Known molecular weights of the materials are all in excess of 1×10^6 . It appears evident that high molecular weight, non-ionic, polyacrylamides have been shown to be the most effective polyelectrolytes for use at the Hanford water treatment plants.

Results of this study have shown five polyelectrolytes to be as effective as Magnifloc 990N when used as filter bed conditioners. Based on these results, it is recommended that each of these polyelectrolytes undergo half-plant tests to further examine the possibility of their use on a routine basis at Hanford. Justification for these tests can be made solely a matter of economics.

It is quite probable that concentrations of the various polyelectrolytes required on a full scale basis will not be the same as for Separan NP10 and Magnifloc 990N. Thus the economic picture should be considered when determining the range of concentrations over which the polyelectrolytes will be tested. Even if concentrations were required which led to no financial savings, it would be advantageous to have a larger number of both polyelectrolytes and companies involved in the bidding for the supply contract.

New polyelectrolytes are continually appearing on the market and each of these should be evaluated for its application at Hanford. We recommend that a continuing program of polyelectrolyte evaluation be maintained. For future evaluations of polyelectrolytes we also recommend that the jar test coagulation procedure developed in this study be used for initial screening prior to filter testing.

FIGURE 1. Headloss and Turbidity Versus Time

FIGURE 2. Headloss and Turbidity Versus Time

FIGURE 3. Headloss and Turbidity Versus Time

FIGURE 4. Headloss and Turbidity Versus Time

FIGURE 5. Headloss and Turbidity Versus Time

FIGURE 6. Headloss and Turbidity Versus Time

FIGURE 7. Headloss and Turbidity Versus Time

FIGURE 8. Headloss and Turbidity Versus Time

FIGURE 9. Headloss and Turbidity Versus Time

FIGURE 10. Headloss and Turbidity Versus Time

FIGURE 11. Headloss and Turbidity Versus Time

FIGURE 12. Headloss and Turbidity Versus Time

FIGURE 13. Headloss and Turbidity Versus Time

FIGURE 14. Headloss and Turbidity Versus Time

FIGURE 15. Headloss and Turbidity Versus Time

FIGURE 16. Headloss and Turbidity Versus Time

FIGURE 17. Headloss and Turbidity Versus Time

FIGURE 18. Headloss and Turbidity Versus Time

FIGURE 19. Headloss and Turbidity Versus Time

FIGURE 20. Headloss and Turbidity Versus Time

FIGURE 21. Headloss and Turbidity Versus Time

FIGURE 22. Headloss and Turbidity Versus Time

FIGURE 23. Headloss and Turbidity Versus Time

REFERENCES

1. C. S. Oulman, D. E. Eurns, and E. R. Baumann. "Effect of Filtration of Polyelectrolyte Coatings of Diatomite Filter Media," Jour. AWWA, vol. 56, p. 1233. September 1964.
2. T. M. Riddick. "Zeta Potential and Polymers," Jour. AWWA, vol. 58, p. 719. June 1966.
3. G. G. Robeck, K. A. Dostal, and R. L. Woodward. "Studies on Modifications in Water Filtration," Jour. AWWA, vol. 56, p. 198. February 1964.
4. W. R. Conley and R. W. Pitman. "Innovations in Water Clarification," Jour. AWWA, vol. 52, p. 1219. October 1960.
5. W. R. Conley. "Experience with Anthracite-Sand Filters," Jour. AWWA, vol. 53, p. 1473. December 1961.
6. A. P. Black, F. B. Birkner, and J. J. Morgan. "Destabilization of Dilute Clay Suspensions with Labeled Polymers," Jour. AWWA, vol. 57, p. 1547. December 1965.
7. R. W. Pitman and G. W. Wells. "Progress Report I - Testing of Filter Conditioners," Douglas United Nuclear Document No. 2469. May 1967.

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