Rheological properties of selected polyelectrolyte aqueous solutions for dewatering sewage sludge

A. Krupińska[1], M. Ochowiak[1], M. Hyrycz [1,2], S. Włodarczak[1] and M. Matuszak[1]

[1] Department of Chemical Technology and Engineering, Poznan University of Technology, Poznan, 60-965, Poland
[2] Aquanet S.A., Poznan, 61-477, Poland
(Presenting author email: andzelika.krupinska@put.poznan.pl)

Introduction

Thickening and dewatering are among the basic processes that lead to a reduction in the volume of sludge, in turn changing its consistency, and thus creating the possibility of its transport, use, storage or processing. Without its pretreatment and conditioning, dehydration effects and the degree of phase separation are very low. An improvement of the efficiency of the process can be achieved through the use of chemicals that contribute to the aggregation of sludge particles. Aggregation can be based on two distinct phenomena, which are called coagulation and flocculation (Figure 1).

In dewatering and thickening processes, appropriately selected types and doses of conditioning agents such as polyelectrolytes (flocculants) are used to improve the ability of sludge to release water. In the process of: treating drinking water, water recycling, industrial wastewater treatment, and for the dewatering of flotation and biological sludge are used polyelectrolytes. These can be polymer compounds of natural (starch, cellulose, and gelatin) or synthetic origin (polyethylene oxide, polyacrylic acids, and polyacrylamides). One of the most important factors affecting the efficiency and course of the flocculation process are the rheological properties of polyelectrolytes. It is necessary to achieve an even distribution of polyelectrolyte chains throughout the sludge's volume in the shortest possible time with the use of intensive mixing, without mechanical destruction of flocs. Flocculant solutions that are too viscous cause an excessive exploitation of pumps, and an increased consumption of the electricity used for their pumping. In addition, the high viscosity of flocculant solutions adversely affects the mixing of polymer chains with sludge particles, and may also cause mechanical destruction of the flocs during transport.

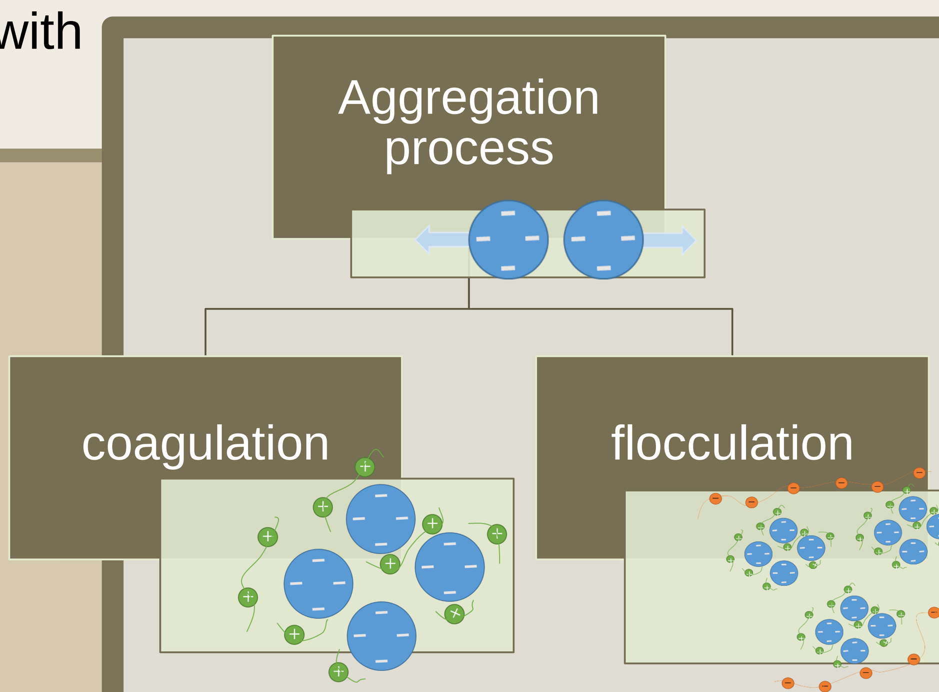

Figure 1. Aggregation proces.

Results & Discussion

The aim of this work was to investigate the rheological properties of selected polyelectrolytes. Cationic polyacrylamide (Zetag 8187) from Solenis Company, and a water-soluble cationic polymer (polyelectrolyte F 7055) from SNF Company were tested. The rheological properties of polyelectrolyte aqueous solutions were tested in the plate-cone system using the MCR-501 rheometer from Anton Paar GmbH Company (Figure 2).

Figure 2. The MCR-501 rheometer from Anton Paar GmbH Company.

On the basis of the obtained results, curves of the dependency between the shear stresses and shear rate were plotted for the polyelectrolyte F 7055 (Figure 3a) and polyelectrolyte Zetag 8187 (Figure 3b). The tests were carried out for a concentration of polyelectrolyte in water ranging from 0.2 to 0.6%, and for shear rates from 10 to 1000 1/s.

It was noticed that with an increasing polyelectrolyte concentration in the solution, the features of non-Newtonian fluids appear. The values of the flow coefficients decrease, which at higher polyelectrolyte concentrations means that the Ostwald de Waele model of the following form should be applied:

$$\tau = k \cdot \dot{\gamma}^n$$

where:
k is the experimentally determined rheological parameter,
n is the flow coefficient.

Table 1 presents the values of the *k* and *n* coefficients for various concentrations of polyelectrolytes.

Table 1. Consistency and flow coefficients of polyelectrolytes.

Concentration (%)	F 7055		Zetag 8187	
	k (Pa·s^n)	n (-)	k (Pa·s^n)	n (-)
0.2	0.012345	0.98	0.025588	0.96
0.3	0.021019	0.97	0.042545	0.95
0.4	0.027218	0.97	0.050458	0.95
0.5	0.03234	0.96	0.062886	0.95
0.6	0.04094	0.96	0.073609	0.95

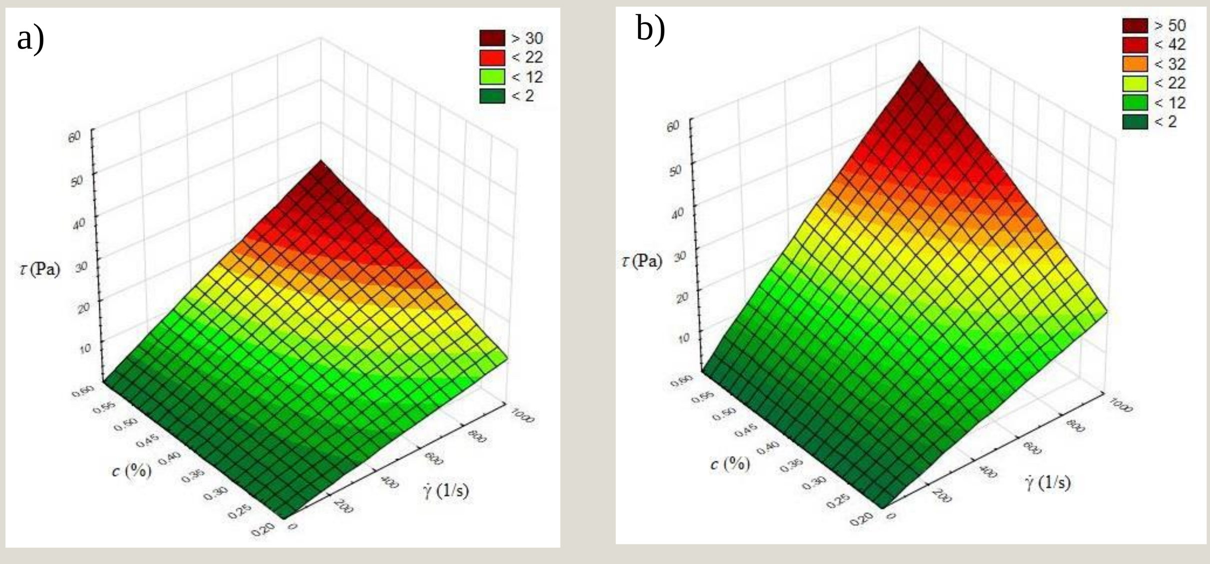

Figure 3. Relationship between the shear stresses, shear rate and polyelectrolyte concentration: a) F 7055, b) Zetag 8187.

Conclusions

On the basis of the obtained data, it was found that the tested solutions of the polyelectrolyte F 7055 exhibit properties of Newtonian fluids (values of flow coefficients n > 0.98) at low concentrations, and non-Newtonian fluids at higher polyelectrolyte concentrations in the solution. Zetag 8187 solutions are closer to non-Newtonian fluids. An increasing concentration of the polyelectrolyte causes an increase in viscosity. Aqueous solutions of the Zetag 8187 polyelectrolyte were characterized by higher viscosity values when compared to the F 7055 solutions at the same concentration, which may affect the efficiency of mixing with sewage sludge. In order to achieve a high mixing and flocculation efficiency, the concentration of Zetag 8187 solution should be lower when compared to the concentration of F 7055.

Acknowledgments
This research was funded by the Ministry of Education and Science in Poland (SBAD) and was carried out under the Implementation Doctorate Program of the Ministry of Education and Science implemented in the years 2020-2021 (Agreement no. DWD/4/23/2020).