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# Discussion on setting shear coefficient of viscous concentration parameter in numerical simulation of chemical flooding

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**Abstract.** Chemeor software is the only application of chemical flooding analog and digital simulation software in our factory at present. Viscosity parameter is the most important parameter affecting water cut and ultimate recovery in software. The polymer viscosity at zero shear rate is used in calculating viscous concentration parameters. Usually, after artificial shearing, the viscosity parameters of polymer are estimated, which are in accordance with the actual production. Because it is impossible to give a more accurate shear coefficient, Often, the initial calculated viscosity is quite different from the actual one. It has caused great difficulties for subsequent adjustment. In this paper, the shear behavior under different injection systems is discussed. Finally, the optimum initial operating viscosity shear coefficient is determined.

**Key word:** Chemeor software, Polymer viscosity, Injection system, Viscosity shear coefficient.

## 1. Preface

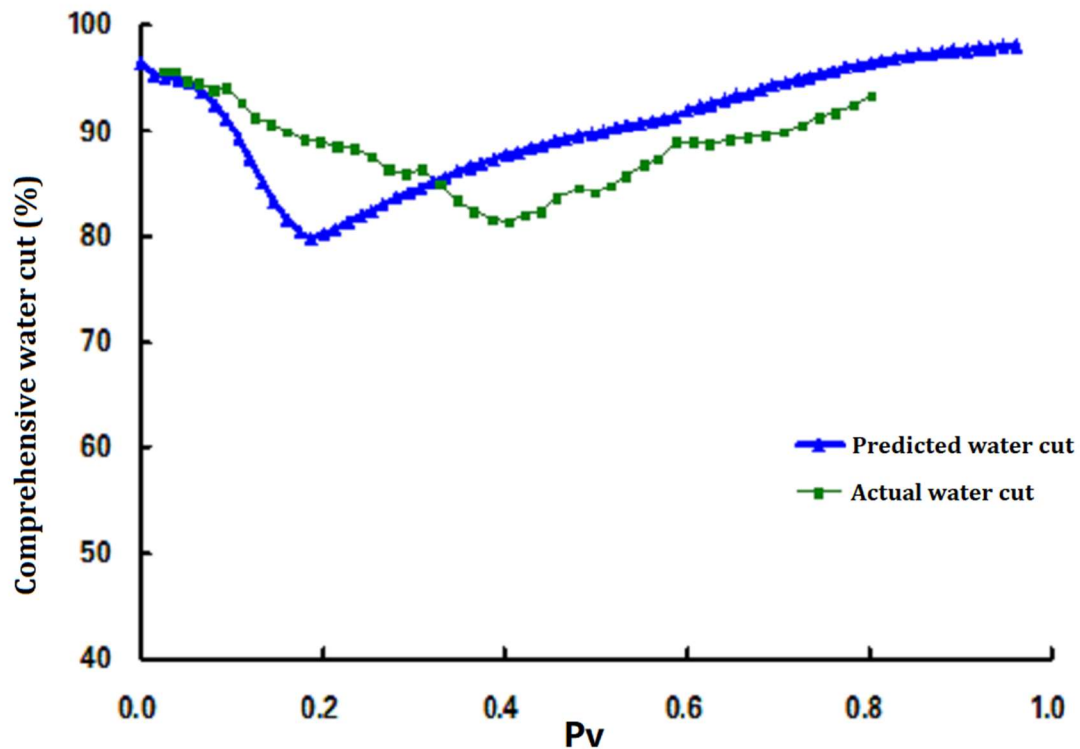
Numerical simulation technology of chemical flooding. It has been developed into one of the main research means in the design of tertiary oil recovery development plan, prediction and evaluation of oil displacement effect, and formulation of late adjustment and tapping potential measures.[1] At present, Chemeor software is only used to simulate chemical flooding in our factory. The accuracy of parameters of digital and analog software directly affects the results of digital and analog software. The viscous concentration parameters of polymer solution directly affect the water cut decline rate, the lowest water cut point and the ultimate recovery factor in the numerical simulation results. Therefore, the accuracy of polymer solution viscosity plays an important role in improving the accuracy of numerical simulation of polymer flooding.[2] In Chemeor software, the viscous concentration parameters can only be estimated by the polymer viscosity at zero shear rate. In order to simulate the loss of polymer viscosity caused by underground shear, the polymer viscosity was sheared artificially. The shear coefficient is usually set according to experience, which results in inaccurate estimation of viscous concentration parameters. The error between the digital-analog curve and the actual production situation is large. In order to explore different shear coefficients under different injection systems, the calculation principle of viscous concentration parameters is introduced. Based on the historical fitting of representative blocks, the initial operational shear coefficients suitable for different injection systems are explored[3-5].

## 2. Current Shear Coefficient Setting Method



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The viscosity parameters of polymer in Chemeor software have a great influence on the final numerical simulation results, especially on the rate of water cut decline, the lowest point and the ultimate recovery. Therefore, the accuracy of viscous concentration parameters directly affects the accuracy of digital and analog. However, the software itself can not shear the viscosity of polymer solution. Therefore, in estimating the viscosity concentration parameters, it is necessary to simulate the shear of the laboratory viscosity. Limited by the inaccurate knowledge of the shear capacity of formation and water quality to polymers, So the shear coefficient ( $k = 0.6$ ) is usually given based on experience when shearing polymer viscosities. This method neglects the shearing effect of salt content in water on polymer viscosity, and can not accurately express the shearing ability of different injection systems. As a result, the predicted and simulated curves of each chemical flooding block are quite different from the actual ones in the early stage (Fig. 1). By exploring the calculation principle of viscous concentration parameters and fitting the history of different injection system blocks, the optimum initial calculation shear coefficients under different injection systems are summarized [6-9].



**Fig. 1** Comparison between predicted water cut curve and actual water cut curve in the middle of Apricot Sixth Area

### 3. Calculation Principle of Viscous Concentration Parameters

Viscosity of polymer solution can improve oil-water flow ratio, thus enlarging sweep volume and enhancing oil recovery.[10-12] In Chemeor software, the viscous concentration curve of polymer is calculated by giving three viscous concentration parameters. The calculation equation is the cubic polynomial of polymer viscosity and polymer solution concentration at zero shear rate.

$$\mu_p^0 = \mu_w \left( 1 + (A_{p1}C_p + A_{p2}C_p^2 + A_{p3}C_p^3)C_{SEP}^{S_p} \right) \quad (1)$$

$\mu_p^0$ —Viscosity of Polymer Solution at Zero Shear Rate, mPa·s;

$\mu_w$  \_\_\_ Water viscosity, mPa·s;  
 $C_p$  \_\_\_ Polymer solution concentration, wt%;  
 $C_{SEP}$  \_\_\_ Salt content in water phase,  
 $A_p, S_p$  \_\_\_ Viscosity parameter to be solved;

### 3.1. Calculating Method of Salt Content $C_{SEP}$

Salt content in aqueous phase is determined by the concentration of cations and anions in water. The anions mainly refer to chloride ions ( $Cl^-$ ), while the cations mainly refer to calcium ions ( $Ca^{2+}$ ) and magnesium ions ( $Mg^{2+}$ ). The solution formula is:

$$C_{SEP} = C_{40} + (\beta - 1) \times C_{50} \quad (2)$$

Among them:  $C_{40}$ —Anion concentration;  $C_{50}$ —Cation concentration;  
 $\beta$ —Experimental constants

### 3.2. Calculating Method of Ion Concentration

The concentration of anions and cations in the test data need to be converted to be applied in Formula 2. The conversion process is the same for anions and cations. Taking anions as an example: The concentration of chloride ion in laboratory data is 1500mg/L. The relative molecular mass of chlorine is

known to be 35.5. The valence is 1. Therefore formula 2  $C_{40} = \frac{1500}{1000 \times 35.5} \times 1 = 0.042$

Cation is the same.

## 4. Determination of shear coefficient

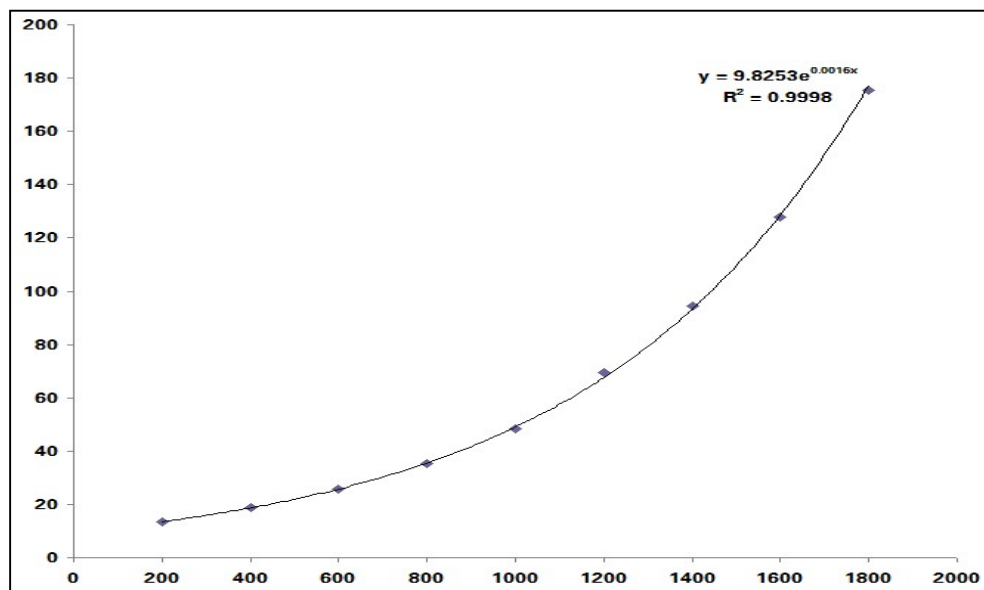
The main factors affecting the viscosity of polymers are as follows: Molecular weight of polymer, Water quality and surface technology. Based on the injection system of the main polymer injection blocks in Xingbei Oilfield, the shear coefficients of the three injection systems, i.e. clean-up 19 million, clean-up 25 million and clean-up 25 million, are discussed respectively[13-15].

### 4.1. Clearing up and Distributing 19 million Injection Systems

Referring to the data of water quality test in 2017, we can know the average ion concentration in clear water of Xingyi Water Distribution Station. The chloride ion concentration was 96.26 mg/L, the calcium ion concentration was 55.76 mg/L and the magnesium ion concentration was 7.85 mg/L. By calculation, the anion concentration ( $C_{40}$ ) is 0.0027 mg/L and the cation concentration ( $C_{50}$ ) is 0.0033 mg/L.

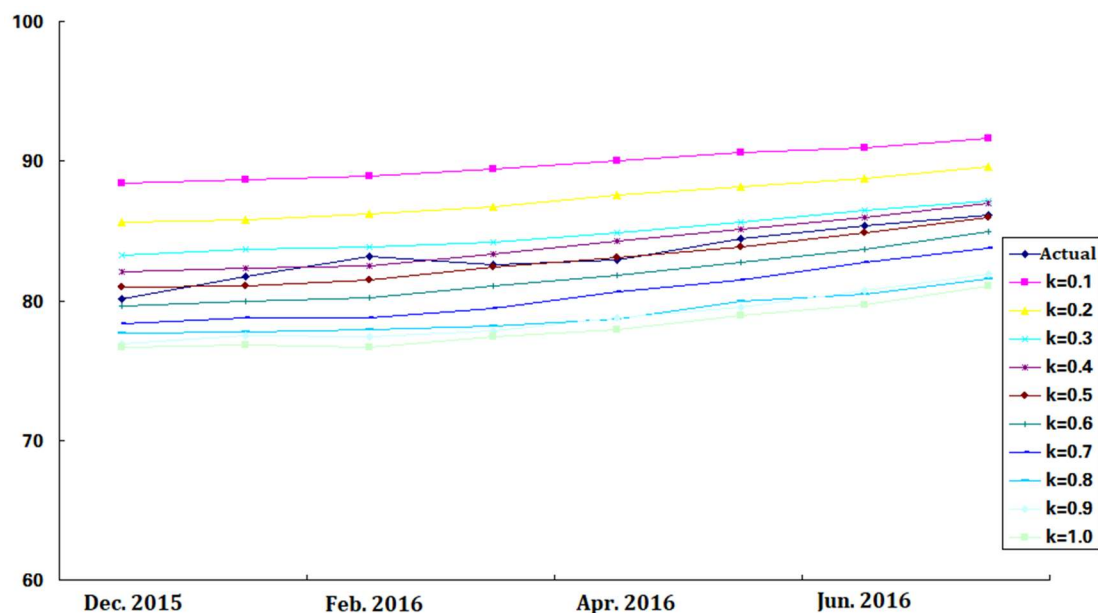
$$C_{SEP} = C_{40} + (\beta - 1) \times C_{50} = 0.0027 + (7.5 - 1) \times 0.0033 = 0.02415$$

From December 2015 to July 2016, XingbeiMiddle polymer injection block. Continuous injection of clear 19 million molecular weight polymer. The average value of the injected liquid viscous concentration test data in the middle of the six regions of apricot during this period was used to obtain the average viscous concentration relationship of the blocks.



**Fig 2** Xingbei Laboratory Viscosity Curve of 19 million Molecular Weight for Cleaning and Distillation

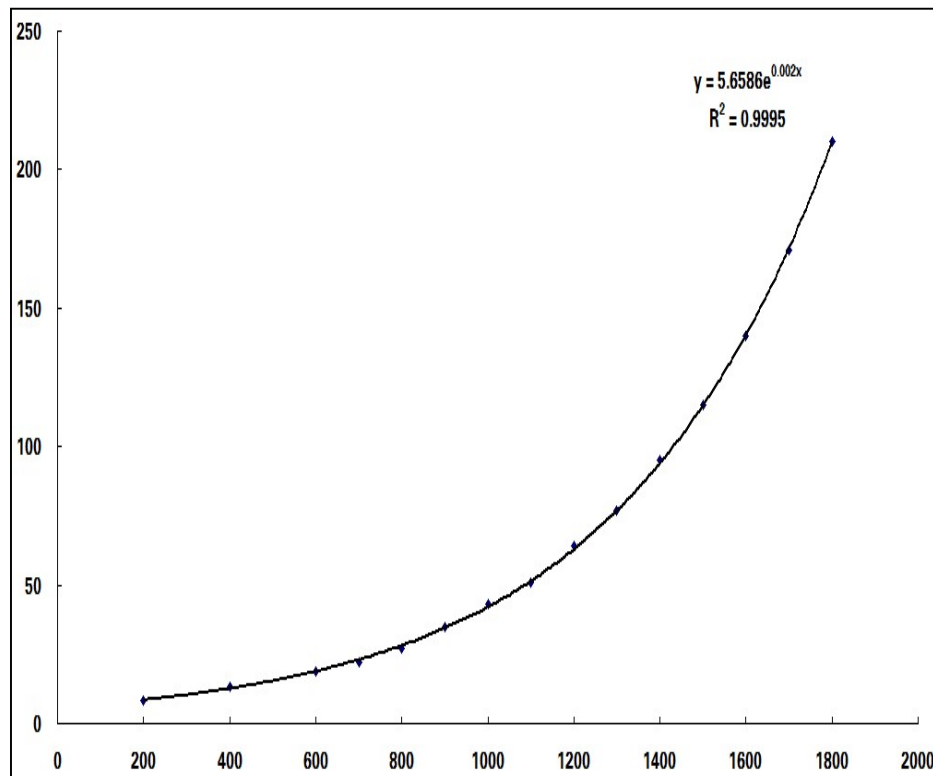
In the numerical model, the water content of different shear coefficients is fitted separately under the condition that other parameters remain unchanged. According to the fitting results, when the shear coefficient is 0.5, the water content curve is the closest to the actual value.



**Fig. 3** Xingbei Water Content Curves with Different Shear Coefficients for Cleaning 19 Million Molecular Weights

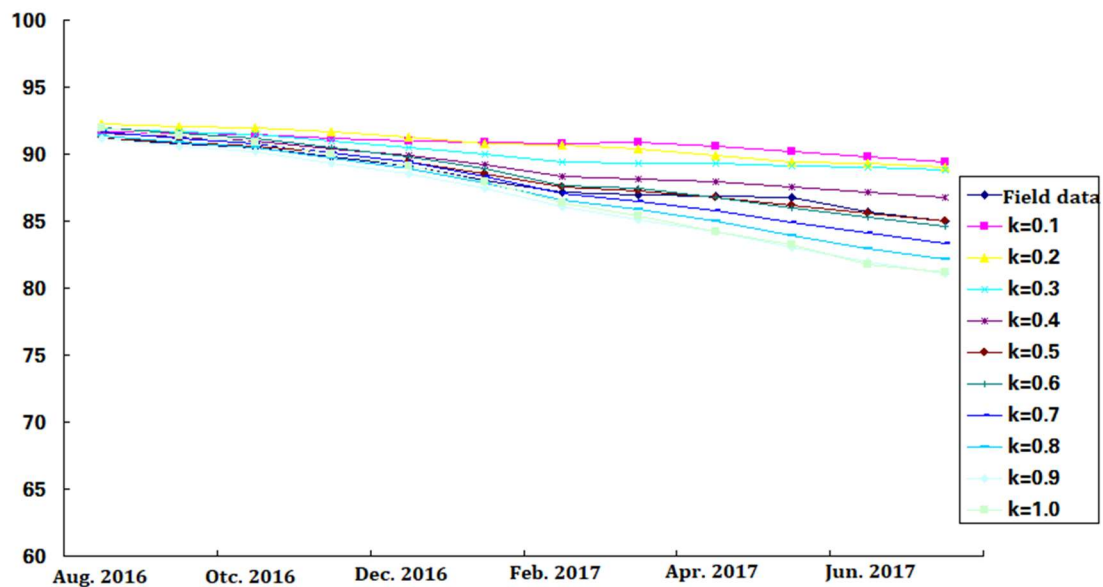
#### 4.2. Clearing up and Distributing 25 million Injection Systems

The average value of the injected liquid viscous concentration test data in the western part of Xingliu District during this period was used to obtain the average viscous concentration relationship of the blocks.



**Fig. 4** Xingbei Laboratory Viscosity Curve of Cleaning 25 Million Molecular Weight

In the numerical model, the water content of different shear coefficients is fitted separately under the condition that other parameters remain unchanged. According to the fitting results, when the shear coefficient is 0.5, the water content curve is the closest to the actual value.

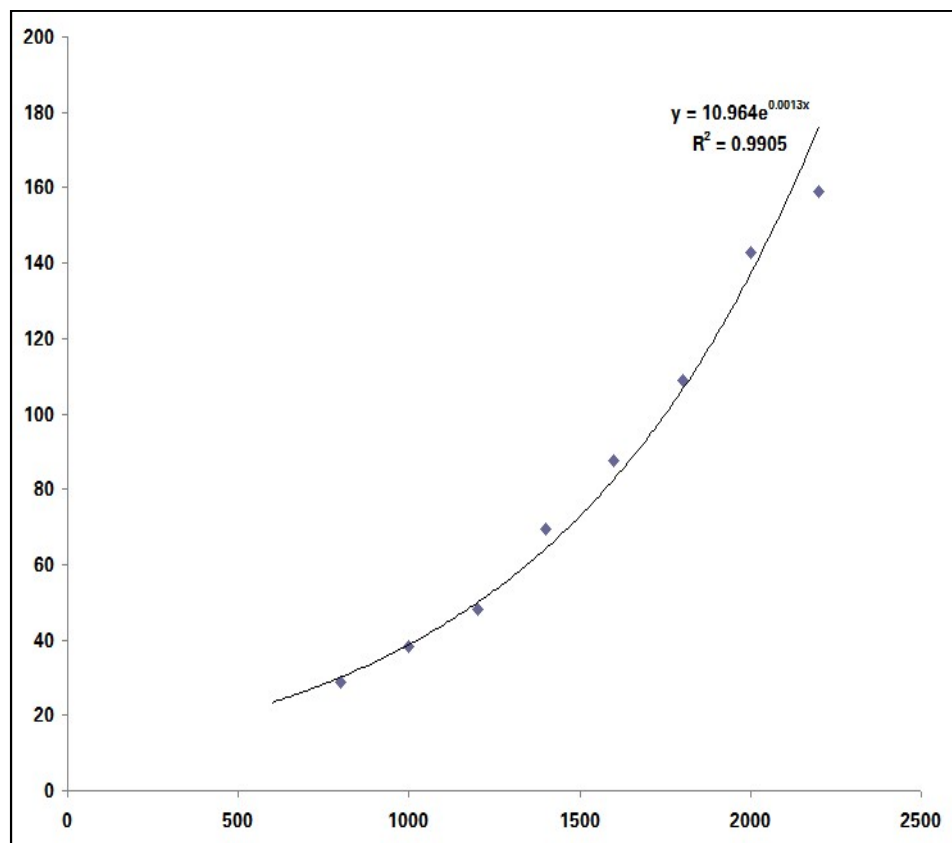


**Fig. 5** Water Content Curves with Different Shear Coefficients for Cleaning 25 Million Molecular Weights

#### 4.3. Cleaning and Distribution of Waste Water 25 million Injection System

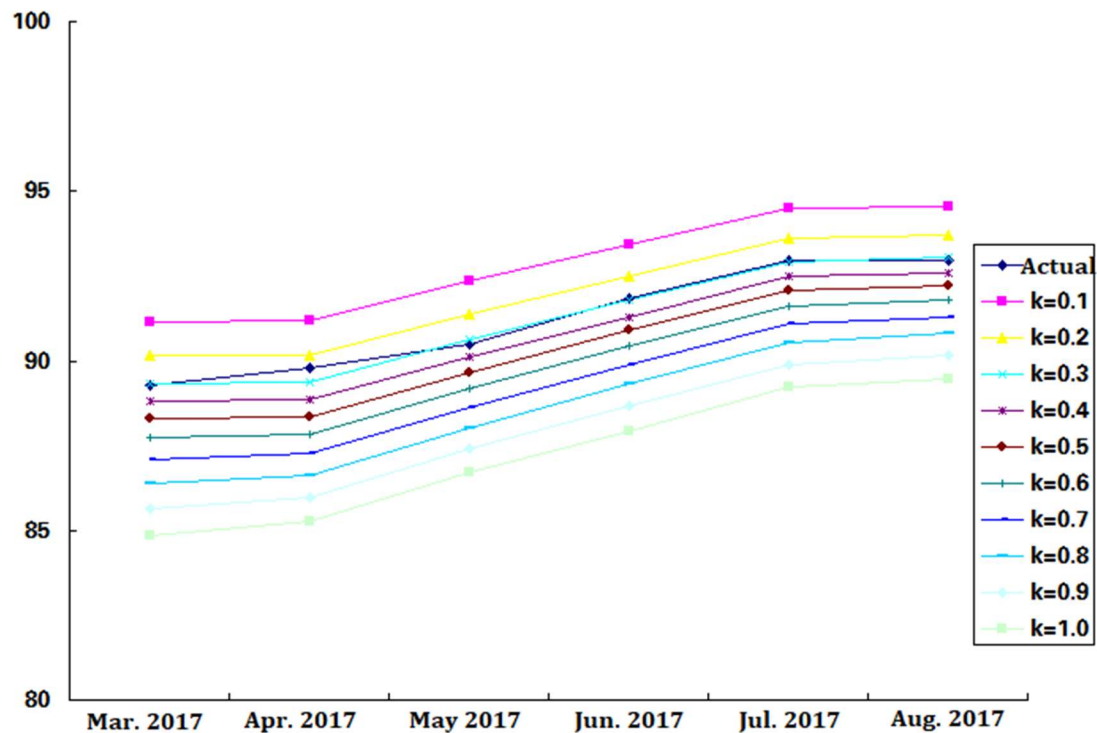
According to the ionic test data of Xing 12 water injection station since March, the average concentration of chloride ion is 770.4 mg/L, the average concentration of calcium ion is 46.09 mg/L and the average concentration of magnesium ion is 9.12 mg/L. According to formula 2:  $CSEP = C40 + (\beta - 1) \times C50 = 0.217 + (7.5 - 1) \times 0.003 = 0.2365$

Average Viscosity-Density Relation of Blocks



**Fig. 6** Laboratory Viscosity Curve of 25 Million Molecular Weight for Cleaning and Distributing Pollutants

Through calculation, the average laboratory viscosity was sheared, and the shear coefficient range was 1-0.1. The corresponding viscous concentration parameters were calculated respectively. Therefore, the shear coefficient should be 0.3 for the 25 million injection system of Xingliuzhong Cleaning Distribution Pollution, and the initial calculation should be carried out.



**Fig. 7** Water Content Curves of Different Shear Coefficients with 25 million Molecular Weight for Cleaning up Pollutants

## 5. Conclusion

(1) The parameters of polymer viscous concentration in Chemeor software are mainly related to the test viscous concentration and salt content in water.

(2) The shear coefficients of polymer solutions from different injection systems and sewage sources are different due to the different salt content in water.

(3) The initial shear coefficient  $k=0.5$  of 19 million molecular weight polymer and 25 million molecular weight polymer is the best, and the shear coefficient of the dilute system should be determined by its salt content in water.

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