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PROSPECTS OF USING COMPLEX COAGULATION SYSTEMS BASED ON CHITOSAN IN WATER TREATMENT PROCESSES

1. Introduction. Nowadays involving environmentally friendly reagents and materials is gaining additional importance in water treatment processes, especially if we take into consideration the latest developments in science. Aluminium sulfate, aluminium chloride and ferric chloride are widely used in coagulation processes, however, as a result of involving these coagulants the concentration of metal ions dissolved in water increases. Therefore, it is advisable to give preference to inorganic coagulants in combination with synthetic or natural flocculants. Due to the growing demand for environmentally friendly materials it could be advisable to use flocculants based on chitosan in order to improve the coagulation and flocculation processes. Chitosan, which is a polysaccharide produced by chitin deacetylation, is a positively charged natural and non-toxic polyelectrolyte widely used in the flocculation of negatively charged suspended particles in water treatment (Figure 1) [1]. Therefore, studying and developing effective complex coagulants that could replace conventional coagulation systems becomes a topical problem nowadays. In this research we analyzed the optimum dosage and pH of complex coagulation systems with chitosan using Jar test methodology.

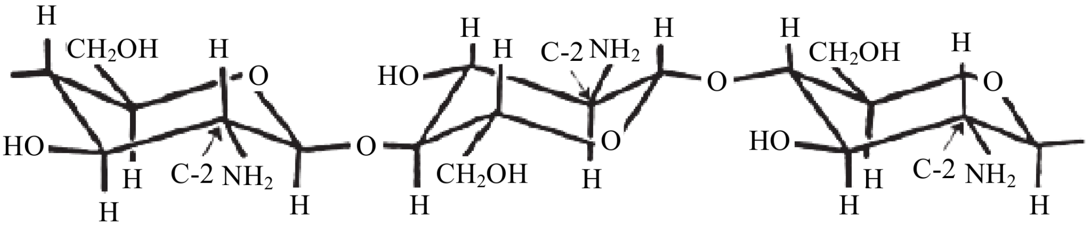


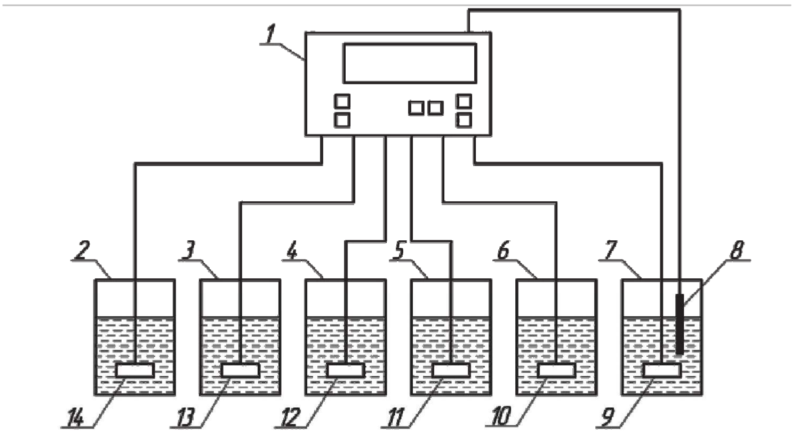
Figure 1 – Chitosan

2. Methods and materials. For experimental studies we used a conventional jar test apparatus (Figure 2) which consists of 6 1 L beakers, 6 mechanical stirrers with adjustable rotation speed and mixing time. These parameters are regulated by using Flocculator 2000. The device is additionally equipped with a pH electrode to control the pH in water samples. The pH of water sample was adjusted using HCl and NaOH solutions with concentration 0.1M. All tests were carried out by using synthetic coloured water. To prepare dyed solutions, 0.1 g of dye (active blue 3SWT) was dissolved in 1 L of distilled water and stirred on a magnetic stirrer at a rate of 20 rpm. This solution was used as a starting material for preparation of model solutions with a dye concentration of 0.02 g/l. Experiment was conducted at 140 rpm of mixing rate for 3 min after adding coagulant then the speed was redused to 50 rpm for 10 min and 20 min of setteling time.

In the experiment, $FeCl_3 \cdot 6H_2O$ and $Al_2(SO_4)_3 \cdot 18H_2O$ were used as coagulants. To prepare solutions of coagulants, 10 g of the substance was dissolved in 100 ml of distilled water, thus obtaining a concentration of 10% coagulant solution. Flocculant solution was prepared by dissolving 1 g of chitosan (manufactured by ZAO Bioprogress with a degree of deacetylation of 82%) in 1 ml acetic acid and diluted in 100 ml of distilled water. The resulting solution was stirred with a magnetic stirrer until chitosan dissolves completely.

Residual iron levels were measured with the help of the spectrophotometry method. Colour levels were determined using visual method.

3. Results. The objective of the first stage of the research was to determine the optimal dose of coagulant $FeCl_3$. The results are presented in Figure 3. The effect of the dosage under question was analyzed at pH 7.5 for a range of coagulant dosage which varied from 20 mg/l to 70 mg/l.



1 – Flocculator 2000 Kemira; 2-7 – beaker volume of 1 L; 8 – pH electrode; 9-14 – mechanical stirrers

Figure 2 – Laboratory equipment for Jar tests

Figure 3 demonstrates that an increase in the dose of coagulant colour level remained almost the same (from 74 to 73 units), while iron concentration in treated water increased from 1 to 33 mg/l. Therefore, the optimum ferric chloride dosage for this research was determined at 20 mg/l.

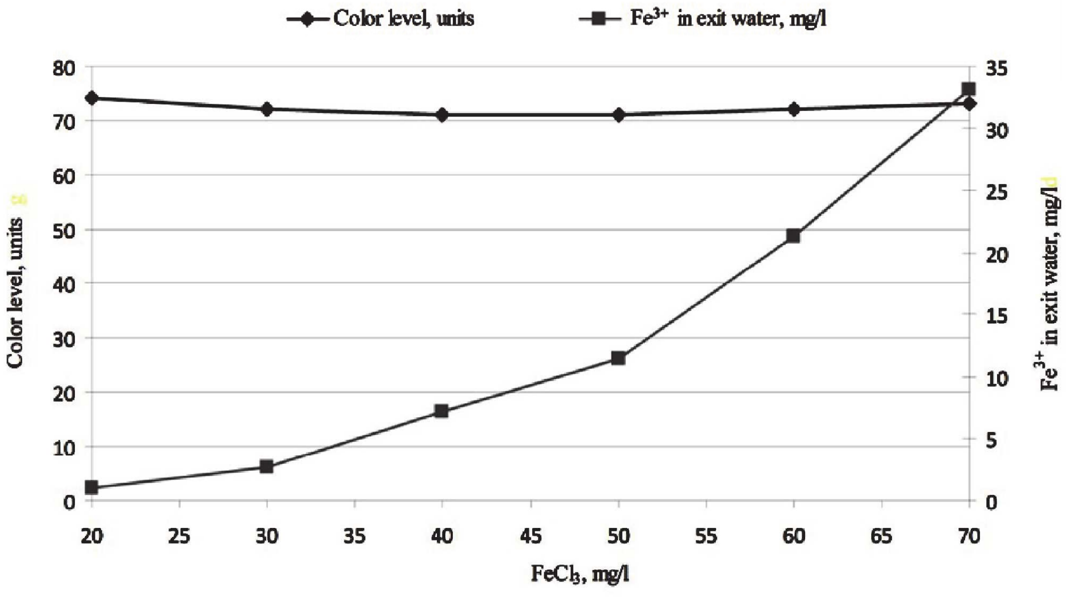


Figure 3 – Determination of $FeCl_3$ optimum dosage (mg/l) f or removal of colour level in synthetic water at pH of 7,5

The next stage of the experiment served to determine the optimal dose of chitosan in combination with coagulant at pH = 7.5. The experimental results are shown in Figure 4. $FeCl_3$ (20 mg/l) was used as the coagulant. Dosage of chitosan varied from 2 to 20 mg/l.

Taking the figures into consideration, the optimum dosage of chitosan was established as 15 mg/l in complex with $FeCl_3$. Increasing the specified dosage causes more intensive colour levels, probably due to restabilization of suspended solids. The current experiment also demonstrated that removing colour was more effective and its level dropped to 21 units in comparison to 74 units in the previous experiment.

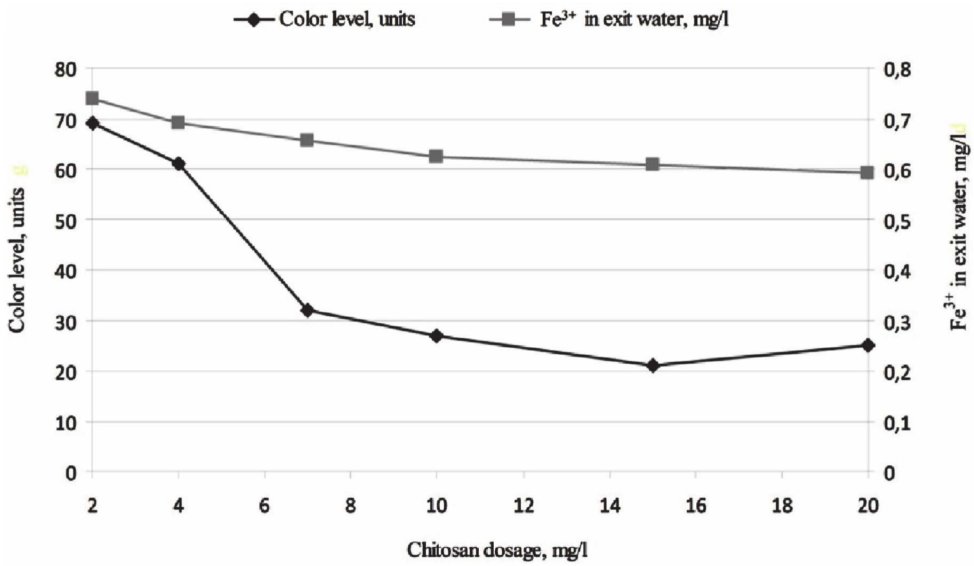


Figure 4 – Determining optimum dosage of chitosan in combination with $FeCl_3$ concentration of 20 mg/l at pH 7.5 to decrease colour levels in water solutions

In the next experiment Jar tests were conducted to determine optimum pH values for comlex coagulants. The results were presented in Figure 5.

The effect of pH was analyzed at previously determined optimum dosages of complex coagulants, for pH range varying from pH 3.5 to pH 9.5.

By analyzing this curve, it was proved that complex produces significant reduction of colour levels between pH 8.5-9.5. The highest degree of cleaning was achieved at pH 9.5 – colour level was 10 units, residual iron remained 0.17 mg/l. The excess alkalinity in water was required to complete hydrolysis of coagulant.

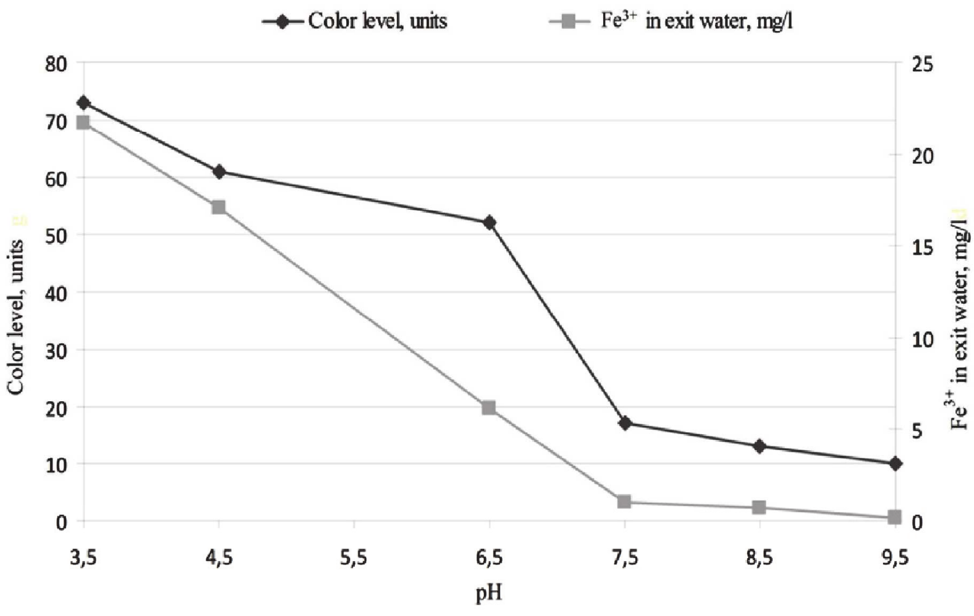


Figure 5 – Effect of pH on the colour removal in water solutions, using complex coagulant: $FeCl_3$:chitosan at ratio of 1.3:1

4. Conclusions. The results of this study prove that using complex systems has several advantages as compared with conventional coagulants for water treatment: they increase formation of flakes and their sedimentation, reduce costs of coagulants and flocculant, reduce the concentration of ions Fe^{3+} in purified water, increase the level of cleaning coloured solutions. It was shown that chitosan successfully promotes flocculation of anionic suspended particles and reduces content of metal ions in purified water.

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ФЛОТОЭКСТРАКЦИОННОЕ УДАЛЕНИЕ ИОНОВ ТЯЖЕЛЫХ МЕТАЛЛОВ ИЗ СТОЧНЫХ ВОД

Одним из основных источников загрязнения поверхностных вод тяжелыми металлами являются сточные воды гальванических производств, а также сточные воды обогатительных фабрик. Для удаления ионов тяжелых металлов из сточных вод гальванических производств используют в основном реагентные методы очистки, основным недостатком которых являются безвозвратная потеря ценных компонентов и необходимость утилизации больших количеств влажного осадка. Поэтому поиск методов, позволяющих проводить регенерацию ценных компонентов, является одним из основных направлений развития технологий очистки сточных вод от ионов тяжелых металлов.

К числу распространённых методов очистки сточных вод от ионов токсичных металлов относятся флотация и экстракция. Экстракция эффективна, когда концентрация токсичных веществ превышает 1 г/дм^3, а кислотность водной фазы высока. При выделении металлов из более разбавленных растворов применение экстракции нецелесообразно из-за повышенного расхода дорогостоящих экстрагентов. Ионная флотация, в свою очередь, высокопроизводительна и эффективна при переработке низкоконцентрированных растворов, однако в этом случае часто наблюдается загрязнение пенного продукта очищаемым раствором и содержащимися в нём примесями. Флотоэкстракция является комбинацией ионной флотации и жидкостной экстракции и сочетает положительные стороны обоих методов. Под флотоэкстракцией понимают такой флотационный процесс, при котором сфлотированное вещество (сублат) концентрируется в тонком слое органической несмешивающейся с водой жидкости, находящейся на поверхности водной фазы. В отличие от обычной жидкостной экстракции, в данном процессе массопередача из водной в органическую фазу происходит с участием пузырьков газа. Процесс реализуется при небольших расходах газа, не разрушающих верхний слой органической жидкости. Сублат может, как раство-