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THE EFFECTIVENESS OF COAGULANTS FOR TURBIDITY AND COLOR REMOVAL FROM NATURAL WATER

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ABSTRACT

In this work, the effectiveness of the use of coagulants $Al_2(SO_4)_3 \cdot 18H_2O$ and RM-1 in reducing the level of turbidity and colour (reduction in colour) of natural water was investigated. The object of the study is natural water, namely water from the Dnipro River. The results showed that the optimal dose of coagulant $Al_2(SO_4)_3 \cdot 18H_2O$ was 10.0 mg dm^{-3}. The optimal dose of coagulant RM-1 was also 10.0 mg dm^{-3}. Residual turbidity and colour are reduced to 0.0 mg dm^{-3}, 12.5^0, 19^0, when using $Al_2(SO_4)_3 \cdot 18H_2O$ and RM-1, respectively. Since the residual concentration of aluminium in purified water in all samples after purification with coagulants was less than 0.05 mg dm^{-3}, it is reasonable to use these coagulants, as they do not have a negative effect on the health of consumers. The efficiency of using the RM-1 coagulant to remove turbidity and reduce the colour of the natural water of the Dnipro is high, so this coagulant has the potential to be chosen as a new coagulant.

Keywords: coagulant, RM-1, $Al_2(SO_4)_3x18H_2O$, turbidity, colour, low-waste technologies, coagulation, filtration.

INTRODUCTION

Today, the main sources of centralized water supply in Ukraine are surface sources, especially in large cities [1 - 3]. Unfortunately, almost all water from surface sources, from which consumption is carried out, has been significantly affected by harmful anthropogenic factors in recent years [4 - 6]. The main reasons for the significant deterioration of aquatic ecosystems are the following lack of systematic monitoring studies of water quality and the presence of frequent facts of pollution due to irresponsible economic activity [7, 8]. Today there is an ecological non-conformance of the state of river basins [9, 10]. The main expedient technological technique for removing coarsely dispersed impurities from water, and not only those in a suspended state, but also colloidal organic pollutants that are present in water in dissolved form, is the process of coagulation due to the introduction of coagulants into the water. The effectiveness of lighting is determined by the choice of coagulant and the right dose, etc [11, 12].

In modern society, to comply with the basic requirements for the quality of drinking and technical water consumed, it is usually clarified and then disinfected as needed. In the process of clarification, suspended and colloidal particles, organic and inorganic impurities, such as suspended or colloidal particles and dissolved organic substances, which are the main pollutants of natural waters, are removed [13 - 15].

It is worth noting that standard drinking water purification processes include coagulation, flocculation, sedimentation, filtration, and disinfection [16 - 18]. Coagulation is the first and main stage of purification. It is an effective process for removing small solid and colloidal particles from natural water.

Coagulants, in turn, consist of inorganic salts, such as Al^{3+} or Fe^{3+}. They also contain Mg^{2+} ions, which serve mainly for water purification and purification of polluted wastewater [19 - 21]. Compounds, i.e., coagulants, are added to the water to be purified, which can glue even the smallest particles together and, accordingly, increase their weight [22 - 24]. As a result, the enlarged conglomerates settle to the bottom of the sumps faster, and the processes that could take weeks take place in just a few hours, so that the water reaches the houses faster. The main advantages and disadvantages of using coagulants in water preparation and water treatment are shown in Fig. 1.

The aim of the work was to develop an effective technology for chemical treatment of water from the Dnipro River using coagulants $Al_2(SO_4)_3 \cdot 18H_2O$ and RM-1, to obtain high-quality water suitable for various industrial applications.

EXPERIMENTAL

The experimental part of the work was carried out in a modern laboratory. It was for the purpose of conducting the experiment that samples were taken from the Dnipro River at monthly intervals, 3 times. (The time difference between the three samplings was 1 month). There were 3 such fences. The characteristics of the water of the Dnipro River are given in Table 1.

Coagulation analysis was performed in the laboratory in 1000 ml beakers. The study consisted of two stages: the first stage included rather dynamic mixing of water samples of the Dnipro River for 5 min. After mixing, the settling process was carried out for 60 min. At the end of the settling process, the process of measuring the

Table 1. Characteristics of qualitative variability of the Dnipro River.

Characteristics	Months		
	April	May	June
Suspended particles, mg dm^{-3}	3.80	3.60	3.90
Color, degrees	95.00	75.00	123.00
Turbidity, mg dm^{-3}	14.50	10.10	19.80
Temperature, °	10.00	13.20	16.80
pH	8.00	7.80	8.30
CO_2, mg dm^{-3}	10.08	12.30	13.00
O_2, mg dm^{-3}	10.09	11.70	11.00

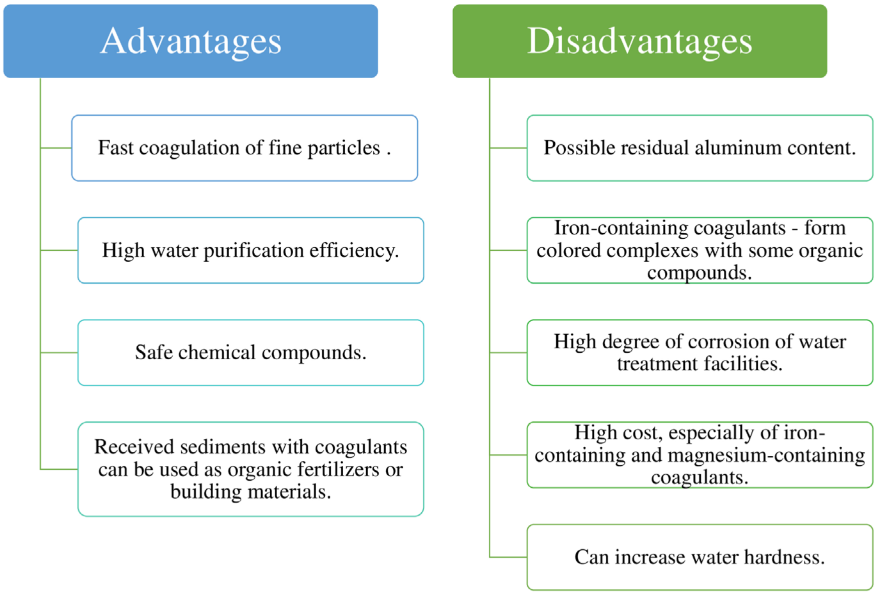

Fig. 1. The main advantages and disadvantages of using coagulants in water treatment or wastewater treatment.

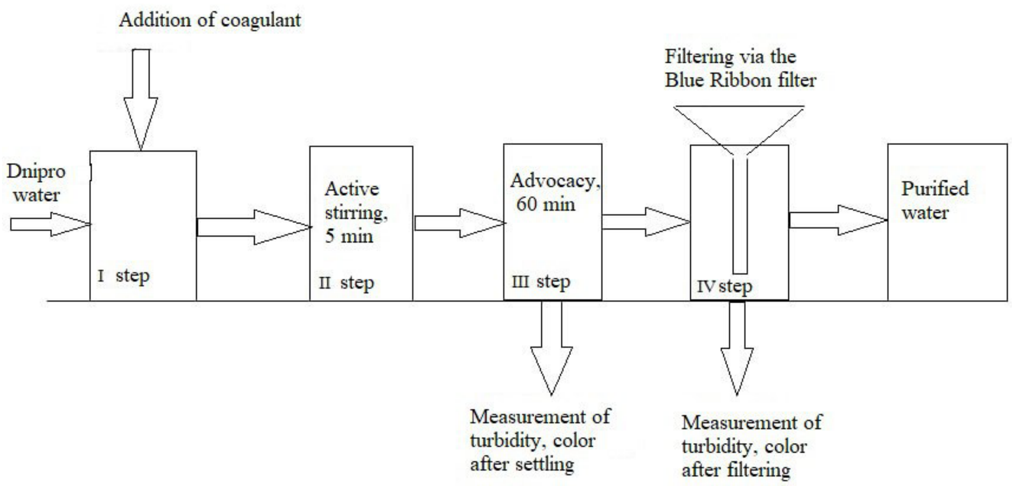

Fig. 2. The main stages of an experimental study on the effect of coagulants $Al_2(SO_4)_3$ 18 H_2O and RM-1 on reducing turbidity and colour.

turbidity and colour of the water was carried out. The second stage included filtering the coagulated water after the settling process. The settled water from the previous stages was filtered using a Blue-Ribbon filter, and then the turbidity and colour were again measured (Fig. 2).

The obtained samples were also examined for residual turbidity, colour and aluminium ion content. All experimental studies were conducted according to standard methods of water and wastewater analysis.

Water turbidity is an indicator that characterizes the decrease in water transparency due to the presence of inorganic and organic finely dispersed suspensions, as well as the development of planktonic organisms. The reasons for the turbidity of water can be the presence of clay, inorganic compounds (aluminium hydroxide, carbonates of various metals), as well as organic impurities or microorganisms. Oxidation of iron and manganese compounds by air oxygen can also be the cause, which leads to the formation of colloids.

The turbidity of water in rivers and coastal areas of reservoirs increases during rains, floods, and melting glaciers. As a rule, the level of turbidity in reservoirs is lowest in winter, highest in spring and during summer rains.

The turbidity of drinking water is regulated mainly because turbid water protects microorganisms during ultraviolet disinfection and facilitates the growth of bacteria, as well as for aesthetic reasons.

Water samples for determining turbidity are not preserved. The analysis is carried out in the laboratory as soon as possible, but no later than 6 hours after sampling, and for turbidity determination no later than 24 hours after sampling.

The determination of turbidity is based either on the registration of scattered radiation, which occurs when radiation in the visible or near-infrared region of the spectrum passes through a water sample containing suspended particles (nephelometric method), or on the registration of the attenuation of radiation passing through a water sample containing turbidity (turbidimetric method).

We determine turbidity with the help of FEK. We use the wavelength & -670 nm (worm), r = 3, L = 50 mm. The sample is measured relative to distilled water. And accordingly, we determine the obtained results according to the schedule. If the sample was diluted, we consider the dilution after determination on the calibration graph. If the sample was diluted, we consider the dilution after determination on the calibration graph.

We determine the colour with the help of FEK. We use the wavelength & -400 nm (vial), r = 2, L = 50 mm. The sample is measured relative to distilled water. And accordingly, we determine the obtained results according to the schedule. If the sample was diluted, we consider the dilution after determination on the calibration graph.

It should be noted that the entire spectrum of analysis, namely, turbidity, color and residual aluminium, was carried out in accordance with the methods of DSTU and GOST. Thus, turbidity according to DSTU ISO 702: 2003 – "Water quality. Determination of turbidity", colour according to DSTU ISO 7887:2003 - "Water quality. Determination and study of colouring" and residual aluminium according to GOST 18165-89.

In the work, two coagulants were used for research. The first and well-known coagulant was $Al_2(SO_4)_3 \cdot 18H_2O$, purchased from Multichem. The second coagulant is RM-1, it is a coagulant manufactured in laboratory conditions from secondary spent raw materials, namely from the red sludge of the Mykolaiv Alumina Plant.

For a detailed evaluation of the efficiency of water purification, namely the reduction of turbidity and color, five doses of coagulants were used during the experimental study: 1.0, 2.5, 5.0, 7.5 and 10.0 mg dm^{-3} (in calculated on Al_2O_3).

Water sampling was carried out three times, with a frequency of one month, for a better understanding of the results obtained from the initial characteristics of the Dnipro River.

RESULTS AND DISCUSSION

The content of suspended solids in spring water (turbidity and transparency) changes throughout the year, increasing during the rainy season and being maximal during floods. Water turbidity during this period is also high (up to ~ 20 mg dm^{-3} and more). The lowest turbidity of river water is observed in winter. The high colour of water impairs its organoleptic properties and affects the development of aquatic plant and animal organisms as a result of a sharp decrease in the concentration of dissolved oxygen in water, which is spent on the oxidation of iron compounds and humic substances.

$Al_2(SO_4)_3 \cdot 18H_2O$ is a well-known coagulant, but it was interesting to determine the optimal doses for different water parameters. The synthesized coagulant RM-1 allows effective removal of sulfates while simultaneously softening water [25] and clarifying water [26]. However, only 1 model solution has been tested, which requires further research for different compositions as water quality varies.

For the coagulant synthesis, the red mud of the Mykolaiv alumina plant (Ukraine) was used. The chemical composition of red mud was investigated by means of X-ray diffraction analysis, the results of which are shown in Table 2.

After carrying out a number of laboratory studies, the effect of doses of coagulants $Al_2(SO_4)_3 \cdot 18H_2O$ and RM-1 on the effectiveness of removing turbidity and color can be seen in the Tables 3, 4.

As a result of the conducted experimental research, $Al_2(SO_4)_3 \cdot 18H_2O$ and RM-1 are quite effective reagents for cleaning polluted waters from turbidity, reducing the latter from 20 mg dm^{-3} to 0.00 mg dm^{-3}. The coagulant, which was synthesized by us, based on its high-performance indicators, shows sufficient potential for large-scale industrial implementation, as it is a more cost-effective and affordable option for use in water treatment and water treatment industries. Therefore, these findings nullify concerns about turbidity affecting the performance and performance of water filters.

Thus, the results obtained reduce concerns about turbidity affecting the maintenance and operation of water filters. Although turbidity is not a direct indicator of health risk, numerous studies show a strong relationship between the removal of turbidity and the reduction of protozoa in treated water. The residual turbidity of the water purified by settling and filtering with $Al_2(SO_4)_3 \cdot 18H_2O$ and RM-1 was 0 mg dm^{-3}, which is a very good level.

If we talk about the effectiveness of colour reduction with the coagulant PM-1, we can note that according to experimental data, the coagulant PM-1 removes approximately 89 % of colour from natural Dnipro water. If the dose of coagulant is increased to 10.00 mg dm^{-3}, the effectiveness of reducing turbidity and color

Table 2. Chemical composition of red mud.

Component	Content of components in red mud, wt. %
Fe_2O_3	40 - 55
Al_2O_3	14 - 18
SiO_2	5 - 10
CaO	5 - 10
TiO_2	4 - 6
Na_2O	2 - 4

Table 3. Effect of coagulant RM-1 on the effectiveness of reducing turbidity and color of natural water after settling (2 h) and filtration.

Coagulant doze, mg dm^{-3}, by Al_2O_3	Turbidity					Filtrate color				
	Turbidity, mg dm^{-3}			Degree of clarification, A, %		Filtrate color, degrees on the CCS			Degree of discoloration, A, %	
	primary	after settling	after settling and filtering	after settling	after settling and filtering	primary	after settling	after settling and filtering	after settling	after settling and filtering
-	10.10	10.00	3.80	0.99	62.38	75.00	75.00	43.80	0.00	41.60
1.0	10.10	3.90	0.00	61.39	100.00	75.00	48.10	27.40	35.87	63.47
2.5	10.10	4.10	0.00	59.41	100.00	75.00	51.10	22.00	31.87	70.67
5.0	10.10	6.70	0.00	33.66	100.00	75.00	53.30	19.10	28.93	74.53
7.5	10.10	6.90	0.00	31.68	100.00	75.00	54.50	17.40	27.33	76.80
10.0	10.10	7.70	0.00	23.76	100.00	75.00	52.80	12.50	29.60	83.33
-	14.50	14.30	3.90	1.38	73.10	95.00	95.00	55.70	0.00	41.37
1.0	14.50	5.90	0.00	59.31	100.00	95.00	55.10	36.70	42.00	61.37
2.5	14.50	6.00	0.00	58.62	100.00	95.00	61.90	32.70	34.84	65.58
5.0	14.50	10.80	0.00	25.52	100.00	95.00	78.10	27.10	17.79	71.47
7.5	14.50	11.10	0.00	23.45	100.00	95.00	75.30	21.50	20.74	77.37
10.0	14.50	14.30	0.00	1.38	100.00	95.00	71.10	13.10	25.16	86.21
-	19.80	19.60	4.00	1.01	79.80	123.00	123.00	61.10	0.00	50.33
1.0	19.80	6.50	0.00	67.17	100.00	123.00	59.40	45.30	51.71	63.17
2.5	19.80	6.80	0.00	65.66	100.00	123.00	61.30	39.30	50.16	68.05
5.0	19.80	12.50	0.00	36.87	100.00	123.00	63.70	29.10	48.21	76.34
7.5	19.80	12.90	0.00	34.85	100.00	123.00	62.80	21.90	48.94	82.20
10.0	19.80	15.10	0.00	23.74	100.00	123.00	59.90	13.50	51.30	89.02

Table 4. The effect of the coagulant $Al_2(SO_4)_3 \cdot 18H_2O$ on the effectiveness of reducing the turbidity and color of natural water after settling (2 h) and filtration.

Coagulant doze, mg dm^{-3}, by Al_2O_3	Turbidity					Filtrate colour				
	Turbidity, mg dm^{-3}			Degree of clarification, A, %		Filtrate color, degrees on the CCS			Degree of discoloration, A, %	
	primary	after settling	after settling and filtering	after settling	after settling and filtering	primary	after settling	after settling and filtering	after settling	after settling and filtering
–	10.10	10.00	3.95	0.99	60.89	75.00	75.00	43.70	0.00	41.73
1.0	10.10	4.10	0.00	59.41	100.00	75.00	71.00	39.40	5.33	47.47
2.5	10.10	4.40	0.00	56.44	100.00	75.00	70.70	38.00	5.73	49.33
5.0	10.10	7.00	0.00	30.69	100.00	75.00	70.90	28.50	5.47	62.00
7.5	10.10	7.10	0.00	29.70	100.00	75.00	71.40	19.90	4.80	73.47
10.0	10.10	7.90	0.00	21.78	100.00	75.00	72.00	19.30	4.00	74.27
–	14.50	14.30	4.00	1.38	72.41	95.00	95.00	55.70	0.00	41.37
1.0	14.50	12.90	0.00	11.03	100.00	95.00	89.00	41.30	6.32	56.53
2.5	14.50	7.30	0.00	49.66	100.00	95.00	89.50	39.00	5.79	58.95
5.0	14.50	6.70	0.00	53.79	100.00	95.00	91.30	29.20	3.89	69.26
7.5	14.50	14.50	0.00	0.00	100.00	95.00	90.90	25.30	4.32	73.37
10.0	14.50	14.50	0.00	0.00	100.00	95.00	91.70	19.90	3.47	79.05
–	19.80	19.60	4.20	1.01	78.79	123.00	123.00	61.10	0.00	50.33
1.0	19.80	7.30	0.00	63.13	100.00	123.00	107.10	47.30	12.93	61.54
2.5	19.80	7.50	0.00	62.12	100.00	123.00	106.50	41.10	13.41	66.59
5.0	19.80	13.30	0.00	32.83	100.00	123.00	105.20	35.30	14.47	71.30
7.5	19.80	13.90	0.00	29.80	100.00	123.00	106.30	27.40	13.58	77.72
10.0	19.80	15.90	0.00	19.70	100.00	123.00	104.00	19.90	15.45	83.82

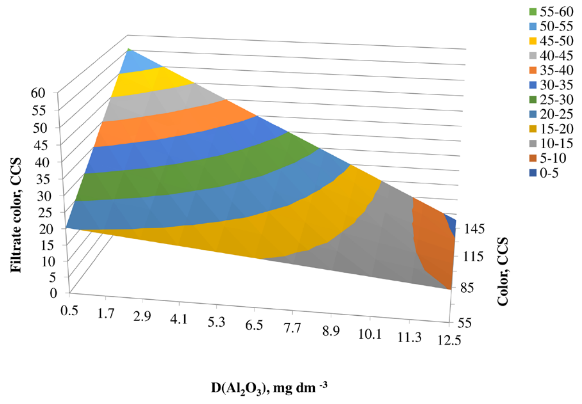

Fig. 3. Residual colour of RM-1 depending on initial colour and dose of coagulant.

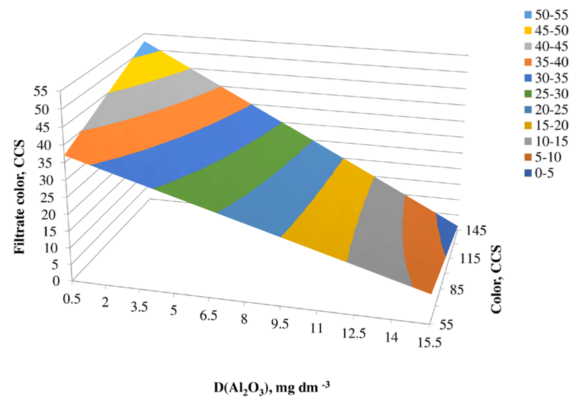

Fig. 4. Residual colour $Al_2(SO_4)_3$ 18 H_2O depending on the initial colour and coagulant dose.

increases (as in Fig. 3). During the experiment, it was observed that when the dose of coagulant PM-1 was increased to 10.00 mg dm^{-3}, the efficiency of colour removal increased from 62 to 89 %, which is quite a positive result. (Table 2, 3.).

If we compare the use of $Al_2(SO_4)_3 \cdot 18H_2O$, we see that the results were relatively smaller. At a coagulant dose of 10.0 mg dm^{-3}, the degree of colour extraction was 75 - 79 % (Fig. 4). Thus, the fact follows that the use of coagulant RM-1 is more effective and more appropriate. As the use of the latter allows you to get rid of colour by almost 90 %, obtaining coagulant from secondary raw materials, namely from the red sludge of the Mykolaiv Aluminous Plant, is promising and economically profitable in production as a new product on the market of coagulants. It also does an excellent job of removing turbidity.

Since the residual concentration of aluminum in purified water in all samples after purification with coagulants was less than 0.05 mg dm^{-3}, it is reasonable to use these coagulants, as they do not have a negative effect on the health of consumers.

Today, the direction of zero-waste and low-waste technologies is the dominant trend among global manufacturers, which reduces the negative impact on the environment, and more precisely, reduces the amount of accumulated solid waste, the volume of discharges of liquid polluting effluents and m^3 emissions of harmful and poisonous gaseous emissions. Therefore, it is advisable to develop low-waste technologies for desalination and water purification. The efficiency of using coagulant RM-1 to remove turbidity and reduce the colour of natural water of the Dnipro is high, so this coagulant has the potential to be chosen as a new coagulant, namely a coagulant that is relatively cheaper, economically beneficial and available in the field of environmental protection. The production of this RM-1 coagulant is the result of applying the rhetoric of low-waste technologies.

CONCLUSIONS

It was established that the most optimal dose for treatment of natural water of the Dnipro River and $Al_2(SO_4)_3 \cdot 18H_2O$, and PM-1 is 10.0 mg dm^{-3}. These coagulants showed a high level of efficiency in removing turbidity (100 %), while the degree of decolorization was 79 % for $Al_2(SO_4)_3 \cdot 18H_2O$ and 89 % for RM-1.

Quite positive results of many laboratories experimental studies really indicate that the coagulant RM-1 obtained by us has a great high potential for large-scale use in water treatment plants. Coagulant RM-1 is produced from industrial secondary waste, namely the Mykolaiv Alumina Plant. This factor makes it more affordable. Also, it is worth noting that it is environmentally friendly, as it is produced according to the principle of low-waste technologies, which contribute to the elimination of production waste. Importantly, RM-1 coagulant is highly effective, reducing turbidity by 100 % and removing 89 % of natural water colour, meeting regulatory standards.

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