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Original article

Physico-chemical and microbiological parameters of natural, industrial recycled water and its treatment

Galina I. Boiko[1], Raushan G. Sarmurzina[1], Nina P. Lyubchenko[1], Zhazira A. Baltabekova[2], Kuanysh T. Tastambek[1], Pavel V. Kenyaikin [1], Anel Taubatyrova[1]

[1]Satbayev University, Almaty, Kazakhstan
[2]Institute of Metallurgy and Ore Beneficiation, Almaty, Kazakhstan

ABSTRACT

Background: Under conditions of anthropogenic impact, the chemical composition of water in surface rivers and groundwater bodies is subjected to pollution, which leads not only to a decrease in water quality, but also to an increase in the number of pathogenic and opportunistic bacteria.

Aim: The purpose of this work is to study the physicochemical and microbiological parameters of natural and industrial recycled water before and after treatment with coagulants based on activated aluminum alloys.

Materials and methods: As natural waters were analyzed: natural waters from water intake “Almaty SU”, “Medeu” tract, Zhaiyk river, from the well of experimental metallurgical production of IMOB. As recycled water was analyzed water taken from the water treatment unit of deep oil refining production. Turbidity was measured using HACH 2100Q turbidimeter and 2100Qis turbidimeter (USA). Cell morphology of microorganism cultures was studied by light microscopy using a MicroOptix MX-1150 (T) stereoscopic-sotrinocular microscope.

Results: An effective and technologically simple method of obtaining aluminum polyoxychloride with the content of the main substance from 33 to 41.0% by Al_2O_3 and basicity from 55.1 to 66.5% has been developed. The method consists in dissolution of aluminum alloy activated by metal-activators (indium, gallium, tin) in the amount
of 0.5–1.0 wt.% of each in 3% HCl. Physico-chemical and microbiological parameters of natural and industrial recycled water have been studied. The efficiency of the obtained aluminum polyoxychloride for treatment and conditioning of drinking water and industrial recycled water was evaluated.

Conclusion: Unique alloys with high energy characteristics based on aluminum containing indium, gallium, tin from 0.5–1.0 wt.% have been created. The alloy has high activity in various oxidizing media (water, hydrochloric acid). A technologically simple method of obtaining aluminum polyoxychloride has been developed. Chemical and microbiological composition of natural and industrial recycled water has been studied. Coagulants based on activated aluminum alloys are effective in the processes of conditioning and purification of natural and recycled water from toxic compounds, have bactericidal activity, the level of gram-negative bacteria is reduced to 73%,
gram-positive bacteria to 84% and to 96% of other groups of microorganisms. Fungi and yeasts (Mucor, Fusarium) were not detected after water treatment. Efficiency of water turbidity reduction reaches 90–99%, permanganate oxidizability up to 93%.

Keywords: *activated aluminum alloys, aluminum polyoxychloride, coagulant, microbiological parameters, natural water, pathogenic bacteria, recycled water.*

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Оригинальное исследование

Физико-химические и микробиологические показатели природных, промышленных оборотных вод и их очистка

Г.И. Бойко[1], Р.Г. Сармурзина[1], Н.П. Любченко[1], Ж.А. Балтабекова[2], К.Т. Тастамбек[1], П.В. Кеняйкин[1], А. Таубатырова[1]
[1]КазНИТУ им. К. И. Сатпаева, г. Алматы, Казахстан
[2]Институт металлургии и обогащения, г. Алматы, Казахстан

АННОТАЦИЯ

Обоснование. В условиях антропогенного воздействия химический состав воды в поверхностных реках и подземных водоёмах подвергается загрязнению, что приводит не только к снижению качества воды, но и к увеличению количества патогенных и условно-патогенных бактерий.

Цель. Целью данной работы является изучение физико-химических и микробиологических показателей природной, промышленной оборотной воды до и после очистки коагулянтами, полученными на основе активированных сплавов алюминия.

Материалы и методы. В качестве природных вод анализировались: природные воды из водозабора «Алматы СУ», урочища Медеу, р. Жайык, из скважины опытного металлургического производства Института металлургии и обогащения. В качестве оборотной воды анализировали воду, отобранную с установки водоподготовки производства глубокой переработки нефти. Мутность измеряли с помощью турбидиметра HACH 2100Q и турбидиметра 2100Qis (США). Морфологию клеток культур микроорганизмов изучали методом световой микроскопии с помощью стереоскопически-сотринокулярного микроскопа MicroOptix MX-1150 (T).

Результаты. Разработан эффективный и технологически простой способ получения полиоксихлорида алюминия с содержанием основного вещества от 33% до 41,0% по Al_2O_3 и основностью от 55,1% до 66,5%. Способ заключается в растворении сплава алюминия, активированного металлами (индий, галлий, олово) в количестве 0,5–1,0 масс.% каждого в 3%-ной HCl. Изучены физико-химические и микробиологические показатели природных и промышленных оборотных вод. Осуществлена оценка эффективности полученного полиоксихлорида алюминия для очистки и кондиционирования питьевой воды и промышленных оборотных вод.

Заключение. Созданы уникальные сплавы с высокими энергетическими характеристиками на основе алюминия, содержащие индий, галлий, олово от 0,5–1,0 масс.%. Сплав обладает высокой активностью в различных окислительных средах (вода, соляная кислота). Разработан технологически простой способ получения полиоксихлорида алюминия. Исследован химический и микробиологический состав природных и промышленных оборотных вод. Коагулянты на основе активированных сплавов алюминия эффективны в процессах кондиционирования и очистки природных и оборотных вод от токсичных соединений, обладают бактерицидной активностью: уровень грамотрицательных бактерий снижается до 73%, грамположительных бактерий до 84% и до 96% других групп микроорганизмов. Грибы и дрожжи (Mucor, Fusarium) после обработки воды не были обнаружены. Эффективность снижения мутности воды достигает 90–99%, перманганатной окисляемости – 93%.

Ключевые слова: *активированные алюминиевые сплавы, коагулянт, микробиологические показатели, оборотная вода, патогенные бактерии, полиоксихлорид алюминия, природная вода.*

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Түпнұсқа зерттеу

Табиғи, өнеркәсіптік қайта өңделген судың физика-химиялық және микробиологиялық көрсеткіштері және оларды тазарту

Г.И. Бойко[1], Р.Г. Сармурзина[1], Н.П. Любченко[1], Ж.А. Балтабекова[2], Қ.Т. Тастамбек[1], П.В. Кеняйкин[1], А. Таубатырова[1]
[1]Қ.И.Сәтбаев атындағы ҚазҰТЗУ, Алматы қаласы, Қазақстан
[2] Металлургия және кен байыту институты, Алматы қаласы, Қазақстан

АННОТАЦИЯ

Негіздеу. Антропогендік әсер ету жағдайында жер үсті өзендері мен жер асты су қоймаларындағы судың химиялық құрамы ластануға ұшырайды, бұл судың сапасының төмендеуіне ғана емес, сонымен қатар патогендік және шартты патогенді бактериялардың көбеюіне әкеледі.

Мақсаты. Бұл жұмыстың мақсаты белсендірілген алюминий қорытпалары негізінде алынған коагулянттармен табиғи, өнеркәсіптік айналымдағы судың тазартылғанға дейін және тазартылғаннан кейін физика-химиялық және микробиологиялық көрсеткіштерін зерттеу болып табылады.

Материалдар мен әдістер. Табиғи сулар ретінде: "Алматы СУ" су жинағышынан, "Медеу" шатқалынан, Жайық өзенінен, МжКБИ тәжірибелі металлургиялық өндірісінің ұңғымасынан табиғи суларға зерттеу жұмыстары жүргізілді. Мұнайды терең өңдеу өндірісінің Су дайындау қондырғысынан алынған су, айналымдағы су ретінде зерттелді. Бұлыңғырлық HACH 2100Q турбидиметрімен және 2100qis турбидиметрімен (АҚШ) өлшенді. Микроорганизмдердің өсінділер жасушаларының морфологиясы стереоскопиялық-сотринокулярлық микроскоп MicroOptix MX-1150 (Т) көмегімен жарық микроскопиясы арқылы зерттелді.

Нәтижелері. Алюминий полиоксихлоридін алудың тиімді және технологиялық тұрғыдан қарапайым әдісі әзірленді, оның құрамында Al_2O_3 бойынша 33-тен 41,0%-ға дейін және негізділігі 55,1-ден 66,5%-ға дейін негізгі зат бар. Бұл әдіс 0,5–1,0 масс.% мөлшерінде активатор металдармен (индий, галлий, қалайы) белсендірілген алюминий қорытпасын әрқайсысының 3%-дық HCl ерітуден тұрады. Табиғи және өнеркәсіптік айналым суларының физика-химиялық және микробиологиялық көрсеткіштері зерттелді. Алынған алюминий полиоксихлоридінің ауыз су мен өнеркәсіптік айналым суларын тазарту және кондиционерлеу тиімділігін бағалау жүзеге асырылды.

Қорытынды. Құрамында 0,5–1,0 масс.% болатын индий, галлий, қалайы бар алюминий негізіндегі жоғары энергетикалық сипаттамалары бар бірегей қорытпалар жасалды. Қорытпа әртүрлі тотығу орталарында (су, тұз қышқылы) жоғары белсенділікке ие. Алюминий полиоксихлоридін алудың технологиялық қарапайым әдісі жасалды. Табиғи және өнеркәсіптік айналым суларының химиялық және микробиологиялық құрамы зерттелді. Белсендірілген алюминий қорытпаларына негізделген коагулянттар табиғи және өнеркәсіптік айналымдағы суларды улы қосылыстардан тазарту және кондиционерлеу процестерінде тиімді, бактерицидтік белсенділікке ие, грам-теріс бактериялардың деңгейі 73%-ға дейін, грам-позитивті бактериялар 84%-ға дейін және басқа микроорганизмдер топтарының 96%-ға дейін төмендейді. Саңырауқұлақтар мен ашытқылар (Mucor, Fusarium) суды өңдегеннен кейін табылған жоқ. Судың лайлану көрсеткіші төмендету тиімділігі 90–99%, перманганаттың тотығуы 93% дейін жетеді.

Негізгі сөздер: *белсендірілген алюминий қорытпалары, коагулянт, микробиологиялық көрсеткіштер, қайта өңделген су, патогендік бактериялар, алюминий полиоксихлориді, табиғи су.*

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Introduction

Under conditions of anthropogenic impact factor determining the magnitude of the negative impact on water bodies is the insufficient level of wastewater and recycled water treatment. The relevant problem is the reduction of natural water consumption for production needs, replacement of natural water for recharge of circulating water systems with alternative sources of water supply surface rivers and groundwater.

The relevant problem is the reduction of natural water consumption for production needs, replacement of natural water for recharge of circulating water systems with alternative sources of water supply. According to data [1] at many enterprises of chemical and petrochemical industries in biologically treated wastewater COD value reaches 150–200 gO/m³ and salt content exceeds 2500 g/m³. The most common and effective coagulants for water treatment from salts and pollutants are aluminum polyoxychlorides (PAC). The theoretical basis for the production of PAC is discussed in detail in papers [2–4]. Mechanism of coagulation water purification in works [5–7].

Earlier [8, 9] we developed a fundamentally new technology of PAC production on the basis of multicomponent active aluminum alloys as metals-activators, we used (Ga, In, Sn) 5 wt.% of each.

The purpose of this work is to study physicochemical and microbiological parameters of natural, industrial recycled water and their treatment by new generation coagulants based on activated aluminum alloys with the content of metal-activators from 1.5 to 3.0%, which will significantly reduce prices

Materials and Methods

As natural waters were analyzed: natural waters from water intake "Almaty SU", tract "Medeu", from the well of pilot metallurgical production (EMP) of the Institute of Metallurgy and Ore Beneficiation (IMOB), the river Zhaiyk (Ural). As recycled water was analyzed water sampled from the water treatment unit of deep oil refining production (WTU of PDOR)

Activated aluminum alloys Rau-97, Rau-98, Rau-98.5, containing metals-activators: gallium, indium, tin (from 0.5 to 1 wt%) were obtained by the method described in works [9,11].

Aluminum polyoxychlorides (PAC) were obtained by interaction of aluminum activated by metal-activators (indium, gallium, tin) in the amount of 0.5–1.0 weight % each with 3% hydrochloric acid. Quality parameters – mass fraction of Al in terms of Al_2O_3 33,2–36,9%, basicity 56–67%, corresponded to GB 15892–2009 standard.

As natural waters were analyzed: the water of the Zhaiyk River was analyzed as natural water for water supply to industrial enterprises in Atyrau and irrigation (transboundary water artery of Kazakhstan and Russia) [12] Water samples were taken from the main collector of "ANPZ" LLP, as well as water intake "Almaty SU", tracts "Medeu", from the well. The water sample taken from the water treatment unit of deep oil refining production (WTP) was analyzed as recycled water.

Water samples were taken according to state standard No. 59024–2020, were evaluated by organoleptic (smell, taste, color), physical (turbidity, pH, conductivity, permanganate oxidation), chemical parameters (total salt content, the content of anions-hydrocarbonates, sulfates, chlorides) in accordance with the sanitary rules Order of the Minister of Health of the Republic of Kazakhstan February 20, 2023 No 26.

Water treatment methodology: a certain amount of PAC was injected into 500 ml of test water while intensely stirring, after 3 minutes the speed was reduced to 50 rpm for 15 minutes, and was allowed to stand for 30 minutes afterwards.

Turbidity before and after treatment of natural and recycled water was measured directly with a turbidity meter HACH 2100Q Turbidimeter (USA).

Permanganate index (PI) was determined according to ISO 8467:1993.

Bacteriological analysis was carried out on water samples taken from the "Medeu" tract. The number of microbes and microbial composition were determined by sowing on selective nutrient media. The number of bacteria using organic nitrogen and some groups of microorganisms using mineral nitrogen were counted on Tryptone soya agar (TSA) and Meat infusion agar (MIA), enterobacteria on Endo differential diagnostic medium, all species of Pseudomonas group on Pseudomonas isolation agar (PIA). The number of fungi and yeasts was counted on selective medium Sabouraud dextrose agar (SDA). The seeded cups were incubated at 30ºC and 37ºC. Cell morphology of microbial cultures was studied by light microscopy using a Micro-Optix MX-1150 stereoscopic-trinocular microscope. Bacterial colonies were counted on day 2–3, yeasts and fungi on day 5–7. In the inoculations, dilutions of 1:102 and 1:104 were used.

Results and Discussion

In order to evaluate the coagulation efficiency of reagents created based on activated aluminum alloys their tests were carried out on different types of natural and recycled water. The assessment of quality of the tested water consisted in its analysis and in comparison, with the sanitary and epidemiological standards established for drinking water supply, recycled and wastewater intended for discharge into water bodies.

Physico-chemical parameters of the investigated natural waters are presented in Table 1.

Analysis showed that natural waters, in general, are slightly alkaline, low-mineralized fresh, moderately hard (Table 1). Alkalinity and turbidity increase in the samples taken in autumn compared with spring. The content of salts in the water of the river Zhaiyk (Atyrau) exceeds, allowable by regulations upper levels, not more than 1000 mg/cm³. The main cations are sodium, potassium, calcium, magnesium, in concentrations below the maximum permissible concentration, iron less than 0.1%. All investigated natural surface waters by turbidity exceed the allowable standards (not more than 2.6 FNU).

Microbiological Composition

Table 2 shows the taxonomic groups of microorganisms detected in water samples from the "Medeu" tract. The level of microbial infestation reached 12.8x10² CFU/ml.

Presence of aerobic Gram-negative, facultatively anaerobic microorganisms, Gram-positive cocci; Gram-positive bacilli and endospore-forming cocci (genera Bacillus; Bacillus spp. cocci; Gram-positive bacilli and cocci forming endospores (genera Bacillus; Clostridium), and also the presence of Escherichia coli bacteria, Proteus bacteria and saprophytic bacteria of the genera Aeromonas and Pseudomonas [13, 14]. The presence of saprophytic bacteria from 1x10 to 13x10² CFU/ml in water indicates the pollution of the water body with by organic substances. In addition, a comparative study was conducted on the number of representatives of the genus Pseudomonas. It was found that the total number

Table 1. Physic-chemical parameters of natural waters quality before PAC treatment

Parameters	Natural Water				
	Zhaiyk river	Almaty SU water intake	Medeu tract	Medeu tract	Well EMP
	04.11.2022	20.05.2022	29.11.2022	03.04.2023	05.04.2023
Hydrogen Index	7.50	7.65	7.71	8.61	8.17
Density, g/cm³	1.02	0.984	0.998	0.999	0.999
Salt content, mg/dm³	1195	99.3	226.0	226.0	243.0
Content of hydrogen carbonate ions, mg/dm³	256.2	91.5	207.4	103.7	128.1
Sulfate-ions, mg/dm³	81.78	29.70	30.6	30.6	24.0
Chloride-ions, mg/dm³	220.0	4.85	27.4	14.2	7.1
Nitrates, mg/dm³	4.0	-	20.0	20.0	17.0
Water turbidity, FNU	22.2	4.52	26.10	360.0	0.43
Permanganate index, mgO/dm³	-	0.517	1.67	1.01	0.60
Conductivity, μS/cm	1078	125.4	215.8	215.8	260.6
Total water hardness, mg-eq/dm³	3.21	2.0	2.44	2.44	1.85
Chromaticity, degrees; odour, points	0	0	0	0	0

Table 2. Taxonomic groups of microorganisms in water from the "Medeu" tract

Taxonomic groups of microorganism	CFU/ml
Microbial infestation level	12.8x10²
Saprophytic bacteria (Pseudomonas)	2.4x10²
Microbial population of microflora – fungi and yeast (Mucor, Fusarium)	8x10²
Number of Gram-negative bacteria (Enterobacter, Proteus, Aeromonas, Flavobacterium, Alcaligenes)	7.3x10²
Numbers of Gram-positive bacteria (bacilli, cocci and endospores as Bacillus, Clostridium, Micrococcus, Enterococcus)	4.2x10²
Other groups of microorganisms	1.3x10²

The number of microorganisms, Enterobacteriaceae was determined according to the methods described in [13]

Table 3. Characteristics of PACs synthesized using activated aluminum alloy

Coagulant cipher	Alloy cipher	Alloy composition Al:In:Ga:Sn, wt%	Product output, g	Mass fraction of Al in terms of Al_2O_3, %	Basicity, %
Coagulant №20	Rau-97	97:1:1:1	5.5	33.2	55.8
Coagulant №25	Rau-98,5	98,5:0,5:0,5:0,5	4.8	37.9	55.1
*Coagulant №31	Rau-98	98:1:1:0	4.2	40.4	60.9
Coagulant №35	Rau-98,5	98,5:0,5:0,5:0,5	5.0	34.9	58.6

Coagulants №20,25,31 – hydrochloric acid solution (3%) were prepared on distilled water, coagulant №35 – solution on water from the well of EMP

**Synthesis time is 4.5 h.*

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of bacteria in 1 ml, according to the method of serial dilutions, is 2.4x10².

Coagulant Analysis

In order to treat natural water as well as industrial recycled water, samples of aluminum alloys with the content of activating additives from 0.5 to 1 wt% were prepared and PACs were synthesized on their basis.

PAC synthesis was carried out by dissolution in 3% hydrochloric acid, activated alloy with aluminum content from 97% to 98.5% at an initial process temperature of 25ºC without heat supply from the outside. The reaction is accompanied by emission of heat and hydrogen and temperature rise to 65–70ºC, which is maintained by the heat of exothermic reaction. The process is completed in 2–4.5 hours (Table 2). In contrast to the known methods of obtaining PAC [2–4], the process temperature is 30–40ºC lower, more than three times lower in concentration of hydrochloric acid applied and 1.5 times faster in implementation time. Depending on the composition of the activated alloy used and reaction conditions, the mass fraction of aluminum in terms of aluminum oxide (Al_2O_3) in PAC varies from 33.2% to 41.0%, basicity from 55.1% to 66.5%.

The characteristics of PACs synthesized using activated aluminum alloys are shown in Table 3.

Natural Water Treatment

The results of evaluation of PAC efficiency for natural water treatment are presented in Tables 4, 5. Turbidity reduction efficiency reaches 99.8%. The treated water complies with the normative requirements for hydrogen index, chemical oxygen demand, turbidity, cations and anions content. The effectiveness of reducing permanganate oxidation of the water sample from the "Medeu" tract reaches 90.7% (Table 6). Also found that in the water after treatment with coagulants aluminum content is 0.03 mg/l which corresponds to Sanitary and epidemiological requirements for sources of water supply, places of water intake for domestic drinking purposes, domestic drinking water supply.

The number of bacteria in 1 ml and species composition of microorganisms after treatment of "Medeu" water in two concentrations were studied. In "Medeu" water samples before treatment the level of microbial contamination reached 12.8x10² CFU/mL, whereas after treatment with coagulant No. 20 (0.1% solution in terms of Al_2O_3) 0.1 ml/l (0.3 g/t dry) (dose, this indicator was 0.3x10² CFU/mL). At a concentration of 5 ml/L (15.1 g/t of dry), the total number of saprophytic microorganisms did not exceed 0.1x10² CFU/mL.

Total number of bacteria in 1 ml according to the serial dilution method before treatment with 2.4x10² cells/mL in the samples after the treatment with the dose (0.1ml/L,) 0.2x10² cells/ml, in the concentration of 5 ml/L no representatives of this genus were found.

Microbial diversity in natural water of Medeu tract before and after treatment with 0.1% coagulant solution №20 in terms of Al_2O_3 is illustrated in Fig.1.

Microbiological Composition after Treatment

In the water sample before coagulant treatment the number of Gram-negative bacteria (Enterobacter, Proteus, Aeromonas, Chromobacterium, Flavobacterium, Alcaligenes) was ~7.3 CFU/mL. Gram-positive bacteria (Bacillus, Bacillus, Clostridium, Micrococcus, Enterococcus cocci and endospores) was ~4.2 CFU/mL, other groups of microorganisms were about ~1.3 CFU/mL,

After RAS treatment at a concentration of 0.1 ml/L: Gram-negative bacteria decreased to ~5.1 CFU/mL (by 30.1%), Gram-positive bacteria decreased to ~2.2 CFU/mL (by 48%), other groups of microorganisms decreased to 0.1 CFU/mL ~(by 92%). After treatment at a concentration of 5 mL/L, the number of gram-negative bacteria decreased to ~2.0 CFU/mL (73%), gram-positive bacteria to ~0.7 CFU/mL (84%), other groups of microorganisms decreased from 1.3

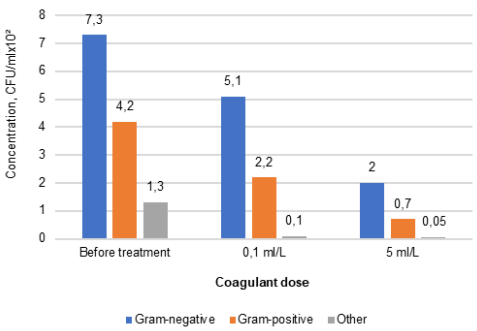

Figure 1. Microbial diversity in the natural water of "Medeu" before and after treatment with 0.1% coagulant solution №20 in terms of Al_2O_3

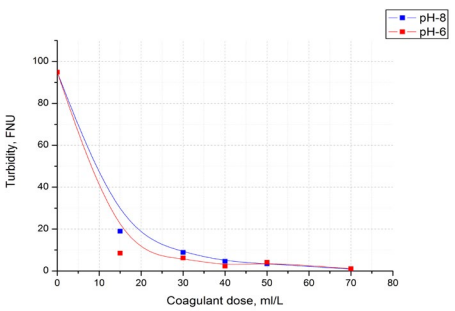

Figure 2. Turbidity of water, sampled on the WTU of the CCR unit №1, treated with coagulant №20 at initial pH 8 and acidified to pH 6

to -0.05 CFU/mL ~96%. Up to 16.0% of Gram-positive bacteria and up to 27% of Gram-negative bacteria were retained in the treated water at a concentration of 5 ml/L. Fungi and yeasts (Mucor, Fusarium), their number was 8x10² CFU/mL, after treatment representatives of this genus were not detected in both concentrations.

Recycled Water Treatment

The results of assessing the effectiveness of treatment of recycled water, selected from the WTU of PDOR are shown in Table 7. Table 7 shows the results of assessing the effectiveness of reducing turbidity of recycled water samples taken from the WTU of PDOR when treated with PAC solutions based on activated aluminum alloys in comparison with the industrial Aqua-Aurat. Water turbidity for sample №1 was 94.9 FNU, for sample №2 -182 FNU. Optimization experiments on coagulants doses were conducted to determine an acceptable and sufficient dose of coagulant. The coagulant dose is an important technological parameter in reagent water treatment. If the coagulant dose is insufficient, the required degree of purification is not achieved while consumption in excess can

Table 4. Comparative results of efficiency of natural water turbidity reduction by treatment with PAC solutions

Coagulant cipher	Coagulant dose, g/t	pH	Turbidity, FNU	Effectiveness of reducing the turbidity, %
Natural water from Medeu tract, sampled on 19.02.22, turbidity 14.8 FNU				
Aqua-Aurat 30	0.3	7.7	0.79	94.7
Coagulant №20	0.3	7.7	1.22	91.8
Coagulant №25	0.1	7.7	1.38	90.7
Coagulant №25	0.3	7.7	0.57	96.2
Coagulant №25	2.5	7.7	0.37	97.5
Coagulant №31	0.1	7.7	1.26	91.5
Coagulant №31	0.2	7.3	1.02	93.1
Coagulant №31	2.5	7.3	0.47	96.8
Natural water from Medeu tract, sampled on 29.11.22, turbidity 26.1 FNU				
Coagulant №20	0.3	7.3	1,20	95.4
Coagulant №20	3.0	7.3	0.82	96.9
Natural water from Medeu tract, sampled on 03.04.23, turbidity 360 FNU				
Coagulant №20	0.3	8.6	37.7	89.5
Coagulant №20	1.5	8.6	2.93	99.2
Coagulant №20	3.0	8.6	0.51	99.9
Coagulant №25	0.3	8.6	38.5	89.3
Coagulant №25	1.3	8.6	2.12	99.4
Coagulant №25	2.6	8.6	0.56	99.8
Natural water from "Almaty Su", sampled on 29.11.22, turbidity 4.52 FNU				
Coagulant №20	0.3	7,3	0.53	88.3
Coagulant №20	3.0	7.2	0,48	89.4

Aqua-Aurat 30 – industrial coagulant. Mass fraction of Al in terms of Al_2O_3 – 30%

Table 5. Residual turbidity after treatment with coagulant №25 of water samples from the Zhaiyk River

Water sample from the Zhaiyk River	Turbidity, FNU				Suspended particles (sediment), g/l			
	Before processing	After treatment with coagulant №25, g/t			Before processing	After treatment with coagulant №25, g/t		
		0.1	0.7	1.3		0.1	0.7	1.3
№1	22.2	1.5	0.4	0.6	0.3	0.1	0.1	0.1
№2	21.4	1.5	0.4	0.5				

Date of sampling from the river 04.11. 2022, water pH 7.5

Table 6. Residual permanganate index of "Medeu" water samples after coagulant treatment

Coagulant cipher	Coagulant dose, g/t	PI, mgO/dm³	Efficiency of PI reduction, %
Aqua-Aurat 30	0.3	0.5	72.2
Coagulant №20	0.3	0.7	60.6
Coagulant №25	0.1	0.3	80.3
Coagulant №25	0.3	0.2	90.7
Coagulant №25	2.6	0.3	84.9
Coagulant №31	0.1	0.3	80.3
Coagulant №31	0.2	0.1	93.0
Coagulant №31	2.5	0.4	76.8

PI of source water 1.67, mgO/l. Date of sampling 29.11.22

 DOI: 10.54859/kjogi108767

affect water quality (change the aluminum content in the treated water).

Analysis of the data in Table 7 indicates that the required coagulant dose to achieve the highest degree of purification (99%) depends on the mass fraction of aluminum in terms of Al_2O_3 in the PAC. As the mass fraction of aluminum in PAC increases, the sufficient coagulant dosage to the required effect decreases. Therefore, for Akva-Aurat (mass fraction of Al_2O_3 is 30%) the dose of coagulant is 233 g/t. For coagulant №25 (mass fraction is 37.9 %) it is 184 g/t. For coagulant №20, (mass fraction is 33.2%) a sufficient dose is 210 g/t. Turbidity is reduced for sample №1 from 94.8 FNU to 1 FNU, for sample №2 from 182 to 1.8 FNU. In the pH range of 6–8.5, coagulants are effective for high turbidity water treatment. The pH values at which the appropriate coagulant acts most effectively were determined. Figure 2 shows curves of the degree of decrease in the turbidity of raw water with pH of 8.5, compared with water acidified to pH 6.0 depending on the dose of coagulant №20. Sedimentation of suspended solids is more effective for water with pH 6.

Consequently, PACs synthesized using activated aluminum alloys are effective coagulants for natural water and recycled water treatment and exhibit bactericidal properties.

Conclusion

Chemical and microbiological composition of natural and industrial recycled water has been studied. Unique alloys with high energy characteristics based on aluminum activated by metal-activators: indium, gallium and tin have been created. The content of each additive is 0.5 to 1.0 wt.%. Alloy with such additions possesses high activity in different oxidizing environments (water, hydrochloric acid). Coagulants PAC synthesized using them are efficient in processes of water conditioning and physical-chemical treatment of recycled and wastewater from toxic compounds of natural and anthropogenic origin. In addition, coagulants possess bactericidal activity. The use of coagulants allows to avoid primary chlorination, the level of Gram-negative bacteria in treated water is reduced to 73%, Gram-positive bacteria to 84% and up to 96% of other groups of microorganisms. Fungi and yeasts (Mucor, Fusarium), their number was $8x10^2$ CFU/mL, after treatment of representatives of this genus were not found in both concentrations. Coagulants are effective in a wide pH range from 6 to 8.5.

The results of analysis of treated water comply with the requirements for drinking water supply and wastewater disposal Order of the Minister of Health Republic of Kazakhstan dated February 20, 2023 No. 26 and ISO5667.

ADDITIONAL INFORMATION

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Вклад авторов. Все авторы подтверждают соответствие своего авторства международным критериям ICMJE (все авторы внесли существенный вклад в разработку концепции, проведение исследования и подготовку статьи, прочли и одобрили финальную версию перед публикацией). Наибольший вклад распределён следующим образом: Бойко Г.И. – концептуализация, методология, системный анализ; Сармурзина Р.Г. – руководство, администрирование проекта, а также получение финансирования, валидация; Любченко Н.П. – сбор и обработка материалов, анализ полученных данных; Балтабекова Ж.А. – анализ известных литературных источников патентной литературы по рассматриваемой теме, формальный анализ; Тастамбек К.Т. – анализ микробиологического состава природных вод в данном исследовании, написание, рецензирование и редактирование; Кеняйкин П.В. – разработка методов получения

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AUTHORS' INFO

***Galina I. Boiko**
Doct. Sc. (Chemistry)
ORCID 0000–0002-2912-3384
e-mail: *galina.boyko.kaznitu@gmail.com.*
Raushan G. Sarmurzina
Doct. Sc. (Chemistry), professor
ORCID 0000–0002-9572-9712
e-mail: *sarmurzina_r@mail.ru.*
Nina P. Lyubchenko
Cand. Sc. (Chemistry)
ORCID 0000–0002-7133-808X
e-mail: *amtek@bk.ru.*
Zhazira A. Baltabekova
ORCID 0000–0003-3076-0652
e-mail: *jazira001@mail.ru.*
Kuanysh T. Tastambek
PhD (Biotechnology)
ORCID 0000–0002-2338-8816
e-mail: *tastambeku@gmail.com.*
Pavel V. Kenyaikin
ORCID 0000–0002-4360–1573
e-mail: *kenyaikin.p@gmail.com.*
Anel Taubatyrova
ORCID 0009-0001-1329-0372
e-mail: *gggnika465@gmail.com.*

ИНФОРМАЦИЯ ОБ АВТОРАХ

***Бойко Галина Ильясовна**
докт. хим. наук
ORCID 0000–0002-2912-3384
e-mail: *galina.boyko.kaznitu@gmail.com.*
Сармурзина Раушан Гайсиевна
докт. хим. наук, профессор
ORCID 0000–0002-9572-9712
e-mail: *sarmurzina_r@mail.ru.*
Любченко Нина Павловна
канд. хим. наук
ORCID 0000–0002-7133-808X
e-mail: *amtek@bk.ru.*
Балтабекова Жазира Амангельдыевна
ORCID 0000–0003-3076-0652
e-mail: *jazira001@mail.ru.*
Тастамбек Куаныш Талгатович
PhD (Биотехнология)
ORCID 0000–0002-2338-8816
e-mail: *tastambeku@gmail.com.*
Кеняйкин Павел Витальевич
ORCID 0000–0002-4360–1573
e-mail: *kenyaikin.p@gmail.com.*
Таубатырова Анель
ORCID 0009-0001-1329-0372
e-mail: *gggnika465@gmail.com.*

*Автор, ответственный за переписку/Corresponding Author