Using Resource-saving Wastewater Treatment Technology in an Industrial City

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Abstract: Rapid demographic growth of the population has led to the fact, that the renewable water resources are not renewable over time. Already, today there is a shortage of fresh water. Methods for purification and resource saving technology of water is the only alternative directions in coming decades. Therefore, there is a great need for the development of suitable, inexpensive and fast wastewater treatment and reuse or conservation methods in this century. Various types of water treatment and recycling methods were discussed in terms of their fundamentals, applications, costs, maintenance and suitability. In addition, a systematic approach to water purification and recycling was presented, including their understanding, assessment and selection of parameters. A quick guide on the selection of appropriate technologies for specific applications was evaluated. The article discusses not only global issues related to solutions to the problem of water shortage, but also the results of experimental studies showing the feasibility of using a purification method using coagulants.

1 INTRODUCTION

One of the most important international political agendas is the conservation of resources, today conditionally renewable fresh water resources – so in July 28, 2010 The UN General Assembly has included the right to water in the list of basic human rights. The aggravation of global and regional problems related to freshwater water resources has led, according to the UN, to the fact that in the 21st century water is a strategically valuable resource, gradually displacing oil and gas from the market.

According to the research of Petukhova E.O. (Petukhova, 2018) "… In many countries of the world, programs are being developed to ensure water security, since a ton of clean water in an arid climate is already more expensive than oil. Today this problem is relevant in various areas and industries.

Conservation, efficient using (recycling) and securing of clean freshwater render focus of sustainable development policies and economic growth in the countries including the Russian Federation, as Russian input in Top 5 largest countries in the world by fresh water reserves (Fig. 1).

In terms of fresh water reserves, the Russian Federation ranks second after Brazil, more than 2.5 million rivers and 2.7 million lakes and freshwater depots are glaciers (Gupta et al, 2012, Danilov-Danilyan, 2009, Sazhin et al, 2012).

In order to preserve water resources in the main drainage areas, it is necessary to solve the following problems, considered on the example of the North Caucasian Federal District, the solution of which will stabilize the economic situation associated with this region (Gupta et al, 2012, Danilov-Danilyan, 2009, Sazhin et al, 2012).

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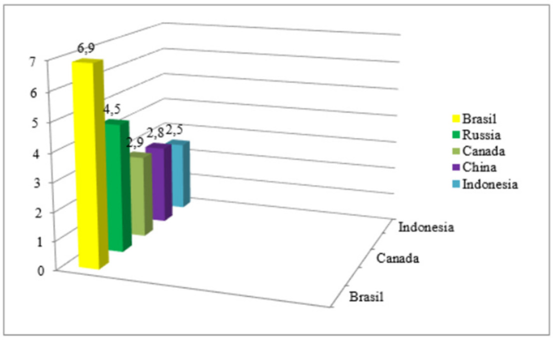

Figure 1: Countries of the world rich in fresh water reserves.

Pollution Pool and Don River sewage led to shortages of freshwater sources, depletion and degradation of small rivers.

Kuban River basin - one the of the strategic objects of water resources in the region, has led to water use restrictions for the needs of the population, agricultural organizations and industry.

This situation is a consequence of the presence of a fairly large number of problems related to water use in Russia and the North Caucasian Federal District in particular.

One of the main problems of water use in Russia is excessive pollution of water bodies. On average, per year in the Russian Federation, wastewater discharge into surface water bodies is 54,712 million m3, of which polluted wastewater is 36%, including 21% without any treatment (Gupta et al, 2012, Danilov-Danilyan, 2009, Sazhin et al, 2012).

The demand for water is enormous and increases every year. But, even realizing the importance of the role of water, a person still continues to toughly exploit water bodies, irrevocably changing their natural regime with discharges and waste.

At present, the problem of water pollution is perhaps the most urgent. And one of the most important aspects of environmental protection is the protection from pollution of water resources and ensuring the needs of the population and the national economy with clean water.

"… .According to Rosstat, economic growth in Russia is accompanied by a disproportionate deterioration in the environmental situation, Fig. 1 . , it is noted that in third place, as a pollutant, is energy, more precisely, "production and distribution of electricity, gas and water" (21.2%) ... " (Sazhin et al, 2012).

To reduce the negative impact on the environment, it is necessary to implement the necessary environmental protection measures, such as the treatment of waste, industrial and storm water.

This is possible at sewage treatment plants, where wastewater used in the process of life is cleaned and neutralized to such an extent that it does not have a harmful effect on the environment. But despite all the measures taken to protect water bodies, treatment of waste water, which are formed as a result of household and industrial activities, not always is so effective event and requires continuous improvement.

Disposal of waste water and neutralization is a one second of the most important ecological problems of the present time and in this direction continuously carried out a wide variety of research, which are based on physico-chemical or biochemical degradation processes harmful components of waste water.

2 MATERIALS AND METHODS

What do we mean by the concept of "waste water"? It is the water, the former in the domestic, industrial or agricultural use, as well as passing through any contaminated areas. Depending on the conditions of formation, wastewater is divided into domestic or household fecal, atmospheric (storm) and industrial.

Domestic water formed from Stock s showers, baths, kitchens, toilets, washing floors and from others. They contain impurities, of which approximately contains 58% organic matter and a 42% mineral (Gupta et al, 2012).

Atmospheric waters are formed as a result of atmospheric precipitation and flowing down from the territories of enterprises. They are contaminated with organic and mineral substances. Industrial wastewaters are liquid wastes which arise during extraction and processing organic and inorganic materials. The quantity and quality composition of industrial wastewater depends on the type of production.

The WHO committee recommended the following classification of chemical water pollutants:

1) biologically unstable organic compounds;
2) low toxic e inorganic salts;
3) petroleum products;
4) biogenic compounds;
5) substances with specific toxic properties, including heavy metals.

There are several ways to reduce the amount of contaminated wastewater, including such as: development and implementation of anhydrous technological processes; improvement of existing processes; development and implemented equipment; introduction of air coolers; reuse of treated wastewater in recirculating and closed systems.

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The lack of clean natural waters and the high demand of the industry for water determine the need to continue work on the further improvement of treatment systems.

Under these conditions, the development of new technological solutions that ensure high and stable quality of wastewater treatment is relevant and in demand.

The choice of one or another treatment method is carried out taking into account the sanitary and technological requirements for treated wastewater for the purpose of their further discharge into a water body and use, as well as taking into account the volume of wastewater and the concentration of pollution in them, the necessary material and energy resources, and economic efficiency. process.

The use of physicochemical methods for wastewater treatment has a number of advantages over biochemical ones:

1) the ability to remove toxic biochemically non-oxidizable organic pollutants from wastewater;

2) achieving a deeper and more stable degree of cleaning;

3) smaller structures;

4) less sensitivity to load changes;

5) the possibility of full automation;

6) a deeper study of the kinetics of some processes, as well as issues of modeling, mathematical description and optimization, which is important for the correct choice and calculation of equipment;

7) methods are not related to control over the activity of living organisms;

8) the possibility of recovering various substances.

Of the most common methods of physicochemical purification, it is necessary to single out, first of all, the use of various reagents that cause coagulation of contaminants, which are indispensable in cases where it is necessary to remove finely dispersed suspended substances from wastewater.

What is coagulation? Coagulation is the process of conglomeration of suspended particles through interaction and aggregation. Used in clearing (recycling) of waste water with the aim of accelerating the precipitation of fine impurities and emulsified substances under the influence of special compounds – coagulants, forming flakes of metal hydroxides, precipitate. Aggregation occurs due to the difference in charges of colloidal and suspended particles (weak negative charge) and coagulating agents (weak positive charge), which leads to aggregation (Joss et al, 2006).

The process of hydrolysis of coagulants and the formation of flocs occurs in the following stages:

$Me^{3+} + HOH \rightarrow Me(OH)^{2+} + H^{+}$

$Me(OH)^{2+} + HOH \rightarrow Me(OH)_2^{+} + H^{+}$

$Me(OH)_2^{+} + HOH \rightarrow Me(OH)_3 + H^{+}$

$Me^{3+} + 3\,HOH \rightarrow Me(OH)_3 + 3\,H^{+}$

In reality, the hydrolysis process is much more complicated. The metal ion forms a number of intermediates through reactions with hydroxide ions and polymerization. The formed compounds have a positive charge and are easily adsorbed by negatively charged colloidal particles (Bernet et al, 2000, Rodionov et al, 2000).

As coagulants, salts of aluminum, iron or their mixtures are usually used. The choice of coagulant depends on its composition, physicochemical properties and cost, the concentration of impurities in the water, on the pH and salt composition of the water.

As coagulants used aluminum sulfate $Al_2(SO_4)_3 \times 18\,H_2O$; sodium aluminate $NaA1O_2$; oxyaluminum chloride $Al_2(OH)_5Cl$; tetraoxo c ulphates of aluminum-potassium and aluminum-ammonium [alum - potassium alum $KAl(SO_4)_2 \times 12\,H_2O$ and ammonia $NH_4Al(SO_4)_2 \times 12\,H_2O$]. Of these, the most widespread is aluminum sulfate, which is effective in the range of pH = 5-7.5. It is highly soluble in water and has a relatively low cost. It is used in dry form or as 50% - of the solution.

Of iron salts, iron sulfates $Fe_2(SO_4)_3 \times 2\,H_2O$, $Fe(SO_4)_3 \times 3\,H_2O$ and $FeSO_4 \times 7\,H_2O$, as well as ferric chloride $FeCl_3$, are used as coagulants . The greatest clarification occurs when using ferric salts. Ferric chloride is used in dry form or in the form of 10 - 15% solutions. Sulfates are used in the form of powders.

The coagulant dose depends on the pH of the wastewater. Fe^{3+} the pH is 6-9, and for Fe^{2+} the pH is 9, pH is 9.5 and higher. For alkalinization of wastewater, NaOH and $Ca(OH)_2$. Water treatment with coagulants is the most common method for purifying large volumes of water from coarsely dispersed and colloidal contaminants. The use of the coagulation method has increased in recent years, and this trend continues. In this regard, the assortment of coagulants and related reagents, offered for the purification of natural waters in order to improve the quality of treated water, is rapidly growing. In currently increasingly widespread coagulants are highly BASIC spine-oxy chlorides of aluminum, which until recently only been used in water purification obtained for drinking purposes.

Recently, the variety of impurities in wastewater has increased significantly with significant fluctuations in their composition and color. This requires a lot of effort in wastewater treatment, for which aluminum sulphate is traditionally used, which no longer always meets the requirements.

To provide a comprehensive solution to these problems, we propose to use a coagulant - aluminum oxy chloride (polyaluminium- hydrochloride) of the highest quality category with a basicity index of "5/6", which received 1st place in the international competition for coagulants.

Development of production and application of technology oxy chloride and aluminum "BOPAK" to purify water in the cities of Russia took place in the framework of inter-regional environmental programs.

Production hydroxy chloride and aluminum for organizations - water channels carried in Azov, Rostov region and Ekaterinburg on TU 216350-002-39928758-02.

Coagulant " Bopak-E " is a low-hazard compound of the 3rd hazard class, the limiting hazard indicator is sanitary-toxicological, maximum concentration limit is 0.5 mg / l (for aluminum).

Guaranteed quality indicators water treatment technical and economic advantages of using oxy chloride Aluminum:

· Causes highly effective coagulation of colloidal-dispersed particles and organic substances from water, as a result of which a rapidly precipitating and well-filtered flock is formed;

Decrease in the content of organochlorine compounds;

Ensuring the content of residual aluminum is less than 0.2 mg / l;

Consumption of the reagent in the range of 0.3 - 3.0 mg Al / liter of water;

Stability of the coagulation process, including at low water temperatures;

When introduced into water, it practically does not reduce the alkalinity and pH of the treated water, as in comparison with traditionally used coagulants, which contributes to: a decrease in the rate of corrosion of metals in water supply and heat supply systems, by eliminating the formation of aggressive carbon dioxide and the possibility of refusing to use alkaline agents;

In comparison with traditional coagulants, it reduces the amount of anions introduced into the water by 10 times;

Easy-to-use and stored solution, which is easily diluted to the required degree before dosing;

Transition to a new reagent in the conditions of operating stations, as a rule, does not require reconstruction of the existing reagent facilities, greatly facilitates the work of the service personnel;

Approved for use in drinking and hot water supply systems.

Application hydroxy chloride and aluminum has many advantages, directly affecting the economics of its use (including and in comparison with a conventional aluminum sulphate):

- being a partially hydrolyzed salt, aluminum oxy chloride has a greater ability to polymerize, which accelerates flocculation and precipitation of coagulated suspension;
- work confirmed hydroxyl chloride and aluminum in a wider pH range as compared with aluminum sulfate, which leads to a complete hydrolysis and, consequently, reduce the concentration of residual aluminum in the drinking water;
- reducing alkalinity when coagulating oxy chloride ohm aluminum is substantially smaller that, along with the absence of the addition of sulphate results in a reduction of corrosion of water activity, exclusion stabilization treatment, to improve water pipelines status urban distribution network and preserve consumer properties of water during transportation and also allows to completely abandon from the use of alkaline agents and leads to savings of those at the middle station up to 20 tons per month;
- low residual aluminum content at high doses administered;
- reduction of the working dose of the coagulant by 1.5 - 2.0 times in comparison with aluminum sulfate;
- delivery in a ready-made working solution, which makes it possible to abandon the process of dissolving the coagulant, leading to energy savings for stirring at the middle station up to 100 thousand kW / h annually;
- during the transition to oxy chloride, aluminum does not require changes in the technology of the station with the drinking water;
- reduction of labor intensity and operating costs for storage, preparation and dosing of the reagent, improvement of sanitary and hygienic working conditions.

Inorganic cationic polymer coagulant " Bopak-E " has the ability to form complex compounds with a wide range of organic and inorganic substances in water.

It fundamentally differs from ordinary aluminum salts in that it has a so-called surface acidic shell, which ensures the highest possible efficiency of water purification from suspended solids and metals.

According to sanitary characteristics, it corresponds to the quality required for food products and is made from pure hydrochloric acid and metallic aluminum.

The technical characteristics of the coagulant are shown in Table 1.

Table 1: Specifications hydroxy chloride and aluminum.

Formula is the product	$Al_2(OH)_5CI$, aqueous solution
basicity	5/6
mass fraction of aluminum	(10 ± 1)%
mass fraction of Al_2O_3	(17.0 - 20.8)%
mass fraction of chlorides	(6.2 ± 0.5)%
specific gravity	(1.27 ± 0.03) kg / dm ^{3}
pH	4.5 ± 0.5
viscosity	30 ± 10 cps
freezing point	minus 18 ^{o}C , after defrosting does not lose coagulation properties

Application area:

- in drinking water treatment systems;
- treatment of municipal, industrial waste water;
- preparation of water for technical needs, for heat power engineering.
- in perfumery, pulp and paper, leather industry (Chong et al, 2010, Zapolsky, Baran, 1987).

Oxychloride, aluminum " Bopak -E" can deliver any chemically resistant containers: cans, barrels, containers, tanks and other containers.

The coagulation rate depends on the concentration of the electrolyte. At low electrolyte concentrations, the efficiency of particle collisions, that is, the ratio of the number of collisions that ended in adhesion to the total number of collisions, is close to zero. As the concentration increases, the rate of coagulation increases, but not all collisions are effective; such coagulation is called slow. Further, rapid coagulation occurs, in which all collisions of particles end in the formation of aggregates.

In polydisperse systems, coagulation occurs faster than in monodisperse systems, since coarse particles, when settling, entrain smaller ones. Particle shape also affects the rate of coagulation. For example, elongated particles coagulate faster than spherical ones.

The size of the flakes (in the range of 0.5-3 mm) is determined by the ratio between the molecular forces holding the particles together and the hydrodynamic forces of detachment, which tend to destroy the aggregates.

The strength of the flakes depends on the particle size distribution of the resulting particles and plasticity. Agglomerates of particles that are inhomogeneous in size are stronger than homogeneous ones. Due to the release of gases from the water, as well as a result of aeration and flotation, gas saturation of the flocs occurs, which is accompanied by a decrease in the density of the flocs and a decrease in the sedimentation rate.

The process of wastewater treatment by coagulation consists of the following stages: dosing and mixing of reagents with wastewater; flocculation and sedimentation.

Various mixers are used to mix coagulants with water. In hydraulic mixers, mixing occurs due to changes in the direction of movement and the speed of water flow. In mechanical mixers - devices with a stirrer, the stirring process should be uniform and slow so that the particles, when approaching, form flakes that would not collapse when the mixer rotates.

After mixing the waste water with the reagents, the water is sent to the flocculation chambers. Cloisonne, vortex, and mechanical-agitated chambers are used. The formation of flakes in the chambers proceeds slowly - within 10-30 minutes. They are reservoirs, divided by partitions into a series of corridors, in succession, passable by water, in which the coagulant is mixed with waste water. The speed of the water in the corridors is 0.2-0.3 m / s.

The settling of flakes occurs in sedimentation tanks and clarifiers. Hour then mixing step of coagulation and precipitation carried out in a single apparatus. Coagulant flakes are formed in the annular zone. Suspended particles with flakes settle to the bottom and are removed from the apparatus. Clarified water through the hole enters the tray, from where it is sent for further purification (Babenkov, 1983. Danilov-Danilyan, Bolgov, 2009, Sazhin et al, 2012)

The optimal dose of the mouth of the reagent - the time here to probe based coagulation laboratory Company, successively changing the dose of coagulant. At the same time, the properties of its macromolecules and the nature of dispersed particles are considered.

3 RESULTS AND DISCUSSSIONS

Taking into account the composition and properties of wastewater entering the Lermontov wastewater treatment plant, we proposed to use as a trial coagulant aluminum oxychloride with a concentration of 2 mg / l instead of aluminum sulfate determined by the technological regulations with an optimal dose of 20 mg / l. The results of water analyze before and after vertical sedimentation tanks using aluminum oxychloride are shown in Table 2.

The complex of treatment facilities in the city of Lermontov consists of two technological lines with a capacity of 25 thousand m3 / day.

Wastewater from the municipal and industrial sewage system is pumped from the sewage pumping station to the receiving chamber of the treatment plant. The receiving chamber with the help of surface shield gates directs part to the first stage of treatment facilities, and the remaining part to physical and chemical treatment facilities.

The first technological line is designed for wastewater treatment in the amount of 10 thousand m 3 / day. The operation of this line is based on the method of biological wastewater treatment. The second technological line is designed to receive and purify 15 thousand m 3 / day of waste water. The operation of this line is based on the method of physical and chemical cleaning. It is on this technological line that the coagulation process is used.

Table 2: The results of analyzes of the use of coagulant about aluminium oxychloride in vertical settling tanks.

The substance to be determined	Incoming for cleaning, mg / l	After settling tank, mg / l		Cleaning effect	
		Using $Al_2(OH)_5$ CI	Without using $Al_2(OH)_5$ CI	Using $Al_2(OH)_5$ CI	Without using $Al_2(OH)_5$ CI
Suspended substances	158.6	3.97	14.9	97.5	90.6
Ammonia nitrogen	30.4	21.1	24.7	30.7	18.75
Nitrite	0.57	0.34	0.36	40.4	36.8
Phosphates	8.2	3.5	7.8	56.7	4.9
Aluminum	0.022	0.0134	0.0154	39.0	30.0
BOD_5	178.89	60.3	75.7	66.2	57.6
Copper	0.052	0.019	0.021	64.0	59.6
Fluoride	0.45	0.31	0.36	31.1	20.0

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It can be seen from the results obtained that the use of aluminum oxychloride as a coagulant makes it possible to obtain a higher cleaning effect in terms of such indicators as suspended solids, ammonium nitrogen, nitrites, phosphates, aluminum, BOD 5 , copper and fluorides.

Wastewater, after being cleaned on two technological lines, goes to the post-treatment section, where it is additionally processed on sand filters and disinfected in tanks by chlorination. Comparative results of complete wastewater treatment at the wastewater treatment plant in the city of Lermontov are shown in Table 3.

Table 3: Wastewater analysis results.

Substance to be determined	After PCH, mg / l		After biological treatment, mg / l	After cleaning, mg / l		Cleaning effect,%	
	Using $Al_2(OH)_5CI$	Without using $Al_2(OH)_5CI$		Using $Al_2(OH)_5CI$	Without using $Al_2(OH)_5CI$	Using $Al_2(OH)_5CI$	Without using $Al_2(OH)_5CI$
Suspended substances	3.97	14.9	53.53	2.7	4.2	92.1	87.71
Ammonia nitrogen	21.1	24.7	6.4	1.58	2.5	89.87	83.97
Nitrite	0.34	0.36	0.279	0.11	0.13	65.62	59.37
Phosphates	3.5	7.8	2.37	0.061	0.27	98.91	95.17
Aluminum	0.0134	0.0154	0.0176	0.003	0.005	75.75	69.69
BOD_5	60.3	75.7	24.5	1.25	3.28	97.5	93.45
Copper	0.019	0.021	0.0312	0.003	0.004	88.46	84.61
Fluoride	0.31	0.36	0.44	0.19	0.22	52.5	45.0

4 CONCLUSION

The use of a new technological solution will significantly reduce the content of pollutants in the discharged wastewater into the receiving water within the limits of the MPD, which will significantly reduce the amount of payments for pollution of the Gorkaya River and, thereby, improve the financial performance of the enterprise. An approximate calculation of the prevented annual economic damage is shown in Table 4.

Table 4: Ecological characteristics of discharges before and after the implementation of environmental protection measures and the prevented annual economic damage.

Pollutant name	MPC_i p/x, mg/l	A_i	Reduced discharge mass (M_i), t/year		Specific annual damage (D_i)		Averted economic annual damage (D)
			Before events	After the events	Before events	After the events	
Suspended substances	3,20	0,31	4,657	2,9938	268062,26	172326,55	95735,71
Ammonia nitrogen	0,500	2,0	18,384	11,303	1058204,27	650613,72	407590,55
Nitrite	0,080	12,5	5,8123	4,9181	334562,71	283091,51	51471,2
Phosphates	0,020	5	4,82868	1,145824	277944,40	65954,94	211989,46
Aluminum	0,005	200	3,5768	2,14608	205884,74	123530,82	82353,92
BOD_5	3,00	0,33	3,8715	1,4754	261885,46	84925,71	176959,75
Copper	0,001	1000	14,3072	10,7304	1386270,94	617654,19	768616,75
Fluoride	0,180	5,55	4,36727	3,77173	251385,10	217105,11	34279,99
Total output	-	-	59,80475	38,484334	4044199,88	2215202,55	1828997,33

Thus, the use of coagulant aluminium oxychloride in urban wastewater treatment plants instead of traditional aluminum sulfate will allow achieving a higher degree of wastewater treatment and reducing the negative impact on the environment.

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