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## Section 1. Technical sciences in general

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### RESEARCH, PATENT ANALYSIS AND PROSPECTS OF APPLICATION OF IN-LINE SEPARATOR TECHNOLOGY

**Abstract.** This paper is devoted to research and analysis of in-line separator technology – innovative devices designed for effective phase separation in multicomponent media flows inside pipelines. In the course of the study, a review of existing scientific and patent sources devoted to in-line separators and related technologies was carried out. The main attention is paid to technical characteristics, principles of operation.

**Keywords:** in-pipe separation systems, oil transportation, infrastructural loss elimination, pipeline system management, crude oil processing, oil and gas industry, process optimization, pipeline efficiency, energy industry lenity, separator.

Due to the constant development of technology and market needs, conducting patent and literature searches becomes necessary to investigate existing developments, identify new trends and determine the prospects for the application of in-line separators.

The purpose of this article is to review modern developments in the field of in-line separators, to analyze patent information and scientific publications devoted to this topic, to determine the prospects for the development of this equipment.

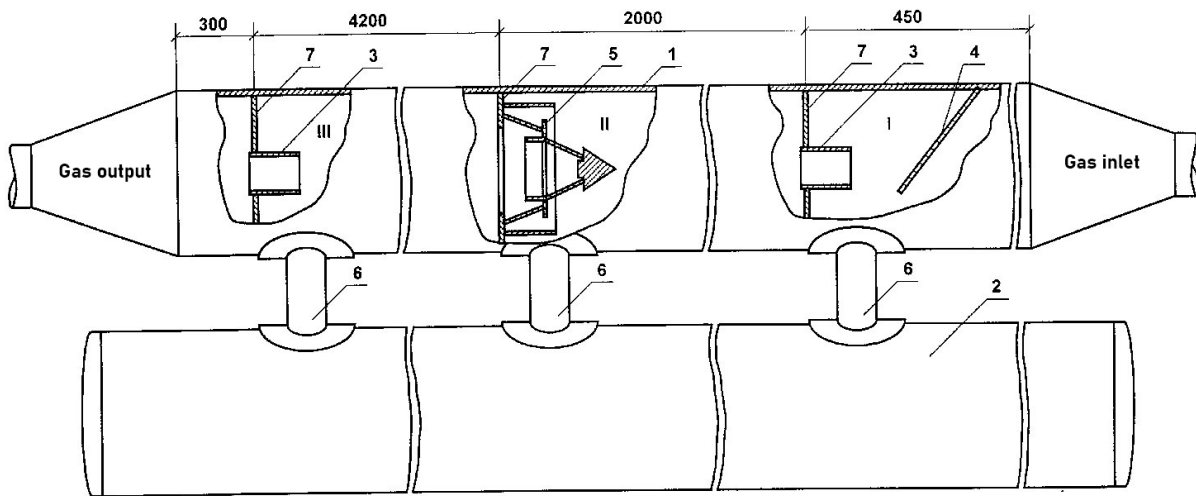


Figure 1. Drawing of in-line separator from patent No. 19658: 1 – body of in-line separator; 2 – condensate collector; 3 – branch pipe (partitions); 4 – reflector; 5 – swirler; 6 – branch pipe connecting the body with condensate collector; 7 – partitions

Patent No. 19658, describes a device called an in-line separator. It is designed for in-line purification of gas from liquids at fields and facilities. The closest analogs of the in-line separator from the devices are a centrifugal separator and an expansion chamber. The simplicity of construction, lower metal intensity, ability to capture finely dispersed liquid phase, which is in the form of a mist, are claimed as advantages [1].

This device is designed for gas purification, which does not fulfill the required purpose, namely,

purification of oil and gas liquids from high concentration of associated petroleum gas (hereinafter – APG).

Patent No. 2747403 describes an in-line separator device. The invention relates to the field of devices for separating liquid from gas, in particular, to separators widely used in the oil and gas industry for separating hydrocarbon condensate and water from natural or associated gas [2].

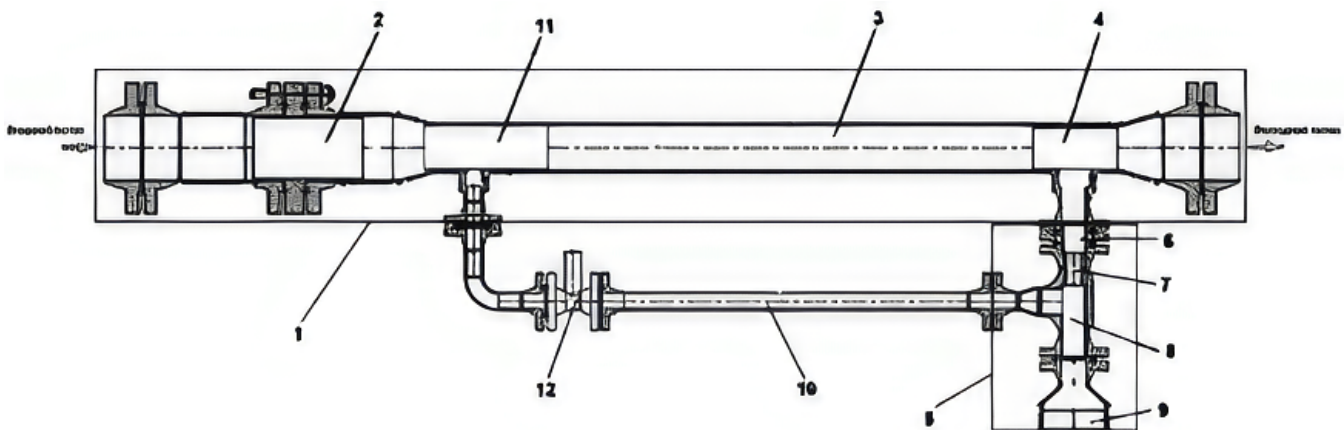


Figure 2. Drawing of in-line separator from patent No. 2747403: 1 – main channel; 2 – first swirler; 3 – first liquid separation section; 4 – gas-liquid flow extraction section; 5 – first additional channel; 6 – second swirler; 7 – second liquid separation section; 8 – liquid extraction section; 9 – vessel; 10 – second additional channel; 11 – ejector; 12 – regulating valve

Patent No. 107070 describes a device similar in principle of operation to an in-line separator called a flow separator [3].

The device is used to separate components from the flow in the oil and gas industry. It con-

tains a cylindrical body with a fairing, swirler, diffuser, confuser and collecting vessel. It allows to increase the flow velocity of gas-liquid mixture and increase the efficiency of liquid separation from this mixture.

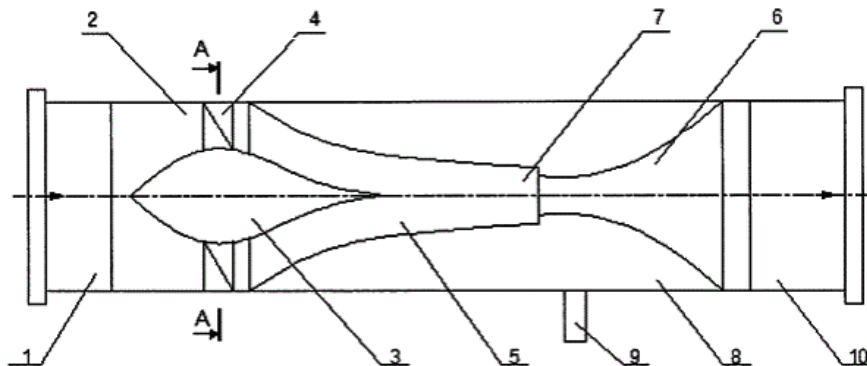


Figure 3. Drawing of in-line separator from patent No. 107070: 1 – inlet pipe, 2 – cylindrical body, 3 – fairing, 4 – swirler, 5 – diffuser, 6 – confuser, 7 – annular gap, 8 – collecting vessel, 9 – drainage pipe, 10 – outlet pipe

In addition to the considered device, patent No. 94479 [4] entitled “Straight Spiral Separator” has been investigated.

The device is used to separate dispersed particles from gases or vapors in various industrial applications. It includes a housing with inlet and outlet connections, a multi-bore screw column and other components. The separator provides direct gas-liquid flow, improves the efficiency of liquid-gas separation, and has certain dimensional parameters, such as the diameters of the shell, separator and drift eliminator. The distributor insert, shell, cut-off device and droplet eliminator achieve the required phase separation and removal of liquid from the gas stream.

Foreign patents were analyzed to find alternative designs. Patent No. 2229922 describes a device called “Inertial separator and method for supersonic separation of a component” [5].

The invention is intended for separating components from a stream. The inertial separator includes a taper-expanding nozzle for creating an emulsion flow with supersonic velocity.

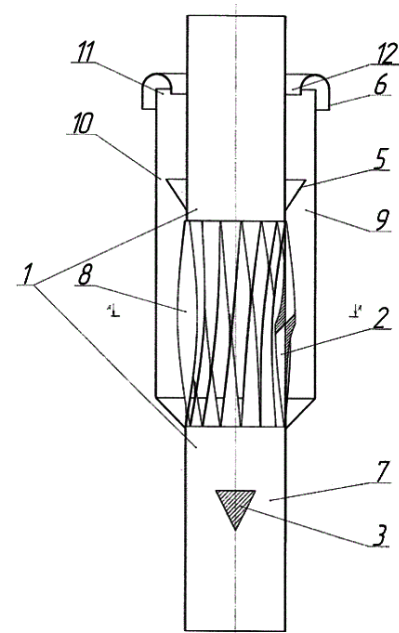


Figure 4. Drawing of the in-line separator from patent No. 94479: 1 – body; 2 – helical multi-start column; 3 – distributor insert, 4 – shell, 5 – cutoff device, 6 – drop eliminator, 7 – annular channel, 8 – blades; 9 – cavity, 10, 11, 12 – annular gap

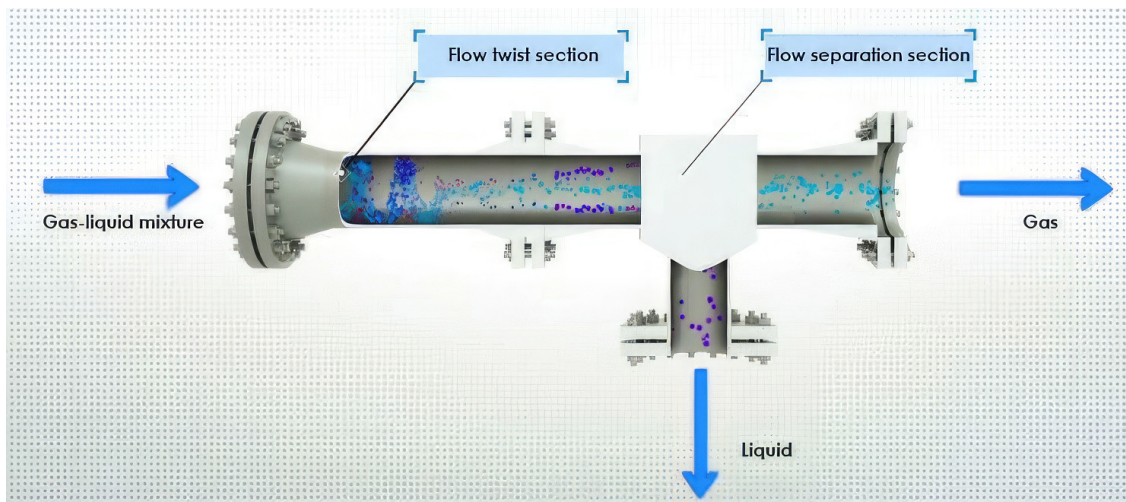


Figure 5. General view of in-line separator

The manufacturer’s website describes the principle of operation of the in-line separator, which is based on the use of centrifugal forces in an axial cyclone. The gas-liquid mixture is swirled in a tangential or vane swirler installed at the inlet of the device

and is directed into a cylindrical channel, where the liquid is separated on the walls of the channel. A liquid film is formed on the walls of the cylindrical channel, and a stream of purified gas is formed in the near-axis zone. At the outlet of the cylindrical



channel there is a separating section where the flow is separated into gas and liquid flow. All separator elements are mounted inside the pipeline [6]. A brief illustration of the device is shown in (Figure 5).

The article “Application of In-line Separation Systems to Prevent Droplet Liquid Entrainment from Condensate De-ethanization Columns” describes the experience of applying in-line separation systems after a condensate stabilization column at the Termokarstovoye field gas treatment unit of Terneftegaz, a subsidiary of NOVATEK. The launch of the in-line separator eliminated the drift of liquid hydrocarbons (C3+) from the top of the column and ensured additional production of de-ethanized condensate in the amount of more than 12 tons per day [7].

In the article of the journal “Oil and Gas of Siberia” [8], describes the application of the in-line separation system within the installation of the intelligent block “Metering-Well”. The main principle of its operation is the separation method of measuring well

flow rate, but unlike conventional capacitive separators, the intelligent block metering system (hereinafter – IBMS) uses compact in-line separators. In the course of the tests the specialists made sure that the mobile block of the IPMS provides stable measurement of well flow rates in a wide range of oil and gas flow rates. The arithmetic average error for all measurements amounted to 2.3% for well fluid flow rates and 3.6% for associated gas flow rates. At the same time, the maximum gas factor at the wells reached 1200 st. m<sup>3</sup> per ton of oil.

In the article of the Gas Industry magazine [9] the difference between the use of in-line separators and ejectors is described [9] describes the difference between the use of in-line separators and ejectors, the main scenarios for the use of in-line separators, advantages and disadvantages.

The article of the journal “Engineering Practice” describes the scope of application of in-line separators and ejector systems based on them [10].

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10. Technologies of in-line gas treatment / S. Z. Imaev // Engineering practice.– № 2. 2022.– 5 p.

## Section 2. Chemistry

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### INVESTIGATION OF THE STRUCTURE OF DIALDEHYDE POLYSACCHARIDES WITH VARIOUS DEGREES OF OXIDATION

**Abstract.** Chemical modification of starch and cellulose was carried out using the periodate oxidation reaction. The structure of oxidized polysaccharides with different aldehyde group contents was studied by titrimetric analysis, X-ray diffraction analysis, and electron microscopy. According to the X-ray diffraction analysis data, amorphization of the structure of polysaccharides occurs in the process of periodate oxidation. Electron microscopy substantiated that as aldehyde groups grow in the macromolecular chain of starch and cellulose, there is a significant change in the morphology of polysaccharides.

**Keywords:** polysaccharides, starch, cellulose, periodate oxidation, structure, morphology.

**Introduction.** Due to their unique physical and chemical properties, biocompatibility, and high availability, polysaccharides, as well as their various derivatives, find a variety of practical applications. To date, to obtain new derivatives of polysaccharides with valuable properties, preference is given to the preliminary modification of the macromolecular

chain of biopolymers, in which alcohol groups are replaced by more reactive groups. In turn, the presence of new functional groups in the main macrochain of natural polymers makes it possible to synthesize derivatives of polysaccharides [1–3]. For example, dialdehyde derivatives of polysaccharides are of great interest as intermediates. They can be



used for various chemical transformations involving electrophilic aldehyde groups [4–6]. The synthesis of aldehyde-containing polysaccharide derivatives can be carried out in several ways, the most common of which is the periodate oxidation reaction [7; 8]. The formation of -CHO groups in the monosaccharide units of polysaccharides occurs as a result of the nucleophilic attack of oxygen atoms of  $\text{IO}_4^-$  ions at the vicinal hydroxyl groups, usually located at  $\text{C}_2$  and  $\text{C}_3$ , contributing to the rupture of -C-C- and leading to the formation of two aldehydes simultaneously. Depending on the reaction conditions and the structure of the oxidized polysaccharide, the rate-limiting step can be the formation of a cyclic intermediate or its decomposition [9].

Usually, the periodate oxidation reaction is carried out at a temperature not higher than room temperature, since with an increase in temperature, reoxidation of -CHO to -COOH is observed. The duration of the reaction for each polysaccharide may be different from several minutes to several days and mainly depends on the physicochemical characteristics of the initial biopolymers. During the periodate oxidation of polysaccharides under heterogeneous conditions, products are obtained that differ greatly in supramolecular and morphological structure.

Since there is practically no information in the literature devoted to the direct observation of the structural features of dialdehyde polysaccharides synthesized under heterogeneous conditions, we set the task of studying the nature of changes in the structure of starch and cellulose after their chemical modification by periodate oxidation. The availability of such data will allow a deeper understanding of the relationship between the structure and physicochemical properties of oxidized polysaccharide derivatives.

**Materials and methods.** The following were used in the work: Sodium periodate (AR) was obtained from the GuangFu of Tianjin Fine Chemical Industry Research Institute; cotton cellulose (CC) with a degree of polymerization of 1400 and a mo-

lecular weight of 226.8 kDa; potato starch was purchased from Potato Industrial Enterprise “Nowamyl” S.A., Nowogard, Poland.

*Periodate oxidation of starch and CC.* Starch was modified as follows: 0.02 mol of dried starch was placed in a 500 ml dark glass flask, and 200 ml of acetate buffer pH 4.25 and 0.2 N  $\text{NaIO}_4$  solution were added at a molar ratio of starch:  $\text{IO}_4^- = 1:1.5$ . The reaction of periodate oxidation of starch lasted 1–8 hours at  $t = 20^\circ\text{C}$ . The target products of the periodate oxidation reaction were considered to be the insoluble fraction of modified starch. The obtained samples of starch dialdehyde (DAS) were filtered on a Shotta filter and successively washed with 0.5–1 L of water with the addition of a hydrochloric acid solution to pH 1, then with 1 L of acetone/water, and finally with 0.2–0.25 L of acetone until a negative reaction to  $\text{IO}_4^-$  and  $\text{IO}_3^-$  (control by reaction with a solution of silver nitrate). The reaction products were dried in the dark under a vacuum over  $\text{P}_2\text{O}_5$ . The degree of oxidation of the samples was calculated by back iodometric titration [10].

Periodic oxidation and purification of CC were carried out similarly to starch modification. The duration of cellulose oxidation was 1–7 days. The obtained samples of cellulose dialdehyde (DAC) after completion of oxidation were filtered on a linen filter, dried in the dark under vacuum over  $\text{P}_2\text{O}_5$ , and analyzed.

Comparative X-ray diffraction analysis of the initial polysaccharides, DAS, and DAC samples with different oxidation states was carried out on an XRD-6100 powder diffractometer (Shimadzu, Japan). The morphological structure of the samples was studied by scanning electron microscopy (SEM). To obtain electronic images, the presented samples were covered with a 15 mm thick carbon layer in a vacuum using a Q 150 RES device (QUORUM, USA) and then analyzed using an EVOMA10 scanning electron microscope (Zeiss, Germany).

**Results and discussions.** In the chemical modification of starch and CC with sodium periodate, oxidation occurs under heterogeneous conditions.

Table 1. – Influence of the reaction time on the degree of oxidation and the yield of DAS (starch:  $\text{IO}_4^- = 1:1.5$ ;  $t=20^\circ\text{C}$ ; pH 4.25)

Duration of starch oxidation, hour	Iodine number	*Degree of starch oxidation, mol%	Content of aldehyde groups, %	The yield of DAS from the initial mass of starch, %
1	31.4	12	4.3	92.6
3	93.5	36	12.9	90.0
5	116.7	45	16.2	85.4
8	156.0	60	21.6	82.5

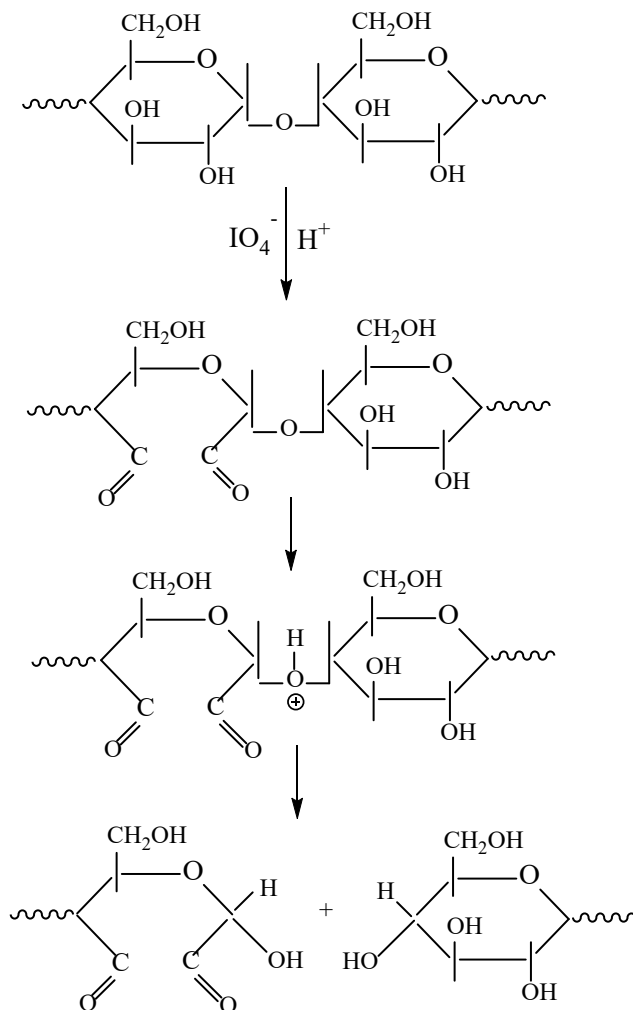
\* The degree of oxidation – the number of oxidized units for every 100 units of the polysaccharide

Table 2. – Influence of the reaction time on the degree of oxidation and the yield of DAC (starch:  $\text{IO}_4^- = 1:1.5$ ;  $t=20^\circ\text{C}$ ; pH 4.25)

Duration of CC oxidation, days	Iodine number	*Degree of CC oxidation, mol%	Content of aldehyde groups, %	Yield of DAC from the initial mass of CC, %
1	42.0	16	5.8	98.2
2	98.7	38	13.7	97.6
3	131.2	50	18.0	94.5
5	175.8	67	24.2	92.0

Therefore, the total rate of this reaction depends on the rate of penetration of the reagent from the external environment into the accessible regions of polysaccharide macromolecules. During the oxidation of polysaccharides, it was revealed that each is characterized by a different rate of oxidation. The different kinetics of the periodate oxidation of polysaccharides are associated with their supramolecular structure and physicochemical properties. Tables 1 and 2 present comparative data on the effect of periodate oxidation time on the content of aldehyde groups and the yield of reaction products.

The data presented in (Tables 1 and 2) show that with an increase in the time of periodate oxidation, a regular increase in the number of aldehyde groups in the composition of the reaction products occurs. However, along with an increase in the degree of oxidation of polysaccharides, a decrease in the yield of DAS and DAC was observed. This is explained by the fact that during the modification of starch and CC in the presence of  $\text{IO}_4^-$  in an acidic medium, polysaccharide macromolecules are hydrolyzed according to the following scheme:



The results of X-ray diffraction analysis indicate the occurrence of the reaction of periodic oxidation in a heterogeneous medium. Figures 1 and 2 show that with an increase in the number of aldehyde groups in the modified starch and CC, there is a gradual disappearance of crystalline regions in the original polysaccharides, which is caused by the oxidation of -OH groups involved in the formation of inter- and intramolecular hydrogen bonds. On X-ray patterns of DAS and DAC, a smoothing of the peak is observed in the range of angles from 15 to 25°.

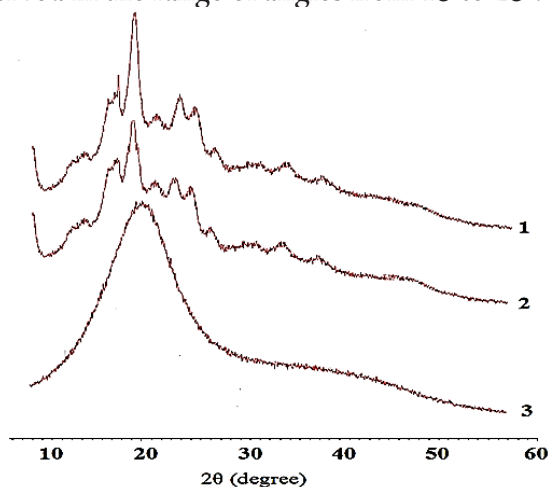


Figure 1. X-ray patterns of starch (1) and DAS with oxidation states of 12 mol% (2) and 60 mol%

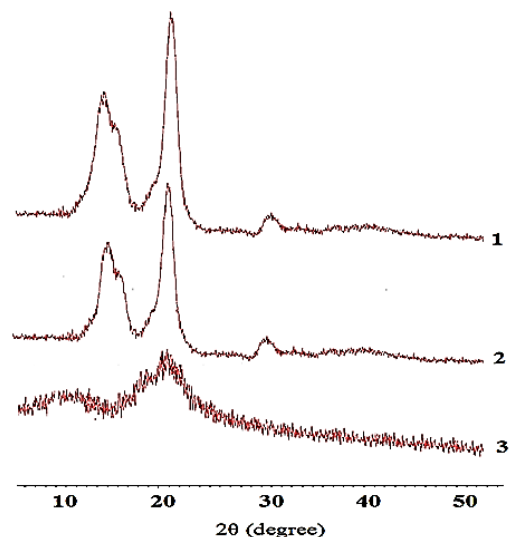


Figure 2. X-ray patterns of CC (1) and DAC with oxidation states of 16 mol% (2) and 82 mol%

The resulting DAS with different degrees of oxidation were studied by SEM (Fig. 3). It was found that after periodate oxidation, DAS samples with different aldehyde group contents consist of inhomogeneous particles differing in shape. At the same time, with an increase in the degree of oxidation of the modified starch, pores and microcracks expanded, and the shape and geometry of the particles changed.

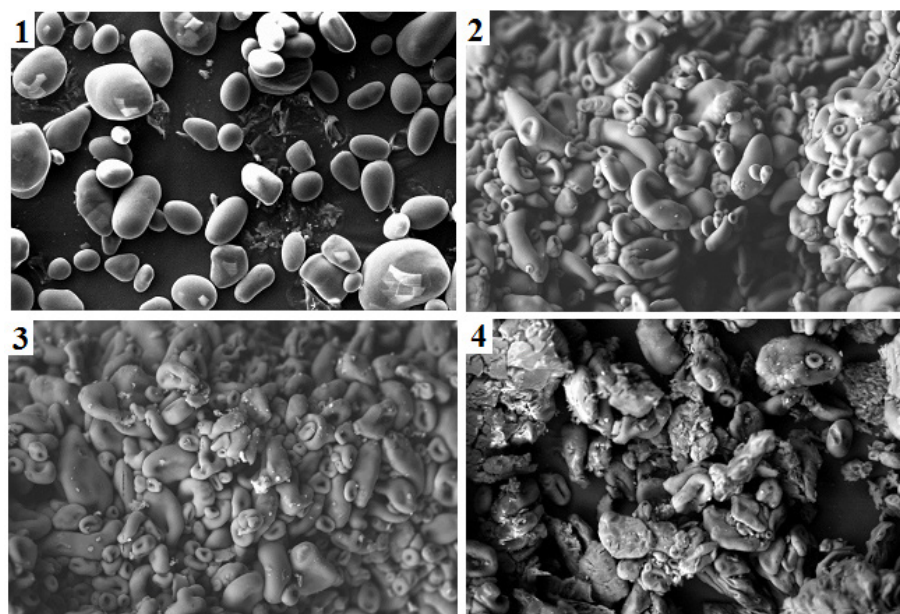


Figure 3. SEM images of (1) starch and DAS samples with (2) 12, (3) 36, and (4) 60 mol% oxidation states

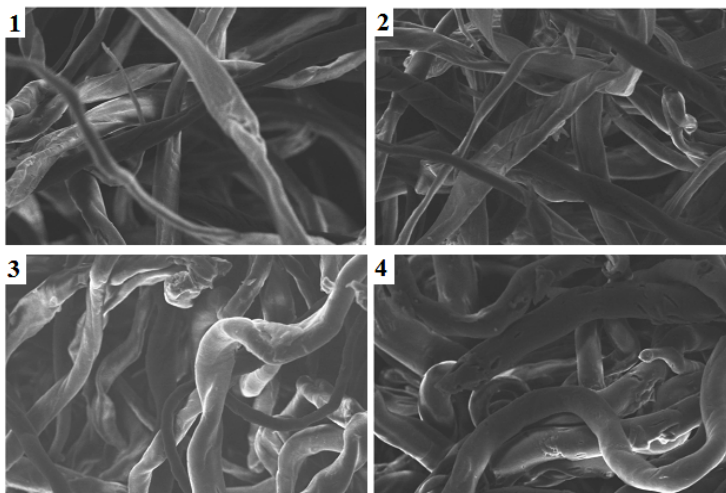


Figure 4. SEM images of (1) CC and DAC samples with (2) 16, (3) 50, and (4) 82 mol% oxidation states

The SEM images (Fig. 4) show that the original cellulose is characterized by straightened and mostly crimped fibers. After the periodate oxidation of CC under heterogeneous conditions, the initial state of the fibers begins to change and is characterized by the formation of loose areas. These changes directly correlate with the degree of oxidation of the resulting DAC samples.

**Conclusion.** The studies performed have shown that the inclusion of aldehyde groups in the polymer molecules of starch and cellulose leads to a change in the structure of the initial polysaccharides. With an increase in the degree of oxidation of polysaccharides, their amorphization increases and profound changes are observed in the morphology of the studied samples.

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## INFLUENCE OF ACID ENVIRONMENT CHANGES ON SORPTION PROPERTIES DURING CLAY POWDER PROCESSING

**Abstract.** Based on today's information, the areas of application of sorbents are different depending on which products are received. Sorbents are mainly used for water purification, extraction of precious metals, purification and bleaching of vegetable oils, purification of oil and petroleum products, purification and regeneration of various used motor oils, grape and wine production, air and gas purification. If you pay attention to the methods of obtaining and using sorbents, their composition will change in different ways. The cheapest and most profitable side of obtaining sorbents depends on what components are used to obtain them and the processes for their production.

**Keywords:** Palygorskite clay powder, porosity, sulfuric acid, grinding, bleaching, activation.

### The urgency of the issue

One of the most basic and necessary ingredients for obtaining the cheapest and most convenient is the use of various clay powders found in many countries. Soils in the clay layer, which have sorbent properties, mainly have an octahedral structure. Tetrahedral clay soils are used for other purposes. In this case, it has a structured, i.e. octahedral structure, and its properties vary depending on the percentage of metals and the way they are mixed.

Another way to activate clay powders is to change the proportions of the mixed components. In this method, 10 g of clay powder is mixed with 20 ml of water and 1.5 ml of acid. The resulting mass is washed on the filter until a pH of 3.0–3.2 is reached. The washed mass is dried at a temperature of 110 degrees.

The method of obtaining a sorbent for clarification of cottonseed oil is carried out in the following sequence.

1. PP clay is crushed to a particle size of 20–25 mm, then a suspension is prepared in water in the ratio  $S; L = 1 : 2.2$ .

2. Then sulfuric acid is introduced in an amount of 15% by weight of dry clay obtained for activation.

The acid concentration in the activator was adjusted to 7.5%.

3. The activation process is carried out for 1 hour at a temperature of 110–1150 C with vigorous stirring.

4. Humidity is about 9–10%.

The degree of grinding should ensure the passage of at least 94% of the sorbent through a 0044 K sieve (fraction 44 microns).

As a result of the research, it was found that the more passive the ability of clay powders to react with acid, the more it is necessary to reduce the amount of acid and increase the temperature. Also, when filtering, it is required to increase the acidity of the medium. Because during the drying process, the medium begins to move towards neutral. It can be concluded that during the drying process, reaction processes with acid take place, and porosity increases. The following table shows the number of colors of cottonseed oil, which requires 1.2 ml of clay powder.

Such results were achieved by changing the temperature, the proportions of the components and the time during the processes.

Table 1. – Results obtained when applied to cottonseed oil red 16 and blue 2

S/N	Clay powders	How many units decreased red?	How many units decreased blue?
1	pH medium 2.8	10	0.5
2	pH medium 3.2	14	1.5

Even if we increase the steps of the experiment, it has been observed that the level of porosity has changed. An increase in porosity led to an improvement in the properties of the sorbent. In this method, 10 g of clay powder is mixed with 20 ml of water and 1.5 ml of acid. The resulting mass is washed on

the filter until a pH of 1.5 is reached, then dried at a temperature of 90–100 degrees. The dried mass is washed on the filter until a pH of 3.5–3.7 is reached. The washed mass is dried at a temperature of 110 degrees. The following figure shows that the sorbent obtained by us gave a very good result.

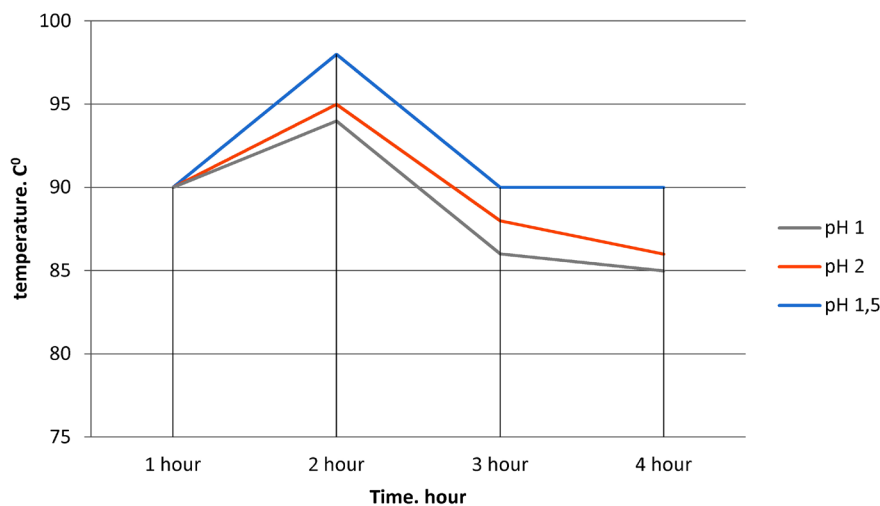


Figure 1. Influence of an acidic environment on the properties of the sorbent

The method of obtaining a sorbent for clarification of cottonseed oil is carried out in the following sequence.

1. PP clay is crushed to a particle size of 20–25 mm, then a suspension is prepared in water in the ratio S; L = 1 : 2.2.

2. Then sulfuric acid is introduced in an amount of 15% by weight of dry clay obtained for activation. The acid concentration in the activator was adjusted to 7.5%.

3. The resulting mass was washed on the filter until a pH of 1.5 was reached, then dried at a temperature of 90–100 degrees for 1 hour.

4. The activation process is carried out for 1 hour at a temperature of 110–1150 C with vigorous stirring.

5. Humidity is about 9–10%.

The degree of grinding should ensure the passage of at least 94% of the sorbent through a 0044K sieve (fraction 44 microns).

Bleached clay is a product of the decomposition of rocks (basalts, volcanic ash and ashes, as well as various mixtures) and their weathering under the influence of water, carbon dioxide and other factors. With prolonged exposure of water and substances dissolved in it to erupting rocks, alkalis, earth hydroxides and acidic iron are removed from the rocks. As a result, rocks with a loose and porous structure are formed, which have significant sorption properties. Due to the complete weathering of volcanics, typical bleached clays (bentonites, fuller's earths, etc.) containing hydroaluminosilicates of various compositions are formed.

The end products of the weathering process are low-alkali silicates (silicolite) or semioxide hydrates

(bauxites, laterites and ferrolites). The absorption capacity of bleached clays is related to their porous structure, which determines the highly developed surface and surface character. Not only adsorption, but also other sorption (capillary condensation, chemisorption) and colloid-chemical (flocculation, coagulation, etc.) processes play a role in purification.

The main task of the bleaching process is the removal of peroxides and secondary oxidation products. In addition, pigments and any system resin and soap ceramics are removed. The bleaching process is carried out under a steam/nitrogen blanket, under vacuum or in an open tank. Vacuum offers the benefits of drying oils at low temperatures, removing moisture from the clay, and preventing contact with atmospheric oxygen. This is because activated clay powders can act as an oxidation catalyst in the presence of oxygen at high temperatures. The resulting oxidation products lead to degeneration and a short service life of the end products. Typically, the bleaching process is carried out at a contact temperature of 80–120 °C and under vacuum for 20–40 minutes. During this time, the absorption of dyes by the active clay powder can be balanced with sufficient activation.

The dosage of bleaching clay may vary depending on the type of oil. In chemical cleaning usually use 0.5–2% by weight. However, 2–4% recycled primer can be used to meet final color requirements. In ad-

dition, the active clay powder dosage should be minimal to remove impurities as measured by peroxide reduction.

Typically, oil loss is caused by the sorbent used for the filtered mass. It turned out that the typical value of the retention of vegetable oil is about 40%. This value can be reduced to 20–30% by an appropriate intermediate process such as using steam or nitrogen at the end of the filtration. They estimate that for every 100 kg of freshly processed clay flour, 2–4 kg of oil is lost. The fine particle size of clay powders gives good polishing results. However, filtration rate and oil retention can be adversely affected. Thus, efficient filtration, short filtration times and minimization of oil retention on the filter cake are essential. Bleaching clays typically contain 5–18% moisture. If the removable sorbent is completely dried before use, its structure will be destroyed, and the polishing ability will decrease due to a decrease in surface area.

In addition, when hot oil is added to the clay, the adsorption capacity of the acid-activated clay powder decreases. This is due to the fact that the moisture in the sorbent is very quickly displaced and causes the destruction of the structure of the clay powder. Acid-activated clay should be added to vacuum-dried clarified oil at 80 °C, then quickly brought to operating temperature and kept at this temperature for a sufficient time for maximum bleaching.

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## PHYSICO-CHEMICAL ANALYSIS OF CLAY POWDER WITH SORPTION CHARACTERISTICS

**Abstract.** Clay soils have been and remain one of the most important industrial minerals. Clay and clay minerals are widely used in many areas of our society. They are important in geology, agriculture, construction, technology industries. Some more important applications include ceramics, paper, paints, plastics, drilling fluids, foundry metal alloys, chemical carriers, liquid barriers, and catalysis. The research and development activities of clay soil scientists in academia, government and industry are constantly leading to the production of new and innovative clay powder products, many of these new applications are the result of improved processing resulting in higher purity clay powders., with finer particle size and distribution., whiter and brighter color, modified surface chemistry and other physical and chemical modifications. Some new and improved clay products have been adapted or developed as paper-coated kaolins, advanced thickeners for paints, nanocomposites for plastics, columnar clays as specialty absorbents and catalysts, clays for liquid fertilizer slurries, animal waste absorption includes clay, kaolins, activated in an alkaline environment. Faster pouring of clay and very high modulus of break, high gloss and low friction.

**Keywords:** Kaolin, bentonite, palgorskite, carotenoids, anthocyanin, phleon, modification, adsorption, octahedral, porosity, sulfuric acid, grinding, bleaching, activation.

### **The urgency of the issue**

Natural clays (kaolin, bentonite, palgorskite) naturally have low sorption properties, depending on their mineralogical and chemical composition, their enrichment and activation according to various properties gives excellent results. The presence of color in cottonseed oil indicates the presence of alpha- and beta-carotenoids, anthocyanins, phleon pigments.

The main composition of adsorbents is silicon and aluminum oxides (natural clays, synthetic aluminosilicates, silica gel, aluminum gel).

The absorbed substance in the bulk phase (gas, vapor or liquid) is called the adsorbent, and the absorbed substance is called the adsorbate.

The difference in chemical composition is not decisive in terms of adsorption properties in clay or

soil. Of primary importance is the porous structure, which creates a large active surface of the adsorbent.

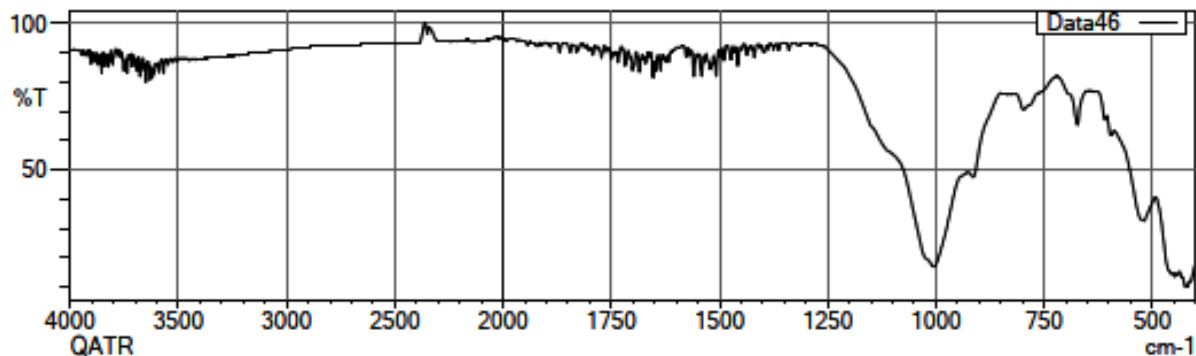
The industrial applications of the three most important types of clay minerals are varied and in most cases very different. This is primarily due to the fact that their physical and chemical properties are different depending on their structure and composition. The structure and composition of kaolins, smectites, and palygorskite-sepiolites vary greatly, although each uses octahedral and tetrahedral plates as basic building blocks.

The arrangement and composition of these octahedral and tetrahedral plates explain the major and minor differences in the properties of these clay minerals and therefore in their end use.

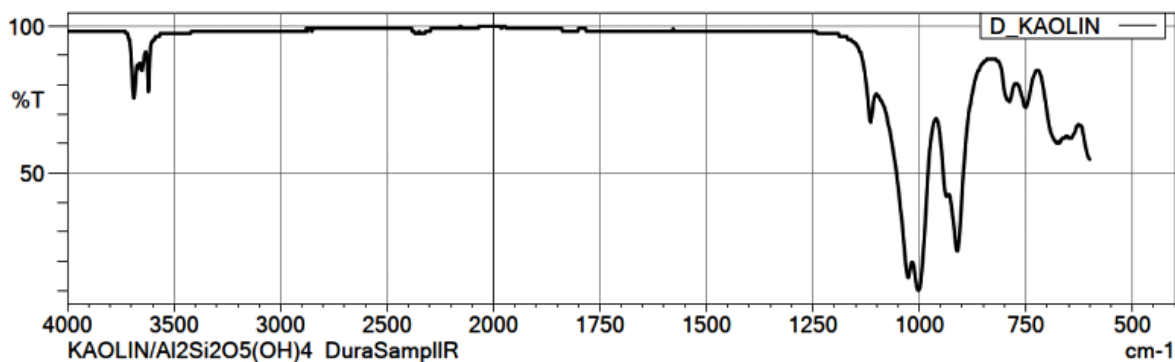


The layers of clay deposits contain clay powders of various compositions. Although their content is similar, their functions are very different from each other. From this we can say that the composition and structure should be similar. Clay powders with sorp-

tion characteristics are more often used for cleaning various products. The composition and structure of clay powders with sorption properties are not the same. On fig. 1 below shows the IR structure of natural clays (kaolin, talc).



a)



b)

Figure 1 (a, b). IR Spectroscopic Analysis of Kaolin and Talc

It also differs in hardness, color and other properties. As a result of the experiments, it was found that the amount of active metals (when treated with acid) should be removed from the structure of the clay flour in an amount of 1 to 3 percent, taking into account the composition and structure of the clay flour.

The sorbent properties of clay powder are also increased by stable organic substances. During the activation process, many changes are made to the treatment process, taking into account the impact of the acid. These changes are made mainly depending on the composition and structure of the clay. It has been repeatedly established that the structure of clay soils with sorption features mainly has an octahedral structure.

The adsorption capacity of palygorskite is due to its relatively large surface area and the net negative charge it contains, which attracts cations such as Fe(III). On (fig. 2) shows a diagram of the structure of palygorskite and its active surface areas (adapted from Bailey).

The aim of this work is to remove organic matter, rather than magnetite nanoparticles, using magnetite clay after Fe(III) adsorption. This process allows the use of additives produced during mining.

Palygorskite is a natural layer – a filamentous porous hydrated magnesian, aluminosilicate soil mineral type of a pure chemical element, usually an unstable system with the theoretical formula



$Mg_2Al_2Si_8O_{20}(OH)_2(OH_2)_4 \cdot 4H_2O$ . Due to the special structural properties of palygorskite, the layered-ribbon porous structure has many physical

and chemical properties and is formed by alternating an octahedral layer of Mg, Al, O and a tetrahedral layer of Si, O.

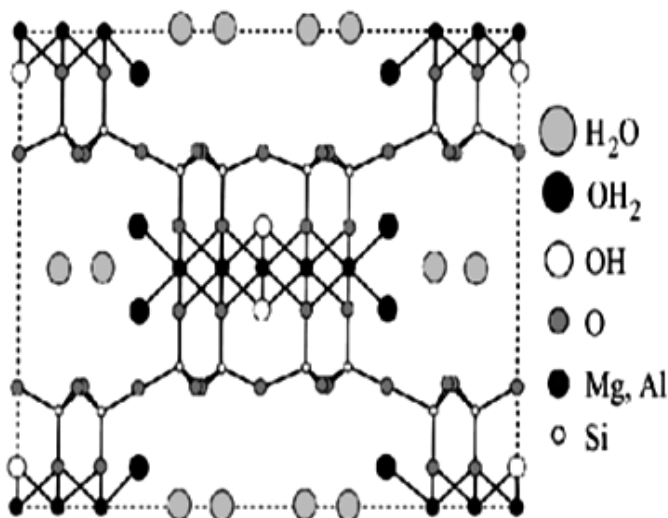


Figure 2. The structure of palygorskite and its active surface

A crystal structure diagram of palygorskite is shown in the FIC. The main building block of palygorskite consists of pairs of  $SiO_4$  tetrahedra parallel to the S axis. Each band is connected to the next one by inversion of the  $SiO_4$  tetrahedron along the oxygen atom.

In order, such tetrahedra are connected by continuous ribbons, starting from a vertical section along the C axis, forming phyllosilicate ribbons, forming oc-

tahedral layered-ribbon blocks, forming zeolite-like channels of approximately the same volume with two tetrahedral layers.  $0.38 \text{ nm} \times 0.63 \text{ nm}$  layers-strips and channel blocks are arranged alternately.

Palygorskite has a unique structure containing organic molecules and ions included in the internal structure of water channels and zeolite bonds, and exhibits good adsorption properties, rheological properties and catalytic activity.

Table 1.– Chemical composition of sorbent raw materials, %

Clay or sediment	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	FeO	MnO	MgO	CaO	TiO <sub>2</sub>	Na <sub>2</sub> O	K <sub>2</sub> O	CO <sub>2</sub>	SO <sub>3</sub>	Sulfide	Palygorskite powder
Paligorskit	36.1-	7.43-	2.44-	0.56-		6.76-	12.2-		1.43-	1.32-				
Tul	57.6	9.46	3.16	0.86		11.7	12.4		2.25	1.36				
Kaolin														
Angren	60.2	25.2	1.44			0.23	0.64	0.45		0.94		0.16		10.7
Bentonit														
Azkamar	53.5	25.1	3.96			5.22	2.16	0.15	2.16	0.83				7.26
Bentonit														
Tomditog'	58.4	14.0	10.4		0.04	3.10	2.50	0.65					1.17	
Bentonit	62.4-	10.2-	3.60-			2.98-	0.00-	0.50-	1.76-			Foot prints		4.92-
Angren	71.0	16.4	4.40			3.82	3.50	0.60	2.80					8.20

As a new adsorbent, the coal-clay powder mineral composite has attracted a lot of attention due to its potential application in water treatment. In recent decades, she has focused on the preparation and properties of one-dimensional carbon/palygorskite

composites. In 2013, the modification and morphology of palygorskite, as well as adsorption properties, were investigated by a hydrothermal method using a range of biomass carbon sources, including xylose, fructose, sucrose, and cellulose.

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## **INFLUENCE OF RHEOLOGICAL MODIFIERS ON THE PROPERTIES OF FILMS OF THE ADHESIVE COMPOSITIONS BASED ON OXIDIZED STARCH**

**Abstract.** The article studied the hydrodynamic properties of adhesives based on oxidized starch with rheological modifiers. The development is aimed at solving the problems of wet strength of glue joints based on them when used for surface gluing of corrugated boards.

**Keywords:** adhesive, oxidized starch, rheology, modifiers, wet strength, glue, corrugated board.

### **1. Introduction**

Starch is one of the oldest and most common auxiliaries used in the manufacture of paper and board. It is one of the main binding materials used in paper production, and, moreover, the cheapest compared to other binders [1]. The main use of starch is to increase the strength of paper (especially surface strength). The use of modified starches gives an additional effect associated with an increase in the retention of fine fibers, filler, optical bleaching, and sizing agents by them [2].

This effect is expressed in a decrease in the uneven properties of the paper on the sides of the sheet, which is especially important for those types of products in which both sides are working, for example, paper for writing and printing. The addition of starch to the mass reduces the dustiness of the paper, increases the retention of fillers, and improves and stabilizes the rosin sizing [3]. The production

of many types of packaging papers and boards, such as board for flat layers, corrugated paper, and wrapping paper, uses recycled paper as the main raw material. This range requires the lowest cost per ton of product. In order to use waste paper in a wide range of pulp and paper products, it must be subjected to deep refining with a high degree of recovery of paper-forming properties, which requires significant investments. Materials obtained from such raw materials do not have a sufficient level of strength, rigidity, and surface finish [4].

One of the significant disadvantages of cardboard is its weak wet strength. This significantly narrows the scope of its application in cases where it is required to maintain the strength of the package in conditions of high humidity. At the same time, a decrease in the wet strength of cardboard also negatively affects its adhesive properties, which in turn increases the number of manufacturing defects [5].

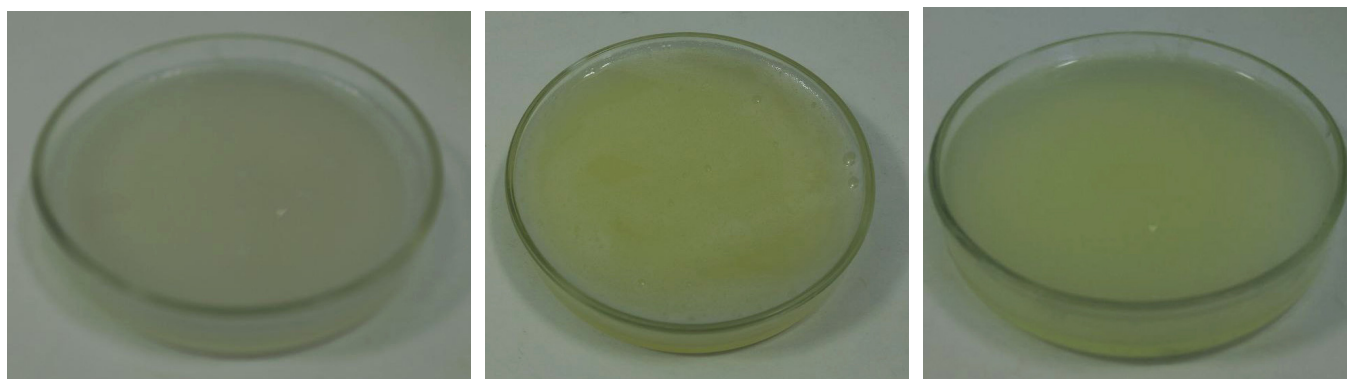
With insufficient water-holding capacity of the adhesive, a rapid loss of the first portions of moisture occurs. With a lack of moisture, starch is simply not able to gelatinize and show its adhesive properties. The moment when the starch is able to gelatinize with the manifestation of adhesive properties stops when the moisture content in the starch suspension becomes less than 60%. If up to this point, the starch grains have not had time to gelatinize, then further they behave as an inert filler of the glue joint [6].

Therefore, it is important that the adhesive has increased water-retaining capacity at the initial stage, when starch gelatinization occurs, and quickly dries at the second stage after gluing, so as not to reduce the productivity of the equipment. This problem can be reduced by developing new formulations of adhesives for the production of corrugated cardboard. Namely, by introducing water-retaining additives and additives into the composition of the adhesive, which would accelerate the drying of the adhesive at the stage of drying out of the adhesive joint [7]. So, referring to the properties and glue compositions of adhesive materials, we have developed other compositions based on corn starch oxidized by  $H_2O_2$  [8].

## 2. Practical part

The methods for preparing adhesives from oxidized starch (OS) granules may for convenience be classified under three main headings: 1) Heat treatment of OS gelatinized pastes with  $Na_2SiO_3$  paste. 2) Polyacrylamide (PAA) treatment of the OS as paste; 3) Preparation of the adhesive based on OS formed by the addition of PAA and  $Na_2SiO_3$ . Various modifying agents such as PAA and  $Na_2SiO_3$  were added to the adhesive of OS formed to ensure that a suitable working consistency was obtained and also to effectively prolong the shelf time of the adhesive composite formed.

The results of experimental studies have shown that when using various modifications of glue based on corn starch, the following patterns can be traced. First to obtain an adhesive of optimal composition, studies were carried out on homogeneity, medium, viscosity and humidity [9]. The humidity of adhesive films directly affects to wet strength of corrugated board. The resulting compositions by adding the components step by step gave a homogeneous adhesive composition with a yellowish tint. Forming of adhesives based on OS are shown in the (figure 1).



A B C  
Figure 1. Glues based on OS with PAA (A), with  $Na_2SiO_3$  (B) with all of them (C)

It is interesting that the resulting pastes have different attitudes to different solvents when obtaining their films. Five films formulations were prepared using the concentration of oxidized starch varied from 6 to 8 g and included sodium silicate in relation to the dry weight of starch from 0.1 to 0.3 g and polyacrylamide

from 1.2 to 1.8 g and distilled water to complete 100 g of solution. A two-component paste containing OK in each and silicate or PAA was prepared, followed by a variation of the mixture of the latter with OK in a three-component composition. The solvents used were ethyl acetate, dioxane, and propyl alcohol. Some



formulations did not give good films with, some with propanol and some with dioxane. For example, the composition OK-silicate gives a very brittle film with

propanol. A mixture of OK-PAA with ethyl acetate did not give an equal film thickness. Some of these good films obtained with solvents are shown in (Figure 2).

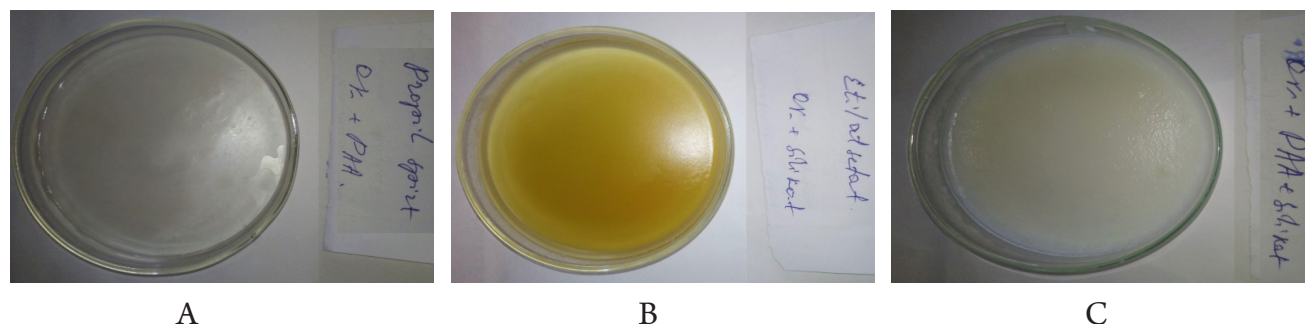


Figure 2. The films obtained from pastes OS with PAA in dioxane (a), with  $\text{Na}_2\text{SiO}_3$  in ethyl acetate (B), and with all of them in propanol (C)

The shown film drawings show that adhesive mixtures give good films in the indicated solvents, but these mixtures did not give good films in other solvents. If we compare the strength characteristics of films, it turns out that with an increase in the size

of supramolecular formations, the strength of the film and its elongation increase (table). But in the table given also the values of physical-mechanical properties of glues without OS were no in (Figure 1.2) also.

Table 1. – Physical-mechanical properties of films based on OS, PAA, and  $\text{Na}_2\text{SiO}_3$

Contain solution (in mass.%)	Tensile Strength, (MPa)	Elongation of break (%)	Contain solution (in mass.%)	Tensile Strength, (MPa)	Elongation of break (%)
OS (8) – $\text{Na}_2\text{SiO}_3$ (0.1)	$1.4 \pm 0.1$	$7.2 \pm 0.2$	OS (6) – PAA (1.6)	$4.3 \pm 0.3$	$14.3 \pm 0.8$
PAA (1.8)	$2.1 \pm 0.2$	$8.1 \pm 0.3$	OS (7) – – $\text{Na}_2\text{SiO}_3$ (0.2) – PAA(1.2)	$5.5 \pm 0.5$	$18.2 \pm 0.9$
$\text{Na}_2\text{SiO}_3$ (0.3) – PAA(1.4)	$3.2 \pm 0.4$	$12.4 \pm 0.6$			

The noted tendency of an increase in the tensile strength of the film with the introduction of PAA is apparently related to the acceleration of the process of formation of supramolecular formations during formation from the studied highly dispersed systems (rather large supramolecular formations already exist), which, in turn, causes an increase in the degree of crystallinity of the films. An increase in elongation at break indicates the influence of an additional factor inherent in systems containing additives of highly dispersed PAA. Obviously, the introduction of PAA

prevents the mutual ordering of the formed enlarged supramolecular formations.

As a result, under tension, the process of mutual ordering of crystallites makes a significant contribution to the magnitude of deformation, which can explain the increase in the elasticity of films obtained from polymer compositions containing OS-PAA- $\text{Na}_2\text{SiO}_3$ . It follows that when PAA is introduced into the composition, the elastic-viscous solid-like system transforms into an elastic-plastic system, which is one of the important requirements for the properties of adhesives.

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