# Sediment from clarification facilities for wash water of stations using PolyDADMAX

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**Abstract.** Natural water treatment plants at surface water sources generate significant amounts of precipitation. The physical properties of sediments of washing waters of fast filters, clarifying water using the PolyDADMAX flocculant, were determined. A change in the specific filtration resistance during the measurement process was established, as well as the possibility of determining the physical properties of the sediment not only directly, but also indirectly. Various levels of correlation of physical properties among themselves are established.

## 1 Introduction

The well-known drainless schemes of water treatment plants that prevent the discharge of rinse water and sediment into open reservoirs solve the problems of environmental safety [1, 2, 7, 8]. This water sediment during the clarification of natural water can accumulate in significant quantities [1, 2, 7, 8, 14, 15].

At the same time, water sediment is a complex system [1, 2, 7–9, 14, 15], the main components of which are the products of hydrolysis of chemical reagents in combination with mineral and organic substances from rinse water [1, 2].

In addition, insoluble impurities applied into water with coagulant, as well as the unreacted part of it, fall into sediment [7–9].

The use of flocculants makes it possible to clarify natural water well enough. Many scientists have been researching the clarification of natural water with flocculants [3, 4], in particular PolyDADMAX [5]. Also, this flocculant can be used to clean rinse water of filters.

According to G.S. Kachalova, the joint treatment of rinse water with flocculant or applying of aluminum oxychloride mixture with aluminum sulfate in various ratios is the most effective both in winter and summer [6].

A group of scientists studied the effect of cationic flocculants [5] such as Polydadmac for the water clarification process (it showed very high quality indicators). These studies allowed giving recommendations for working with them.

The sediments formed by these flocculants are less studied. The study of the rheological properties of sediment was carried out by Parthenos et al. (Greece) using the ARG2 rheometer with the setting of shift modes [10]. The important property of precipitation is the determination of sediment's solid phase [11]. Systematic studies conducted by Knokke

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et al. found that the dehydration of both alum and ferruginous sludge improves when pH level decreases. Larger aggregates were formed at the high pH level, but they were worse dehydrated due to their lower density, which dominated any increase due to its size. A group of scientists from China conducted studies of flocculated silt treated with sawdust [13]. This sludge has demonstrated obvious advantages over flocculated sludge in terms of increasing the filtration rate. The sawdust-conditioned and flocculated sediment required less than 3 minutes to reach an equilibrium state, whereas the flocculated sediment required approximately 16 minutes, the untreated sediment and the sawdust-conditioned sediment required more than 2 hours.

The purpose of the current study was to research the rheological properties of sediment from sinker tanks and rinse water from stations using PolyDADMAX.

## 2 Materials and methods

### 2.1 Collection of sediment samples

The studies were carried out with the sediment of horizontal settling tanks of the Central and Alexandrovsky water supply system of Rostov-on-Don and were carried out during two decades with variability in the reagent used at the station:
- insertion into the suction lines of the I-th rise pumping station pumps of the VPK-402;
- joint use of ЦРК-402 (PolyDADMAX) and aluminum oxychloride (Aqua-Aurat-10) (dosing also at the pumping station of the 1st lift);
- application into rinse water an analogue of VPK-402 (PolyDADMAX) type FL-4540 PWG as the only reagent.

### 2.2 Experiments

The studies of sediment properties after rinse water clarification of the rapid filters of the same water treatment plants.

The coagulant and flocculant used at the stations changed the properties of the sediment. At the same time, there was a change in the quality of the suspension in rinse water both by periods of years and during the entire duration of the work. The study of organoleptic properties, including fixing the color, texture, and smell of the sediment, was performed after its extraction from the sump in laboratory conditions (Table 1). Also, measurements of the physical properties of the sediment presented in Table 2 were carried out in the laboratory.

Previously performed studies indicate the difference in the properties of sediment formed during the colored water treatment, from sediment during the clarification of low-turbidity and medium turbidity water, and even more turbid water.

**Table 1.** Sediment properties and characteristics of its distribution along the length of the horizontal sump.

| Characteristics | Conditions of sediment formation | | |
|---|---|---|---|
| | Sediment VPK- 402 | Sediment with Aqua-Aura | Sediment from VPK - 402 and Aqua-Auratom |
| Invoice | Viscous, dense | Not viscous (liquid), not dense | Non-viscous, medium density |
| Colour | Dark- grey | Grey-brown | Light grey |
| Smell | With a pungent smell | The smell is not pronounced | The smell is pronounced |
| Characteristics during | Settles slowly, lays down | Settles quickly, falls | Settles quickly, lays down |

| | | | |
|---|---|---|---|
| sedimentation of flakes and location along the length of the sump | evenly | unevenly | evenly |
| Characteristics during compaction | When compacted, it has a smooth structure | When compacted, it has a porous structure | When compacted, it has a smooth structure |
| The size of the flakes | small (almost invisible) | large up to 1 cm | small < 4 mm |
| Sediment Features | Sediment and water contain an oily film | There are a lot of drifting particles, sediment separation is observed, individual flakes float in the process of compaction | The sediment and water contain an oily film, the sediment after compaction tends to swell and change volume |

The analysis of the data presented in Tables 1 and 2 once again confirms the significant influence of the reagent used on the quality of sediment, as well as the need to consider at least two accumulation periods – "autumn, winter" and "spring, summer" when designing sediment removal systems. The sediment formed in the facilities for the reuse of flushing water of rapid filters is close to the sediment of sinker tanks (when using PolyDADMAX, humidity, volume and specific gravity, but significantly greater filtration resistivity and high ash content.

**Table 2.** Averaged physical properties of sinker tanks sediment and rinse water of rapid filters.

| Parameter | Sediment formed in the sump during the spring-summer period | | | Sediment formed in a sinker tank during the autumn-winter period | | | Sediment of rinse water of rapid filters |
|---|---|---|---|---|---|---|---|
| | Reagent | | | Reagent | | | |
| | VPK-402 | VPK-402+AA | FL-4540 PWG | VPK-402 | VPK-402+AA | FL-4540 PWG | |
| Humidity, % | 89.88±1.17 | 97.52±0.84 | 91.48±2.12 | 89.56±2.07 | 94.41±4.36 | 92.52±4.75 | 92.95±2.40 |
| Weight concentration, g/dm$^3$ | 108.16±12.89 | 59.56±3.17 | 106.0±9.7 | 111.74±23.8 | 60.14±49.43 | 100.47±29.27 | 75.14±27.18 |
| Volumetric weight, g/dm$^3$ | 1.068±0.012 | 1.07±0.04 | 1.052±0.013 | 1.068±0.016 | 1.042±0.044 | 1.047±0.012 | 1.046±0.031 |
| Specific gravity of sediment, g/dm$^3$ | - | 1.705±0.375 | 1.736±0.111 | - | 1.869±0.26 | 1.806±0.033 | 1.711±0.423 |
| Filtration resistivity-10$^{10}$, cm/g | 20.24±5.05 | - | 22.75±12.97 | 40.18±21.075 | 59.13±13.80 | 67.29±17.66 | 31.62±23.00 729±176.03 |
| Ash content, % | - | - | - | - | - | - | 75.02±10.25 |

A distinctive feature of the chemical composition of the studied treatment facilities' sediment is a small amount of Al2O3, what is understandable when water is clarified with the VPK-402 reagent (PolyDADMAX). In decanted water, there is a high content of iron, manganese and, in some cases, aluminum ions, an alkalinity of 4,2÷10,8 mg-eq / l. The quality of the decanted water prevents its return to the head of the structures without dilution, but two options for its further movement can be considered: dilution with return water from the facilities of reuse of flushing water or discharge into the sewer.

## 2.3 Organoleptic properties

Were studied in sediment samples, including fixing the color, texture, and smell of the sediment, which was performed after its extraction from the sump in laboratory conditions. Measurements of the sediment physical properties were also carried out in the laboratory.

In the sediment sample, the filtration resistivity is measured according to the standard method with the creation of the vacuum of 67,000 Pa or 500 mmHg with a sediment volume equal to 100 ml. Throughout the measurement, the vacuum is maintained at the predetermined level, which is especially important at the initial stage of filtration, when its intense drop occurs. The amount of filtrate was measured at the same time intervals equal to five seconds, starting counting only after equalizing the vacuum at the beginning of the measurement. The end of the measurement is considered to be the moment of formation of cracks on the surface of the sediment or the immutability of the amount of filtrate in 5 – 15 s.

With a sediment humidity of more than 97%, the use of the RV-4 viscometer is impossible, since the value of the attached load is very close to the value determining the friction force in the bearings, therefore, the measurement was performed on a Brookfield DV-II+Pro rotary viscometer.

### 2.4. Statistical analysis

Was performed using the Microsoft Excel 2013 Analysis Package and Statistica 7.0 or 11.0.

## 3 Results and discussion

### 3.1. Sediment of rapid filters of rinse water

Filtration resistivity is the most important parameter of the sediment, integrally describing its ability to release free water trapped in the sediment structure.

There is practically no correlation between humidity and filtration resistivity (shear stress limit), therefore, different factors are responsible for changing these parameters (Figure 1), and the correlation between filtration resistivity and the bulk weight of dry sediment (Figure 2) is very high.

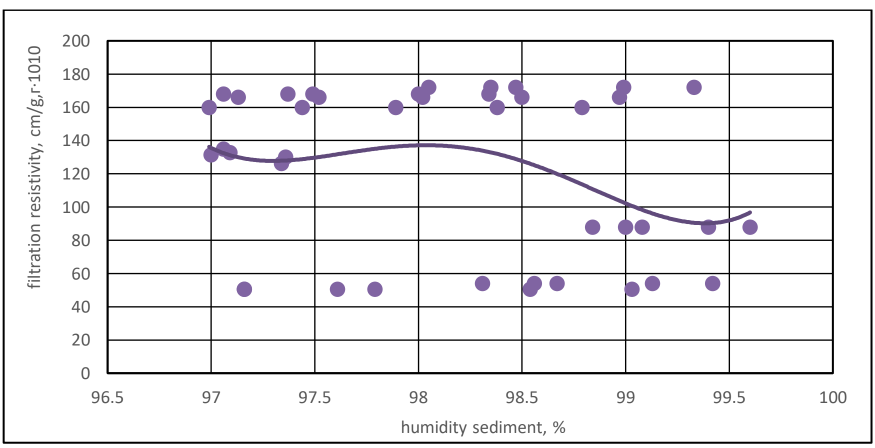


**Fig. 1.** Influence of humidity on the specific resistance of compacted sediment filtration of sinker tanks.

The study of the filtration resistivity of the rinse water sediment of rapid filters revealed the difference in the type of graph in V-t/V coordinates from the one shown in Figure 3. Two filtration zones are clearly distinguished on the graph – two straight lines with a different slope (hence the coefficient "b") and the presence of the "fracture" point. At the

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same time, the measurement procedure was carried out strictly, and the vacuum value was kept constant. The time from the beginning of the experiment corresponding to the "turning point" in the experiments was in the range from 20 to 45 seconds from the moment of the beginning of the measurement.

The curve given in Figure 3 shows a sharp increase in the filtration resistivity when a certain state of the test sediment is reached. The feature of the rinse water sediment of rapid filters should be considered initially smaller flakes in the water applying the filters compared to those that come from the flocculation chamber into the sump, i.e. the particles of the rinse water sediment consist of smaller components. Being exposed to vacuum in the sediment, the structure formed at the second stage of compaction is destroyed, with its compression and the decrease in water-releasing capacity. Based on the above, two values of the filtration resistivity are calculated – before and after the "point" of the fracture. Calculations show the increase in filtration resistance by 1-3 orders of magnitude with the maximum obtained in our experiments of 3197,95·1010  cm/g.

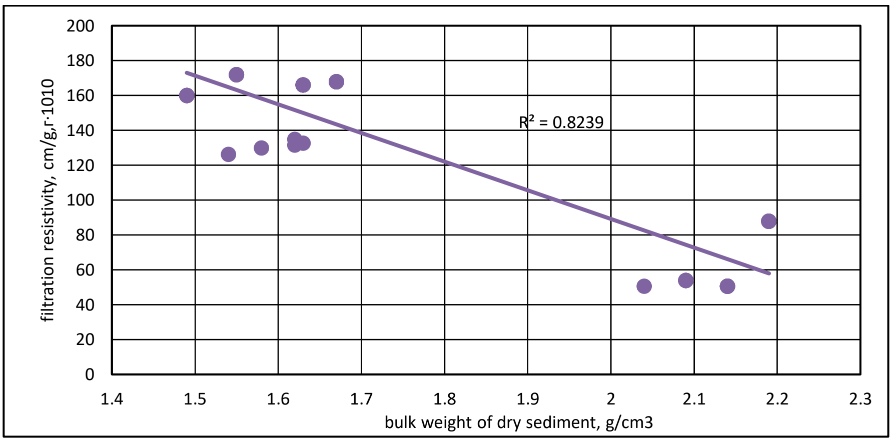


**Fig. 2.** Correlation dependence of dry sediment volume weight and the specific resistance of filtration.

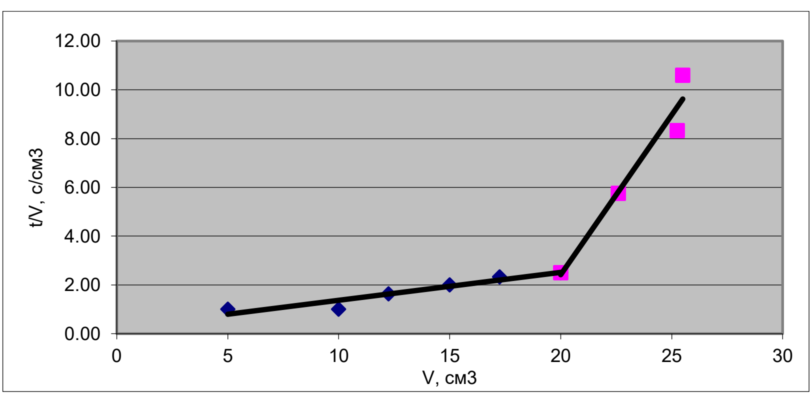


**Fig. 3.** A typical graph for determining b parameter when calculating the filtration resistivity of rinse water sludge of rapid filters.

The correlation between the initial precipitation moisture and the filtration resistivity is low (Figure 4) for both aggregates (before and after the "breaking point").

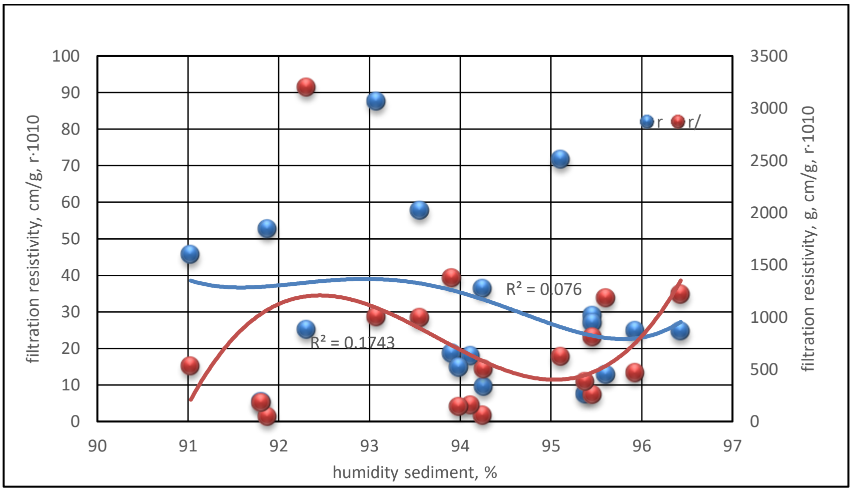


**Fig 4.** The effect of humidity on the specific resistance of the rinse water filtration of the rapid filters. r and r are the specific resistance of filtration, respectively, to the point of "fracture" and after.

Similarly with the sediment of horizontal sinker tanks, the volume weight of the dry sediment affects the specific filtration resistance calculated to the point of "fracture" (Figure 5). There is no correlation of the same indicator with the filtration resistance after the "breaking point".

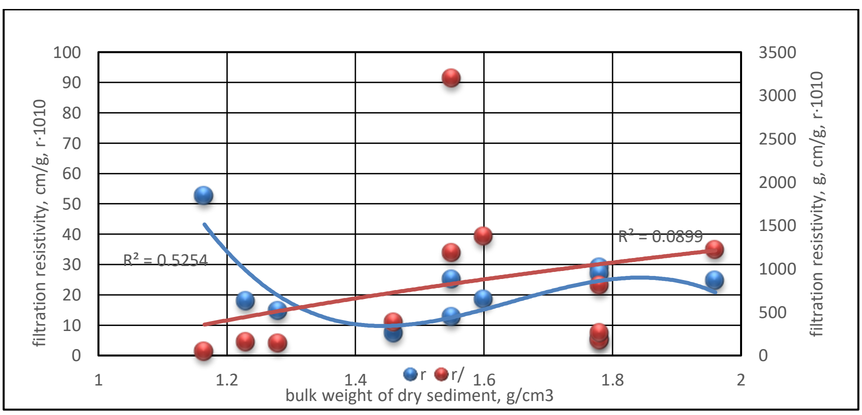


**Fig 5.** The effect of the bulk weight of dry sediment on the specific filtration resistance of the rinse water sediment of the rapid filters. r and r are the specific resistance of filtration, respectively, to the point of "fracture" and after.

Along with the production cycle of research, laboratory studies were carried out to determine the rheological properties of the sediment.

The decrease in the moisture content of the sediment should theoretically lead to the increase in shear resistance, since the mass (volume) of the dispersion phase decreases and the concentration of the dispersion medium increases. The results of studies of sediments of sinker tanks and rinse water of rapid filters with different humidity are presented in Table 3, Figures 6, 7, 8.

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**Table 3.** Shear resistance of sediment with Polydadmach+Aqua-Aurate 10 (PC and AA-10) and aluminum sulphate (CA) at its different humidity.

| Precipitation humidity, % | Shear resistance of sediment of sinker tanks with CA, Pa (min-max) | Shear resistance of sediment of sinker tanks with PC и AA-10, Pa (min-max) | Shear resistance of the rinse water sediment of the rapid filters,Pa (min-max) |
|---|---|---|---|
| 1 | 2 | 3 | 4 |
| 97-94 | - | 1.3-8.46 | 54.04-86.56 |
| 94-90 | 2.6-13.3 | 2.05-19.5 | 54.98-65.85 |
| 90-87 | 23.0-53.0 | 2.34-13.4 | 59.69-121.13 |
| 87-84 | 19.0-77.0 | 3.12-39 | - |
| 84-81 | 19.0-82.0 | 5.57-41.8 | - |
| 81-78 | 16.0-70.2 | 4.64-91.9 | - |
| 78-75 | 22.3-84.9 | 5.57-95.5 | - |
| 75-72 | - | 13.6-95.5 | - |
| 72-69 | - | 4.64-95.5 | - |

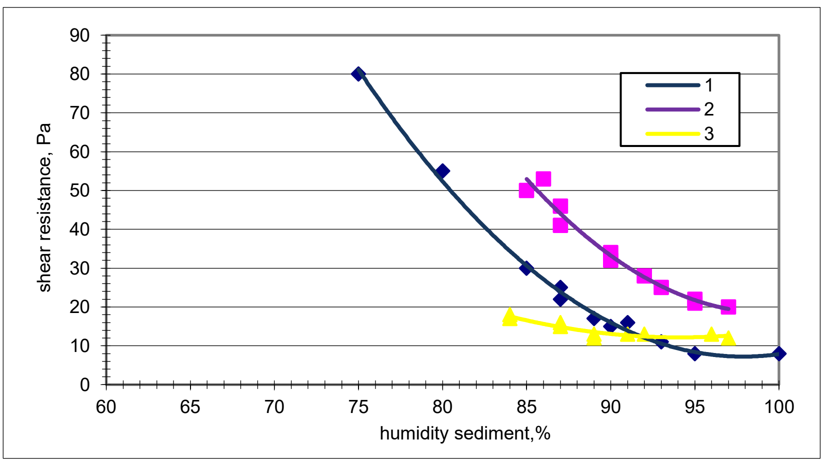


**Fig 6.** Correlation dependence of sediment shear resistance on humidity 1 – mineral sediment during clarification of water with aluminum sulfate; 2 – sediment during clarification of water with MIC-402 (PolyDADMAX); 3 – sediment during clarification of water with aluminum sulfate and MIC-402 (PolyDADMAX).

The general appearance of the obtained curves corresponds to the dependencies obtained earlier in the study of muddy soils, which indirectly confirms the correctness of the obtained regularity. Having considered the curves in Figures 6 and 7 of different variants of the source water reagent treatment, it should be noted that the use of a high-molecular coagulant-PolyDADMAX flocculant leads to a significant (almost twofold) decrease in the amount of sediment resistance to shear. The effect of a high-molecular reagent on reducing the viscosity of the dispersion medium is obvious.

The exponential dependence quite satisfactorily describes the relationship between the resistance of the sediment to the shear and the moisture content of the sediment. With the decrease in humidity below 70-60%, the exponential dependence turns into a linear one. Apparently, in this case, the shift is already taking place along the layers of the solid and the resistance of the sediment to the shift will depend on the properties of the suspension, in particular the ratio of the mineral and organic parts, the particle sizes of the dispersion phase, etc.

In the contrast to the sediment of horizontal sinker tanks, the shear resistance of the rinse water sediment correlates significantly less with its humidity (Fig. 8.). The study of the shear resistance dependence on the specific gravity of the sediment and the bulk weight of the dry sediment showed the values of the Pearson correlation coefficient (R2), respectively, 0.27 and 0.56.

Plastic viscosity characterizes internal friction between adjacent layers of the dispersion medium, dispersed particles, as well as interfacial interaction. Its value depends on the viscosity of the dispersion medium, on the concentration, size and shape of the dispersed particles.

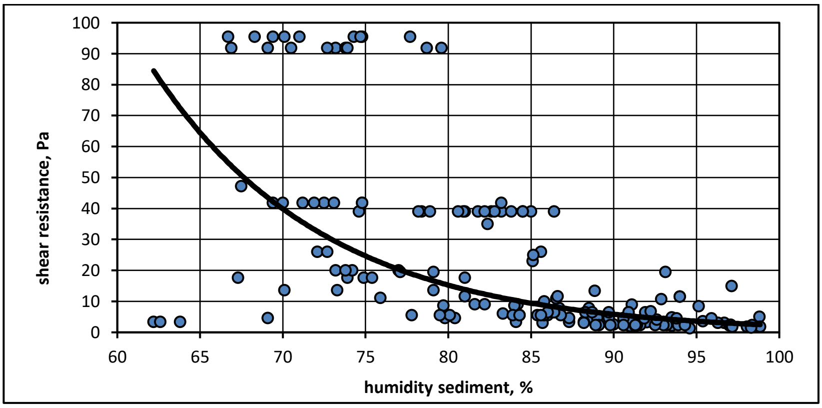


**Fig 7.** Correlation dependence of sediment shear resistance on humidity during clarification of PolyDADMAX water with Aqua-Aurate 10.

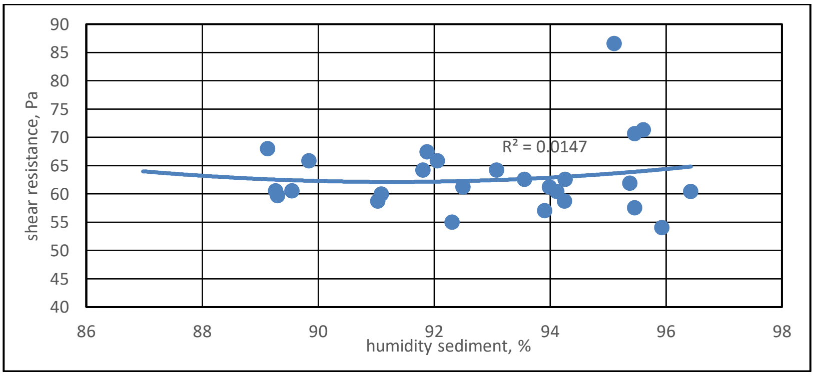


**Fig 8.** Correlation dependence of the sediment resistance of the rinse water of rapid filters to the shift from its sediment moisture.

The value of the coefficient of plastic viscosity of the rinse water sediment of the rapid filters in our studies ranged from 0.0015 to 0.151 Pa • s, showing a good correlation with the mass concentration of the solid phase in the sediment (Figure 9).

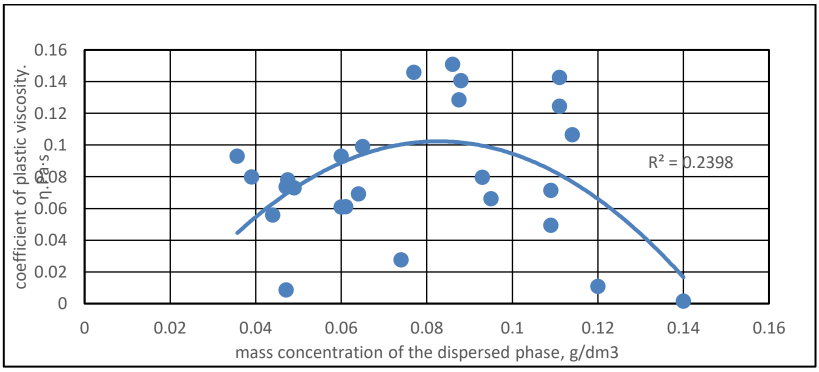


**Fig 9.** Dependence of plastic viscosity coefficient of the rinse water sludge of the fast filters on the mass concentration of the solid phase in it.

## 4 Conclusions

The study of the rheological properties of the sediment from the rinse water from the stations using PolyDADMAX made it possible to give a comparative assessment with the sediments of horizontal sinker tanks. Graphical dependences of the sediment plastic viscosity coefficient of the rinse water of the rapid filters with the mass concentration of the solid phase in the sediment are established. The qualitative characteristics of sedimentation facilities of water treatment plants operating on medium and low turbidity water are determined not only by the quality of the suspension coming from the river, but also by the type of reagent used for clarification. A significant content of residual reagent, iron, manganese and, in some cases, aluminum ions was found in the sediment. According to microbiological and parasitic indicators, the sediment requires additional treatment before its use or disposal. The sediment formed in the facilities for the reuse of flushing water of rapid filters has humidity close to the sediment of sinker tanks (when using PolyDADMAX), volume and specific gravity, but significantly greater filtration resistivity and high ash content. The sediment of the rinse water of the rapid filters is close in composition to the sediment of the settling facilities and they can be treated together.

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