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Experience of Suckling Perfection of Secondary Clarifier of Aeration Station in Almaty, Kazakhstan

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ABSTRACT
This article presents the results of experimental studies pertaining to the suckling improvement of secondary clarifier in an aeration station in Almaty. According to the obtained research results, the work of secondary clarifiers was evaluated for the removal of suspended solids, concentration of returned sludge and sediment moisture. The technical specifications of aerations, secondary settling tanks and cesspool emptier in the aeration station of Almaty were defined. Additionally, it was shown that the use of the articulated sucker with movable scrapers can increase the efficiency of cleaning the bottom of the circular tanks. In this practical test, the proposed suckling radial settler in aeration station of Almaty during the year showed that the sucker reduces the costs for the installation and maintenance of cesspool emptier and has no damaging effects on the bottom of the sump.

Keywords: water disposal, waste water, secondary sedimentation tank, activated sludge, cesspool emptier, sucker

INTRODUCTION

The treatment of sewage water in the cities of Kazakhstan is mainly performed by using biological aeration tanks with secondary clarifier. A forecast for the future and future developments in the field of wastewater treatment show that this method will remain the primary one in the future, but it is important to pay attention to the improvement of the facilities related to the biological method. The efficiency of biological wastewater treatment is determined by the work of secondary settling tanks, which should ensure the allocation of the activated sludge from the purified water. As the secondary clarifier runs efficiently, greater concentration of returned sludge and lesser degree of recycling should be used while operating the aeration tank [Andreev et al. 2006, Burger et al. 2011, Zhmur 2003]. The main parameters of the biological cleaning process must be interconnected, namely: the volume of the aeration tanks, the amount of oxidation and contaminants in the wastewater, the contact time of wastewater with activated sludge. In addition, the sedimentation properties of the activated sludge, which are defined by all of the above-mentioned parameters must comply with the technological capabilities applied by secondary clarifiers – satisfactorily separation of the effluent from the sludge [Dziubo and Alferova 2014, Hunze 2005, Zhmur 2003]. Activated sludge is constantly forming new cells, carrying the biochemical oxidation of organic pollutants. The intensity of the sludge on the growth of cells is regulated by several factors and depends on: the nature of the oxidized substrate; the temperature of treated wastewater, which determines the degree of the assimilation processes; self-oxidizing capacity of the activated sludge, depending on the load and the period of aeration on structures; sedimentation characteristics of the sludge and the removal of suspended solids from the secondary clarifiers; the presence of toxicants (lowering increase) or mutagens-growth stimulants [Al-Bastaki 2004, Hunze 2005, Pijuan et al. 2012].

The majority of activated sludge in the secondary settling tank, should be pumped back into the aeration tank. This constitutes the circulating active sludge, which falls into the aeration tank through the regenerator. Usually, the amount of sludge in the secondary settling tank is greater than needed for the circulation; therefore, the excess is sent for recycling.

The volume of the returned sludge removed from the secondary settling tanks and supplied to the regenerator constitutes from 30 to 70% of the volume of the treated wastewater. For each treatment plant, the figure is individual and determined by the calculation of the degree of recycling. The excessive sludge with a moisture content of 99.2% was 4 dm^3 / day per resident, and has a greater moisture content than the raw sludge from a primary sedimentation tank, which increases the total amount of sludge [de Clercq 2003, Zhmur 2003].

The work of secondary clarifiers is estimated by the removal of suspended solids, concentration of returned sludge and sediment moisture. These parameters characterize their main functions such as separating the purified water from the activated sludge and silt seal [Ni and Yu 2012, Zhmur 2011].

Control of the secondary clarifiers operation is a very important task of the operating service, because the efficiency of the secondary settling directly affects the course of biochemical oxidation in the aerotanks and, to a large extent, determines the content of suspended solids in purified water, i.e. loss of active biomass sludge and, accordingly, its growth.

The effectiveness of the secondary clarifiers is influenced by other causes such as hydrodynamic flows; secondary clarifiers are more sensitive to load and unevenness in volume of inflow of sewage than the primary ones, since they are loaded from the circulating flow of returned sludge, and the sludge precipitates easier; the type of sump and sludge collection system used; characteristics of the activated sludge and a variety of biological processes [Sanin et al. 2011, Solovieva 2008, Zhmur 2003].

In contrast to the raw sludge, the active sludge is more sensitive to fallow lands, which requires the use of more sophisticated sludge collection and pumping system from the bottom of the sump and from pits [Mishukov and Solovieva 2001, Zhmur 2003]. The activated sludge in the sumps is more susceptible to the process of rotting in a packed bed, where anoxic conditions are present. The height of the packed bed in the sump depending on the mode of shipping sludge may range from 0.5 to 1.0 m in the radial sumps [Ivanov et al. 2012].

During the exploitation of secondary clarifiers, it is very important to establish and maintain an optimal state of the bed height of sludge. In winter, the height of the sludge layer can be 25% from the depth of the settler, and in summer – no more than 10%.

With the accumulation of sludge in the sumps, and exceeded the optimum layer height of standing sludge, the humidity of returned sludge decreases, but its concentration is increased, which may contribute to an excessive removal of suspended solids. Excessively frequent release of excess sludge from the settling tank and overly active circulation of returned sludge lead to an increase in the excess sludge moisture, which increases the volume of the necessary facilities for the processing and disposal of sludge [Hunze 2005, Vaxelaire et al. 2004].

In other words, if more than optimal amount of sludge is withdrawn from the secondary clarifier , then the excess volume returns to the aeration tank of water, if less, then most of the settled sludge collects in the sump and the quality of the treated water reduces.

Therefore, technological operation mode of the secondary clarifier was given to ensure adequate parameters of the envisioned projects.

The efficiency of the secondary clarifier depends on the compliance of real hydraulic load and its design values and the uniformity of its distribution, as well as the timely and continuous uniform flow of sediment removal. The optimal level of standing sediment can be controlled by the values of returned sludge doses. Experience has shown that with the returned sludge at a dose of 4–6 g/dm^3, theremoval of suspended solids from the secondary clarifiers is about 15 mg/dm^3, whereas returned sludge at a dose greater than 6 g/dm^3 increased the removal from 15 to 20 mg/dm^3.

A significant increase in the removal of suspended solids from the secondary clarifiers (40 mg /dm^3) occurs with the return sludge concentration of 8 g/dm^3, which, apparently, is the threshold for typical structures, treating municipal wastewater [Pijuan et al. 2012, Vaxelaire et al. 2004].

At the same time, the major factors contributing to the excessive removal of suspended solids from the secondary clarifiers are hydraulic overload, which is caused by excess amount of wastewater entering the treatment, the structural imperfections of secondary settling tanks or unsatisfactory operation of secondary settling tanks, the formation of sludge deposits on the bottom of the secondary settling tank, which can be due to the irregularities in the bottom of the settling tank, poor performance of the cesspool emptier, untimely removal and the sludge system without delay in its shipment for recycling [Canales et al. 1994, Deleris et al. 2002, Zhmur 2003].

The secondary clarifiers differ radically from the primary ones in respect to the properties of substances. While the sludge in primary settlers may lie for some time without decay, in the secondary one, even small deposits of sediment decay and deteriorate the aeration mode throughout the system. Rotting returned sludge treatment upsets the system of treatment and as a result, its effect significantly reduces.

Therefore, the sludge removal system of secondary settling tanks should include work under daily peak load, rather than around the clock.

The humidity of shipped and returned sludge can vary within wide limits from 99.2 to 99.7%, which corresponds to the content of dry matter in the sludge from 3 to 8 g/ m^3.The results pertaining to determination of moisture and solids of returned sludge should be consistent with each other, which is an indirect validation of the measurements [Guest et al. 2009, Ivanov et al. 2012, Yasui and Shibata 1994].

The most perfect system of sediment collecting is found in the radial secondary clarifiers, which divide into a system with scraper and cesspool emptier. The residence time of the sludge in the bottom of the sump depends on the radial velocity of the scraping device, number of wings or cesspool emptier, and the distance between the scrapers to radial mud pit or the length of the wings cesspool emptier.

The presence of mud deposits on the bottom peripheral part of the settler effects on increasing the removal of suspended solids, as hydraulic wastewater streams coming from the central pipe, are directed to the periphery of the sump and washed sludge settled in the sump to the surface of the walls [Auerbach et al. 2007, Denisov et al. 2016].

In the radial sumps, due to unevenness or the bottom or because of the presence of zones with sediment, deposits may unevenly accumulate at the bottom of the settler in certain areas, which is the reason for its fermentation and buoyancy, and cause deterioration of the properties of return sludge. In such cases, the sump is emptied, cleaned reservoir, and the causes are eliminated as far as possible [Denisov et al. 2016, Radjenovic et al. 2009, Zhmur 2003].

Sometimes, the elimination of sludge deposits requires serious reconstruction settlers. For example, if the cesspool emptier bead does not reach several meters, only the center well of the settler precipitate is removed and observed at the periphery of the permanent sludge deposits. This deficiency can be corrected by replacing the scrapers on the cesspool emptier [David et al. 2009, Ratkovich et al. 2013].

MATERIALS AND METHODS

The Almaty sewage system works on incomplete separate system, one of them the storm – with the tap water in the small river, the other citywide – for industrial and domestic wastewater.

The drains of the city received in citywide sewer system are cleaned in the wastewater treatment plant. High-rise building's location provides gravity mode movement of the main mass of the waste water, using the natural terrain.

The station carries out mechanical and complete artificial biological wastewater treatment, with additional purification to storage and bioponds as well as subsequent disinfection with chlorine at the discharge of effluent into the Ili river. The design capacity of aeration station is 640 000 m^3 per day.

The actual volume of waste water in Almaty arriving at the wastewater treatment plant in 2016 has averaged 395 000 m^3 per day.

The wastewater enters the treatment plant by three collectors, the diameter of the two of them in front of the aeration station is d = 1500 mm and d = 1000 mm.

A special receiving chamber which is used to equalize the rates and even distribution of waste on working grates is found here.

The chamber on the ferro-concrete drainage channels are directed to the grid. Metal gates with electric drive to switch off from the work of the individual arrays are installed in the connecting channels [Technological regulations 2005].

The scum trapped on lattices was collected in a special container and was disinfected with a solution of bleach; then, they were transported to the Aeration station sludge beds together with the municipal solid waste.

Detention of heavy solids occurs in the horizontal sand catchers. The precipitated solids and sand were transported to the pits with the hydraulic system, where sand is pumped to the hydro elevator platform.

After sand traps drain the common tray, which enabled their quantitative measurement, it enters to the distribution bowl of primary clarifiers. The removal of suspended solids wastewater, which is capable of settling or floating under the gravity, occurs in radial primary sedimentation tanks. The crude residue precipitated in each sump scrapers installed on the farm scraper is shifted to the pit from which it is pumped to the sludge beds. After settling in a settler, the clarified effluent is collected in a common channel and sent to biological purification facilities. The wastewater enters the airlift pump chambers by receiving reinforced concrete channel, where airlifts pump it into the aeration tanks for biological treatment [Technological regulations 2005].

Technical characteristics of aeration station are given in Table 1.

After mixing in the aeration tank, the waste water of the activated sludge from the supply line is sent into the secondary clarifiers. The technical characteristics of the secondary clarifiers are presented in Table 2.

In the secondary settling tanks, the activated sludge settles and using the cesspool emptier brand, PSI-40 is removed from the bottom of sumps. [Technological regulations 2005] Technical Specifications of cesspool emptier RWI-40 shown in Table 3.

The cesspool emptier design consists of a rotating mechanism with a suckling and a periph-

Table 1. Technical characteristics of aero tanks in the aeration station in Almaty

The name of indicators	The value of indicators
Number of aero tanks	2 blocks
Block of aero tank #1	experimental, deep, consisting of the sections A and B
Volume of section	V = 63140 m^3
Dimensions (inplan) block	110 x 164 m
Sizes of one section	110 x 80 m
Workingdepth	H = 7.0 m
The number of corridors in section	8
Project (planned) performance of block	320 thousand.m^3per day
Block of aero tank #2	Sample consisting four sections, consisting of aerotank №1, №2, №3, №4
Volume of one aero tank	V = 25000 m^3
Volume of one regenerator	V = 6250 m^3
Dimensions (inplan) block	144 x 144 m
Sizes of one aero tank	144 x 36 m
Workingdepth	H = 5.0 m
The number of corridors in section	4 ;
Project (planned) performance of block	320 thousand.m^3per day

Table 2. Technical characteristics of the secondary sedimentation tanks of aeration station in Almaty

The name of indicators	The value of indicators
Type of sump	typical secondary radial settling tank
Thenumberofsumps	12
The diameter of the sump	D = 40 m
Hydraulicdepth	H = 4.35 m
The depth of the flow in the settler	H_1 = 3.65 m
The height of the sludge zone	H_2 = 0.7 m
The diameter of the supply line	D = 1500 mm
The diameter of the discharge pipe	D = 1200 mm
Diameter of sludge conductor	D = 800 mm
Cesspoolemptier	ИВР-40
Number of suckling in a sump	4
Locationof suckling	one suckling for four lines of different lengths, with different radius of rotation
Rotational speed of the movable truss to the sump	one turn of 35 to 45 minutes
Sludgereturnmethod	transfer pumps in the return sludge channel, then transmission of gravity in the aerotank regenerators
Volume of the settling zone	V = 4580 m^3

Table 3. Specifications of cesspool emptier RWI-40

The name of indicators	The value of indicators
Productivity, m^3 / h	1728
Frequency of rotation of cesspool emptier, vol/ hour	1÷3
Electricmotorpower, kW	1.5
Overall dimensions, mm, no more: – length – width – height	40850 6000 7100
The mass of the rotating parts, kg, no more	14170
Weight of the fixed leg portions kg, no more	6330
Total weight, kg, not more	20500
Ratedmainsvoltage, V	380

eral drive. The working bodies are suckling cesspool emptier, which are connected to the collector pipe. The secondary settling tank is designed according to a standard project 902–2-377.83 [1983] in which suckling cesspool emptier looks as shown in Figure 1.

The activated sludge enters the chamber sludge shield and the movable weir gate through conduit, and then is pumped into the axial distribution channel return sludge and from there it is transported to aeration.

Excess activated sludge is pumped to the sludge beds with the help of the main pumping station. The sewage treatment plant wastewater treatment plant operates continuously, day and night, treating all the waste water of the city and its suburbs to the required degree of purification.

After complete biological treatment, the purified water, is sent to the drive Sorbulak across the earthen channel (49 kilometers) or, through a special water divider sent to biopонds for deep cleaning. From bioponds, the water after disinfection on chlorinator is discharged into the Ili river.

The secondary clarifiers of the Almaty aeration station have significant drawbacks, leading to a decrease in the efficiency of wastewater treatment. Additionally, the cesspool emptier 902–2-377.83 model project for secondary radial sumps is produced with little or no design changes. However, the requirements for the quality of wastewater after secondary clarifiers have significantly tightened since then, and sample design cesspool emptier is no longer able to fulfill their tasks. The analysis of the aeration station in Almaty showed that the so-called “dead zones” formed in the settler due to non-parallelism of the planes and the side of the settler bottom part, uneven bottom of the settler, various construction and installation of deviations between the bottom of the settling tank and the suckling.

In these zones, rotting and subsequent flotation ascent of the sludge not collected from the bottom occurs and, as a consequence, results in an increase in the content of suspended substances in the purified water.

At the bottom of the settler zone, the average concentration of sludge is 15–22 g/l and it significantly reduced by a distance greater than 15 cm, which is comparable to the distance from the bottom of the settling tank to the intake slot suckling in compliance with all technical requirements for the installation cesspool emptier. Thus, a significant amount of compacted mud is not going to suckling, and is stirred up when driving along the circumference of suckling. This results in an is inevitable dilution of the sludge by trapping boundary layers, up to a breakthrough in the water sucking, which leads to a sludge collection with high humidity.

RESULTS AND DISCUSSION

In order to eliminate the above-mentioned drawbacks, we developed and implemented a sucker for cleaning the bottom of the circular tanks on the aeration station of Almaty. There is a patent for the invention of the Republic of Kazakhstan [Ospanov et al. 2014].

Figure 2 shows the suckling scheme for cleaning the bottom of the circular tanks.

The proposed sucker for the mechanical purification of bottom circular tanks is made of reinforced metal and rubber. The fixed part 1 of the suckling is made from sheet metal with the thickness of 6 mm, the frame 4 on which are fixed

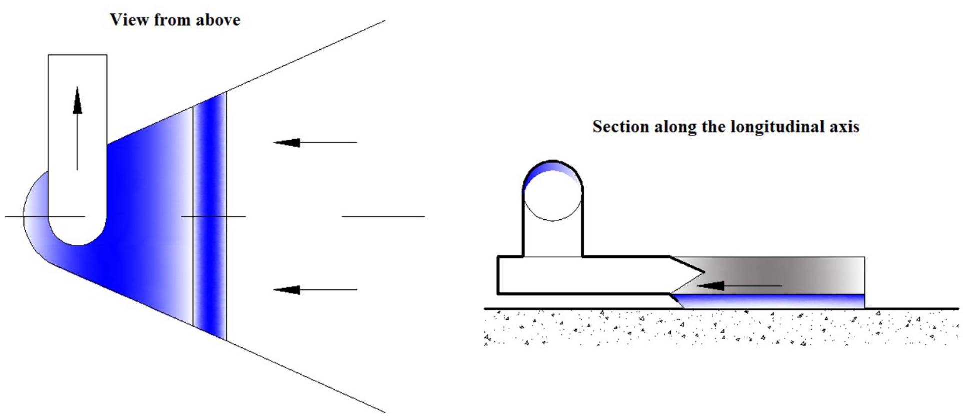

Figure 1. Scheme of sucking on a standard project 902–2-377.83 [1983]

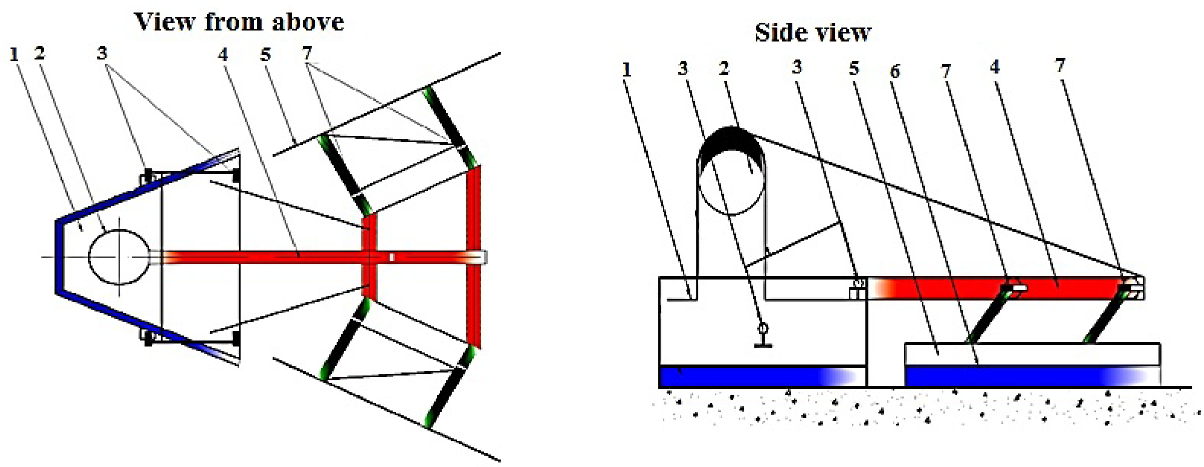

Figure 2. Scheme of suckling for cleaning the bottom of the circular tanks [Ospanov et al. 2014]:
1 – fixed part of the suckling; 2 – cesspool emptier pipeline for the removal of sludge; 3 – the hinges of the moving part of suckling; 4 – mounting (frame) scoops scraper; 5 – scoops scraper; 6 – flexible component scoops scraper; 7 – hinges scoops scraper.

mounted scraper scoops of pipes has a diameter of 100 mm, whereas the scoops scrapers 5 are made from sheet metal with the thickness of 3 mm. In order to provide stiffness in the longitudinal direction, reinforced metal area of the scrapers is 50×50 mm. A 20 mm thick reinforced rubber is mounted under scraper with M16bolts. Each of the two wipers are pivotally 3 secured to the frame tubes of the arms of the corner 63×63 mm. In order to stiffen the levers, a further reinforcement with Ø16mm was used.

The device operates as follows: When wastewater is present in the sump, radial cleaning processes by deposition of suspended particles on the bottom of the settler occur, so the bottom of the sump forms a radial layer of sludge. The sludge formed at the bottom is removed by suction through a fixed part of the suckling in the cesspool emptier pipeline 2.

The use of the proposed mobile scrapers allows efficient and reliable operation of the sucker, as the size and location of the scoops scraper provide them passage across the surface to be cleaned the bottom of the circular tanks. This flexible component scoops scraper 6 completely in contact with the bottom of the circular tanks, covering all surface irregularities. Compound scraper scoops hinged 3, 7 allowing them to rotate relative to each other in a vertical plane and the best fit to the uneven floor, which also improves the quality of cleaning.

This sucker for cleaning the bottom of the circular tanks successfully works in Almaty aeration station and removes sludge from the entire area of circular tanks, improving the state of the sludge pumped to the aeration tanks. The photos of suckling for cleaning the bottom of the circular tanks during the reconstruction of the city of Almaty aeration station are shown in Figure 3.

The economic benefit was also provided because the sucker can be repaired on site, resulting in minimum operating costs. Figure 4 shows the process of replacing the flexible component scoops scraper that is reinforced rubber.

In general, this sucker was introduced in the secondary clarifier aeration station in Almaty in April 2014 and works successfully to this day.

In order to evaluate the effectiveness of suckling works for the secondary clarifier, we defined the concentration of suspended solids and BOD_5 were determined before and after reconstruction. The analyses of the comparison results before and after reconstruction are given in Table 4.

The table shows that after the reconstruction of the secondary clarifier suckling Almaty aeration station concentrations of suspended solids and BOD_5 as compared with the reconstruction to declined.

CONCLUSIONS

The analysis of the secondary clarifier in Almaty aeration station showed that sludge accumulation zone is formed at the bottom of the settling tank. Thus, there is a decay of the sludge as a consequence, reduced overall efficiency of the biological purification, and also increases in the

Figure 3. Photo of suckling of aeration station in Almaty [Ospanov 2017]

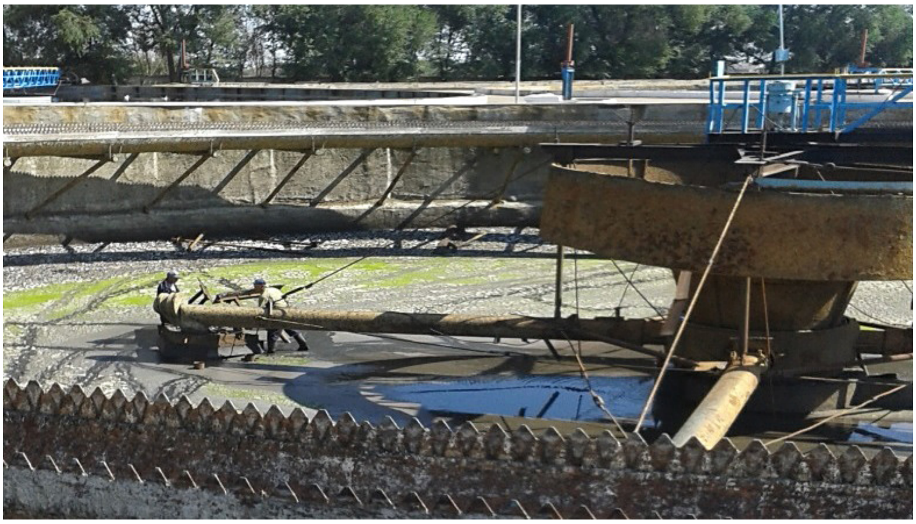

Figure 4. Picture showing replacement of flexible component scoops scraper [Ospanov 2017]

Table 4. Analysis comparing the degree of purification of waste water before and after reconstruction of the secondary clarifier suckling Almaty aeration station [Ospanov 2017]

Indicators, mg/l	Beforereconstruction			After reconstruction		
	Incoming water	Mechanical purified water	Biological purified water	Incoming water	Mechanical purified water	Biological purified water
Suspended solids	387.8	101	12.7	375.6	100.5	8.1
BOD_5	311.8	85.3	9.6	391.2	88.7	5.7

content of suspended solids in the purified water occur. In order to eliminate the above-mentioned drawbacks, improving the design of the secondary clarifier suckling Almaty aeration station can be applied. This problem is solved with the use of a hinge suckling with mobile scrapers. The use of the proposed mobile scrapers allows covering all the irregularities of the surface of the bottom of the secondary settling tank. The design of the proposed sucker for cleaning the bottom of the settler was tested in circular tanks of Almaty aeration station during the year. At the same time, the following observations were pointed out:

- possible swelling of sludge in the settling tank;
- providing the silt fence with a maximum concentration;

- the degree of water purification increases;
- construction has no damaging effects on the bottom of the sump;
- depreciation of the flexible components does not exceed the permissible limits for a year of continuous operation.

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