MECHANICS. WATER SUPPLY

Butko D.A., Lysov V.A., Nechaeva L.I.

REMOVAL OF SLUDGE FROM SEDIMENTATION TANKS WITH HORIZONTAL FLOW

Abstract

Available research publications concerned with the design and calculation procedures for pressurised hydraulic sludge removal systems generally refer to experimental installations covering one third of the tank's length. A full-sized system designed in a similar fashion as the experimental set does have its own "infantile" diseases that compromise its functional performance. These issues were resolved later on.

Pressurised hydraulic systems covering the entire length of the tank were built on a number of sites across the North Caucasus and the Transcaucasian region, and called for the development of specialised design standards.

The application of this particular sludge removal system is not limited to horizontal tanks. The system can also be used in clarifying tanks with horizontal refining zones, as well as in vertical tanks and wash water recycle tanks with high-rate filters.

Over the system's extended operating cycle, its active systems have been studied to introduce some improvements and upgrade their performance characteristics.

Keywords: horizontal tank, pressurised hydraulic system, nozzles, variable cross-section collectors, sludge shear strength.

Purification of surface spring waters using two- or three-stage schemes is supported through the use of sedimentation tanks that assume the lion's share of contaminant pollution. Sedimentation is inextricably linked with the formation of sludge, and this is why sedimentation tanks are equipped with sludge refining and accumulation zones. Unfortunately, the volume of the latter has its limits. When it comes to the removal of sludge from the installation, modern design practices address this challenge using mechanical or hydraulic systems. These systems must comply with some basic requirements, such as the quality of the system operation, the duration of the sludge removal process, and the volume of purified water leakage. The pressurised hydraulic sludge removal system was developed over 40 years ago by Professor V.A. Lysov of the Department of Water Supply and Disposal, and has during this period of time won recognition as a highly reliable, efficient and economically viable solution.

Design and calculation procedures developed for the experimental pressurised system for removal of sludge from sedimentation tanks, as well as the results of its production tests, were previously published in the leading national research magazine [1] along with the recommendations for use in water treatment plants clarifying turbid water (the North Caucasus, the Transcaucasian region, Central Asia, etc.). The experimental plant was installed across the initial third part of the length of one of the open horizontal sedimentation tanks of the industrial water supply system at Nevinnomyssk Chemical Plant, i.e. it covered the section that accumulated the greater portion of overall sludge in the tank. The sludge removal scheme suggested in the paper [1] was approved for the textbooks on water supply for university students specializing in construction, water supply and water disposal, where the scheme was published without any alterations [2, 3, 4, 5].

Successful test results obtained for the experimental plant allowed to proceed with the design and construction of the pressurised hydraulic system across the entire length of the tank (Figure 1).

For sedimentation tanks of 48–72 m in length and 6.0 m axial width, the system consists of two variable cross-section collectors of 100–400 mm in diameter, attached on the metal mounts along the tank at the distance of 3.0 m from each other and 1.5 m from the walls at a height of 0.1 m above the floor. The distance between the nozzles amounts to 1.0 m, the direction of internal nozzles is set at an angle of 45^o to the horizontal axis, and the direction of external nozzles is set at an angle of 78^o to the same axis. The axis of internal and external nozzles is located on the same plane with the axis of pressurised telescopic collectors. The system is applied in 8 sections of horizontal sedimentation tanks on the industrial water supply system of Nevinnomyssk Chemical Plant, in pre-sedimentation tanks of the public water supply system in the city of Armavir, as well as in sedimentation tanks of Kurinskiy water supply system in Baku.

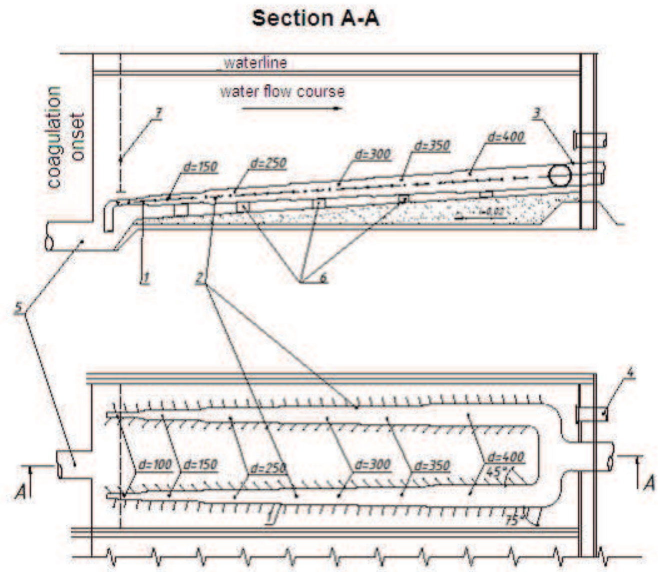

Figure 1. Design of the pressurised hydraulic sludge removal system installed across the entire tank length. 1 – nozzles; 2 – pressurised telescopic collector; 3 – pressurised lead line (from the pump); 4 – suction pipe to the pump; 5 – sludge (pulp) discharge pipeline; 6 – metal support poles; 7 – perforated membrane.

Unfortunately, the design of the full-size system is relatively unknown, although Rostov Water Service Project developed a twofold design model (series 4.901-22) for steel and plastic alternatives. The fact is that the schemes suggested in textbooks differ from the actual scheme applied across the entire length of the tank. This results in questionable decisions and ultimately compromises an otherwise efficient engineering solution.

The system is implemented in the projects realised by Rostov Water Service Project and other organisations with not only the horizontal sedimentation tanks, but with a variety of other installations intended for processing of natural waters.

A similar system was considered in a project for a clarifying tank with a horizontal refining zone, and according to the data provided in [8], the system was implemented at the water purification plant in the city of Anapa in 2008 (Figure 2).

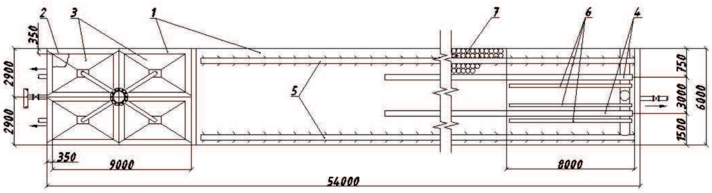

Figure 2. Figure 2. Clarifying tank with a horizontal refining zone by Rostov State Construction University – Rostov Institute of Civil Engineering (Anapa). 1 – reservoir, 2 – coagulation chamber, 3 – sludge blanket bin, 4 – collection trough, 5 – sludge removal pressurised system, 6 – distributed assembly system, 7 – modules.

Water treatment facilities located in Azov apply the scheme with vertical sedimentation tanks. The scheme was designed in 2008 in the framework of a redesign project. It was built in 2009 and is currently operating to the best advantage (Figure 3).

a) b)

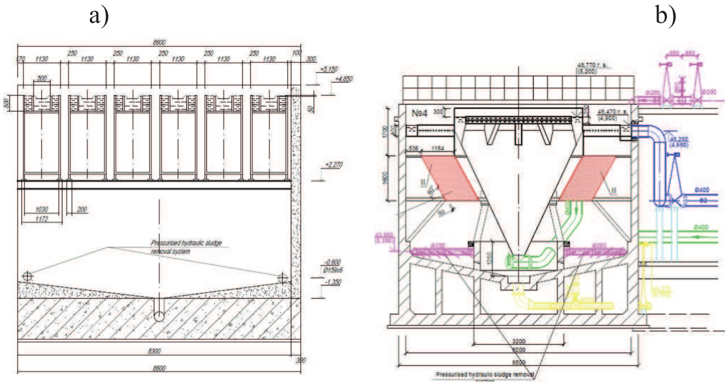

Figure 3. Sediment treatment facilities of Azov - the reconstruction of "Institute" Rostovsky Vodokanalproekt". a – rectangular vertical sump 9,0x9,0 m; б – all vertical sump diameter of 8.0 m.

The pressurised hydraulic sludge removal system was implemented in the design of wash water recycle tanks with high-rate filters. With this type of installations, the system ensures an efficient operation with no routine breaks required for sludge removal reducing the aggregate capacity of all essential reservoirs (Figure 4).

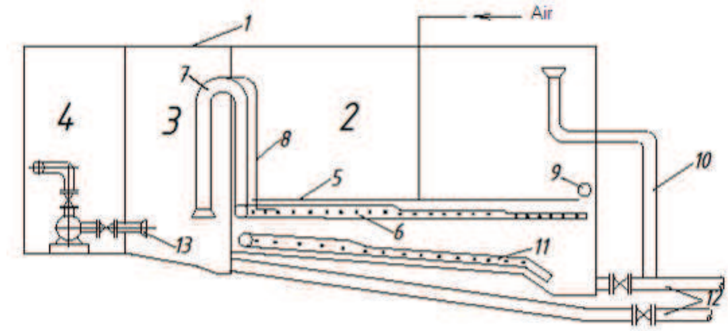

Figure 4. Wash water recycle tank with high-rate filters. 1 – housing assembly; 2 – sludge control reservoir; 3 – holding tank; 4 – engine compartment; 5 – air distribution system; 6 – clarified water collection system; 7 – siphon line; 8 – air tube; 9 – wash water feed pipe; 10 – overflow pipe; 11 – pressurised hydraulic sludge removal system; 12 – sludge removal pipeline; 13 – pump suction.

The operational use of the system in sedimentation tanks in Nevinnomyssk, Baku and Armavir revealed the need to verify system parameters on the basis of the quality of a particular local sludge, and mainly the parameter of sludge shear strength that should be measured directly in the tank using the instrument developed at the Department of Water Supply and Disposal at Rostov State Construction University [6]. Staff members of the Department of Water Supply and Disposal monitored the cleansing procedures on an annual basis to inspect the system and explicitly register the detailed data for all cleansing indicators and the quality of source water. As previously noted, the frequency of tank cleansing procedures depends on the intensity of accumulation and thickening of sludge in the tank, which in its turn varies in terms of the qualitative and quantitative composition of suspended solids in clarified water. According to the study of sludge accumulation and thickening kinetics, with the estimated value of sludge shear resistance for Kuban water equal to 1.5 g/cm^2, the maximum sludge layer thickness in a sedimentation tank should not exceed 1.5 m, and in order to prevent any disruption of the quality of water clarification, the maximum permissible volume of sludge in the tank should not exceed 15–17% of its volume. Thereby, in view of the previously obtained and verified values of mean concentration of compacted sediments, the corresponding calculations were carried out to identify turbid water fill-up time for the specified volume and estimate the frequency of tank cleansing procedures required.

Depending on the concentration of compacted sediments, the estimated frequency of tank cleansing procedures is as follows:

up to 100 mg/L – 20–40 days;
100 to 400 mg/L – 20–10 days;
400 to 1,000 mg/L – 10–7 days;
1,000 to 2,500 mg/L – 7–3 days.

Under actual field conditions of tank operation, inclusive of tanks equipped with pressurised hydraulic systems, the specified frequency is in most cases disregarded, and the actual period of tank service between the cleansing procedures proved to be several times higher.

The operation of the pressurised hydraulic system was most comprehensively and consistently monitored in summer periods of 1977 and 1979, and in the summer and autumn periods of 2000. During this time, the sedimentation tanks were carefully examined, and almost all the tanks underwent a cycle of test cleansing procedures. While the central parts of sedimentation tanks commonly appear to be almost clean along their entire length, and especially around the longitudinal axis of the installation, the wall areas are commonly covered with transverse ridges (sludge runs) interspersed with gullies that match the stream flows coming out of external nozzles. These gullies enter the central part of the tank from under the collector. The part of the sediment (about 30 m thick) remained under the collector around the metal mounts. Considering the analysis of the data obtained, we can state that with high values of sediment thickness (over 1.5–2.0 m) in its lower part (near the bottom), the value of sludge shear resistance significantly exceeds the estimated value. The highest values (around 17–9 g/cm^2) were obtained for the sludge layer, which was not removed in the course of preceding cleansing procedures and was subjected to prolonged and apparently recurrent consolidation. The results obtained for the parameter of sludge shear resistance can be used to appreciate the underlying reasons for insufficient cleansing of tanks evidenced in the context of heavy thickness of sediment and (or) in the light of prolonged inter-cleansing period.

In the course of further inspections, the stated defects of the pressurised hydraulic system showed up recurrently, which is why some appropriate changes were introduced into the design. These alterations were mostly associated with changing the bottom line of the tank and incorporating partial modifications in nozzles location (Figure 5).

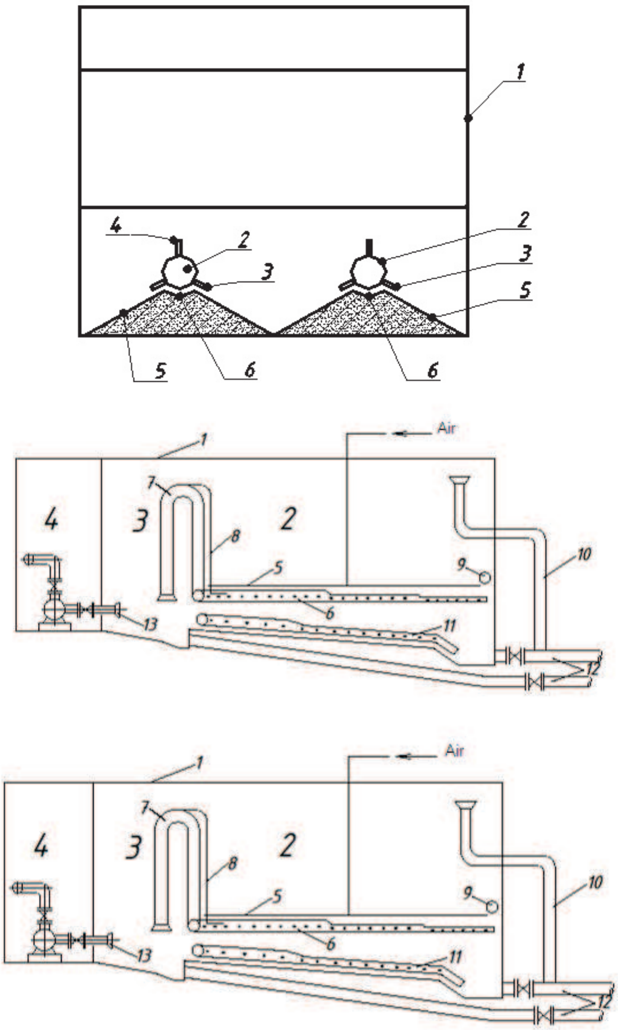

Figure 5. Cross-section of the bottom part of the sedimentation tank. 1 – sedimentation tank; 2 – collector; 3–4 – nozzles; 5 – wave-shaped bottom; 6 – bottom top redesigned for the tube.

The bottom part of the sedimentation tank is redesigned to make a wave-shaped cross-section with wave peaks equidistant to the pressure collectors. The wave-shaped bottom and collectors located on wave peaks allow to eliminate stagnant sludge zones over the pipes. The top generating line of the collector is equipped with L-shaped nozzles welded in every other 2–3 m. These nozzles incline in the direction of sludge movement and serve to reduce sediment detachment in addition to fulfilling their main function (stream mapping). The nozzles on the marginal generating line of the collector are located (in the vertical plane) parallel to the sides of the bottom waves, and remain unchanged in the horizontal plane (i.e. at $45^{o}$to the centre, and at 78^{o} to the side along the direction of sludge movement). The described device was patented under the USSR invention certificate No. 1629074 AH [7].

The analysed data reflecting the ongoing observation of the system operation show that, in general, the pressurised flushing system provides reliable functioning patterns and ensures almost exhaustive removal of sludge from sedimentation tanks.

Conclusions:

1. The developed technology intended for removal of sludge from sedimentation tanks using the pressurised hydraulic sludge removal system in production environments has proven its efficiency and reliability.

2. Reliability of the pressurised hydraulic system is secured by regular (every 1–2 years) inspection and revision coupled with the complete evacuation of the tank.

3. The maximum height of the layer of sediment left in the tank with the application of the pressurised hydraulic sludge removal system should not exceed 1.5–2.0 m.

References:

[1] Lysov V.A., Kurgaev E.F., Mikhailov V.A. Development and Research of a New Method of Removal of Sludge from Horizontal Water-Pipe Sedimentation Tanks Clarifying Turbid Water. In: Water Supply and Sanitary Equipment. No 10, 1974, pp. 15–18.

[2] Nikoladze G.I., Somov M.A. Water Supply. Moscow: Stroyizdat, 1987, p. 451.

[3] Nikoladze G.I. Natural Water Purification Technology. ACB, 1987.

[4] Frog B.N. Water Treatment. Moscow, 2001.

[5] Somov M.A., Zhurba M.G. Water Supply. Part II. ACB, 2008.

[6] Butko D.A., Lysov V.A., Kryukov S.V., Nechaeva L.I. Utility model patent No. 93535. Bulletin No. 12 dated

27.04.2010. Device Determining Sludge Shear Resistance in Sedimentation Tanks.
[7] Lysov V.A., Kurgaev E.F., Mikhailov V.A. USSR Invention Certificate No 1629074 AH. Wash Water Clarification Device. Bulletin No. 7 dated 23.02.1991.
[8] Turyansky I.P., Butko A.V., Lysov V.A., Nechaeva L.I., Reznikova S.N., Skryabin A.Yu. Maintenance and Utilisation of Water Supply Systems. Rostov-On-Don: ACB, 2009, pp. 73–74.