METHOD FOR CALCULATING DESIGN PARAMETERS OF THIN-LAYER MODULES FOR NEW DESIGNED DRINKING WATER TREATMENT UNITS

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Abstract. *This article presents a method for using thin-layer sedimentation tanks in horizontal sedimentation tanks in the process of drinking water purification. The basic requirements and methods for using thin-layer sedimentation tanks are presented. The role of thin-layer sedimentation tanks in accelerating the process of softening drinking water is great. When making recommendations, conclusions are drawn based on the results obtained on a laboratory instrument. The recommendations can be used both for existing settling tanks and for newly developed settling tanks.*

Annotatsiya. *Ushbu maqolada ichimlik suvini tozalash jarayonida gorizontal tindirgichlarda yupqa qatlamli cho'ktirish usuli taqdim etilgan. Yupqa qatlamli cho'ktirgichlardan foydalanishning asosiy talablari va usullari bayon qilingan. Ichimlik suvini yumshatish jarayonini tezlashtirishda yupqa qatlamli cho'ktirgichlarning ahamiyati katta. Tavsiyalar laboratoriya qurilmasida olingan natijalar asosida ishlab chiqilgan. Ushbu tavsiyalardan mavjud tindirgichlarni takomillashtirish va yangi tindirgichlar yaratishda foydalanish mumkin.*

Аннотация. *В данной статье представлен метод использования тонкослойных отстойников в горизонтальных отстойниках в процессе очистки питьевой воды. Изложены основные требования и способы применения тонкослойных отстойников. Роль тонкослойных отстойников в ускорении процесса умягчения питьевой воды значительна. Рекомендации сформулированы на основе результатов, полученных с помощью лабораторного оборудования. Предложенные рекомендации могут быть использованы как для существующих отстойников, так и для вновь разрабатываемых.*

Key Words: *Water, treatment facilities, thin-layer sedimentation tank, horizontal sedimentation tank, sedimentation, sludge.*

Kalit so'zlar: *Suv, tozalash inshootlari, yupqa qatlamli tindirgich, gorizontal tindirgich, cho'ktirish, cho'kindi.*

Ключевые слова: *Вода, очистные сооружения, тонкослойный отстойник, горизонтальный отстойник, осаждение, шлам.*

Introduction. Over the past 25 years, scientists have used a variety of designs to build, renovate, and expand industrial wastewater treatment plants in leading countries around the world (clarifiers and other devices that use gravity separation of solids retained from treated water). From thin ones, multilayer blocks are developed and sold.

Thin-film blocks and devices based on them are produced in many advanced countries (Sweden, USA, Great Britain, etc.) in three modifications: direct-flow, counter-flow and cross-flow, produced in the form of In the above-mentioned developed countries, thin-film blocks are widely used for purification of drinking and waste water. One of the advantages of these devices is that they reduce the space required for use by 50-90% and provide a 3-5 times increase in search efficiency.

Material and methods. It is advisable to use thin-layer settling modules in order to increase their efficiency when reconstructing existing settling and flotation structures and various types of settling tanks. The technical and economic feasibility of the developed schemes for using

thin-layer blocks for new construction and reconstruction of settling tanks and their economic feasibility for industrial use are substantiated [1].

The use of thin-layer blocks is the most economical, and in some cases the only solution for the reconstruction of existing extinguishers of various types. At the same time, it is convenient that the reconstruction of structures can be carried out in the shortest possible time without reducing the design parameters of the structures.

Methodological material in the form of a classifier of thin-layer modular blocks is used to supplement this set of rules and help designers when designing new ones and reconstructing existing ones at water supply (water treatment) treatment plants based on the principle of sedimentation (flotation) water purification, including:

• all standard sizes and systems of grinding machines, sand traps;
• mufflers and separators;
• designed to improve the efficiency of technological processes in flotation devices and oil separators.

Basic design principles and improved methods for calculating the main parameters of structures equipped with thin-walled modular blocks are presented.

Since clarifiers use the traditional method of purifying purified water by gravitational sedimentation of coagulating impurities, developers primarily use these methods as the main measures to increase the efficiency of clarifiers. In these cases, for clarifiers without built-in flocculation chambers, it is recommended to adjust the sequence of measures according to the degree of need as follows:

• Application of thin-layer blocks;
• Improvement of sludge treatment systems (process automation);
• Modernization of wastewater systems;
•Organization of engineering measures to equalize flow and temperature gradients throughout the settling tank and optimize water distribution within the volume of the structure.

Implementing these measures separately or in combination with each other will have a positive effect, the effectiveness of this process has been proven at many sites using various methods. Existing problems in water treatment facilities are solved through the use of thin-layer blocks.

The peculiarity of the operating principle of these structures requires the supply of cooling water at a given time interval in the structure to ensure the suspension of solid phase particles with the calculated hydraulic parameters of the deposits (hydraulic values). In this process, sand traps-clarifiers, together with devices of a certain size, must perform the following tasks:

• removal of formed deposits (hydraulic or mechanical);
• uniform distribution of cooled water by volume;
• collection and transmission of chilled water;
• control of muffler operating modes;
• implementation of technological control;
• performance of operational and preventative work.

To purify drinking water, horizontal, vertical and radial filters, slow-acting, high-speed, single-layer and multi-layer contact filters are used [2]. Coagulation and flocculation methods are used by adding reagents to speed up the settling process. At the same time, small particles become larger, quickly sink and become trapped. Settlements are reinforced concrete piles of rectangular or round shape, and suspended bodies settle due to a decrease in the speed of water movement (5–7 mm/sec). The movement of water in coolers can be in horizontal, vertical or radial direction. Therefore, they are divided into horizontal, vertical and radial types and are studied by science. In horizontal settling tanks, water is distributed through technical walls and moves relatively evenly along its length, and clarified water is transferred to the closing stage using drainage trays [3]. The bottom of the sump has a slope opposite to the direction of water movement, and a bunker is

installed in the front part. Here sediment is collected and removed hydraulically or mechanically. The thin-layer block module is practical when used in water treatment plants with a capacity of 30,000 m^3/day and above. They consist of three layers: a sediment layer of 0.8–1 m, a neutral layer of 0.3–0.5 m, a sediment layer of 0.3–0.5 m and a layer above the water surface of 0.3 m. A good result is obtained by using vertical settling tanks in structures with lower capacity, i.e. up to 3000 m^3/day. Because the principle of their operation is that water moves from bottom to top at a speed of 0.5–0.75 mm/sec, resulting from cleaning and waste removal. Their diameter can reach 12 m, and their depth is D/1.5–2. Radial settling tanks are round reinforced concrete pools with a diameter of 5–60 m, in which water is distributed from the center and moves in the radial direction at a speed of 5–7 mm/sec. Its bottom is inclined towards the center, and the sediment is collected and fed into a hopper in the center. Radial mufflers are an improved type of vertical mufflers and differ from conventional mufflers in the following advantages and disadvantages. The radial filter with a height of 22–25 is filled with fine-grained filter media with a filter height of 1.5–2. The water passes through the filter and is cleared of small particles [4]. In open slow-acting and closed filters, water moves from top to bottom and bottom to top. Water permeability in open filters reaches 100–120 mm/sec.

For optimal operation of the thin-layer block in these coolers, the Reynolds number $Re < Re_{kp} = 500$ for laminar fluid flow and $Fr > 10^{-5}$ for the Froude number are provided. To speed up the particle deposition process and eliminate the disadvantages inherent in traditional clarifiers, the particle deposition process is accelerated in thin-layer blocks, which allows for smaller clarifiers and higher productivity. In semi-continuous clarifiers, liquid enters and exits continuously, and the sediment is periodically cleaned. In continuously operating settling tanks, liquid supply and sediment removal are carried out continuously [5]. The most commonly used are semi-continuous and continuous hardening machines. In horizontal settling tanks, sediment is removed from thin-layer blocks perpendicular to the direction of liquid movement (cross-flow pattern of liquid and sediment); in settling tanks with an upward flow - in the direction opposite to the movement of liquid (reverse flow pattern of liquid and sediment); in settling tanks where liquid flows downward, in a direction corresponding to the direction of liquid flow (direct flow pattern of liquid and sediment movement); In combined-flow settling tanks, sediments are removed in different thin-layer blocks depending on the direction of liquid flow, for which the elements of the thin layer must be located at an angle to the horizontal.

Thin-layer blocks are horizontal (Fig. 1 a), radial (Fig. 1 b), vertical (Fig. 1 c) and ascending (Fig. 1 d), descending or ascending, depending on the direction of the liquid flow - descending. (combined) (Fig. 1 d) is divided into thin-layer block-type blocks with liquid flow. Depending on the direction of liquid movement in thin-layer blocks, sediment removal from them is ensured by drain paths specially designed for each of them.

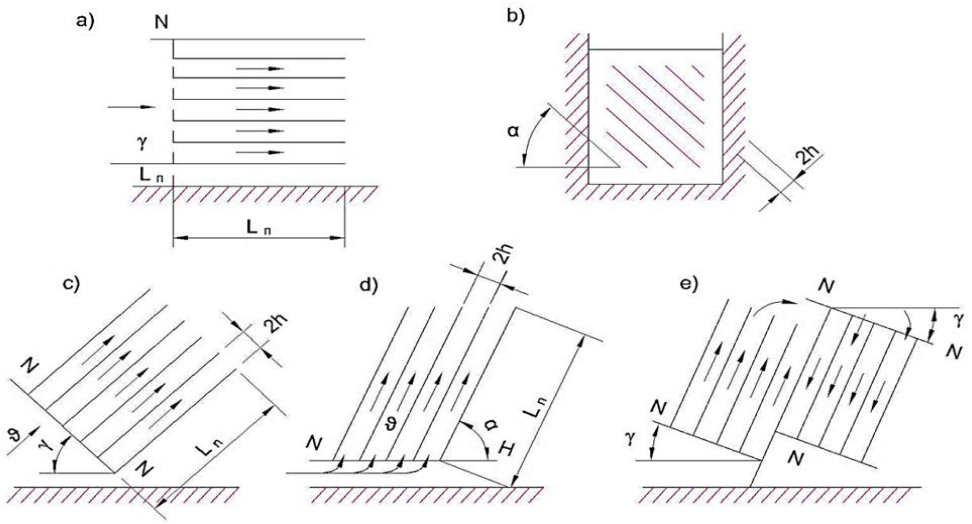

Figure 1. Schematic representation of flow direction in thin-layer blocks

In continuous thin-bedded blocks, this angle should allow sediment to roll into the accumulation zone. Sedimentation processes of polluting particles can occur in thin-layered blocks. Heavy parts of pollutant particles falling on the surface of thin-layered blocks move down, and lighter parts move up, then enter the corresponding accumulation zones and are removed from there using special devices, as in conventional sedimentation clarifiers.

The effectiveness of thin-layer blocks largely depends on the design of water distribution and collection devices. Input water distribution devices must ensure a rapid decrease in flow rate and its uniform distribution at the entrance to thin-layer blocks, and outlet devices must provide a local increase in flow rate, that is, not spread it [6].

The process of particle sedimentation in thin-layer sedimentation tank blocks is carried out due to the continuous movement of liquid from inlet to outlet.

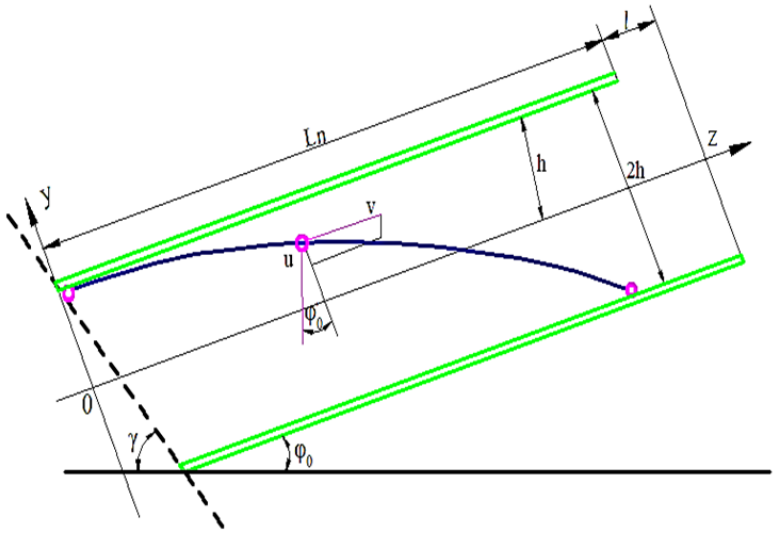

Figure 2. Scheme of depositing sediment into a thin-layer modular element

For different types of thin-layer blocks, the angles of inclination of the input parts of thin-layer blocks to the horizontal plane usually vary from 0 to 90°, and in some cases can be more than 90° (Fig. 2). In horizontal thin-layer blocks, the inlet parts are perpendicular to the direction, the movement of the flow and the sliding of sediments is ensured by the movement of elements in a

plane perpendicular to the direction of the water flow, at an angle α. In settling tanks with an ascending, descending or combined ascending-descending flow direction, the angles of inclination of thin-layer blocks to the horizon and the direction of movement of the liquid in them coincide, as a result of which sludge particles can be observed sliding. Sedimentation occurs in the direction opposite or corresponding to the direction of movement of the fluid flow. In the second case, the process of removing sediment becomes easier, which makes it possible to slightly reduce the angle α, which ensures normal displacement of the sediment.

Figure 2 shows a schematic diagram of the stagnation of particles in a thin-layer element, from which it can be seen that at each minute of time the rest velocity (hydraulic value) in a stationary fluid in a thin layer and the flow rate depend on the actual magnitude and direction of the particle velocity of the two components is the result of the addition of vectors , consisting of The trajectory of movement of the hardened particle during the hardening process and the hardening effect depend on their ratio. In thin-layer blocks, only particles of the lower (resting) or upper (floating) surface of their trajectories can be captured [7].

Due to the properties of particles in a liquid, the longest residence time is typical for particles entering a thin-layer element at its highest formative level. The maximum path determines the calculated modulus length of the thin layer.

When the liquid flows radially from the inlet to the outlet of the sedimentation tank, the flow velocity in the thin-layer element decreases in the central part and increases at the peripheral inlet of the liquid into the sediment.

In the practice of various chemical water purification processes, it is often necessary to use different clarifiers to separate light and heavy particles. The effect of the direction of flow of thin-layer blocks on their performance depends mainly on whether there are many or few light or heavy particles contained in the water being treated. In oil separators and flotation devices, when removing light particles with a density below the density of water, if the release of heavy particles is not limited, downflow is preferred for settling tanks. An upward flow is favorable in the presence of heavy particles whose density exceeds the density of water [8].

1) It is necessary to determine the direction of water movement in thin-layered blocks (horizontal, radial, vertical, upward and downward flow), the direction of sediment sliding and the effect of flow speed on friction speed, as well as hydraulic properties. ;

2) according to the ratio of the cross-sectional dimensions of the thin-layer module (tubular $\frac{b}{2h} = 1$, studded $\frac{b}{2h} > 10$,, limited width $\frac{b}{2h} = 4 - 10$);

3) Material of thin-layer blocks;

4) Placement of blocks (thin-layer elements) in the placement part (inlet, outlet, over the entire surface, at the top of the section) relative to the direction of the main flow velocity;

5) According to the conditions for the removal of sedimentary particles formed from thin-layered blocks (spontaneous, forced, etc.);

6) it is necessary to determine the availability of a stationary and automated system for washing thin-layer blocks.

When calculating thin-layer sediment softeners, it is necessary to take into account the features of water treatment. Special requirements are placed on mixers and heating chambers in water purification processes using thin-layer blocks during primary treatment with a reagent. Due to the fact that the residence time of water in thin-layer blocks is very short compared to conventional ones, it is necessary to pay special attention to the efficiency of mixing water with reagents and create conditions for the heating process during reagent processing. If the ineffective operation of mixers and heating chambers can be compensated for by constantly supplying more water, then the efficiency of the thin film module will be lower.

In newly designed structures, technological calculations are used to select the type of thin-layer blocks, determine the parameters and sizes of thin-layer blocks, and reduce costs [9].

1. The main condition for reliable and efficient operation of structures equipped with thin-layer blocks is to ensure laminar hydrodynamic conditions in the zone of the thin-layer module.

The Reynolds number Re in laminar flow is given by the following expression;

$$Re = \frac{v_{o'r}h}{\nu} \leq 500 \quad (1)$$

where v_{mid} – is the average flow rate of purified water in the thin-layer module, sm/s; $h = \frac{\omega}{x}$ - for a thin-layer module with braces; ω - cross-sectional surface of a thin-layer modular block, sm^2; x - wetted perimeter, sm, n - is the kinematic viscosity of water at a certain temperature, m^2/s.

The maximum permissible flow rate v_{max} – of purified water is determined by the following expression:

$$v_{max} \leq \frac{v}{h} \quad (2)$$

2. The length of the thin-layer module l_0 is determined by the following formula:

$$l_0 = \varphi \left[\frac{v_{mid}2h}{(u_0 \cos\alpha)}\right] \quad (3)$$

where: **φ**- is the coefficient for the case when hydrodynamic conditions of destruction are taken into account; ***a*** - the angle of the received thin-layer module is 45-60° relative to the horizon; $\boldsymbol{u_0}$ – hydraulic value, mm/s. $\boldsymbol{v_{mid}}$ - average flow rate of purified water, mm/s, (2-10 mm/s for horizontal softeners; 2-5 mm/s for radial softeners, in thin-layer modules with upper and lower liquid flow); 2h – floor pitch in a thin-layer module or pipe diameter, 0.025-0.2 m is allowed.

Results. In design practice, thin-layer blocks are calculated based on the sedimentation of particles inside the thin-layer element without taking into account the phenomenon of particle sedimentation along their surface under the hydrodynamic influence of the flow. Design measures that prevent or reduce the movement of turbid liquid particles to the surface of thin-layer blocks are not always provided. If necessary, it is covered with an additional length of the thin-layer module or with special devices (coils, etc.) due to compensation. When calculating compensation for the effect of particle settling on the additional length of the modules, it is recommended to use the following formulas:

$$L_t = l_0 + l_q;\ l_q = b(\frac{v_z}{v_{zs}}) \quad (4)$$

Where: **b** - the width of the thin-layer module, m; L_t – total length of the thin-layer module, m; l_q – additional length of the thin-layer module, m; l_q – length of the thin-layer module without settlement, m; v_{zs} - velocity of particle sedimentation in a fluid at rest, mm/s; v_z – particle sedimentation rate, mm/s.

For upward and downward flow, the length of the partition is L_z=0.

For sufficiently small particles

$$R_{ed} = \frac{u_{gk}d_e}{\nu} \leq 1, \quad (5)$$

where $\boldsymbol{d_e}$ – equivalent particle diameter, mm; $\boldsymbol{u_{gk}}$ – hydraulic size of settling particles, mm/s

The stabilization speed $\boldsymbol{v_{zs}}$ is determined from the following expression:

$$v_{zs} = 0{,}288u_{gk}(\sin \propto - k_{sq} \cos \propto), \quad (6)$$

where: k_{sq} - the coefficient of slip resistance determined experimentally, k_{sq} - coefficient depends on the size, characteristics, shape of the turbid particles, as well as the material of the thin-layer blocks. The approximate calculation for discrete spherical particles is in books k_{sq} = 0.1-0.3, and for water treated with reagents (coagulants) k_{sq} = 0.6-0.9 is recommended.

The sedimentation rate of particles v_z is determined by the following relationship:

$$v_z = \left(\frac{a}{h}\right) \nu d_e - 0.288u_{gk}k_{sq} \cos \propto, \quad (7)$$

where: α=1.5 for flat thin-film modules and α=2.0 for tubular modules.

The sliding speed of particles v_z is determined by the formula:

$$v_z = v_{zs} \pm \left(\frac{a}{h}\right) \nu d_e, \quad (8)$$

The "+" sign is used for downward fluid flow and the "-" sign for upward fluid flow.

Conclusion. Purifiers equipped with thin-layer modules (vertical and horizontal) are designed for purification of natural surface waters of low and medium turbidity and color in water treatment facilities of domestic and industrial water supply systems. In thin-bed treatment plants, sedimentation of suspended matter occurs in low-height flow modules. This ensures rapid release of the suspension and its movement along the flow plane of the modules to the flocculation and sediment compaction zones. Thin-layer sedimentation structures can be used both in the reconstruction of existing settling tanks and sedimentation tanks for the purpose of their intensification, and for newly designed water treatment facilities. The recommendations in this manual apply to structures with reverse flow of water and sediment in thin-layer modules. The requirements for the quality and methods of clarification of water with thin-layer modules are similar to the requirements for other types of clarifiers. The effectiveness of thin film quenchers and extinguishers is not limited.

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