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THE EFFICIENCY WATER CLARIFICATION IN MODELS OF VERTICAL TANK

The purpose of this article is to analyze theoretical and experimental data on the structures and analyze the performance of type clarifier, as well as to highlight the shortcomings of the proposed designs. It was found that for the experiments it is necessary to create a physical model of the vertical sediment tank in the laboratory using the following factors: material costs, technological parameters, design parameters. The purpose of this article is to show the effect of the velocity of upward flow of water inside the vertical settler on the efficiency of its lighting on the physical model of the vertical sediment tank. There are mathematical dependences of turbidity of clarified water as well as the efficiency of water clarification from the turbidity of the incoming water for different speed values in the lighting area of the vertical sediment tank. It was established the use of the calculations required area lighting area, vertical settling tanks, water speed, cleansing of water without efficiency loss, which leads to significant savings in capital investments.

Keywords: *water treatment, vertical sump, the efficiency of water clarification, water turbidity, the speed of the water upward movement.*

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ЕФЕКТИВНІСТЬ ОСВІТЛЕННЯ ВОДИ У МОДЕЛІ ВЕРТИКАЛЬНОГО ВІДСТІЙНИКА

У статті проаналізовано теоретичні та експериментальні дані щодо конструкцій та аналізу роботи відстійників цього типу, а також виділені недоліки запропонованих конструкцій. Встановлено, що для проведення експериментів необхідно створити фізичну модель вертикального відстійника в лабораторії використовуючи наступні фактори: матеріальні затрати, технологічні параметри, конструктивні параметри. Розглянуто вплив швидкості висхідного потоку води всередині вертикального відстійника на ефективність її освітлення на фізичній моделі вертикального відстійника. Отримані математичні залежності каламутності освітленої води, а також ефективності освітлення води від каламутності вхідної води для різних значень швидкості її в зоні освітлення вертикального відстійника. Встановлено, що використання у розрахунках необхідної площі зони освітлення вертикальних відстійників швидкості руху води у ній, при якій відбувається очищення її без втрати ефективності освітлення, призводить до суттєвої економії капітальних вкладень.

Ключові слова. *водопідготовка, вертикальний відстійник, ефективність освітлення води, каламутність води, швидкість висхідного руху води.*

Introduction. After the Soviet collapse remained water treatment plant in Ukraine worked at 70-80% of its design capacity. Nowadays, tariffs growth for utilities has significantly reduced the consumption of water by population and industrial enterprises. It has led to irrational use of land resources, electricity the like. The construction of a modern municipal water treatment plants requires compliance with the quality requirements of water purification, which are governed by the regulatory documents. On the other hand, the deterioration of water quality from surface sources requires increasing the effectiveness of water treatment to meet drinking needs of the population [1–3]. It would be achieved by retrofitting municipal water treatment plants and modern water purifying installations [4].

The use of existing industrial water purification plants with small capacity vertical tanks for receiving water output of the necessary quality is more economical than the use of sedimentation tanks of other types. Vertical sumps do not require large areas. They can be grouped in blocks and have sufficient indicators of water clarification efficiency.

Analysis of recent research sources and publications. Improving the efficiency of water clarification in vertical settling tanks is possible by reducing the speed of water upward flow in the clarifying zone, but it will lead to the need of increasing their size or quantity. It is considered in details process of water clarification in sedimentation tanks. Settling (sedimentation) of suspended particles consisting of mineral particles, as well as, under some assumptions, and unstable suspensions is described by the linear law of Stokes

$$F_C = 3\pi \cdot \mu \cdot u \cdot d \ , \tag{1}$$

where μ – coefficient of fluid dynamic viscosity;

u – the settling velocity of the particle;

d – particle diameter.

This law is valid for particles of small size deposited with low speed when viscosity forces only affect the resistance to their motion. More generally, the drag force of particle settles is represented by Newton-Rayleigh's law. [5]

$$F_C = \psi \cdot \rho_1 \cdot u^2 \cdot d^2 , \tag{2}$$

where ρ_1 – the density of the liquid;

u – particle sedimentation rate;

d – the equivalent particle diameter;

ψ – the coefficient of particles sedimentation, which depends on the Reynolds number and is determined by the expression

$$\psi = \frac{\rho_2 - \rho_1}{\rho_1} \cdot g \cdot \frac{\pi \cdot d}{6 \cdot u^2} , \tag{3}$$

where ρ_2 – the density of the particle.

In view of this, the sedimentation rate of the particles of certain type can be determined by the formula

$$u = \sqrt{\frac{\rho_2 - \rho_1}{\rho_1} \cdot g \cdot \frac{\pi \cdot d}{6 \cdot \psi}} . \tag{4}$$

Dependence of resistance coefficient on the Reynolds number is set empirically. Zegzhda V. P. obtained experimental data of sedimentation of grains of sand and gravel of different grain size [5].

At small values of Reynolds number in small particle sizes and small values of the speed of their subsidence, the dependence of resistance coefficient on the Reynolds number has direction at an angle of 45°. With the increase in the settling velocity of the particles and their size, linear law can be broken.

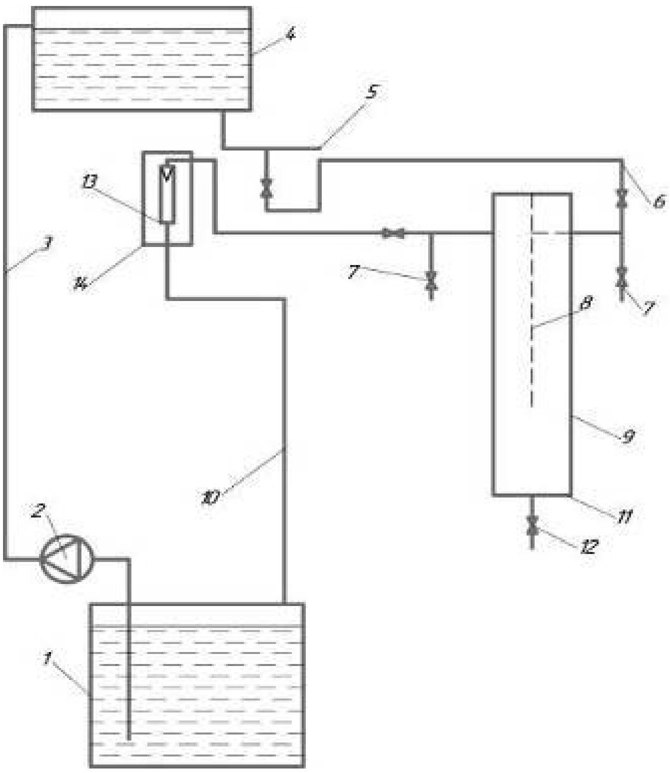
The limit of justice of the linear law is determined by the value of Reynolds number equal to 1.0. Suspended solids contained in water from natural sources have different shape and hydraulic size. The curve of suspended matter sedimentation, obtained experimentally, allows to determine the average value of its hydraulic size [6]. These curves determine the necessary residence time of water in the sump, corresponding to the required value of the illumination efficiency.

Selection of the unsolved parts of problem. Technological simulation of sedimentation of water in the sump [7] is to determine under laboratory conditions the design parameters for settling tank – the sedimentation velocity of suspension and the length of water stay in it that provides given effect of water clarification. This method is based on the similarity of the curves suspended solids precipitation obtained for different values of t cylinder laboratory height where it is settling.

In view of movement lack in laboratory cylinder, the values of energy efficiency obtained from the results of such experiments will be different from the values obtained for ponds in which there is water movement.

According to norms [8], the ratio of tank diameter to its height must be 1.0 or 1.5. Speed of water movement in the area of lighting vertical tank for reagent-free cleaning should not exceed 0,08-0,15 mm/s. Such a wide range of water velocity values can lead to the need for specific zone area lighting septic tanks, which will also depend on the total water consumption. For example, water consumption of 3,000 m^3/day or 125 m^3/hour, required area lighting zones septic tanks, depending on the water speed in it will be in the range of 300 to 560 m^2.

Statement of the problem. The aim of this work was to obtain the dependence on water clarification efficiency from the turbidity of the incoming water at different values of its movement speed in the lighting area. For the experiments it was established the physical model of the vertical sediment tank (Fig. 1), which consists of the camera flaking (Central tube) and lighting zones and accumulation of sediment (case) [9].



1 – tank for clarified water;
2 – circulating pump, clarified water;
3 – duct circulation of clear water;
4 – tank for preparation of working solution with paddle stirrer mechanical type;
5 – «comb» to distribute the supply of working solution among settings;
6 – the pipe feeding the working solution in a sedimentation tank;
7 – ball valve for sampling water;
8 – camera flaking (Central tube);
9 – sump body;
10 – the pipeline of the withdrawal of the clarified water;
11 – area of sediment accumulation;
12 – ball valve for sediment sampling;
13 – rotameter;
14 – panel for mounting flow meter

Figure 1 – Installation diagram model of the vertical sediment tank with flowmeter

General material and results. To simulate the process of water precipitation as research water it has been used cloudy solution obtained after mixing of clean water with sand or loam. Before starting work, each time it was carried out the calibration of the flow meter by the volumetric method. To do this, it was measured the time in which the filled measuring cylinder with certain specific indications of the rotameter costs. According to the results of the calibration it was constructed graphic dependence of the water movement rate in the clarifying zone model of the clarifier of flow rate with rotameter (Fig. 2).

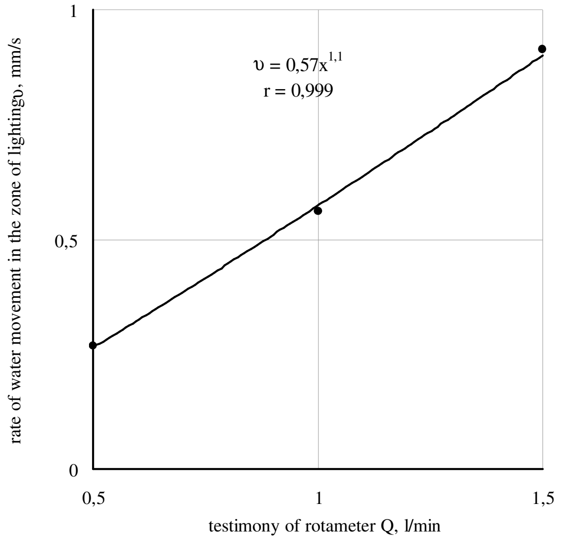


Figure 2 – Tiruvalla curve to determine the value of the rate of water movement in the zone of lighting according to the testimony of rotameter

The turbidity measurement was conducted as follows. The research sample of water was taken in cuvette and set in the single-beam photoelectric colorimeter (RPO-1). The second cell selected distilled water and with the help of the device determined the amount of light transmission through both the cuvette and thiruvallam schedule. It was determined by the test sample turbidity. Similarly, it was determined water sample turbidity at the outlet of the septic tank. The results of the experiments are shown in figures 3 – 5. The magnitude of the motion velocity in the lighting area of the vertical sediment tank 0,169 mm/s corresponds to water flow according to indications of the flow meter 0.5 l/min, and the speed 0,417 mm/s – 1, 5 l/min.

The results of determining the turbidity of clear water, depending on the velocity of its motion in the lighting area of the obtained graphical dependence on water bleaching effect in the physical model of vertical sump from the turbidity of the incoming water are shown (Fig. 6 – 7).

For example, it is calculated the required area of vertical sedimentation tank for reagent-free lighting cloudy water flow m^3/day. It is calculated the required area of illumination zone [8, formula (8)]

$$F_{в.о.} = \beta_{об} \cdot \frac{q}{3{,}6 \cdot v_p \cdot N_p} = 1{,}3 \cdot \frac{3000}{3{,}6 \cdot 24 \cdot 0{,}15 \cdot 3} = 100{,}3 \text{ m}^2, \quad (5)$$

where $\beta_{об}$ – factor considering the use of tank volume, the value of which adopted 1.3 (ratio of the diameter of the tank to its height as 1,0);

v_p – the estimated rate of upward water flow [8, tab. 16] is adopted for the lighting of water for industrial purposes $v_p = 0{,}15$ mm/s;

N_p – number of working septic tanks (tentatively accepted N_p =3 pcs.)

If vertical tanks used for preparation of drinking water, the design speed of the rising water flow in the area of lighting, the reagent-free cleaning must not exceed v_p = 0,08 mm/s [8, table. 16]. In this case, the required area of vertical clarifiers is

$$F_{в.о.} = \beta_{об} \cdot \frac{q}{3,6 \cdot v_p \cdot N_p} = 1,3 \cdot \frac{3000}{3,6 \cdot 24 \cdot 0,08 \cdot 3} = 188,1 \text{ m}^2, \quad (6)$$

As it is shown in Fig. 7, the efficiency of water clarification in the model of vertical sediment tank with the speed of motion in the lighting area 0,417 mm/s has quite high value from 43 to 86% (average value $E = 72\%$).

The required area lighting vertical zones septic tanks at speed of 0.417 mm/s, without the use of reagents will be important

$$F_{в.о.} = \beta_{об} \cdot \frac{q}{3,6 \cdot v_p \cdot N_p} = 1,3 \cdot \frac{3000}{3,6 \cdot 24 \cdot 0,417 \cdot 3} = 36,1 \text{ m}^2, \quad (7)$$

Thus, when calculating the required area lighting vertical settling tanks, the speed of water movement in the clarifying zone is 0.4 mm/s, in contrast 0,08...0,15 mm/s [8, tab. 16]. Savings of capital investments in the construction of the sumps will be: when cleaning industrial water to 64%, and in the purification of drinking water – up to 81%.

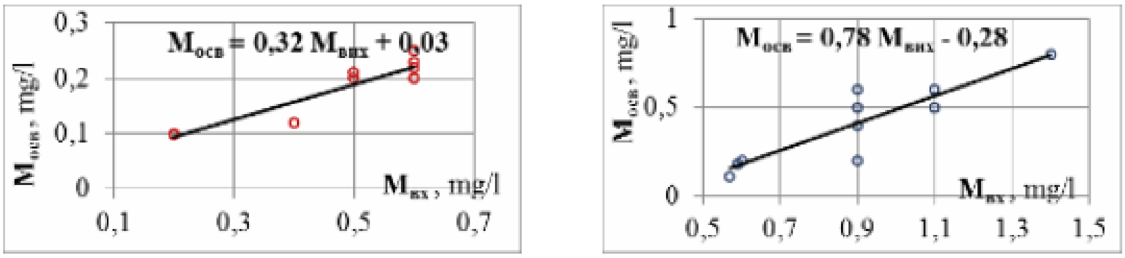


Figure 3 – The dependence on the turbidity of the clarified water $M_{осв}$ from the input $M_{вх}$ for sand

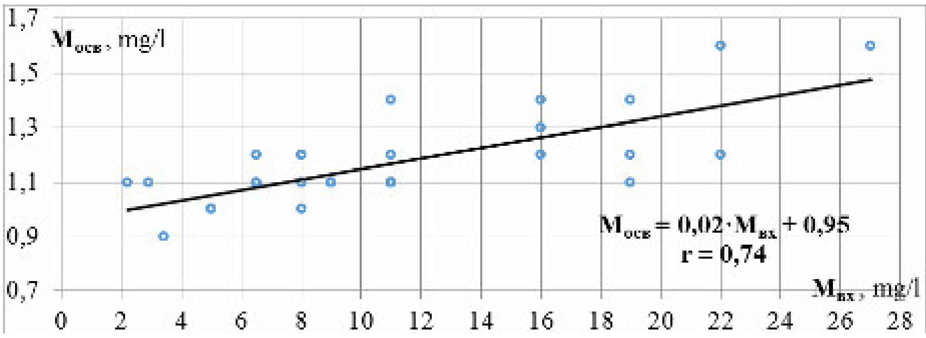


Figure 4 – The dependence of the turbidity of the clarified water $M_{осв}$ from $M_{вх}$ input to loam at a speed 0,169 mm/s

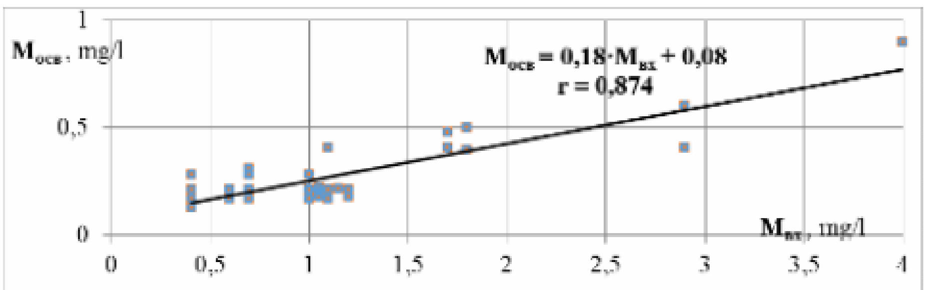


Figure 5– The dependence of the turbidity of the clarified water $M_{осв}$ from $M_{вх}$ input to loam at a rate of 0,417 mm/s

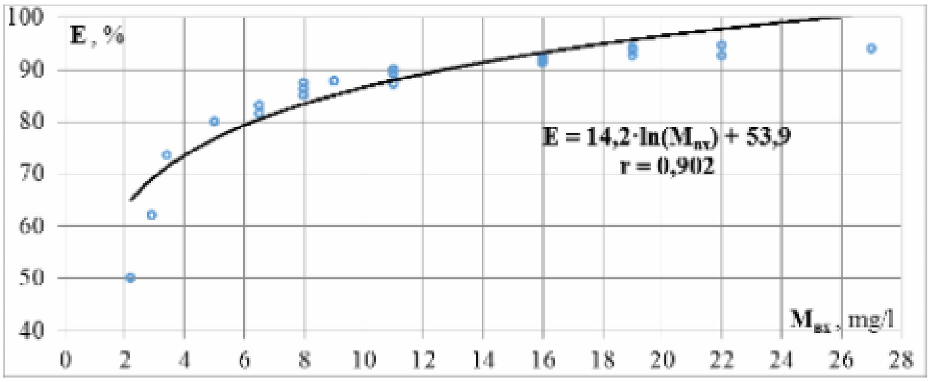


Figure 6 – The dependence on the effect of water clarification in vertical sump model E from the turbidity of incoming water Мвх when the velocity of its motion in the lighting area is 0,169 mm/s

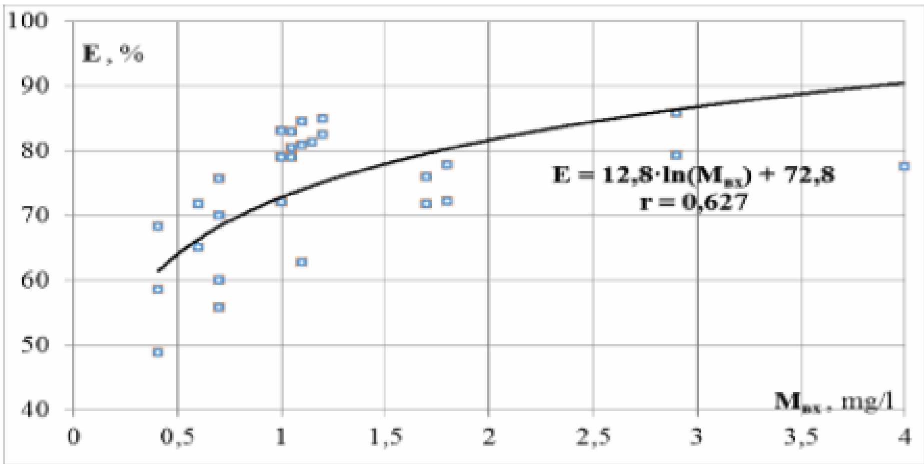


Figure 7 – The dependence on the water clarification effect in a model of vertical sump from the turbidity of the incoming water when the velocity of its motion in the lighting area is 0,417 mm/s

Conclusions.

1. The study of the water clarification process on physical model of the vertical sediment tank showed that water purification without the use of reagents can increase water speed in the clarifying zone to 0.4 mm/s (in contrast to suggested standards [8] 0,08–0,15 mm/s); lighting efficiency remains rather high (average value $E = 72\%$).

2. Water speed increase in the area of lighting to 0.4 mm / s reduces the area of the zone coverage to 64% – for industrial water and up to 81% – for drinking water; the results can be used in the design of new and existing cleaning operation structures with vertical tank.

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