MECHANICAL WASTE PROCESSING PROCEDURES WATER PRECIPITATORS

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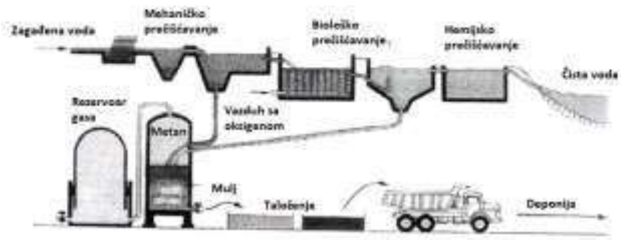
Summary: *Wastewater treatment is a procedure that reduces the present pollution with which the treated wastewater discharged into the recipient does not pose a danger to the environment. The paper discusses the mechanical procedures of wastewater treatment with special emphasis on sedimentation tanks. Sedimentation as a wastewater treatment technology is the oldest and most widely applicable procedure. It is used to separate inorganic and organic honeycomb from wastewater. They are also used in biological wastewater treatment to separate newly formed organic sludge. According to the method of deposition in engineering practice, there are four types of deposition: discrete (free), aggregate, zonal and compressed deposition. The paper considers free (discrete) deposition.*

Key words: *wastewater, treatment, mechanical processes, sedimentation tanks*

1. INTRODUCTION

The main goal of each wastewater is its complete release of unwanted components - pollutants, which is achieved by applying one or more basic treatment processes, [3, 5]. One or more basic processes that are used to achieve a certain processing effect, form the processing line. Several treatment lines form a treatment system, i.e. a system for restoring water quality, [2].

Introduction new standards in production and new laws and penalties for non-compliance with regulations on wastewater treatment impose the use of devices and plants for its processing so that as such it can be discharged into the recipient. Polluter liability principle
– legal entity which by its illegal or incorrect activities leads to environmental pollution is responsible in accordance with the law.
How the composition, especially of industrial wastewater, varies greatly depending on the origin, and there is no single indicator that is common to all wastewater and therefore neither a typical device or plant for wastewater treatment. Standards are formulated on the basis of a number of parameters, such as: color, turbidity, foam, oils and fats, BOD5 and HPK, pH, dry matter, suspended particles, heavy metals, nutrients (nitrogen and phosphorus), toxic substances, etc.
Our devices and wastewater treatment plants are fully automated. They consist of a series of physic - chemical and biological operations that are necessary for the parameters of such water to meet the law on water discharged into a particular recipient. Regular analyzes of such water by an authorized institution result in obtaining a water management permit.



Picture 1.1 Basic water purification scheme

Introduction wastewater to the receiver (recipient) is possible if the values of the characteristic quantities are within the established limit values. Limit values are determined by the state water control services depending on the specifics of the location and the concept of water management development. Determining the limit value may be limited in time. This means that a wastewater treatment plant may be required to emit a higher degree of pollutant components during operation. The basis of water quality management consists of two types of boundary concepts:

- one refers to the quality of water in water intakes,
- the other to discharged wastewater.

Treated wastewater can be discharged into the water intake until it exceeds the prescribed quality limit values for water intake.

2. PROCEDURES WASTE PROCESSING WATER

Pollution water is generated due to the inflow of municipal and industrial wastewater. Water pollution can be: physical, chemical, biological and changes in water temperature. There is no single wastewater treatment process because wastewater has its own characteristics and this is especially true of industrial wastewater. In practice, the following wastewater treatment procedures are used, [1, 2]:

- mechanical procedures,
- physic - chemical processes and
- biological procedures.

As a rule, all wastewater should be treated - treated in wastewater treatment plants, which is not the case in practice.

2.1. Wastewater treatment procedures

Mechanical (physical) purification wastewater removes coarse impurities and a portion of biodegradable ingredients. They are used mainly as a preliminary (primary) purification. These include: screens and sieves, mixers, precipitators, flotation and filtration, [3].

2.1.1. Grids

They are used to remove coarse materials such as branches, leaves, splinters, fabrics and the like. Lattices can be stationary (fixed) and movable. According to the size of the grid, the grids can be:

– Fine lattice	3 - 10 mm
– Medium lattice	10 - 25 mm
– Rough grille	50 - 100 mm

Speed wastewater flow through the grid ranges from 0.6 to 1 m / s.

2.1.2. Sieves

I can be:

– Microsite	"Mesh"> 0.3 mm
– Microsite	"Mesh" <0.3 mm

–

They make are made of stainless steel.

2.1.3. Mixers

Mixers are devices for averaging the characteristics of wastewater and are used where the characteristics of wastewater (wastewater composition) are variable. This non-stationarity of wastewater can be caused by the influence of various factors such as: the application of the mode of operation of the technological process, changes in the regime of wastewater flow through pipelines (sewerage networks) and other factors.

Types of mixers

According to the shape of the mixer, we divide it into:

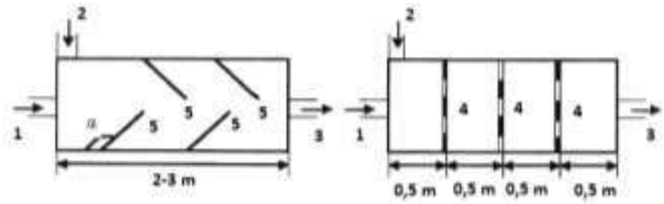
- incomplete partitions and partitions with openings,
- shovels,
- propeller, and
- turbine.
-

According to the speed of the mixer is divided into:

- slow-moving and
- high-speed.

Mixers with incomplete partitions and partitions with openings

In the treatment of wastewater by mixing, mixers with incomplete baffles and baffles with openings are most often used (Figure 2.1).



Picture2.1. Mixers with baffles

a) incomplete partitions b) partitions are openings

1 - water supply pipe, 2 - reagent pipeline, 3 - water drain pipe, 4 - partitions with openings, 5 - partitions for directing current

Partitions to direct current are placed at an angle of 45 - 135^0 in relation to the direction of water movement. Angle of 135^0 gives very good mixing.

Water flow rate in a narrow cross section it's moving in the interval 0.8 - 1 m / s.

Partitions with openings they set up are normally in the direction of water flow at a distance of about 0.5 m from each other.

Usually two or three partitions are installed with openings 20 - 40 mm in diameter. At higher wastewater flows, the diameter of the opening is up to 100 mm. The speed of water flow in the openings of the partitions is 1-2 m / s.

Mixer budget with incomplete partitions comes down to determining the width of the slot and the pressure drop.

According to known expression for fluid flow through pipes and channels, the pressure drop in one slot is:

$$\Delta p = \xi \cdot \frac{\rho \cdot v^2}{2}, Pa \quad (1)$$

there is

ξ - local resistance coefficient,
ρ - water density, kg / m3,
v - water flow velocity in a narrowed cross section (slot), m / s.

Volume flow water in drainage channel is determined by a familiar expression:

$$\dot{Q} = b \cdot h \cdot v, \ \frac{m^3}{s} \quad 2)$$

3

—

there is:

b - drainage channel width, m
h - water height in the canal, m,
v - water flow rate in the drainage channel, m / s.

For mixers with baffles with openings, the pressure drop for each baffle is:

$$\Delta = \frac{\cdot}{2 \cdot} \quad (3)$$

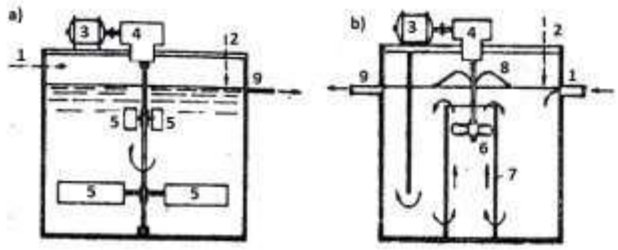
where is

v - water flow velocity through the barrier opening, m / s (ranging from 1-2 m / s),
k - flow coefficient (depending on the thickness of the barrier, ranging from 0.6 -

where is:
e - diameter of the opening, m.

Shovel mixers

Use are for liquids whose dynamic viscosity coefficient does not exceed 1 Pas. They mix a small part of the liquid near the blades. The residence time of the water in the paddle mixers is 3 to 5 min. Number revolutions the blade is 0.3 to 0.5 s^{-1} (Picture 2.2).

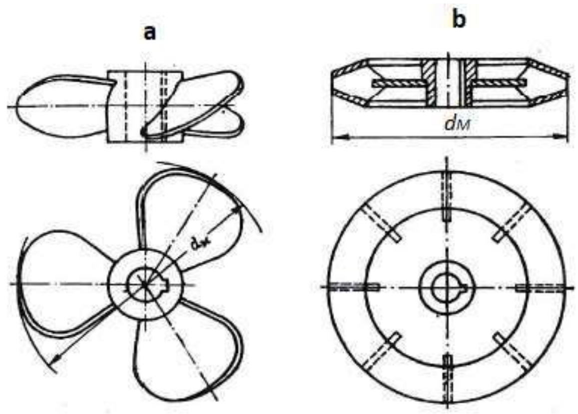


Picture 2.2. Scheme of mixer with mixer
a) with blades, b) with propeller

1 - wastewater inlet, 2 - reagent inlet, 3 - electric motor, 4 - reducer, 5 - blades, 6 - propeller, 7 - fixed jacket, 8 - bumper, 9 - wastewater drainage

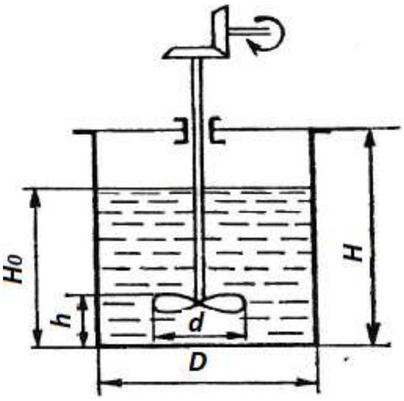
Propeller mixers

Propeller scheme the mixer is shown in Figure 2.2bi in Figure 2.3a. The turbine mixer is shown in Figure 2.3b.



Example 2.1.

The mixture has a density of 1600 kg / m3, dynamic viscosity 2 · 10-2 Pa · s, is prepared in an apparatus without partitions, diameter 1200 mm, height 1500 mm filled to 0.75 volume. The initial mixture is mixed with a propeller mixer with a speed of 3.5 s-1 (Figure 2.4). Determine the required installed power of the electric motor.



Picture 2.4. Propeller mixer

Solution:

According to Picture 2.3. the diameter of the mixer propeller is:

$$d = \frac{D}{3} = \frac{1,2}{3} = 0,4\,m,$$

where is:

D = 1.2 m - diameter of the mixer.

The mixing regime is determined by the expression:

$$R_{ec} = \frac{\rho_1 \cdot n \cdot d^2}{\mu_1} = \frac{1600 \cdot 3,5 \cdot 0,4^2}{2 \cdot 10^{-2}} = 44800,$$

where [5]:

q1 = 1600 kg / m3 - mixture density,

n = 3,5 s-1 - speed of propeller of the mixer,

µ1 = 2 · 10-2 Pa · s - dynamic viscosity of the mixture.

As 500 <Re = 44800 <2 · 105, the operating mode is turbulent.

We determine the value of the power criterion using graphs. KN = 0.27.

The power used by the mixer during the established operating mode is calculated using the expression:

N = KN · q · n 3 · d 5 = 0.27 · 1600 · 3.53 · 0.45 = 200 W = 0.2 kW.

The power at the time of commissioning is usually 2 to 3 times greater than the working power:

N0 = 2 · N = 2 · 0.2 = 0.4 kW.

Installed power, adopting the efficiency of the electric motor with a transmission of 0.98 and a power reserve of 20% is:

$$N_{ins} = 0,4 \cdot \frac{1,2}{0,95} = 0,51\,kW\ .$$

3. SEDMENTATION TANKS

Sediments are used to remove mechanical impurities, organic and inorganic particles and emulsified sludge mainly as a preliminary (primary) stage. They can be used as a subsequent (secondary) stage in the wastewater treatment process.

To describe in the criterion form the process of deposition of a ball-shaped particle in an infinite stationary medium, mainly similarity criteria are used: Archimedes - Ar, Lyashenkov - Ly and Reynolds Re.

The most appropriate form of criterion dependence is Lyashenkov - Ly = f (Ar).

The speed of particle deposition in the general case can be determined using the expression:

$$w_{t\check{c}} = \sqrt{\frac{4}{3} \cdot \frac{d_{\check{c}} \cdot (q_{\check{c}} - q_s) \cdot g}{\xi \cdot q_x}}\ ,m/s$$

(1)

Where are they:

$d_{\check{c}}$- particle diameter, m,

$q_{\check{c}}$ - particle density, kg / m3,

$q_{\check{c}}$ - density of the medium, kg / m3,

g - acceleration of the earth's gravity, m / s2,

ξ - coefficient of resistance of the medium.

The resistance coefficient ξ depends on the characteristics of the medium and is determined depending on the Reynolds number Re.

In the **laminar deposition regime** when Ar <3.6, Ly <2 · 10-3, Re <0.1, the resistance coefficient ξ can be determined using the Stokes formula (George Gabriel 1819 - 1903):

$$\xi = \frac{24}{Re}\ ,\quad Re = \frac{w_{t\check{c}} \cdot q_s \cdot d_{\check{c}}}{\mu_s}$$

(2)

Then the particle deposition speed is:

$$w_{t\check{c}} = \frac{1}{18} \cdot \frac{d_{\check{c}}^2 \cdot (q_{\check{c}} - q_s) \cdot g}{\mu_s}\ ,\frac{m}{s},$$

(3)

where is:

μ_s - dynamic viscosity of the medium, Pa-s

In the gaseous environment, the particle deposition rate is:

$$w_{t\check{c}} = \frac{d_{\check{c}}^2 \cdot q_{\check{c}} \cdot g}{18 \cdot \mu_s} \ , \frac{m}{s},$$

(4)

because q_s can be neglected.

In the range 0.1 <Re <1000 (transient mode) the formula can be applied:

$$\xi = \frac{18{,}5}{Re^{0{,}6}},$$

(5)

so the particle deposition speed can be approximated by the expression:

$$w_{t\check{c}} = 0{,}78 \cdot \frac{d_{\check{c}}^{1{,}14} \cdot (q_{\check{c}} - q_s)^{0{,}714}}{q_s^{0{,}285} \cdot \mu_s^{0{,}43}} \ , \frac{m}{s},$$

(6)

In the turbulent region 1000 <Re <350000 is ξ = 0.44, so the particle deposition rate is determined using the expression:

$$w_{t\check{c}} = 1{,}74 \cdot \sqrt{\frac{d_{\check{c}} \cdot (q_{\check{c}} - q_s) \cdot g}{q_s}} = 5{,}45 \cdot \sqrt{\frac{d_{\check{c}} \cdot (q_{\check{c}} - q_s)}{q_s}}, m/s$$

(7)

If it is a matter of ball-shaped particles and if it is assumed that their deposition takes place in a stationary, infinitely large ambience, i.e. that it is a free and not obstructed deposition (which is correct in the case of lonely particles), the algorithm for calculating the deposition rate in the case where the particle diameter is known is realized as follows:

Determine the Archimedes criterion:

$$A_r = G_a \cdot \frac{\Delta p}{q_s} = \frac{Re^2}{Fr} \cdot \frac{q_{\check{c}} - q_s}{q_s} = \frac{d_{\check{c}}^3 \cdot (q_{\check{c}} - q_s) \cdot q_s \cdot g}{\mu_s^2},$$

(8)

where Ga is the criterion of Galileo: (9) and in the case of deposition in a gaseous medium is:

$$Ga = \frac{Re^2}{Fr},$$

(9)

and in the case of deposition in a gaseous environment is:

$$Ar = \frac{d_{\check{c}}^3 \cdot q_{\check{c}} \cdot q_s \cdot g}{\mu_s^2}.$$

(10)

Based on the calculated value of the criterion Ar, the criterion Re or the Lyashenko criterion is determined (Picture 3.1):

$$Ly = \frac{Re^3}{Ar} = \frac{Re \cdot Fr \cdot q_s}{q_{\check{c}} - q_s} = \frac{w_{t\check{c}}^3}{\mu_s \cdot (q_{\check{c}} - q_s) \cdot g},$$

(11)

or in the case of deposition in a gaseous medium:

$$Ly = \frac{w_{t\check{c}}^3 \cdot q_s^2}{\mu_s \cdot q_{\check{c}} \cdot g},$$

(12)

The deposition rate is then calculated:

$$w_{t\check{c}} = \frac{Re \cdot \mu_s}{q_s \cdot d_{\check{c}}}, \quad m/s$$

(13)

$$w_{t\check{c}} = \sqrt{\frac{Ly \cdot \mu_s \cdot (q_{\check{c}} - q_s) \cdot g}{\rho_s^2}}, m/s$$

(14)

For particles of irregular shape, the deposition rate is determined in the same way from the Lyashenko criterion, but with the use in the Archimedes criterion of the size de instead of dc. Equivalent diameter de, irregularly shaped particles are calculated as the diameter of an imaginary ball, whose volume V is equal to the volume of an irregularly shaped body.

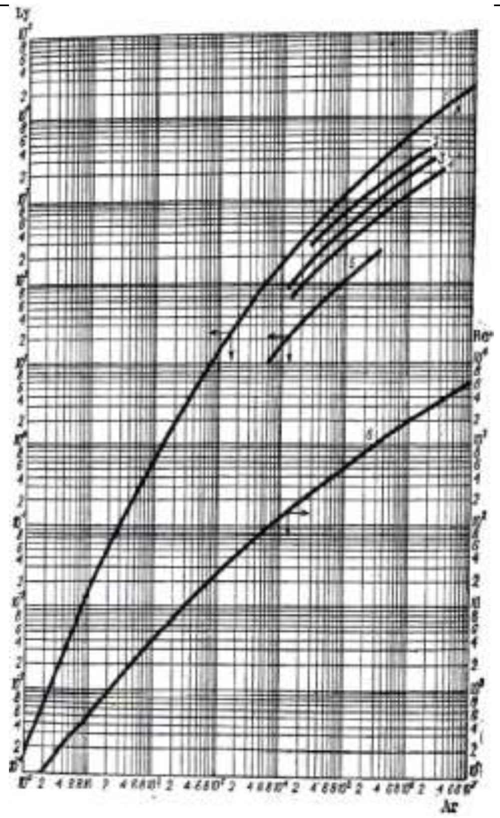
$$d_e = \sqrt[3]{\frac{6V}{\pi}} = 1{,}24 \cdot \sqrt[3]{\frac{m_{\check{c}}}{\rho_{\check{c}}}}$$

(15)

Where are they:

$d_{\check{c}}$ - equivalent particle diameter, m,

m - particle mass, kg.



Picture 3.1. Dependence of criteria Re and Ly on criteria Ar for sedimentation of a lone particle in a stationary environment:

1 and 6 - spherical particles, 2 - round, 3 - angular, 4 - longitudinal, 5 - flat

The diameter of the ball-shaped particle that precipitates at a known deposition rate is found in the reverse way, i.e. first, the Lyashenko criterion is calculated:

$$Ly = \frac{w_{t\check{c}}^3 \cdot q_s^2}{\mu_s \cdot (q_{\check{c}} - q_s) \cdot g},$$

(16)

and based on the obtained value of Ly, the criterion Ar is determined (Picture 3.1.), and from there, using the expression (10), the diameter of the ball-shaped particle is determined. The equivalent particle diameter of an irregularly shaped solid at a known deposition rate is determined in the same way. First, the criterion Ly is determined using expression (17), then from Picture 3.1. read the value of the criterion Ar for the case of a particle of appropriate shape and calculate its equivalent diameter:

$$d_e = \sqrt[3]{\frac{Ar \cdot \mu_s^2}{(q_{\check{c}} - q_s) \cdot \rho_s \cdot g}}.$$

(17)

The deposition area of the dust deposition device or suspension precipitator is determined by the expression:

$$F_t = \frac{\dot{V}}{\dot{w}_{t\check{c}}},$$

(18)

Where are:

F_t- sedimentation area, m2.

$\dot{V}$ – volume flow of gas (liquid) passing through the apparatus parallel to the deposition surface, m / s.

$\dot{w}_{t\check{c}}$ - average calculated particle deposition rate, m/s.

The ratio of the mean calculated particle deposition rate, $w_{t\check{c}}$, lone article deposition rate, $w_{t\check{c}}$, depends on the volume concentration of the suspension. In orientation calculations, taking into account the approximate deviation of real deposition conditions from theoretical ones (compressibility of deposition, particle shape, medium motion), the average calculated deposition rate is often equal to half the theoretical deposition rate of a lone spherical particle.

$$\dot{w}_{t\check{c}} = 0{,}5 \cdot w_{t\check{c}}$$

(19)

When applied to the continuous precipitator for precipitating the suspension (Picture 3.2.) and using expression (18), the form is obtained:

$$F_t = \frac{\dot{m}_{pr} \cdot \left(1 - \frac{\tilde{x}_{pr}}{\tilde{x}_{ug}}\right)}{\rho_s \cdot \dot{w}_{t\check{c}}},$$

$$F_t = \frac{\dot{V}_{t,pr} \cdot \left(\tilde{X}_{ug} - \tilde{X}_{pr}\right)}{\tilde{X}_{ug} \cdot \dot{w}_{t\check{c}}},$$

where are:

F_t - settling sedimentation area, m2,

$\dot{m}_{pr}$ – maseni protok početnog rastvora (suspenzije), $\frac{kg}{s}$,

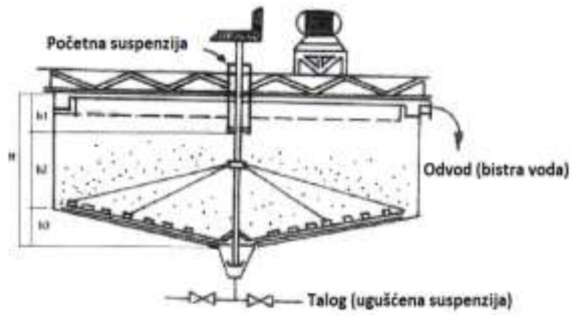
$\tilde{x}_{pr}$ – maseni udio čvrste faze u početnoj suspenziji, $\frac{kg}{kg}$,

$\tilde{x}_{ug}$ – maseni udio čvrste faze u ugašenoj suspenziji, $\frac{kg}{kg}$,

ρ_s – gustina svijetle tečnosti, $\frac{kg^3}{m^3}$,

$\dot{V}_{t,pr}$ – zapreminski protok tečne faze koja se nalazi u početnoj suspenziji, $\frac{m^3}{s}$,

$\tilde{X}_{pr}, \tilde{X}_{ug}$ – masena koncentracija početne i ugušćene suspenzije, $\frac{\text{kg čvrste faze}}{\text{kg tečne faze}}$



Picture3.2.
Continuous precipitator (sedimentation tank)

Example 3.1.

Calculate the deposition rate of quartz particles with a diameter of a) 0.1 mm and b) 0.001 mm in pure water at a temperature of 200C. The specific particle density is 2650 kg / m3. Particle deposition takes place by laminar flow. If the retention time of water in sedimentation tanks (sedimentation tanks) is usually about 2 h, will the particle settle to the bottom of the 3.5 m deep tank during that time.
Solution:
a) Water density and dynamic viscosity of water at a temperature of 200C is qH2O = 998.2 kg / m3, μH2O = 1004 · 10-6 Pa · s [5]. The regime of particle flow is transient 0.1 <Re <1000, so by applying equation (6), the sedimentation rate of the particle is:

$$w_{t\check{c}} = 0{,}78 \cdot \frac{d_{\check{c}}^{1{,}14} \cdot (q_{\check{c}} - q_s)^{0{,}714}}{q_s^{0{,}285} \cdot \mu_s^{0{,}43}} = 0{,}78 \cdot \frac{(0{,}1 \cdot 10^{-3})^{1{,}14} \cdot (2650 - 998.2)^{0{,}714}}{q_s^{0{,}285} \cdot \mu_s^{0{,}43}}$$

0,01159 m/s = 11,59 m/s.

where is:
$d_{\check{c}}$ = 0,1 · 10-3 - quartz particle diameter,
$q_{\check{c}}$ = 2650 kg / m3, quartz particle density [5],
g = 9.81 m / s2 - acceleration of the earth's gravity.
The time required for the particle to settle to the bottom of the precipitator is:

$$\tau = \frac{H}{w_{t\check{c}}} = \frac{3{,}5}{0{,}001159} = 301{,}98\, s = 0{,}08\, h < 2\, h\,.$$

where is:
H = 3.5 m - depth - tank height.
b) Using expression (3)

$$w_{t\check{c}} = \frac{1}{18} \cdot \frac{d_{\check{c}}^2 \cdot (q_{\check{c}} - q_s) \cdot g}{\mu_s}\ , \frac{m}{s},$$

$$w_{t\check{c}} = \frac{1}{18} \cdot \frac{d_{\check{c}}^2 \cdot q_{\check{c}} \cdot g}{\mu_s} = \frac{1}{18} \cdot \frac{(0{,}001 \cdot 10^{-3})^2 \cdot (2650 - 998{,}2) \cdot 9{,}81}{1004 \cdot 10^{-6}} =$$

$$= 8{,}96 \cdot 10^{-7} \frac{m}{s} = 8{,}96 \cdot 10^{-4} \frac{mm}{s}$$

where is:
$d_{\check{c}}$ = 0,001 · 10-^{3} m, - diameter of the quartz particle, so it takes time for the particle to settle to the bottom of the precipitator:

$$\tau = \frac{H}{w_{t\check{c}}} = \frac{3{,}5}{8{,}96 \cdot 10^{-7}} = 3906250\, s = 1085\, h \gg 2\, h\,.$$

Only in case
a) the particles will settle to the bottom of the precipitator. The correctness of the assumption of transient and laminar flow can be checked as follows (expression 2):

a) $$Re = \frac{w_{t\check{c}} \cdot q_s \cdot d_{\check{c}}}{\mu_s} = \frac{0{,}01159 \cdot 998{,}2 \cdot 0{,}1 \cdot 10^{-3}}{1004 \cdot 10^{-4}}$$

=1,15>0,1.

b) $$Re = \frac{w_{t\check{c}} \cdot q_s \cdot d_{\check{c}}}{\mu_s} = \frac{8{,}96 \cdot 10^{-7} \cdot 998{,}2 \cdot 0{,}001 \cdot 10^{-3}}{1004 \cdot 10^{-4}} = 0{,}0089 \cdot 10^{-4}$$

<0,1.

A colloidal quartz particle with a diameter of 0.001 mm (10^{-4} cm) at a temperature of 20^0C has a deposition rate of
8.96 · 10^{-4} cm / s (0.896 · 10^{-6} cm / s). This means that a quartz particle can cross a 1 cm deposition path in 12.92 days. For a deposition path of 100 cm, the deposition time is 1292 days, which is approximately 3.54 years. Colloidal particles can be practically

removed from water only by increasing the particle size, i.e. by increasing the deposition rate to about 2 to 4 m / h. In order to increase the size of colloidal particles, it is necessary to discharge voltage up to ± 5 mV, because in this area electric charged particles can approach the size of up to 10 Å (10^{-7} cm) when the action of Van der Wals force begins (Johannes Diderik van der Wals 1837 - 1923). The eruption of the charge of colloidal particles is called coagulation, and the growth of neutral particles into larger groups (flocs) is called flocculation.
Without coagulation, flocculation or deposition of particles cannot occur, and the coagulation process itself cannot practically remove colloidal particles from wastewater.

3. CONCLUSION

The paper discusses the mechanical procedures of wastewater treatment. Wastewater treatment processes are closely related to the characteristics of the production process.
Mechanical processes include: gratings, sieves, mixers, settling and other processes. Of the mechanical wastewater treatment processes, sedimentation tanks occupy a special place. In the process line of wastewater treatment, sedimentation tanks are used as primary and sometimes as secondary devices.
As secondary devices, they are used mainly in chemical and biological wastewater treatment processes, especially the sedimentation of biological sludge, which can be used as a commercial product in further treatment. The paper presents the basic equations that are necessary for the proper sizing and design of the precipitator, which is especially important for engineering practice.

4.LITERATURE

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