CALCULATION FEATURES OF VERTICAL SETTLING TANKS FOR HEAVY METAL - CONTAINING WASTEWATER TREATMENT

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Abstract: *The article discusses the treatment of wastewater containing heavy metal salts before releasing it into natural water bodies or the urban drainage system. The focus is on environmental protection, human health, and the potential for recovering valuable metals from wastewater. A vertical settling tank was selected for its cost-effectiveness in treating metal-containing acidic wastewater. The article provides a general method for calculating these settling tanks during reagent sedimentation, which can be used to remove various types of heavy metal salts. For this purpose, all calculations related to the use of reagents (their quantities, volumes of reagent storage, solution tanks, and neutralization chambers) were conducted in advance. Additionally, corresponding chemical equations for the reagents and various acids, as well as the equations for the reactions occurring between the reagents and heavy metal salts, were formulated.*

Keywords: *salts of heavy metals, neutralization reactions, hydroxide compounds, wastewater, vertical settling tank.*

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Introduction

Industries involved in the chemical and electrochemical treatment of metals are among the most harmful to the environment. The discharge of wastewater containing poorly treated heavy metal ions into natural water bodies causes significant environmental damage, and the release of such untreated wastewater into water bodies must be entirely prevented [1-3]. Consuming seafood from such water bodies is fraught with dangerous consequences for humans, leading to severe diseases of the nervous system, blood vessels, heart, and liver [4-6]. It should also be noted that various technological processes in metalworking plants consume large amounts of water[1,2]. Therefore, the development of new or improved methods for deeply purifying this contaminated water is highly relevant from an environmental perspective[3] [7]. Deep purification will not only improve the ecology of the surrounding environment but can also serve as a source for obtaining a number of valuable metals [8-13].

Wastewater containing heavy metal ions, including valuable non-ferrous metals, is currently treated using various methods [14-18]. Electrochemical methods, based on physical chemistry, electrochemistry, and chemical technology, involve separation and conversion processes or a combination of both.

These methods are quite complex, and the mechanism and rate of each stage depend on many factors, which are difficult to ensure simultaneously.

Materials and Methods

The calculation methodology is based on reagents' interactions with acids and heavy metal salts. This method includes equipment calculation that neutralizes acidic metal-containing wastewater and a generalized calculation of the vertical settling tanks intended for their purification.

[1] Water management in the steel industry. https://worldsteel.org/wp-content/uploads/Water-management-in-the-steel- industry.pdf
[2] Properties and Uses of Steel and Stainless Steel in Water Treatment Systems. https://3amakina.com/properties-and-uses-of-steel-and-stainless-steel-in-water-treatment-systems/
[3] Methods of wastewater purification from heavy metal ions (in Russian). https://www.vo-da.ru/articles/ochistka-ot-tyazholyh-metallov/metody-ochistki

In metalworking plants, various technological processes consume a substantial amount of water. Developing new or improved methods for extensive purification of this contaminated water is highly relevant from an environmental standpoint. Deep cleaning not only improves the surrounding area's ecology but can also help recover several heavy metals.

Currently, there are several methods used to clean wastewater with heavy metal ions, including precious non-ferrous metals. These methods, like electrochemical techniques, rely on the principles of physical chemistry, electrochemistry, and chemical technology. They mainly involve separation, transformation processes, and complex combined methods. Furthermore, the mechanism and speed of each stage are affected by numerous factors that are challenging to achieve simultaneously.

Calculation of vertical settling tanks and auxiliary structures

The work aims to extract valuable non-ferrous (and other) metals from the wastewater using the most commonly practiced reagent method. This method includes neutralization processes and redox reactions in which heavy metal ions are converted into hydroxide compounds and the resulting sludge is dewatered. If necessary, the pH value of the effluent is adjusted after purification[4,5] [19-21].

The article presents a generalized method for calculating vertical settling tanks for reagent settling, which can be used to remove all types of heavy metal salts. The choice of reagent settling in vertical settling tanks is justified by the relatively small quantities of these industrial wastewater. Settling tanks are particularly well-suited for extracting iron from industrial effluents, given that iron is the Earth's fourth most abundant chemical element (4.5-5%). It's important to note that in most iron-containing industrial effluents, the pH exceeds 8.3, leading to the prevalence of Fe^{3+} in the water over Fe^{2+}.

The efficiency of extracting insoluble Fe^{3+} as precipitated flocs of $Fe(OH)_3$ can be improved by pre-aerating the effluent. For this purpose, a pre-aerator can be designed as a separate unit, integrated, or attached to the vertical settling tank. To accurately calculate the selected vertical settling tanks, initial calculations of all equipment involved in the averaging and neutralization of these effluents need to be conducted [22-24].

The calculation is carried out in the following order:

1. Calculation of the reagents used,
2. Calculation of reagent facilities,
3. Calculation of solution tanks,
4. Calculation of settling tanks.

In our previous section, we outlined the formulas that result from the interactions between various reagents and acids (Table 1), as well as the formulas that arise from the interactions between reagents and heavy metal salts. We also took into account the molecular masses of the substances involved in these reactions (Table 2). The following sequential calculation approach is universal and allows for the calculation of the consumption of the specific reagent used for purification from specific salts of heavy metals. Since the flow of industrial wastewater usually varies over shifts (sometimes even within quite large limits), together with the neutralization installation, a built-in averager was also provided (Fig.1).

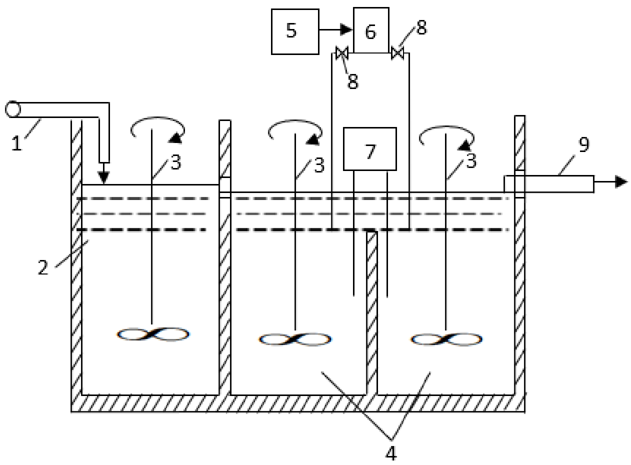

Fig. 1. *Scheme of the installation for averaging structure blending plant and wastewater neutralization*

1. acidic waste supply, 2. low-equalization basin, 3. mixer with mechanical drive, 4. neutralization chamber, 5. dispensable alkaline solution tank, 6. dispenser, 7. regulating pH meter, 8. valve, 9. neutralized drain into settling tank, 10. hole, ensuring the flow into the neutralization chamber

[4] Modern methods of water purification from heavy metals (in Russian). http://elib.bsut.by/bitstream/handle/123456789/6112

[5] Removal of heavy metals from water (in Russian). https://www.ecoindustry.ru/user/skruber/blogview/2053.html

Industrial acid wastes, through pipeline (1) enter the averaging chamber (2), where they are mixed with a stirrer (3) and through hole (10) enter the neutralization chambers. (4). At the same time, the alkaline solution from the supply tank flows into the dispenser (6) and, with open valves (8), is sent to the neutralization chambers. There, with the lowered indicators, the indicator of active hydrogen ions is regulated by the provided pH meter (7). Next, the neutralized wastewater is sent to the settling tank through pipeline (9). Note that mixer with mechanical drives are also used in the wastewater neutralization process.

Table 1. Molecular masses of the most frequently occurring salts of heavy metals in industrial wastewater

Name of heavy metals salts	Chemical formulas of heavy metal salts / molecular masses	Chemical records of metals / molecular masses
Iron sulfate	$FeSO_4$/152	Fe/56
Iron sulfate	$Fe_2(SO_4)_3$/400	Fe/56
Nickel (II) sulfate Nickel(II) chloride	$NiSO_4$/155 $NiCl_2$/130	Ni/59
Copper sulfate Copper (II) chloride	$CuSO_4$/160 $CuCl_2$/135	Cu/64
Zinc sulfate Zinc chloride	$ZnSO_4$/161 $ZnCl_2$/136	Zn/65
Lead (II) chloride	$PbCl_2$/178	Pb/207
Tin(II) chloride	$SnCl_2$/190	Sn/119

Table 2. Reaction equations between various reagents and acids

CaO	$H_2SO_4 + CaO + H_2O = CaSO_4 + 2H_2O$ 98 56 18 136 36 $2HCl + CaO + H_2O = CaCl_2 + 2H_2O$ 73 56 18 111 36 $2HNO_3 + CaO + H_2O = Ca(NO_3)_2 + 2H_2O$ 126 56 18 164 36 $2H_3PO_4 + 3CaO + 3H_2O = Ca_3(PO_4)_2 + 6H_2O$ 196 168 54 310 108
$Ca(OH)_2$	$H_2SO_4 + Ca(OH)_2 = CaSO_4 + 2H_2O$ 98 74 136 36 $2HCl + Ca(OH)_2 = CaCl_2 + 2H_2O$ 73 74 111 36 $2HNO_3 + Ca(OH)_2 = Ca(NO_3)_2 + 2H_2O$ 126 74 164 36 $2H_3PO_4 + 3Ca(OH)_2 = Ca_3(PO_4)_2 + 6H_2O$ 196 222 310 108
Na_2CO_3	$H_2SO_4 + Na_2CO_3 = Na_2SO_4 + H_2O + CO_2\uparrow$ $2HCl + Na_2CO_3 = 2NaCl + H_2O + CO_2\uparrow$ $2HNO_3 + Na_2CO_3 = 2NaNO_3 + H_2O + CO_2\uparrow$ $2H_3PO_4 + 3Na_2CO_3 = 2Na_3PO_4 + 3H_2O + 3CO_2\uparrow$
$MgCO_3$	$H_2SO_4 + MgCO_3 = MgSO_4 + H_2O + CO_2\uparrow$ $2HCl + MgCO_3 = MgCl_2 + H_2O + CO_2\uparrow$ $HNO_3 + MgCO_3 = Mg(NO_3)_2 + H_2O + CO_2\uparrow$ $2H_3PO_4 + 3MgCO_3 = Mg_3(PO_4)_2 + 3H_2O + 3CO_2\uparrow$
$CaCO_3$	$H_2SO_4 + CaCO_3 = CaSO_4 + H_2O + CO_2\uparrow$ $2HCl + CaCO_3 = CaCl_2 + H_2O + CO_2\uparrow$ $2HNO_3 + CaCO_3 = Ca(NO_3)_2 + H_2O + CO_2\uparrow$ $2H_3PO_4 + 3CaCO_3 = Ca_3(PO_4)_2 + 3H_2O + 3CO_2\uparrow$
Dolomite $CaCO_3 \cdot MgCO_3$	$2H_2SO_4 + CaCO_3 \cdot MgCO_3 = CaSO_4 + MgSO_4 + 2H_2O + 2CO_2\uparrow$ $4HCl + CaCO_3 \cdot MgCO_3 = CaCl_2 + MgCl_2 + 2H_2O + 2CO_2\uparrow$ $4HNO_3 + CaCO_3 \cdot MgCO_3 = Ca(NO_3)_2 + Mg(NO_3)_2 + 2H_2O + 2CO_2\uparrow$ $4H_3PO_4 + 3CaCO_3 \cdot MgCO_3 = Ca_3(PO_4)_2 + Mg_3(PO_4)_2 + 6H_2O + 6CO_2\uparrow$

Note: In reactions with slaked lime and quicklime, molecular masses are also given.

Table 3. Reaction equations between various reagents and metal salts

CaO	$FeSO_4+CaO+H_2O=Fe(OH)_2\downarrow+CaSO_4$ $ZnSO_4+CaO+H_2O=Zn(OH)_2\downarrow+CaSO_4$ $CuCl_2+CaO+H_2O=Cu(OH)_2\downarrow+CaCl_2$ $NiCl_2+CaO+H_2O=Ni(OH)_2\downarrow+CaCl_2$ $Fe_2(SO_4)_3+3CaO+3H_2O=2Fe(OH)_3\downarrow+3CaSO_4$ $NiSO_4+CaO+H_2O=Ni(OH)_2\downarrow+CaSO_4$ $ZnCl_2+CaO+H_2O=Zn(OH)_2\downarrow+CaCl_2$ $CuSO_4+CaO+H_2O=Cu(OH)_2\downarrow+CaSO_4$ $SnCl_2+CaO+H_2O=Sn(OH)_2\downarrow+CaCl_2$ $PbCl_2+CaO+H_2O=Pb(OH)_2\downarrow+CaCl_2$
$Ca(OH)_2$	$FeSO_4+Ca(OH)_2=Fe(OH)_2\downarrow+CaSO_4$ $ZnSO_4+Ca(OH)_2=Zn(OH)_2\downarrow+CaSO_4$ $CuCl_2+Ca(OH)_2=Cu(OH)_2\downarrow+CaCl_2$ $NiCl_2+Ca(OH)_2=Ni(OH)_2\downarrow+CaCl_2$ $Fe_2(SO_4)_3+3Ca(OH)_2=2Fe(OH)_3\downarrow+3CaSO_4$ $NiSO_4+Ca(OH)_2=Ni(OH)_2\downarrow+CaSO_4$ $ZnCl_2+Ca(OH)_2=Zn(OH)_2\downarrow+CaCl_2$ $CuSO_4+Ca(OH)_2=Cu(OH)_2\downarrow+CaSO_4$ $SnCl_2+Ca(OH)_2=Sn(OH)_2\downarrow+CaCl_2$ $PbCl_2+Ca(OH)_2=Pb(OH)_2\downarrow+CaCl_2$
Na_2CO_3	$FeSO_4+Na_2CO_3+H_2O=Fe(OH)_2\downarrow+Na_2SO_4+CO_2\uparrow$ $ZnSO_4+Na_2CO_3+H_2O=Zn(OH)_2\downarrow+Na_2SO_4+CO_2\uparrow$ $CuCl_2+Na_2CO_3+H_2O=Cu(OH)_2\downarrow+NaCl+CO_2\uparrow$ $NiCl_2+Na_2CO_3+H_2O=Ni(OH)_2\downarrow+2NaCl+CO_2\uparrow$ $Fe_2(SO_4)_3+2Na_2CO_3+3H_2O=Fe(OH)_3\downarrow+3Na_2SO_4+3CO_2\uparrow$
Na_2CO_3	$NiSO_4+Na_2CO_3+H_2O=Ni(OH)_2\downarrow+Na_2SO_4+CO_2\uparrow$ $ZnCl_2+Na_2CO_3+H_2O=Zn(OH)_2\downarrow+2NaCl+CO_2\uparrow$ $CuSO_4+Na_2CO_3+H_2O=Cu(OH)_2\downarrow+Na_2SO_4+CO_2\uparrow$ $SnCl_2+Na_2CO_3+H_2O=Sn(OH)_2\downarrow+2NaCl+CO_2\uparrow$ $PbCl_2+Na_2CO_3+H_2O=Pb(OH)_2\downarrow+NaCl+CO_2\uparrow$
$MgCO_3$	$FeSO_4+MgCO_3+H_2O=Fe(OH)_2\downarrow+MgSO_4+CO_2\uparrow$ $ZnSO_4+MgCO_3+H_2O=Zn(OH)_2\downarrow+MgSO_4+CO_2\uparrow$ $CuCl_2+MgCO_3+H_2O=Cu(OH)_2+MgCl_2\downarrow+CO_2\uparrow$ $NiCl_2+MgCO_3+H_2O=Ni(OH)_2\downarrow+MgCl_2+CO_2\uparrow$ $ZnCl_2+MgCO_3+H_2O=Zn(OH)_2\downarrow+MgCl_2+CO_2\uparrow$
$MgCO_3$	$FeSO_4+MgCO_3+H_2O=Fe(OH)_2\downarrow+MgSO_4+CO_2\uparrow$ $ZnSO_4+MgCO_3+H_2O=Zn(OH)_2\downarrow+MgSO_4+CO_2\uparrow$ $CuCl_2+MgCO_3+H_2O=Cu(OH)_2\downarrow+MgCl_2+CO_2\uparrow$ $NiCl_2+MgCO_3+H_2O=Ni(OH)_2\downarrow+MgCl_2+CO_2\uparrow$ $ZnCl_2+MgCO_3+H_2O=Zn(OH)_2\downarrow+MgCl_2+CO_2\uparrow$
$CaCO_3$	$FeSO_4+CaCO_3+H_2O=Fe(OH)_2\downarrow+CaSO_4+CO_2\uparrow$ $ZnSO_4+CaCO_3+H_2O=Zn(OH)_2\downarrow+CaSO_4+CO_2\uparrow$ $CuCl_2+CaCO_3+H_2O=Cu(OH)_2\downarrow+CaCl_2+CO_2\uparrow$ $NiCl_2+CaCO_3+H_2O=Ni(OH)_2\downarrow+CaCl_2+CO_2\uparrow$ $Fe_2(SO_4)_3+3CaCO_3+3H_2O=2Fe(OH)_3\downarrow+3CaSO_4+\uparrow 3CO_2$ $NiSO_4+CaCO_3+H_2O=Ni(OH)_2\downarrow+CaSO_4+CO_2\uparrow$ $ZnCl_2+CaCO_3+H_2O=Zn(OH)_2\downarrow+CaCl_2+CO_2\uparrow$ $CuSO_4+CaCO_3+H_2O=Cu(OH)_2\downarrow+CaSO_4+CO_2\uparrow$ $SnCl_2+CaCO_3+H_2O=Sn(OH)_2\downarrow+CaCl_2+CO_2\uparrow$ $PbCl_2+CaCO_3+H_2O=Pb(OH)_2\downarrow+CaCl_2+CO_2\uparrow$
Dolomite $CaCO_3\cdot MgCO_3$	$2FeSO_4+CaCO_3\cdot MgCO_3+H_2O=2Fe(OH)_2\downarrow+CaSO_4+MgSO_4+2CO_2\uparrow$ $2ZnSO_4+CaCO_3\cdot MgCO_3+H_2O=2Zn(OH)_2+CaSO_4+MgSO_4+2CO_2\uparrow$ $2CuCl_2+CaCO_3\cdot MgCO_3=2Cu(OH)_2\downarrow+CaCl_2+MgCl_2+2CO_2\uparrow$ $NiCl_2+CaCO_3\cdot MgCO_3=Ni(OH)_2\downarrow+CaCl_2+MgCl_2+CO_2\uparrow$ $Fe_2(SO_4)_3+CaCO_3\cdot MgCO_3+6H_2O=4Fe(OH)_3\downarrow+3CaSO_4+3MgSO_4+6CO_2\uparrow$ $2NiSO_4+CaCO_3\cdot MgCO_3+2H_2O=2Ni(OH)_2\downarrow+MgSO_4+CaSO_4+2CO_2\uparrow$ $2ZnCl_2+CaCO_3\cdot MgCO_3+2H_2O=2Zn(OH)_2\downarrow+CaCl_2+MgCl_2+2CO_2\uparrow$ $CuSO_4+CaCO_3\cdot MgCO_3+2H_2O=Cu(OH)_2\downarrow+CaSO_4+MgSO_4+2CO_2\uparrow$ $2SnCl_2+CaCO_3\cdot MgCO_3+2H_2O=Sn(OH)_2\downarrow+CaCl_2+MgCl_2+CO_2\uparrow$ $2PbCl_2+CaCO_3+MgCO_3+2H_2O=2Pb(OH)_2\downarrow+CaCl_2+MgCl_2+2CO_2\uparrow$

Reagent consumption (G) is determined by the following formula:

$$G = K_r \cdot Q\left(\sum aA + \sum bB\right)\frac{100}{c}, \quad \frac{kg}{day}, \tag{1}$$

where $K_r = 1.1...1.3$ - reserve coefficient; Q - daily flow rate, m^3/day; A and B - respectively concentrations of acids and salts of heavy metals; $a = \frac{m}{n_a}$ - specific consumption of the reagent used for acid neutralization, kg/kg; m and n_a - the molecular masses of the reagent and acid, respectively; $b = m/n_m$ - specific consumption of the reagent used for the precipitation of heavy metal salts; n_m - molecular mass of heavy metal salts; $C = 40...70\%$ - content of the active substance in the reagent used.

The area of the reagent stock is determined by the following formula:

$$S = \left(Q \cdot ts\right)/h \cdot p, \; m^2, \tag{2}$$

where $ts = 30\,\text{min}$ - reserve time; $h = 1.5...2.0\,\text{m}$ - the height of the reagent layer, $\rho = \left(1...1.2\right)t/m^3$ - specific gravity of the reagent.

Having the surface, we select the dimensions of the storage (width and length).

The volume of supply tanks (W_t) is determined by the following equation:

$$W_t = \frac{G \cdot C}{n_s Z}, \quad m^3, \tag{3}$$

where $n_s = 4...6$ is the number of solutions obtained per day; $z = 4...6\%$ - solution content.

For the volume, we can select the number of tanks (at least two) and their dimensions. The consumption of the reagent solution is determined by the formula:

$$q_r = \frac{1000 \cdot n_s \cdot W_s}{86400} = \frac{n_s \cdot W_s}{86.4}, \quad l/\sec. \tag{4}$$

We also determine the total consumption of wastewater (q_t) and reagent solution by the following way:

$$q_t = q + q_r = \frac{Q_s}{86.4} + q_r, \; l/\sec. \tag{5}$$

Mixer volume (W_m) is determined by the formula:

$$W_m = \frac{60 \cdot q_t \cdot t_m}{1000} = \frac{q_t \cdot t_m}{16.7},$$

where $t_m = 5\,\text{min}$ is the mixing time.

For the volume, the diameter and height of the mixer are determined. Usually, we accept one mixer and its dimensions (diameter and height). The volume of the neutralization chamber is determined by the formula:

$$W_n = \frac{q_t \cdot 60 \cdot t_n}{1000} = \frac{q_t \cdot t_n}{16.7}, \; m, \tag{6}$$

where $t_n = 30$ min is the required time to neutralize the flow.

Taking two neutralization chambers, we get $W_1 = \frac{W_n}{2}$ and the sizes of each of them.

The calculation of settling tanks begins with determining their diameter (B) using the following formula:

$$D = \sqrt{\frac{4qt}{\pi \cdot Vn_{st.t.}}}, \; m. \tag{7}$$

where $V \leq 0.2$ mm/sec - the rate of wastewater in the settling tank; $n_{st.t.}$ – the number of settling tanks, which is advisable to take a multiple of 4, taking into account the fact that $D \leq 9.0$ m.

The height of the deposition zone is determined by the formula:

$$h_{set.} = 3.6 \cdot t_{st.}, \tag{8}$$

where $t_{st.} \geq 24$ is the duration of suspension deposition.

We determine the dry matter content (M) in the accumulated slag using the formula:

$$M = \left[K_s \cdot \frac{100 - C}{C} \left(X_1 + X_2 + X_3 + y_1 + y_2 - 2 \right) \right] \cdot Q, \quad kg / day, \tag{9}$$

where $X_1 = \sum a \cdot A$ - reagent consumption for the neutralization of acids contained in 1m^3 of wastewater, kg/m^3; $X_2 = \sum b \cdot B$ - reagent consumption for the precipitation of metal salts contained in 1m^3 of wastewater, kg/m^3; $X_3 = \sum \frac{m_h}{n_m} \cdot B$ - the amount of hydroxyls that are formed from the metals contained in 1m^3 of wastewater (m_h is the molecular mass of hydroxyls); $Y_1 = \sum \frac{m_s}{n_a} \cdot A$ - the amount of insoluble salts formed during the acid neutralization, kg/m^3; n_s - the molecular mass of insoluble salts; $y_z = \sum \frac{m_s}{n_m} \cdot B$ - the amount of salts formed during reactions between reagents and salts of heavy metal, kg/m^3; z – solubility of calcium sulfate ($CaSO_4$) in water. If $y_1 + y_2 - 2 < 0$, then the negative value of the expression is neglected.

We determine the volume of sludge (W_{sl}) using the formula:

$$W_{sl} = \frac{M}{10(100 - p)}, \quad m^3 / day, \tag{10}$$

where $p = 86...88\%$ is the moisture of the sludge.

We determine the settling tank conical part volume using the formula:

$$W_C = \pi \cdot D^3 / 24, \ m^3. \tag{11}$$

Taking the angle of inclination of the settling tank conical section to be 45^0, we obtain the height of the conical part – $h_{c.q.1} = D/2$.

We determine the settling tank cylindrical part volume (W_C) using the formula:

$$W_C = \frac{W_{sl}}{n_q + 1} - W_c, \ \text{m}^3, \tag{12}$$

where $n_q \geq 2$ is the estimated number of settling tanks.

We can also determine the height of the cylindrical part using the formula:

$$h_c = \frac{4 \cdot W_C}{\pi D^2}, \ \text{m}. \tag{13}$$

Taking the height of the neutral part $h_1 = 0.25$ m, we determine the depth of the settling tank (H):

$$H = h_w + h_c + h_{con} + h_1, \ \text{m}, \tag{14}$$

where $h_W = 0.5$ m is the height of the side wall from the drainage level.

The diameter of the central part of the vertical settling tank (Fig.2) is determined by the equation:

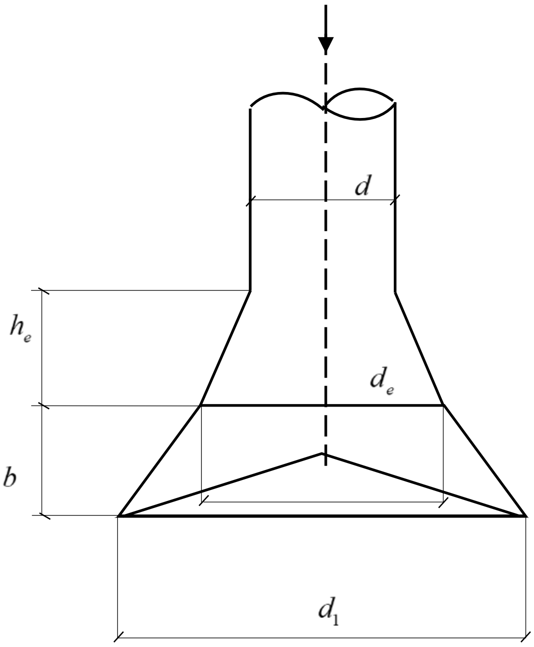

Fig. 2. *The central part of the supply pipe of a vertical settling tank*

$$\frac{Q}{3.6 \cdot W_c} = n_r \cdot \frac{\pi d^2}{4}, \quad (15)$$

where Q - wastewater consumption, m^3/day,

n_r - the estimated number of settling tanks.

The diameter of the central pipe in mm is determined from equation (16):

$$d = \sqrt{\frac{4Q \cdot 1000}{\pi \cdot n_c \cdot V_c \cdot 86400}}, \text{ mm.} \quad (16)$$

where $V = 30$ mm/sec - flow rate in the central pipe.

We also determine the length of the transition part of the central pipe (h_e) and its diameter (d_e) according to the condition $d_e = h_e = 1.35 \cdot d$, mm.

The diameter of the central pipe (d_1) is determined by the following formula:

$$d_1 = 1.3 \cdot d_e, \text{ mm.} \quad (17)$$

After, we determine the length of the central pipe inserted-joint part using the formula:

$$\frac{Q}{3.6 \cdot V_s \cdot V_{s.p.p.}} = \pi \cdot n_c \cdot d_e \cdot b, \quad (18)$$

where $V_{s.p.p.} = 20$ mm/sec is the wastewater velocity at the splashing plate.

Taking into account the need for identical measurements of units, from equations (18) we get:

$$b = \frac{1000 \cdot 1000 \cdot Q}{864000 \cdot \pi \cdot n_c \cdot V_{s.p.p.}}, \text{ m.} \quad (19)$$

Conclusion

1. We have provided the necessary neutralizing reagents and all the appropriate equipment to neutralize industrial metal-containing wastewater, which can have an alkaline or, most often, acidic medium, during the treatment process.
2. A homogenizer is built into the neutralization chambers to reduce capital investments, simplify operations, and ensure accurate calculation of treatment facilities.
3. The suggested method allows for a detailed calculation of the vertical settling tank when removing various metal salts from acidic wastewater using specific reagents.
4. If necessary, wastewater that has been clarified in settling tanks can also undergo further purification, preferably through sand or dual-layer filtration. In all cases, a disinfection process is also planned after the purification process.
5. The sludge accumulated in the conical section of the settling tank can be transferred to sludge pads for dehydration and further extraction of valuable metals.

Conflict of Interest

The authors declare no conflicts of interest.

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