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ABOUT IMHOFF SETTLING TANKS

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Abstract: An important component of municipal infrastructure, whether in rural or urban areas, is the drinking water supply and sewage, wastewater, and rainwater drainage networks. While most localities have a drinking water supply, sewage systems, meaning networks and wastewater treatment plants, are still non-existent in many localities, especially in rural areas. This paper presents the resizing and re-engineering of a settling tank from an existing wastewater treatment plant. It proposes the reuse of the reinforced concrete basin and its re-equipping with new hydraulic installations in order to improve decanting performance.

Keywords: Imhoff settling tank, vertical settling tank, wastewater treatment plants

1 INTRODUCTION

In this paper, the author presents a calculation model whereby a cylindrical structure, developed vertically and based on a truncated cone, is designed as a Imhoff settling tank and subsequently transformed into a vertical settling decanter. The presentation is based on an example.

Currently, there are still small-capacity wastewater treatment plants in operation that use Imhoff tanks followed by biological filters or aeration tanks.

When modernizing a wastewater treatment plant, some of the existing structures and installations are abandoned or demolished to make way for new technologies.

Reusing existing structures can be an interesting challenge for designers and plant operating personnel.

Modern materials for rehabilitating concrete surfaces corroded by sewage water are affordable and easy to use. We therefore considered that some of the existing structures could be reused in the modernization or expansion works. They can be integrated into the new technological flow or used as pilot reactors for various experiments or research.

2 IMHOFF SETTLING TANK, VERTICAL SETTLING TANK

2.1 THE IMHOFF TANK

The Imhoff settling tank was patented in 1906 by Klaus Ludwig Imhoff (1876-1965), a pioneer in the field of wastewater treatment technologies. It is also referred to in the literature as the Imhoff decanter or Emscher decanter and is part of most conventional wastewater treatment plants. It is the last component of the mechanical treatment stage, with the effluent flow being taken over by the biological filter or aeration tank [4].

In terms of its design, the Imhoff tank is a complex vertical structure in which two processes take place simultaneously. The first process is the actual decanting, which occurs in the upper part of the structure. The second process is the storage of the decanted sludge for anaerobic stabilization, which takes place in the lower part of the basin. The tank can also take over, store, and stabilize the sludge from the secondary settling tank. This aspect will be considered when dimensioning the storage volume.

Figures 2.1.1 show some historical sketches of such a decanter and an image during construction figure 2.1.2. These images were taken from a bibliography that is over a hundred years old [1]. Figure 2.1.3 shows the vertical section of the decanter and its main geometric dimensions. The basins are usually cylindrical, but they can also be parallelepiped in shape [2], [3].

It can be observed that the actual settling takes place in the upper part, in a settling trough. This settling trough is a horizontal longitudinal decanter open at the bottom. The opening is a slot with overlapping side walls. This detail is necessary to avoid disturbing the sedimentation process by the rising gas.

The precipitated sludge, which reaches the bottom of the basin, settles over time and stabilizes through anaerobic fermentation. The fermentation gases (biogas) are naturally released into the atmosphere. The stabilization time depends on the temperature and, according to the specialized literature, varies between three and five months.

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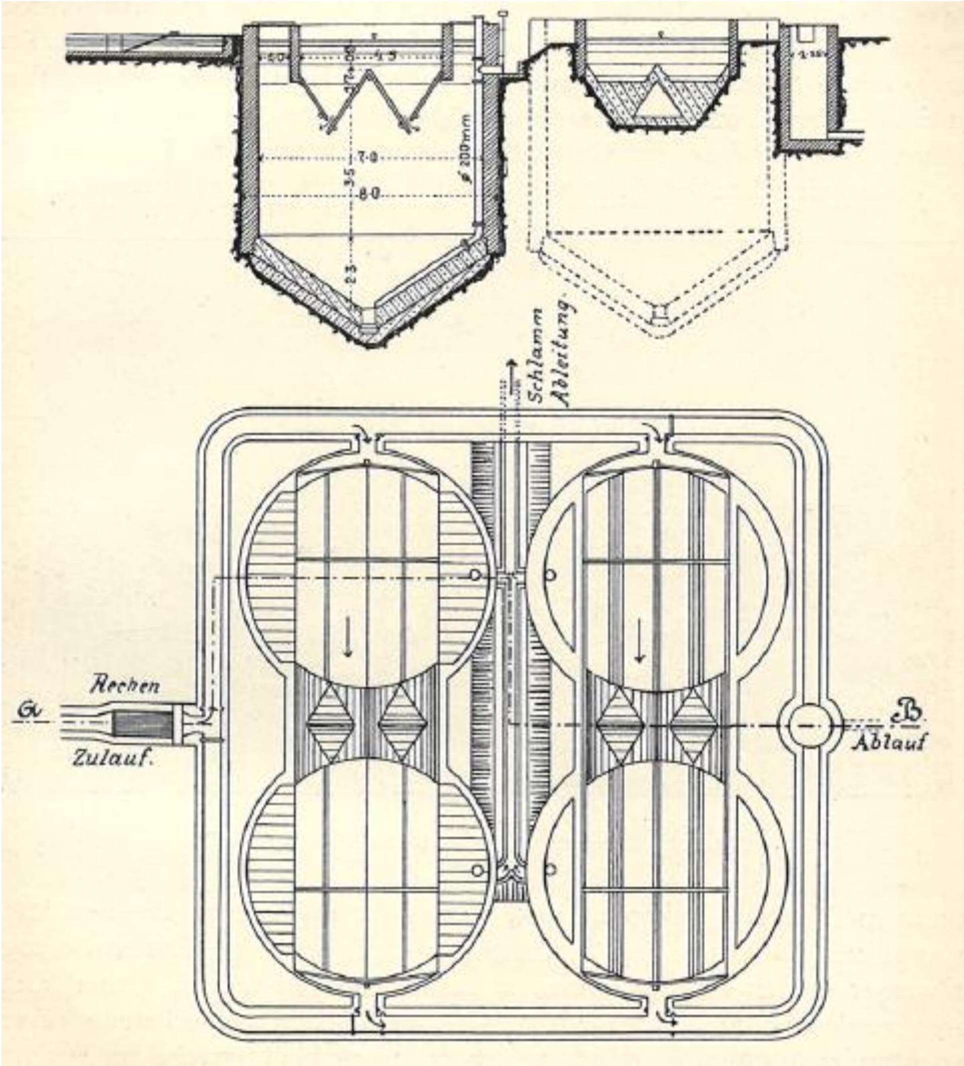

Figure 2.1.1 Group of for Imfoff tanks, vertical section and plan view

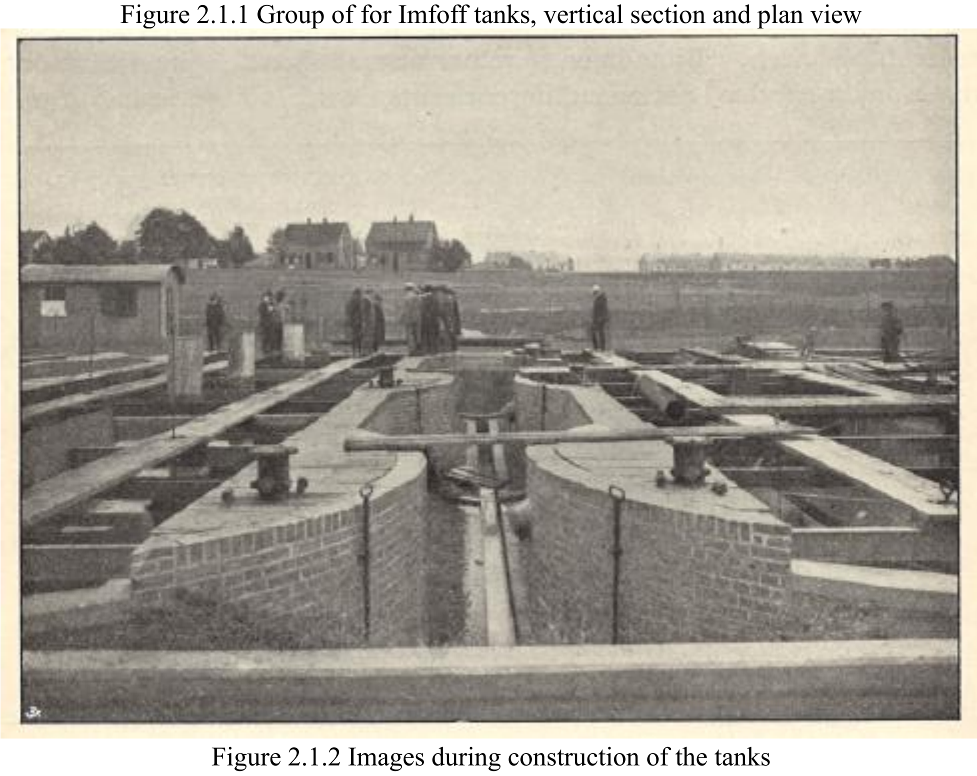
Figure 2.1.2 Images during construction of the tanks

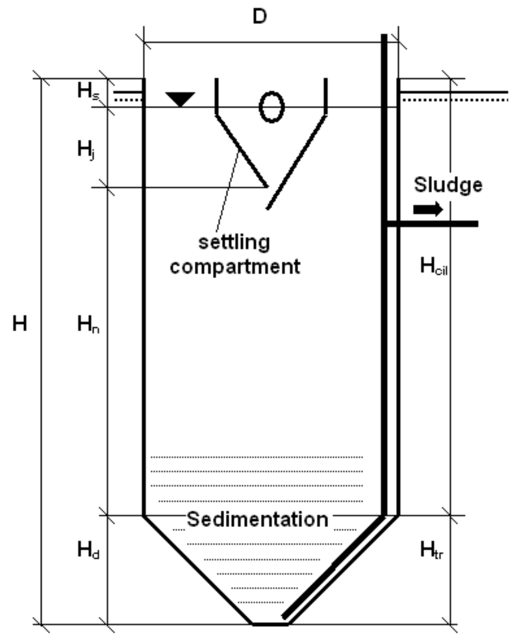

Figure 2.1.3 Vertical section through a Imhoff tank

The calculation formulas for designing the Imhoff tank are [2], [3], [5]:

$$V_j = Q \cdot t_d \qquad (2.1.1)$$

$$L_j = \frac{V_j}{A_j} \qquad (2.1.2)$$

$$n = \frac{L_j}{l_j} \qquad (2.1.3)$$

$$V_d = \frac{c \cdot N}{1000 \cdot n} \qquad (2.1.4)$$

$$H = H_u + H_s \qquad (2.1.5)$$

$$H_u = H_d + H_n + H_j \qquad (2.1.6)$$

$$H = H_d + H_n + H_j + H_s \qquad (2.1.7)$$

Specification of the terms used in the calculation formulas and their units of measurement:

- V_j settling trough volume (m);
- Q design flow (m^3/h);
- t_d settling time (h);
- L_j length of the settling trough (m);
- A_j cross-sectional area of the trough (m^2);
- n number of tanks (-);
- l_j length of trough in a tank (m);
- V_d volume of the sludge collection and fermentation space in a tank (m^3);
- c specific capacity per inhabitant (dm^3/inhabitant);
- N number of inhabitants (-);
- H total height (m);
- H_u useful height (m);
- H_d height of the sludge collection and fermentation space (m);
- H_n height of neutral space (m);
- H_j height of the decanter trough (m);
- H_s safety height (m);
- D diameter of the tank.

Technical recommendations, [3]:
- l_j = D for D < 6m, l_j = 2xD for D between 6m and 8m;
- H < 12,00m;
- H_u >= 6m;
- H_n = 0,50m;
- H_s = 0,30m.

2.2 VERTICAL SETTLING TANK

The vertical settling tank is a circular basin with a truncated cone-shaped bottom, similar to the Imhoff tank, Figure 2.2.1, [2], [3]. Water circulation in the decanter is vertical.

The influent flow is brought through the supply pipe into the central cylinder, from where it continues to move downwards to the deflector panel at the base of the central cylinder. From here, the water passes into the actual settling space, through which it will flow upwards. Heavy particles will settle at the base of the tank by gravitational sedimentation, and the lighter ones, with a specific weight close to that of water, will form a filter volume over the useful height of the decanter. Through this, the fine particles are adsorbed, forming larger sludge formations that will subsequently settle due to their weight.

This ensures excellent separation of the solid phase. The deflector panel at the base of the central tube ensures good distribution of water in the settling chamber and prevents disturbance of the sludge deposited at the base of the settling tank.

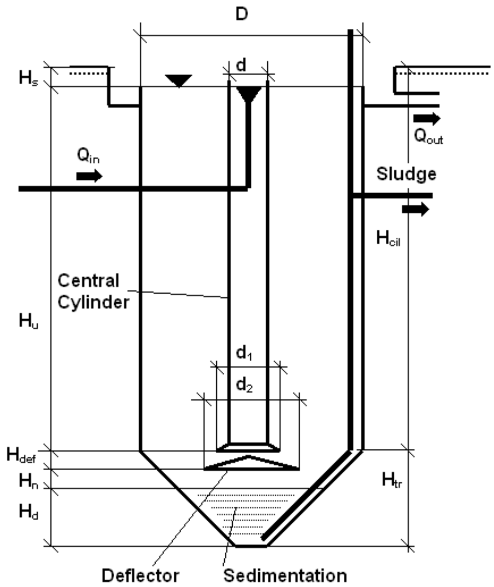

Figure 2.2.1 Vertical section through the tank

The calculation formulas for designing are, [2], [3]:

$$V_{dec} = Q \cdot t_d \qquad (2.2.1)$$

$$a = \frac{Q}{3,60 \cdot \mathrm{v}_c} \qquad (2.2.2)$$

$$A = \frac{Q}{3,60 \cdot \mathrm{v}_r} \qquad (2.2.3)$$

$$H_u = \frac{V_{dec}}{A} \qquad (2.2.4)$$

$$n = \frac{A + a}{\frac{\pi \cdot D^2}{4}} \qquad (2.2.5)$$

$$d = \sqrt{\frac{4 \cdot a}{\pi \cdot n}} \qquad (2.2.6)$$

$$V_d = \frac{p \cdot N \cdot T}{1000 \cdot N} \qquad (2.2.7)$$

$$d_1 = 1,50 \cdot d \qquad (2.2.8)$$

$$d_2 = (1,20...2,00) \cdot d_1 \qquad (2.2.9)$$

$$H_{def} = \frac{Q}{3,60 \cdot \pi \cdot d_1 \cdot n \cdot \mathrm{v}} \qquad (2.2.10)$$

$$H = H_d + H_n + H_{def} + H_u + H_s \qquad (2.2.11)$$

Specification of the terms used in the calculation formulas and their units of measurement:

- V_{dec} useful volume of the tanks (m^3);
- Q design flow (m^3/h);
- t_d settling time (h);
- A useful cross-sectional area of the tank (m^2);
- a useful cross-sectional area of the central cylinder (m^2);
- v_c water descent speed in the central cylinder (mm/s);
- v_r ascent speed of water in the tank (mm/s);
- H_u useful height of the tank (m);
- n number of tanks;
- D diameter of a tank (m);
- d diameter of the central cylinder (m);
- V_d volume of sludge deposited in a tank (m^3);
- p specific amount of sludge per inhabitant (dm^3/zi);
- N number of inhabitants;
- T time between two sludge discharges (day);
- H_{def} distance from the bottom of the central cylinder to the bottom of the deflector panel (m);
- d_1 diameter at the bottom of the central cylinder (flare) (m);
- v the speed of water flow from the central cylinder into the tank (mm/s);
- H total height of the tank (m);
- H_d sludge deposit height (m);
- H_n height of the neutral space (space between deposits and settling volume) (m);
- H_s safety height (m).

Technical recommendations, [3]:

- H_u > 2,75m;
- v_c = 100mm/s if there is a deflector panel;
- v_c 30mm/s without deflector panel;
- v_r <=0,70mm/s;
- D <=9,00m;
- p = 0,80dm^3/(loc/zi);
- T <= on day;
- v = 20mm/s;
- H_n = 0,20m if there is a deflector panel;
- H_n = 0,60m without deflector panel;
- H_s = 0,30...0,40m.

3 CONVERSION OF A IMHOFF TANK INTO A VERTICAL SETTLING TANK. CASE STUDY

Consider a rural locality with a population of 7500 inhabitants generating a wastewater flow of Q_{zimax}= 62.50 m^3/h. The wastewater treatment plant design includes sand and grease separators and Imhoff tanks for mechanical treatment, biological filters, and horizontal radial decanters after the biological filters. For this configuration, the specific capacity per inhabitant will be considered c= 97.50 dm^3/inhabitant, [2], [3], (the sludge separated in the secondary settling tanks will also be stored and stabilised in the Imhoff tanks).

The settling time is considered to be t_d= 1.50h.

The settling trough is designed with a cross-sectional area A_j= 3.125m^2 and a height H_j= 2.00m, dimensions recommended in [3].

From calculation formulas (2.1.1) and (2.1.2) it follows that:

V_j= 93,75m^2;
L_j= 30,00m.

For a tank diameter of D= 7.00m and a single settling trough for each tank, the calculation formula (2.1.3) results in a number of n=4 tanks (we also performed calculations for the variant with two settling troughs for one tank, because D> 6.00m, but this resulted in an excessively large sludge storage volume).

According to calculation formula (2.1.4), the volume of decanted sludge is:

V_d= 182,812m^3.

To determine the height of the deposited sludge H_d, the volume of the cone trunk at the base of the basin was calculated. The angle of inclination is 45° and the small diameter of the cone trunk is 0.50 m. With these geometric data, the volume and height of the cone trunk were calculated:

V_{tr}= 55,178m^3;
H_{tr}= 3,50m.

This means that the volume of sludge V_d will occupy the entire cone trunk and part of the cylinder. Calculations show that:

H_d= 6,39m.

Using the calculation formulas (2.1.6) and (2.1.7):

H_u= 8,89m > 6m;
H= 9,20m.

And the height of the cylinder will be: H_{cil}= H- H_{tr}; H_{cil}= 5,70m.

Next, the performance of a vertical settling tank was determined, whose geometric dimensions will be those previously determined for the Imhoff tank.

The settling time is still considered to be t_d = 1.50 h.

The useful cross-sectional area of the tank A is the total area corresponding to diameter D minus the cross-sectional area of the central cylinder "a".

I set d = 0.75 m, which means an area a = 0.44 m^2.

Then: $A=\frac{\pi\cdot D^4}{4}-a$, the usable area for a settling tank is A = 43.70 m².

Transforming calculation formulas (2.2.2) and (2.2.3) results in the following for flow rate Q:

$$Q=3{,}60\cdot v_c\cdot a=3{,}60\cdot 100mm/s\cdot 0{,}44m^2=158{,}40\frac{m^3}{h};$$

$$Q=3{,}60\cdot v_r\cdot a=3{,}60\cdot 0{,}70mm/s\cdot 0{,}44m^2=110{,}124\frac{m^3}{h}.$$

We chose the lowest value so that both conditions would be satisfied:

Q= 110,124m^3/h.

It follows that a single transformed tank can take over the entire influent flow, while also providing a considerable reserve.

From calculation formulas (2.2.1) and (2.2.4), the following was obtained:

H_u 3,78m.

H_u< H_{cil}= 5,70m, therefore, this condition is also met, leaving a reserve of almost two meters in the cylinder height.

From the calculation formula (2.2.10), the height between the central cylinder and the deflector panel (n=1) is obtained:

H_{def}=0,376m.

And according to (2.27) and n=1, the volume of sludge is:

V_d= 6,00m^3,

which means a height of sludge deposits:

H_d= 3,18m.

H_d+ H_{def}+ H_n= 3,18m < 5,50m = H_{con}.

This check must be performed to ensure that the sludge deposits are not disturbed by the influent flow from the central cylinder.

The total height required is obtained from the calculation formula (2.2.11):

H= 7,26m.

This height is lower than the available height resulting from the calculation of the Imhoff tank.

4. CONCLUSIONS

The calculations showed that the influent flow rate taken up by the vertical settling tank is much higher than that for which the Imhoff tank was designed. It also showed that the required height H_u is lower than the existing one. This allows for a shorter central cylinder.

The conversion is simple: the settling trough of the Imhoff tank can be easily removed and the central cylinder for the vertical tank can be adapted from a plastic or composite pipe.

The vertical tank does not require a scraper bridge for sludge concentration. Vertical flow direction ensures very good separation of the solid phase.

The three remaining units can be used for other purposes. For example, one or two units can be used as secondary settling tanks behind the biological filter. Existing secondary tanks can be used as sludge thickeners.

The current challenges in the field of wastewater treatment are increasingly. For this reason, another use for existing structures is the design of pilot plants for experimental studies and research. This results in a pilot reactor on a technical scale of 1:1 that is very stable in operation.

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