Feasibility of increasing the efficiency of primary settling tanks by using thin layer plates

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Abstract: Background: The increased efficiency of the sedimentation tanks at refineries to the technical and economic reasons are important, therefore the feasibility of increasing the efficiency of sedimentation tanks by modeling and optimization of the tanks, is necessary. **Method**: In this study, using thin layer plates in mineral sedimentation tanks have been investigated in the laboratory practice and by using mathematical modeling, feasibility and efficiency of the actual volume of the tanks equipped with the usual conditions in the sedimentation tanks, have been compared. **Results**:Results indicate that efficiency is the same and equal E = 53% ,Time required for settling tanks equipped with thin layer plates in comparison with conventional tanks, equal to 2.64, is lower.The maximum flow rate in tanks equipped with thin layer plates in comparison with conventional tanks, equal to 1.6, is increased. **Conclusion**: Thin layer plates, improvements the process of mineral sedimentation significantly, this is based on increasing surfaces of sedimentation, the laminar flow, reducing the level of suspended solids from settling and removal of short connections inside the tank, is based.
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Key words: Settling tanks, efficiency, flow rate, suspended solids, thin layer plates.

1. Introduction

Sedimentation is the process of physical separation of the inorganic sediments of water. In practice, all sediments of which relative density is more than that of water are separated in gravity method. On the other hand, the separated particles are sediments in the sedimentation phase. The separated particles are the particles of which size, form and special weight (such as gravels etc) are not time-dependent. The primary sedimentation is a simple sedimentation unit without using the chemicals in sewage treatment which is the same as the primary treatment. The solids sedimentation in this unit is *flocculent* sedimentation. Sedimentation speed of the suspended solids depends on different factors such as special weight, diameter of the particles (when the diameter is doubled, the speed will be fourfold and when the diameter is reduced by half, the speed will be one-fourth) and its temperature (with increase of temperature, we see decrease of the fluid viscosity and precipitation action will be done more rapidly). Sedimentation tanks are the most responsible for mechanical treatment in a sewage treatment plant and also have considerable effect on efficiency of all treatment plants. The primary sedimentation tanks are located before the biological filter units while the secondary sedimentation tanks are located after the biological filters. Relatively coarse suspended particles are precipitated in the primary sedimentation tanks. These matters which are mostly organic are light, have relatively high level and low sedimentation speed contrary to what is separated from the sewage in the grit chambers. The sludge caught by the primary sedimentation tanks is composed of the coarser and undigested, fully unstable and degradable matters contrary to the secondary sedimentation tanks. For this reason, the main difference in design of the primary and secondary sedimentation tanks is the value of surface loading rate, overflow rate and the sewage stopping time. In terms of the sewage stopping time in the primary sedimentation tanks which is selected to be between 20 min and 2 hr, 40 to 73% of the suspended solids of sewage are caught. Different studies showed that the separation action should be done in the shortest time and with the highest efficiency in order to separate the suspended solids with the lowest cost. The main reason is that if density of the solids separated from the sedimentation tanks is enhanced in order to increase the treatment efficiency, size of the equipment which is installed after the sedimentation tanks due to reduction of the capacity resulting from the low density of the suspended solids and this is economically important. Sedimentation and function of the sedimentation tanks depend on different factors such as flow speed and geometry of the tanks as one of the main sections of water and sewage treatment plants. On the other hand, studies done by Camp [41] , Swamee and Tyagi [42] showed that about one -third to one-fourth of total investment cost for water and sewage treatment plants relates to the sedimentation tanks and this cost includes considerable range of costs. Therefore, one can save them in different stages by increasing the sedimentation efficiency using the cross thin beds. The sedimentation level will increase considerably and the distance between the suspended solids and the sedimentation surface will be shortened by installing the sedimentation equipments using the cross thin beds. As a result, we can reduce the retention time and increase the maximum flow rate under the specified and acceptable efficiency conditions for the sedimentation tanks. Therefore, using this technology, one can exploit the old sedimentation tanks of which the project forecast period has been finished and which has desirable efficiency for the flow rate and has not increased at present for the coming years and can save expenses for this purpose. At present, application of the cross thin plates have been expanded in order to equip the sewage sedimentation tanks in different industries such as gravels, mine, stone cutting, beet wash sewage, glasswork industries, petro chemistry etc). Figure 1 shows sedimentation behavior of the separated and flocculent particles in the sedimentation tanks. The sedimentation tanks are classified into three groups in terms of water flow:

- Horizontal flow Tank
- Radial flow Tank
- Upward flow Tank

The sedimentation tanks have four specified areas as follows in terms of entrance and movement of the fluid in any form.

1- The area in which sewage enters the tanks and one tries to reduce speed of flow and turbulence of the sewage by predicting some parts such as baffle wall and it is uniformly distributed in the major part of the tank surface.
2- The sewage sedimentation area in the pool in which speed of the sewage should be minimized and sedimentation action can be improved by selecting the proper length, width and depth.
3- Sludge collection area which is close to the tank floor should cause the sludge to obtain required density by selecting the suitable volume on the one hand and prevent the putrefaction and return of the sludge to the tank on the other hand.
4- The area in which the sewage exists from the tank and which is the last section of the tank and should be designed in such a manner that the sewage can exit from the pool sufficiently and uniformly.
5- In order to increase efficiency of the sedimentation tanks, the designers intend to correct geometry of the tanks and consequently correct flow pattern by installing baffle. Installation of the input baffle and output overflow and their types has been studied by many researchers. Results of the empirical studies and numerical modeling have shown that if the input baffles are installed on surface of the tanks and fluid passes below them, it can prevent short circuit phenomenon. [43]. Figure 2 shows some examples of the input baffles and the output overflow in the sedimentation tanks.

Another hypothesis which relates to increase of the sedimentation tanks efficiency is the use of the cross thin beds in the tanks sedimentation area which is discussed in this study.

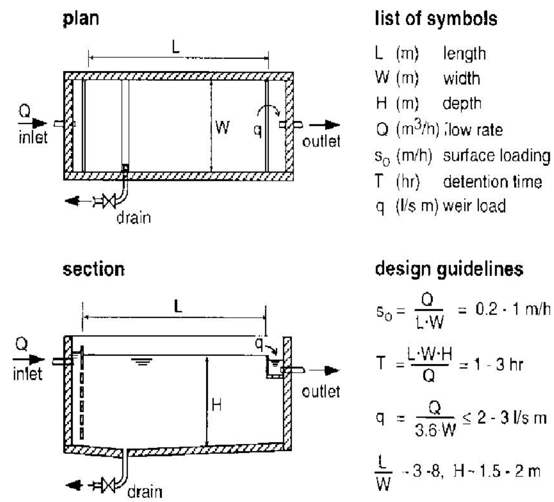


Figure 1. pictures and design guidelines of sedimentation tanks

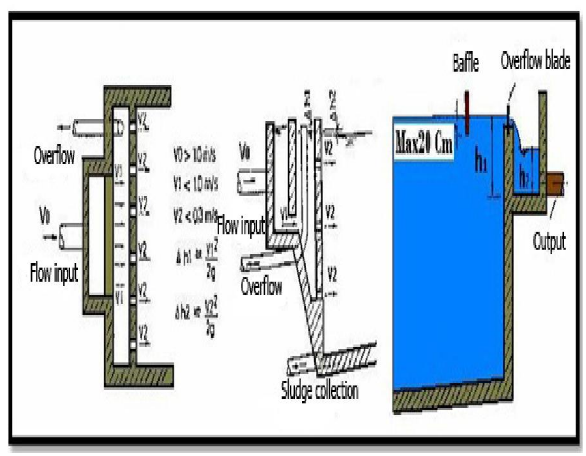


Figure 2. some examples of the input baffles and the output overflow in the sedimentation tanks.

2. Review of literature

Hypothesis of use of the cross thin plates in the sedimentation tanks to increase efficiency of these tanks dates back 1950s. Mr. Qomel could prove the mentioned hypothesis practically in 1952[7]. In 1954, Mr. Aloppo bunu et al confirmed this hypothesis. Since 1995 then, many studies were done to optimize and make different specimens of the cross thin beds in Russia, America, Japan and other countries in the world. In 1970, this technique had been used in more than 50 sewage treatment plants and with total flow rate of above 240000 cubic meters in second in USA. In Japan, use the cross thin beds made by polymer were used for the first time in treatment plants of this country for sewage flow of 110000 cubic meters in second [7]. In recent years, considerable progress was made in use of the cross thin bed and this technology was developed so that it is used in sedimentation tanks of the water and sewage treatment plants and in different industries. Today, these cross thin plates are produced from polypropylene, polyethylene, plastic or antirust steel (Dr. Fekert Guliev-Baku 2006) [4].

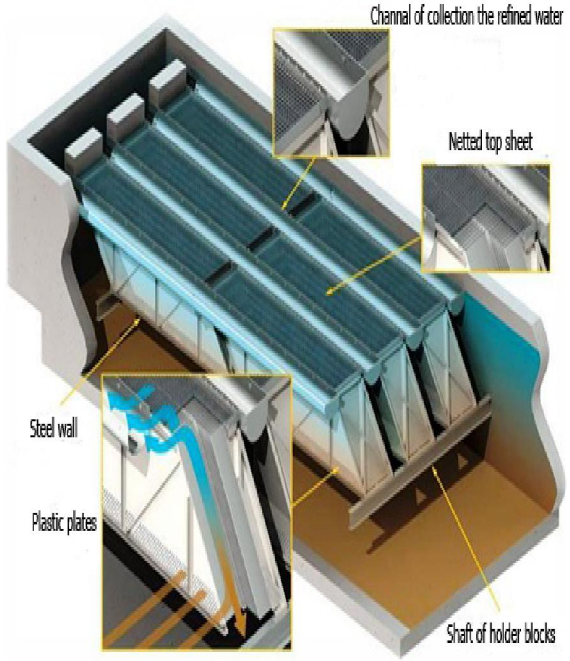


Figure 3. the made model of the rectangular sedimentation tank in which the cross thin beds have been assembled.

3. The cross thin beds

They include several beds or tubes which are installed inside the tanks in paralleled or with angels of 45 to 60 degrees toward the horizon and with distance of 50 to 150 mm from each other. The cross plates are used in the primary and secondary sedimentation tanks but it is more common to install it in the primary sedimentation tanks. It is easier to use the cross beds in the rectangular sedimentation tanks than to install it in the sedimentation tanks with radial flow. In order to install the cross thin beds easily , they make them as blocks in the expected sizes and assemble them after carriage to the place by putting the separate blocks next to each other inside the sedimentation tanks and there are figures of the equipped tank (figure 3) and size of the blocks (figure 5) as follows.

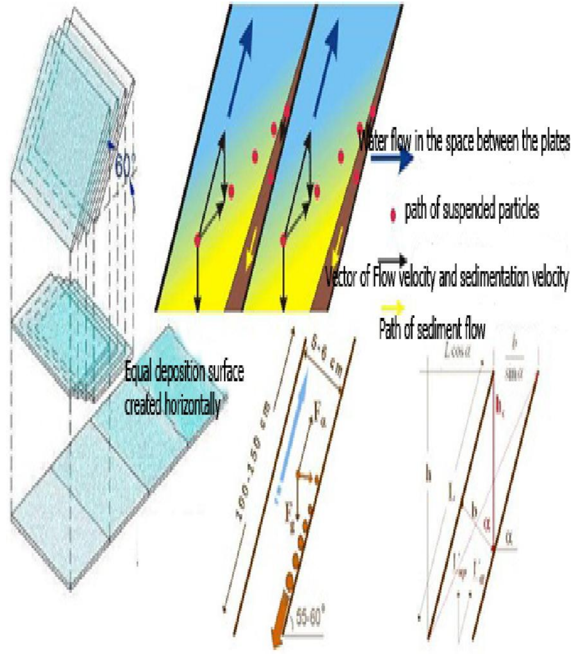


Figure 4. shows increase of the tank sedimentation level in case of installation of the cross beds, dimensions of the beds and water and deposits flow path

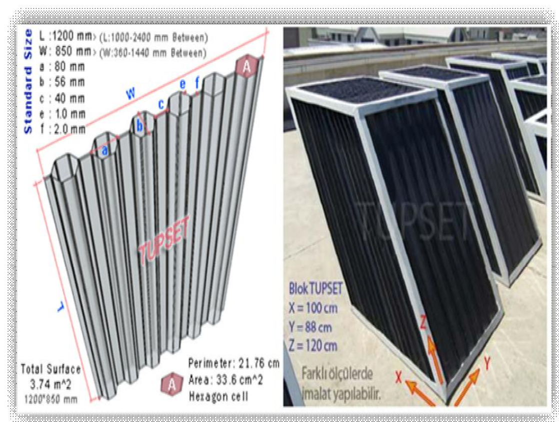


Figure 5. standard size of tubes and blocks are manufactured by the Top Set Co. from Turkey

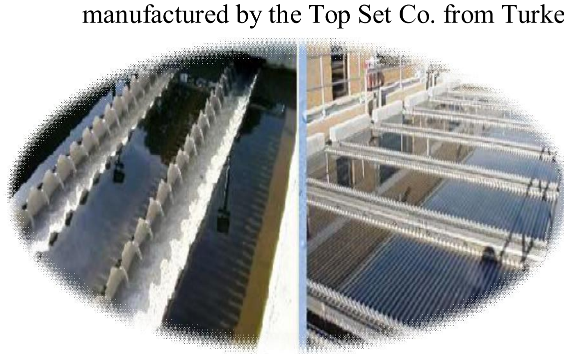
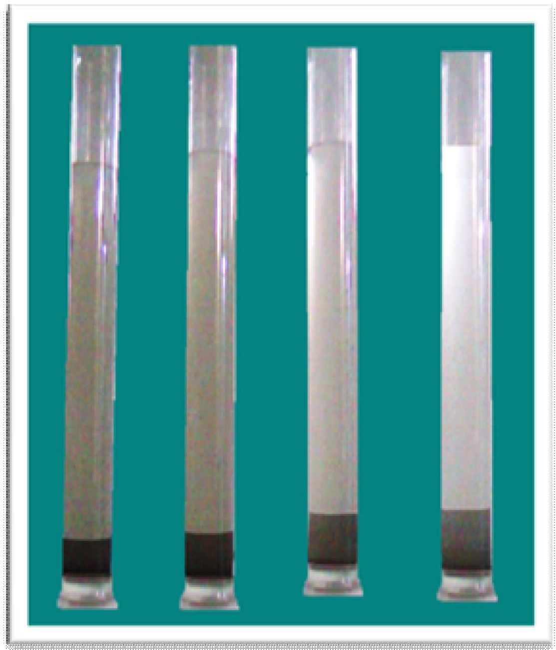
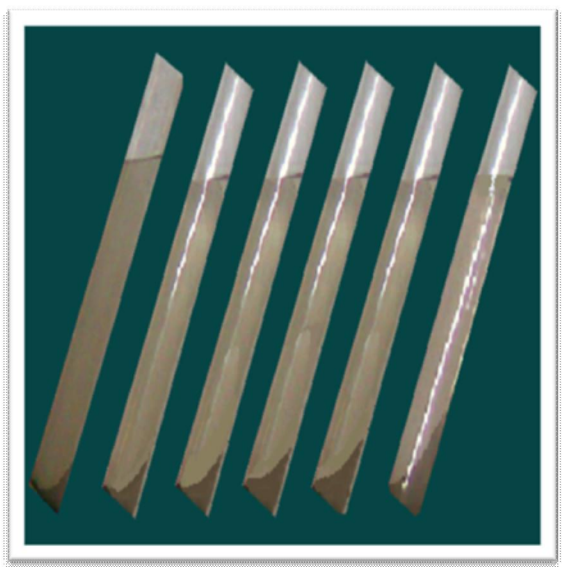


Figure 6. pictures of the active sedimentation tanks which have been equipped using the cross thin beds.



(a)



(b)

Figure 7. Sedimentation modeling technology tests in the test tubes under static conditions in vertical and oblique states

a) Oblique tubes with angel of 45 degrees toward horizon considering the fact that distance between the suspended solids and sedimentation surface has been calculated to be 140 mm.

b) Vertical tubes with height of sewage in column in size of 500 mm.

4. Material and method

In this research , use of the cross thin beds in the salts sedimentation tanks was practically studied in the laboratory model and feasibility study of the tanks efficiency increase in real volumes was calculated using the mathematical modeling and the results of the equipped sedimentation tanks have been compared with the ordinary sedimentation tanks. The method recommended in the reliable scientific sources have been studied and exploited in English and Russian and list of these sources has been introduced in the references section. Firstly, 50 liters of the sewage specimen was prepared from the urban sewage treatment plant in order to perform the tests. Then, definite amount of the sewage with the specified density was poured into 12 test tubes with diameter of 120 mm and height of 50 cm. 6 tubes were placed vertically and 6 tubes were placed horizontally with angel of 45 degrees . At definite times of 10, 15, 20, 30,45 and 60 min , density of the specimens in two diagonal and vertical states was measured and recorded in table 1 as follows.

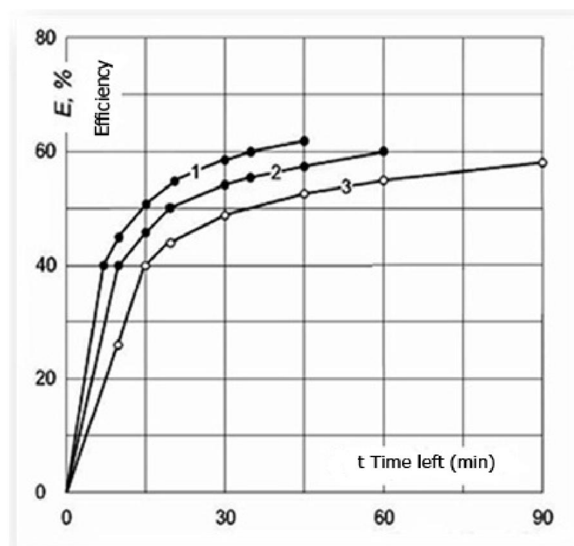


Figure 8- diagram of efficiency of the suspended solids (insoluble) in equal densities but different heights of the sewage column of which efficiency has been calculated due to failure to prepare the test tube with height of 2000 mm.

$$E_1 = f(t)$$

Table 1. Results of the tests for studying efficiency of he removal of the sewage suspended solids in density of 250 mg in liter.

Concentration of Wastewater samplesC_0, mq/l	*t time (min) - Ct suspended solids concentration (mg) - Et deposition efficiency (percent)*											
	t = 10		*15*		*20*		*30*		*45*		*60*	
	C_t	E_t	C_t	E_t	C_t	E_t	C_t	E_t	C_t	E_t	C_t	E_t
Sedimentation height (mm 140 = h) that contains sewage pipe with a height of 500 mm in oblique (angle 45) - Number of samples: 1												
250	*135*	*46*	*116*	*5306*	*107*	*5701*	*100*	*60*	*8805*	*6406*	-	-
Sedimentation height (mm 140 = h) that contains sewage pipe with a height of 500 mm in oblique (angle 45) - Number of samples: 2												
250	*141*	*4306*	*128*	*4808*	*117*	*5303*	*110*	*56*	*10105*	*5904*	-	-
Average Number of Samples: 1, Number 2												
250	*138*	*4408*	*122*	*5102*	*112*	*5502*	*105*	*58*	*95*	*62*	-	-
Wastewater sample height = 500 mm test tube (tube in upright position) - Sample Number 3												
250	*143*	*4208*	*130*	*48*	*119*	*5204*	*110*	*56*	*10105*	*5904*	*97*	*6102*
Wastewater sample height = 500 mm test tube (tube in upright position) - number of: 4												
250	*157*	*3702*	*144*	*4204*	*131*	*4706*	*120*	*52*	*11005*	*5508*	*105*	*58*
Mean Number of specimens: 3, Issue: 4												
250	*150*	*40*	*137*	*4502*	*125*	*50*	*115*	*54*	*106*	*5706*	*101*	*5906*

Table 2.results of the tests for studying efficiency of the removal of the sewage suspended solids in density of 250 mg in liter.

Concentration of Wastewater samplesC_0, mq/l	t time (min) - Ct suspended solids concentration (mg) - Et deposition efficiency (percent)													
	t = 10		15		20		30		45		60		90	
	C_t	E_t	C_t	E_t	C_t	E_t	C_t	C_t	E_t	C_t	E_t	C_t	E_t	C_t
Sedimentation height (mm 140 = h) that contains sewage pipe with a height of 500 mm in oblique (angle 45) - Number of samples: 10														
200	130	35	100	45	104	48	96	52	92	54	86	57	-	-
Sedimentation height (mm 140 = h) that contains sewage pipe with a height of 500 mm in oblique (angle 45) - Number of samples: 11														
250	138	4408	122	5102	112	5502	105	58	95	62	-	-	-	-
Sedimentation height (mm 140 = h) that contains sewage pipe with a height of 500 mm in oblique (angle 45) - Number of samples: 12														
300	135	55	120	60	111	63	102	66	90	70	-	-	-	−

Table 3. results of the study tests of efficiency of the removal of sewage suspended solids in different densities of 200, 250 and 300 mg in liter in the oblique tubes with angel of 45 degrees toward the horizon.

Concentration of Wastewater samples C_0 C_0,	t time (min) - Ct suspended solids concentration (mg) - Et deposition efficiency (percent)													
	t = 10		15		20		30		45		60		90	
	C_t	E_t	C_t	E_t	C_t	E_t	C_t	C_t	E_t	C_t	E_t	C_t	E_t	C_t
Sedimentation height (mm 140 = h) that contains sewage pipe with a height of 500 mm in oblique (angle 45) - Number of samples: 10														
200	130	35	100	45	104	48	96	52	92	54	86	57	-	-
Sedimentation height (mm 140 = h) that contains sewage pipe with a height of 500 mm in oblique (angle 45) - Number of samples: 11														
250	138	4408	122	5102	112	5502	105	58	95	67	-	-	-	-
Sedimentation height (mm 140 = h) that contains sewage pipe with a height of 500 mm in oblique (angle 45) - Number of samples: 12														
300	135	55	120	60	111	63	107	66	90	70	-	-	-	−

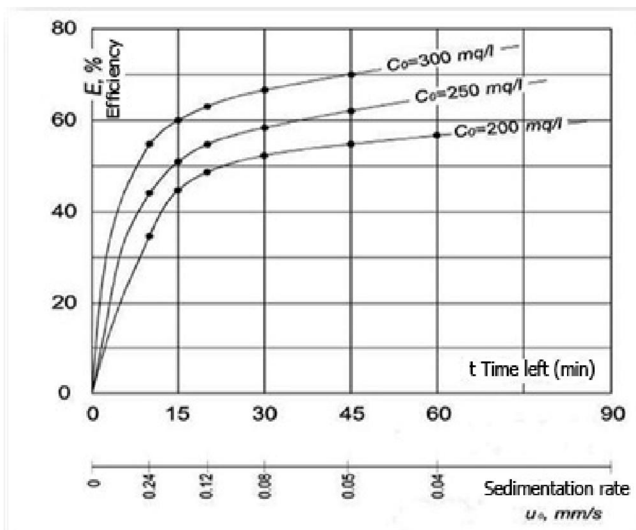


Figure 9- diagram of efficiency of removing the suspended solids in the oblique tubes with angel of 45 degrees toward the horizon and with different densities of sewage

1- tubes with angel of 45 degrees ($E_1 = f(t)$)

2- Height of the specimen , 500 mm ($E_2 = f(t)$)

3- Height of the specimen , 2000 mm ($E_3 = f(t)$)

   1- Tubes with angel of 45 degrees and containing sewage with density of 200 ml ($E_1 = f(t)$)

   2- Tubes with angel of 45 degrees and containing sewage with density of 250 ml ($E_2 = f(t)$)

   3- Tubes with angel of 45 degrees and containing sewage with density of 300 ml ($E_3 = f(t)$)

4- Hydraulic Retention time (min) - C_t density of the suspended solids (mg in liter) - E_t, sedimentation efficiency (%)

5. Design and calculation

The cross thin beds are used in different models and designs in the sedimentation tanks. In the active sedimentation tanks or the tanks which are being constructed, one can increase quality and efficiency of the tanks by equipping the tanks and using the cross thin plates? As we mentioned in the previous pages, there are four specified areas (input baffles, output, and sedimentation and sludge collection) and the cross thin beds are installed in the sedimentation area). The cross thin plates cause to increase efficiency of the sedimentation tanks by creating a uniform flow inside the tanks by decreasing the distance between the deposited matters and the sedimentation level, increasing the sedimentation level considerably and removing short circuits of the flow resulting from wind blow on the water surface inside the tanks or temperature differences in water beds inside the tanks. Considering the flow direction among the cross beds, function of these plates will be different that is one can separate the sediments and the floating matters such as fats using these plates.

Application of the cross plates in order to separate the deposited soils and (left figure). In the present study, the following relations were used to apply the modeling technology using the calculation principles in the primary sedimentation tanks considering the above diagrams:

- Suitable sedimentation conditions

(1) $$T_h = T_1\left(\frac{H_h}{H_1}\right)^n$$

- The calculation relation of removed suspended solids from the specimen

(2) $$E_t = \left(\frac{t}{120}\right)^{a/t} E_{120}$$

- Constant coefficient a

(3) a

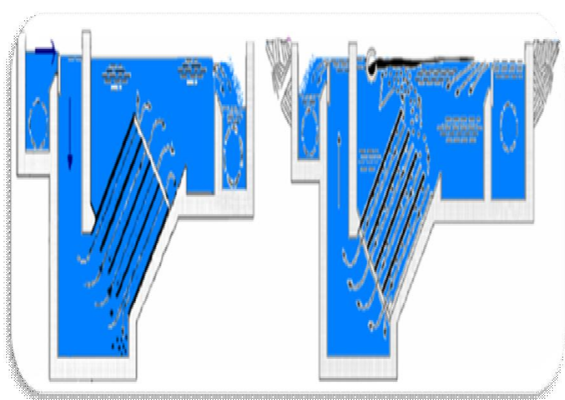


Figure 10. application of the cross plates in order to separate the oil matters and fats with the reverse flow in the tank (right figure

Based on the water flow and movement path of the sediments in the sedimentation tanks, there are three general schemes in the tanks:

1- Carpaz scheme in which water flow direction and sediments movement direction are perpendicular.
2- Reverse flow scheme in which water flow direction and sediments movement direction are reverse.
3- Direct flow scheme in which water flow direction and sediments movement direction are the same. Carpaz and reverse flow schemes have been used in order to do calculation relating to the active sedimentation tanks which have been equipped with the cross thin plates.

Geometrical dimensions of the equipped tank using the cross thin beds are as follows:

- Length of the tank ($L \le 6m$)
- Width of the tank (B=2m)
- General depth of the tank ($H_{um} = 2m$)
- Initial density of the mater ($E \approx \%53$)

Water temperature in centigrade degree (t=10)

- The expected sedimentation efficiency

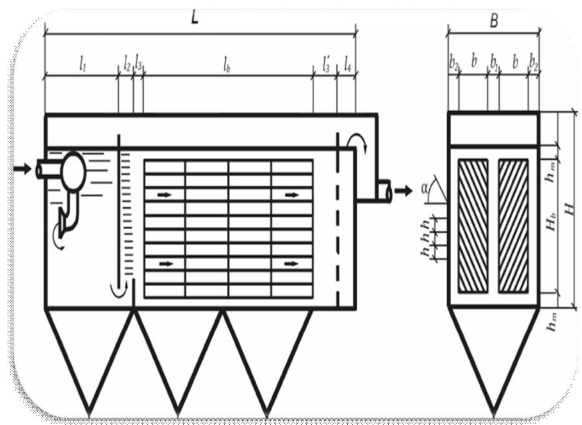


Figure 11. Charpaz scheme from the sedimentation tank and its dimensions which has been equipped using the cross thin plates.

Distance between the plates ($h_{rf} = 0.1m$)

- Angel of the plates toward horizon

($\alpha = 45^{\circ}$)

- Calculation of the distance between the suspended solids and the sedimentation
- Surface in the space between the plates:

$$(h = h_{rf} / \cos\alpha = \frac{0.1}{0.707} \approx 0.14m)$$

- Sedimentation efficiency relation

$$(E = (C_0 - C_T)100/C_0)$$

- The suspended solids sedimentation speed relation

$$(u_0 = 1000h/t, mm/s)$$

Based on the diagram (figure 9) of the efficiency of removing the suspended solids (insoluble) in the tubes inclined to angel of 45 degrees toward the horizon with different initial densities of sewage equivalent to 200,250 and 300 mg in liter, we have achieved the desirable efficiency of E ≈ **53%**in the initial density of sewage equivalent to 25 mg in liter within 17 min.

5.1.Calculation of the suspended solids sedimentation speed:

$$u_0 = \frac{1000 \times h}{t \times 60} = \frac{1000 \times 0.14}{14 \times 60} \approx 0.17 mm/s$$

In order to study whether there is condition for laminar flow without turbulence, we calculate Reynolds number and in case the Reynolds number is below 500, there is condition for laminar flow.

$$\mathrm{Re} = v \times h_{rf} / \mu = \frac{0.4 \times 10}{0.0131} = 305 < 500$$

V: sewage flow velocity in distance between the plates in s:

μ : Cinematic viscosity of the sewage in centigrade ($\mu = 0.0131 cm^2/s$)

5.2.Calculation of the block length of the cross thin plates:

$$l_{bl} = \frac{h_{raf}}{K_{h.ist.\cos\alpha}} . \frac{v}{u_0} = \frac{0.1 \times 1000 \times 4}{0.8 \times 0.707 \times 0.17 \times 1000} \approx 4.16$$

$$K_{hist} = 0.8$$

Coefficient of effective use of the tank volume which is considered to be 0.8 for the tanks equipped with the cross thin plates.

5.3.General length of the tank:

$$L = l_{bl} + l_1 + l_2 + 2l_3 + l_4 = 4.16 + 1 + 0.2 + 0.4 + 0.2 = 5.96m$$

Length of the Impingement area : $l_1 = 1m$

- The considered and accepted lengths based on the tanks design technology for distances between the impingement plate and output baffle and walls of the tank: $l_2 = l_3 = l_4 = 0.2m$
- Length of the blocks in meter: l_{bl}

In case of use of the cross thin plates in the tanks with Carpaz flow scheme to calculate the maximum flow rate of the tanks, the following relation is used (Laskim , 1987-Moscow).

$$Q\max/h = \frac{7.2.K_{hist}.H_{bl}.l_{bl}.u_0}{k_s.h} = \frac{7.2 \times 0.8 \times 1.7 \times 4.16 \times 017}{1.2 \times 0.14} = 41.22 m^3/h$$

Here, we have:

Height of the blocks:

$$H_{bl} = H_{um} - h_3 - h_m = 2 - 0.2 - 0.1 = 1.7m$$

$k_s = 1.2$: A coefficient for considering effects of the plate's material on the sediments falling and motion velocity:

$h_3 = h_m(h_m, h_3)$ **:** general depth of the tank and depth of the tank above height of the blocks

5.4.Under ordinary condition, the following relations are used to calculate the maximum flow rate of the tanks:

(Sorojina , 1986-Moscow [17])

$$u_0 = \frac{1000 \times H \times K_{h.ist}}{t \times (\frac{KH}{h})^n} = \frac{1000 \times 2 \times 0.5}{2100 \times (\frac{0.5 \times 2}{0.5})^{0.25}} = 0.4 mm/s$$

- t: sedimentation time in s : we achieve the sedimentation efficiency equivalent to E=50% in the real tank within 35 min which is equivalent to 2100 s based on the figure 8.
- n: the fixed coefficient which equals to (n=0.25) under condition of $_{C0=}$250 mg/l and E=50%
- $K_{h.ist} = 0.5$

  Coefficient of use of the sedimentation tank volume under the ordinary tank condition
- ***u₀:*** sedimentation velocity of the suspended solids in ml/s in the ordinary tanks

$$Q_{\max/h} = 3.6 \times K_{hist} \times L \times B \times u_0 = 3.6 \times 0.5 \times 18 \times 2 \times 0.4 = 25.9 m^3/h$$

Findings: as shown in diagram of figure 8, we find that in efficiency of E=53% and other equal conditions, the retention time required for sedimentation in the tanks equipped with the cross thin beds (17 min) compared with the ordinary tanks (45 min) is reduced by 2.64 times. (45.17≈**2.64)**

The maximum flow rate in the tank equipped with the cross thin plates (41,22 **m^3/h)** increases by 1.6 times compared with the ordinary tank (25,9 **m^3/h). 41.22/25.9≈1.6**

We find from the figure 9 that the sedimentation efficiency is E=46% in case of the equipped sedimentation tanks using the cross thin plates and within 17 min and sedimentation velocity of the suspended solids equivalent to $u_{0=0}$.14 mm/s in the specimen with density of $\mathbf{C_0}$ =200 mg/l and the sedimentation efficiency increases and equals to E=61% in higher density equivalent to $\mathbf{C_0}$ =300 mg/l.

6. Discussion and conclusion

The cross thin plates promote the sedimentation process of the suspended solids which is based on the uniform flow , reduction of the distance between the suspended solids and the sedimentation surface and removal of the short circuits phenomenon (resulting from wind flow on the water surface and temperature difference and water bedding in the tank etc) inside the sedimentation tank. Using the cross thin plate's makes the better sedimentation possible and it is recommended to use it in the active and new tanks. Considering results of the performed studies, the cross thin plates can be used in the active sedimentation tanks which got closer to the final years of the forecast project period and one can prevent construction of the new unit for many years which is technically and economically cost -effective. Using the cross thin plates in the active primary sedimentation tanks , one can increase the maximum flow rate of the tanks by 1.5 to 3 times and in case it is applied in the new tanks, one can increase the maximum flow rate of the new tanks by 3 to 5 times.

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References:

1) Бараке К.,Бебен Ж., Бернар Ж. и др. Технические записки по проблемам воды.Справочное издание фирмы «Дегремон». Перевод с английского языка. В 2-х т. М.,Стройиздат, 1983.
2) Воронов Ю.В. и др. Реконструкция и интенсификация работы канализационных очистных сооружений. М., Стройиздат, 1990.
3) Guliyev F.S., Guliyev R.F. Investigations on intensification of the secondary radial settlers run of Baku's sewage water biological treatment station. Proceedings of the fourth Baku International Congress «Energy, Ecology, Economy». Baku, 1997.
4) Гулийев Ф.С., Ялийев Н.И., Сцлейманов Т.Р. Шящяр чиркли суларынын тямизлянмяси. «Тящсил» няшриййаты НПМ, 2006
5) Гулийев Ф.С., Гулийев Р.Ф. Су анбарларынын чиркли суларла чирклянмядян мцщафизяси. «ЕЛМ» няшриййаты, 2007.
6) Демура М.В. Горизонтальные отстойники. Киев , Стройиздат УССР, 1963
7) Демура М.В. Проектирование тонкослойных отстойников. Киев, «Будивельник», 1981.
8) Жуков А.И., Монгайт И.Л., Родзиллер И.Д. Методы очистки производственных сточных вод. Справочное пособие. М., Стройиздат, 1977.
9) Калицун В.И. Водоотводящие системы и сооружения. Учебник для вузов. М., Стройиздат, 1987.
10) Канализация. Учебник для вузов. 5-е издание, переработанное и дополненное. Яковлев С.В. и др. М., Стройиздат, 1975.
11) Канализация населенных мест и промышленных предприятий. Справочник проектировщика. 2-е издание, переработанное и дополненное. М., Стройиздат, 1981.
12) Кянэярли А.Ъ. Тябият суларынын тямизлянмяси вя емалы. «Маариф» няшриййаты. Бакы, 1997.
13) Ласков Ю.М., Воронов Ю.В., Калицун В.И. Примеры расчетов канализационных сооружений. М., Стройиздат, 1987.
14) Мяммядов Я.М., Мяммядов Й.Я. Су тяъщизаты вя канализасийа. «Маариф» няшриййаты. Бакы, 1977.
15) Орловский З.А. Очистка сточных вод за рубежом. М., Стройиздат, 1974.
16) Правила охраны поверхностных вод от загрязнения сточными водами. М., Мин-ство здравохранения СССР, 1975.
17) Строительные нормы и правила СНиП 2.04.03-85. Канализация. Наружные сети и соружения. М., 1986.
18) Федоров Н.Ф., Шифрин С.М. Канализация. Изд-во «Высшая школа» М., 1968.
19) Хаммер М. Технология обработки природных и сточных вод. М., Стройиздат, 1979.
20) Черкинский С.Н. Санитарные условия спуска сточных вод в водоемы. Изд-во литературы по строительству. М., 1971.
21) Яковлев С.В., Карелин Я.А., Ласков Ю.М., Воронов Ю.В. Водоотводящие

системы промышленных предприятий. Учебник для вузов. М., Стройиздат, 1990.
22) Яковлев С.В., Калицун В.И. Механическая очистка сточных вод. М., Стройиздат, 1972.
23) Яковлев С.В., Карелин Я.А., Ласков Ю.М., Воронов Ю.В.Очистка производственных сточных вод. М., Стройиздат, 1979.
24) Кянэярли А.Ъ., Мирзяйева Э.С. Назик лайлы су тямизляйиъи гурьулар. Бакы, 2003.
25) Николадзе Г.И.,Минц Д.М.,Кастальский А.А. Подготовка воды для питьевого и промышленного водоснабжения. М.,Высшая школа,1984.
26) Design Manual and Tutorial. Particle/Liquid Separation Systems. Featuring Inclined Corrugated Plates. For Treatment of Process Water, Potable Water & Wastewater Built By: WaterSmart Environmental, Inc. Shawnee Mission, Kansas, WSE Publication No. 796.
27) C.G. Steiner. Gravity separators come in different forms and those variants built around stacks of parallelplates offer the treatment plant owner and designer a number of distinct performance advantages. WSE Publication No. 895, 1997.
28) Bengt Carlsson. An introduction to sedimentation theory in wastewater treatment Systems and Control Group. Uppsala University, Nov 96, rev, 1998.
29) Primer for Municipal Wastewater Treatment Systems. Environmental Protection Office of Wastewater Management, 2004.
30) Wastewater Treatment. Technologies: A General Review. Economic and Social Commission for Western Asia. United Nations New York, 2003.
31) George Tchobanoglous. Water Reclamation and Reuse Workshop. Department of Civil and Environmental Engineering University of California Davis. Sharif University of Technology Tehran, Iran. 2008.
32) Primer for Municipal Wastewater Treatment Systems. United States Environmental Protection Agency. Washington. Office of Water. Office of Wastewater Management. 2004.
33) New York City's. Wastewater Treatment Systems. Cleaning the Water We Use. Protecting the Environment We Live In. New York City Department of Environmental Protection. New York City. 2005.
34) Dr S. Basu, Non-member. Treatment Efficiency of Wastewater from Manufacturing Processes.IE(I) Journal-PR.Vol.86. 2005.
35) Bengt Carlsson. An introduction to sedimentation theory in wastewater treatment. Systems and Control Groupm Uppsala University. 1998.
36) Oscar Gonzalez-Barcelo and Simon Gonzalez-Martinez. Anaerobic prefermentation and primary sedimentation of wastewater in a sequencing batch reactor. Instituto de Ingeneria. Universidad Nacional Autonoma de Mexiko, Water SA, Vol. 32, № 4, 2006.
37) Charles L. Cooney Downstream processing course. Solid liquid separation: centrifugation. MIT Professional Institute, 2005.
38) Metcalf & Eddy. Wastewater Engineering. Collection. Treatment. Disposal. McGraw-Hill Series in Water Resources and Environmental Engineering. New York-San Francisco. 1991.
39) Metcalf & Eddy. Wastewater Engineering. Treatment, Disposal and Reuse. McGraw-Hill, International Edition, Civil Engineering Series. 1991.
40) Wastewater Treatment Systems. Augmenting Handbook operation and maintenance.Unified Facilities Criteria (UFC). Military Handbook. Department of Defense. United States of America. 2005.
41) Camp, T.R., 1946, sedmentation and design of settling tank, Trans. VOL.111,895-952.
42) Swamee,P.K.,and Tyagi,A., 1996, design of classi sedmentation tanks, journal of environmental engineering VOL.122,71-73.
43) Tamayol, A., firoozabadi, B.,ahmadi, g.,2006, a new method for determination of primary sedimentation basins performance 3rd BSME-ASME icte, 20-22 dec.,dhaka, bangladesh.

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