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CENTRIFUGAL DEWATERING OF SEDIMENTS FROM INSTALLATION FOR PRETREATMENT OF WASTEWATER FROM FISH-PROCESSING PLANT

A comprehensive installation for treating wastewater from the fish processing in the SUPERFISH plant in Ustronie Morskie, Poland, allows also utilization of sludge obtained during wastewater treatment. The results of sludge dewatering by means of centrifugal sedimentation combined with flocculation are presented. The results of examinations were approximated with equations applying the method of the central point. Then these equations were verified. The results show that centrifugal sedimentation is effective in the dewatering of sludge, and that the flocculants added (especially F52M) efficiently enhance dewatering process.

1. INTRODUCTION

Water is considered to be one of the renewable resources in the hydrological cycle. However, pollutants in surface water and groundwater may disturb this cycle, which leads to degradation of water in the environment and the shortage of water of a satisfactory quality. Therefore it is of prime importance to treat wastewater 'produced' in manufacturing processes before its discharge into environment [6], [7]. In Poland, the problem of wastewater treatment in existing industrial plants has not properly been solved yet. 376,4 hm^3 of wastewater yearly has not still been treated and 850,1 hm^3/year has been treated only mechanically [1]. Statistical data for the year 2004 shows that food-processing plants in Poland produce each year 88 hm^3 of wastewater that requires treatment. 2.9 hm^3 of this wastewater is not treated at all and 2.7 hm^3 is treated only mechanically [12].

Wastewater from fish processing contains no toxic substances, but it carries a huge load of organic substances. Fats and great amounts of suspensions choke up

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a sewer system. Moreover, fats and wastewater salinity may lead to the deactivation of activated sludge in sewage treatment plant. In the wastewater from fish processing, putrefactive fermentation occurs quickly and results in disgusting odour [5], [11].

The SUPERFISH plant located on the Baltic seashore processes about 60 000 tones of fish annually which is also associated with the production of about 24 m^3 of wastewater per hour [2].

Since 1998 the Division of Water-Sludge Technology and Waste Utilization of Koszalin University of Technology has co-operated with SUPERFISH plant to design the installation for pretreatment of wastewater from fish processing. After many preliminary tests the installation presented in figure 1 was designed and implemented in SUPERFISH plant [2], [4].

The results of investigating a centrifugal sedimentation, one of the steps of pretreatment, are presented.

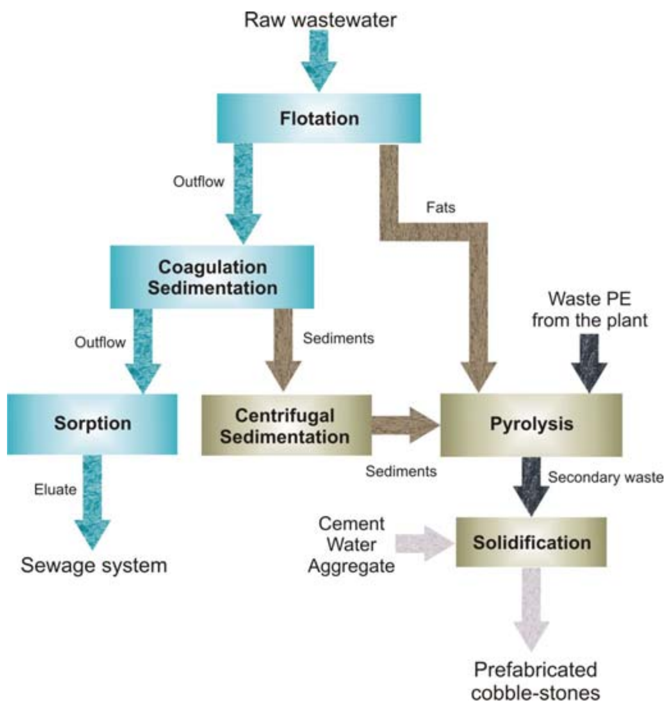

Fig. 1. Installation for pretreating the wastewater from the SUPERFISH plant

2. METHODOLOGY

Independent parameters of centrifugal sedimentation process are as follows: the time of rotation t_R [min], the speed of rotation n [rpm], the dose of flocculant (F52M or Zetag 66) D_X [mg/dm^3], the value of the parameter examined before the sediment pretreatment, i.e., the sludge hydration W_I [%] and the concentration of solids in eluate β_I [g/dm^3].

After pretreatment we obtain the values of the parameters of interest, i.e., W_I and β_I.

In the first stage of examination, the following independent parameters were on the constant level: the speed of rotation n = 3000 rpm and the dose of flocculant (the concentration of flocculants was 0.1%) which amounted to 0 mg/dm^3. The time of rotation x_1 was variable in this stage, ranging from 0 to 15 minutes. In the second stage of examinations, at the same input sediment, the centrifugal sedimentation was carried out at a fixed rotation time of 5 minutes (the central point of approximation), at a fixed dose of flocculant (0 mg/dm^3) and at a variable rotational speed x_2 in the range from 0 to 3000 rpm. In the third stage at the fixed t_R = 5 min and n = 3000 rpm, the F52M flocculent was added into the sediment in the first series and Zetag 66 in the second series in the doses from 0 to 2 mg per one dm^3 of sediment. The fourth stage of examinations consisted in centrifugal sedimentation at fixed t_R = 5 min, n = 3000 rpm and D_X = 0.4 mg/dm^3. Examination was carried out with various doses of input sediments collected randomly in various working days and differing in the degree of pollution.

The parameters of input sediments are presented in Table 1.

Table 1

Parameters of input sediments in four series of testing the centrifugal sedimentation

Series number	Water content [%]	Solid concentration [g/dm^3]
Series I	98.65	13.62
Series II	99.20	8.66
Series III	97.81	22.61
Series IV	98.57	14.39

The results obtained were then approximated applying the method of the central point [3], [8]–[10].

3. RESULTS AND DISCUSSION

3.1. WATER CONTENT OF DEPOSIT

The results of the influence of the time of rotation and the speed of rotation on the hydration of sediment after centrifugal sedimentation are presented in table 2 and figure 2.

Table 2

The influence of the time of rotation t_R and the speed of rotation n on the water content W in sediment after centrifugal sedimentation

Time of rotation t_R [min]	Speed of rotation n [rpm]	Flocculant dose D_X [mg/dm^3]	Water content in input sediment W_I [%]	Water content in sediment after sedimentation W [%]
0				98.65
1				94.83
5	3000	0	98.65	**88.09**
10				87.09
15				87.00
	0			98.65
	500			93.38
5	1000	0	98.65	89.63
	2000			88.27
	3000			**88.09**

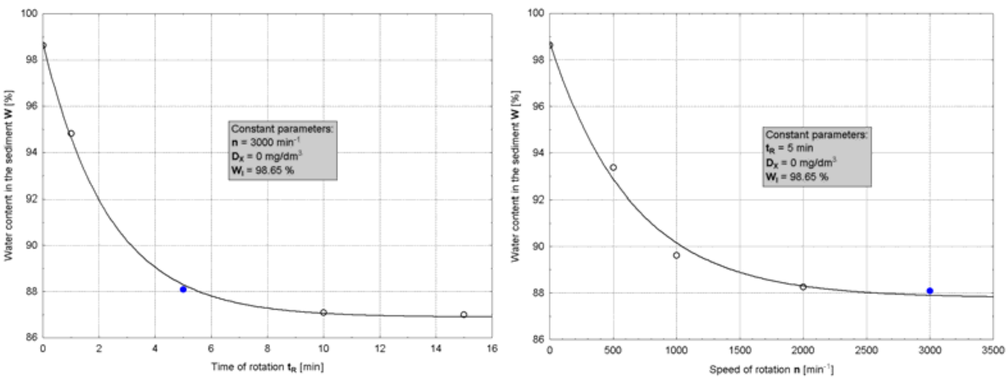

Fig. 2. The influence of the time of rotation t_R and the speed of rotation n on the water content W in the sediment after centrifugal sedimentation

An approximation equation representing the first and the second stages [3], [8]–[10] of the centrifugal sedimentation (figure 2) is as follows:

$$W(t_R, n) = 86.733 + \exp(2.473 - 0.42463 \cdot t_R) + \exp(2.917 - 0.002526 \cdot n) \qquad (1)$$

where:

W – the water content in the sediment [%] after sedimentation,
t_R – the time of rotation [min],
n – the speed of rotation [rpm].

The results of the influence of F52M flocculant dose and the water content in the input sediment on the water content in sediment after centrifugal sedimentation are presented in table 3 and figure 3.

Table 3

The influence of F52M flocculant dose D_F and the water content in the input sediment W_I on the water content W in the sediment after centrifugal sedimentation

Time of rotation t_R [min]	Speed of rotation n [rpm]	F52M dose D_F [mg/dm^3]	Water content in input sediment W_I [%]	Water content in sediment after sedimentation W [%]
5	3000	**0.0**	98.65	**88.09**
		0.2		87.01
		0.4		86.15
		0.8		85.85
		2.0		85.67
5	3000	0.4	**98.65**	**86.15**
			99.20	92.82
			97.81	74.84
			98.57	85.37

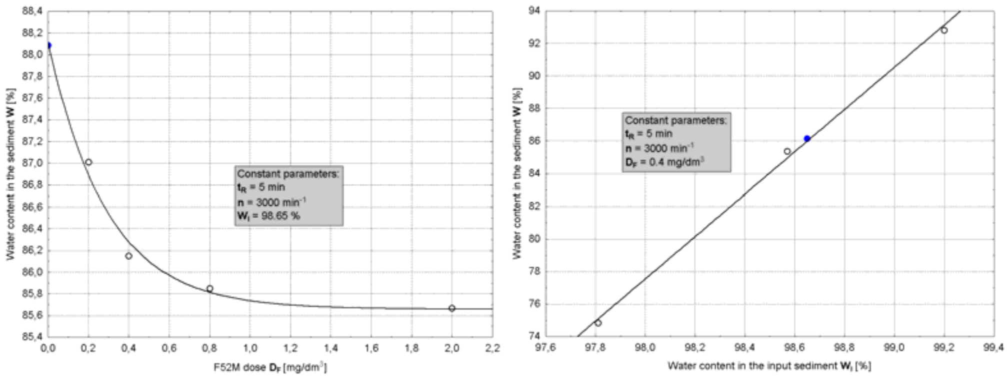

Fig. 3. The influence of the F52M flocculant dose D_F and the water content in the input sediment W_I on the water content W in the sediment after centrifugal sedimentation

An approximation equation (1) for the curves in figure 3 [3], [8]–[10] is given by:

$$W(t_R, n, D_F, W_I) = -1192.3 + \exp(2.473 - 0.42463 \cdot t_R) + \exp(2.917 - 0.002526 \cdot n) + \exp(1.319 - 5.132 \cdot D_F) + 12.935 \cdot W_I, \quad (2)$$

where D_F is the F52M flocculant dose [mg/dm^3].

The influence of the Zetag 66 flocculant dose and the water content in the input sediment on the water content in sediment after centrifugal sedimentation is presented in table 4 and figure 4.

Table 4

The influence of the Zetag 66 flocculant dose D_Z and the water content in the input sediment W_I on the water content W in the sediment after centrifugal sedimentation

Time of rotation t_R [min]	Speed of rotation n [rpm]	Zetag 66 dose D_Z [mg/dm^3]	Water content in input sediment W_I [%]	Water content in sediment W [%]
5	3000	**0.0**	98.65	**88.09**
		0.2		87.94
		0.4		87.80
		0.8		87.65
		2.0		87.47
5	3000	0.4	**98.65**	**87.80**
			99.20	93.59
			97.81	75.54
			98.57	85.53

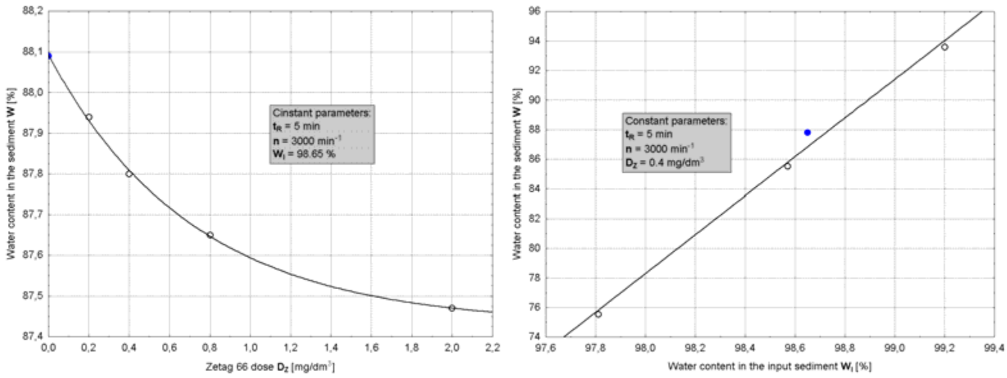

Fig. 4. The influence of the Zetag 66 flocculant dose D_Z and the water content in the input sediment W_I on the water content W in the sediment after centrifugal sedimentation

An approximation equation (1) for the curves in figure 4 [3], [8]–[10] is given by:

$$W(t_R, n, D_Z, W_I) = -1196.4 + \exp(2.473 - 0.42463 \cdot t_R) + \exp(2.917 - 0.002526 \cdot n) + \exp(-0.37101 - 1.663 \cdot D_Z) + 12.986 \cdot W_I, \quad (3)$$

where D_Z is the Zetag 66 flocculant dose [mg/dm^3].

The first variable parameter, whose influence on the water content in the sediment has been examined in the centrifugal sedimentation, is the time of rotation. The results obtained show that in such a case the water content in the sediment decreases along with prolonging the process time. The lowest water content (87%) in sediment was obtained for a 15 min time of rotation. The shape of the curve shows that the most serious decrease of water content in the sediment is measured for a 5 min time of rotation. Further extension of process time does not decrease significantly the water content in the sediment. The decrease in the water content in the sediment may be explained as follows as: the longer the time of rotation, the longer the impact of forces (first of all of the centrifugal force) on the sediment being dewatered, which forces smaller and smaller particles to sediment and thicken.

The centrifugal sedimentation is also affected by the rotation speed. An increase in the rotation speed causes a decrease in water content in the sediment. The shape of the curve shows that the most serious decrease in the water content in the sediment is observed at n approaching 2000 rpm. At the value of n ranging between 2000 to 3000 rpm this decrease is much slower, and above 3000 rpm it is practically insignificant. It is possible to assume that along with an increase in the rotation speed the centrifugal force increases, which affects the grains of sediment in such a way that they sediment and thicken.

A dose of the flocculant was the next parameter under examination. Two flocculants, i.e., F52M and Zetag 66, were tested. The results obtained allow the statement that both flocculants decrease the water content in the sediment. The higher the flocculant dose, the lower the water content in the sediment. Under the same process conditions F52M appeares to be more effective than Zetag 66. The shapes of the curves (figures 3 and 4) also show that the F52M dose of 0.8 mg/dm^3 is the optimal one. At a higher dose the water content decrease is not substantial. In the case of Zetag 66, even the dose of 2.0 mg/dm^3 is not optimal, and although its higher values allow us to decrease the water content in the sediment, it is not clear whether it will be possible to reach F52M level. Generally it may be assumed that F52M and Zetag 66 decrease the water content in the sediment in the same way – the flocculant enables the aggregation of small, slow-settleable particles of suspension into bigger, heavier agglomerates that can be more easily subjected to a centrifugal force.

The last parameter, which affects the water content in the sediment after its settling, is the water content in the input sediment. In the case where both flocculants are applied, the curves representing the process have linear character, hence its efficiency in the examined range of water content in the input sediment is constant and its value depends on the flocculant applied.

3.2. SOLID CONCENTRATION IN THE ELUATE

The influence of the time of rotation and the speed of rotation on the solid concentration in eluate after centrifugal sedimentation was investigated (see table 5 and figure 5.

Table 5

The influence of the time of rotation t_R and the speed of rotation n on the solid concentration β in eluate after centrifugal sedimentation

Time of rotation t_R [min]	Speed of rotation n [rpm]	Flocculant dose D_X [mg/dm^3]	Solid concentration in input sediment β_I [g/dm^3]	Solid concentration in eluate β [g/dm^3]
0	3000	0	13.62	13.62
1				10.85
5				**6.61**
10				3.41
15				1.95
5	0	0	13.62	13.62
	500			8.51
	1000			7.22
	2000			6.81
	3000			**6.61**

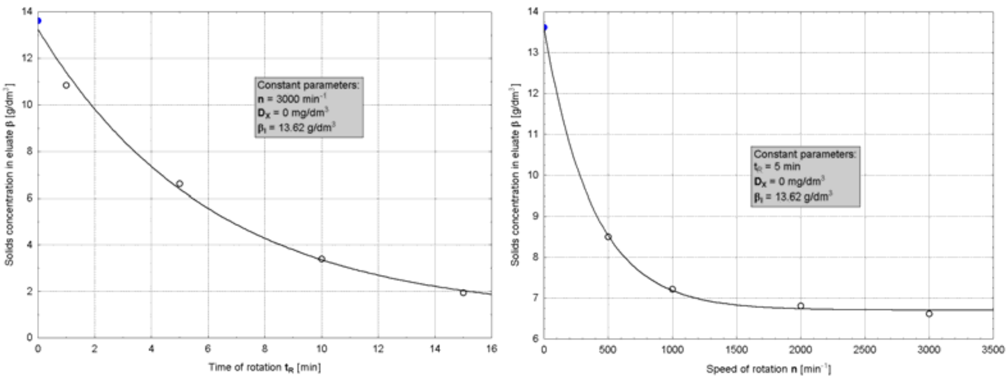

Fig. 5. The influence of the time of rotation t_R and the speed of rotation n on the solid concentration β in the eluate after centrifugal sedimentation

An approximation equation representing the curves in figure 5 [3], [8]–[10] is given by:

$$\beta(t_R, n) = 1.3799 + \exp(2.5066 - 0.16397 \cdot t_R) + \exp(1.9193 - 0.002744 \cdot n), \qquad (4)$$

where β is the concentration of solids in the eluate [g/dm^3].

The influence of the F52M flocculant dose and the concentration of solids in the input sediment on the solid concentration in eluate after centrifugal sedimentation is presented in table 6 and figure 6.

Table 6

The influence of the F52M flocculant dose D_F and the solid concentration β_I in the input sediment on the solid concentration β in eluate after centrifugal sedimentation

Time of rotation t_R [min]	Speed of rotation n [rpm]	F52M dose D_F [mg/dm^3]	Solid concentration in input sediment β_I [g/dm^3]	Solid concentration in eluate β [g/dm^3]
5	3000	**0.0**	13.62	**6.61**
		0.2		3.66
		0.4		2.93
		0.8		2.54
		2.0		2.33
5	3000	0.4	**13.62**	**2.93**
			8.66	1.06
			22.61	5.43
			14.39	3.15

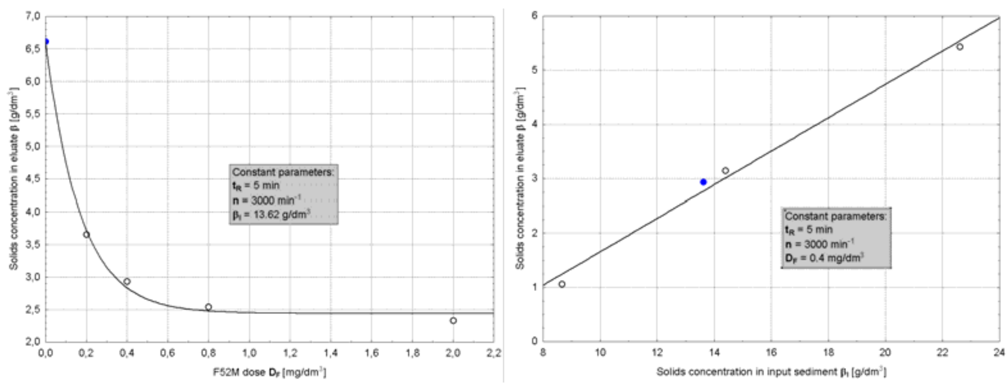

Fig. 6. The influence of the F52M flocculant dose D_F and the solid concentration in the input sediment β_I on the solid concentration β in eluate after centrifugal sedimentation

An approximation equation (4) for the curves in figure 6 [3], [8]–[10] is defined by:

$$\beta(t_R, n, D_F, \beta_I) = -7.658 + \exp(2.5066 - 0.16397 \cdot t_R) + \exp(1.9193 - 0.002744 \cdot n) + \exp(1.0810 - 3.9752 \cdot D_F) + 0.3133 \cdot \beta_I, \quad (5)$$

where:

D_F – the F52M flocculant dose [mg/dm^3],

β_I – the concentration of solids in the input sediment [g/dm^3].

The influence of the Zetag 66 flocculant dose and the solid concentration in the input sediment on the solid concentration in eluate after centrifugal sedimentation is presented in table 7 and figure 7.

Table 7

The influence of the Zetag 66 flocculant dose D_Z and the solid concentration in the input sediment β_I on the solid concentration β in eluate after centrifugal sedimentation

Time of rotation t_R [min]	Speed of rotation n [rpm]	Zetag 66 dose D_Z [mg/dm^3]	Solid concentration in input sediment β_I [g/dm^3]	Solid concentration in eluate β [g/dm^3]
5	3000	**0.0**	13.62	**6.61**
		0.2		4.16
		0.4		3.15
		0.8		2.93
		2.0		2.87
5	3000	0.4	**13.62**	**3.15**
			8.66	1.51
			22.61	5.61
			14.39	3.30

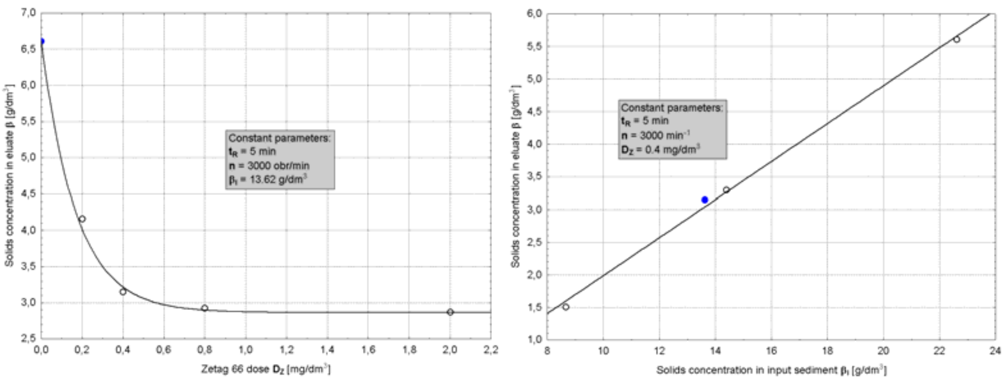

Fig. 7. The influence of the Zetag 66 flocculant dose D_Z and the solid concentration in the input sediment β_I on the solid concentration β in eluate after centrifugal sedimentation

An approximation equation (4) for the curves in figure 7 [3], [8]–[10] is as follows:

$$\beta(t_w, n, D_Z, \beta_W) = -6.7189 + \exp(2.5066 - 0.16397 \cdot t_w) + \exp(1.9193 - 0.002744 \cdot n) + \exp(1.7822 - 7.6380 \cdot D_Z) + 0.2939 \cdot \beta_W. \quad (6)$$

Examining the influence of the time of rotation on solid concentration in eluate after centrifugal sedimentation permits the conclusion that solid concentration in the eluate decreases along with extending the time of rotation. The concentration of solids was reduced from 13.62 g/dm^3 to 1.95 g/dm^3 at the longest rotation time, i.e., 15 minutes. The curve representing this relation shows that due to further extending the time of rotation the concentration of solids in the eluate decreases, although this decrease is not significant. The longer the time of rotation, the more prolonged the impact of forces exerted on suspension particles, which allows their sedimentation, and thus removal from eluate.

The influence of the second parameter, i.e., the speed of rotation, on the concentration of solids in the eluate is as follows: the concentration of solids in the eluate decreases along with an increase in the speed of rotation. The best result was achieved at the highest speed of rotation, i.e., 3000 rpm; in such a case, the reduction of the concentration of solids ranged from 13.62 g/dm^3 in the input sediment to 6.61 g/dm^3. The curve representing this relation shows that along with an increase in the speed to 1000 rpm the concentration of solids decreases sharply. An increase in the speed above 1000 rpm does not cause such a significant decrease. Too short time of rotation (5 minutes) can be responsible for this phenomenon. It is possible that even at high rotation speed the lightest particles of suspension cannot settle. The results of the tests prove that the concentration of solids in the eluate increases significantly along with the time of rotation.

The dose of flocculant was the next parameter under examination. The results obtained allows us to state that both flocculants decrease the concentration of solids in the eluate. The higher the flocculant dose, the lower the concentration of solids in the eluate. F52M flocculant appeared to be more efficient than Zetag 66 one. The former allowed us to obtain better results at the same doses and under the same conditions. The shapes of curves obtained also show that the F52M dose of 0.4 mg/dm^3 is the optimal one. A decrease in the concentration of solids in the eluate at the flocculant dose higher than 0.4 mg/dm^3 is not significant. In the case of Zetag 66, the dose of 0.4 mg/dm^3 is also optimal and its further increase does not allow any sifnificant decrease in the concentration of solids in the eluate. The concentration of solids in the case of Zatag66 flocculant is worse than that in the case of the F52M flocculant. Generally it may be assumed that both F52M and Zetag 66 decrease the concentration of solids in the eluate due to aggregation of small, slow-settleable particles of suspension into bigger, heavier agglomerates that can be more easily subjected to a centrifugal force.

The analysis of the results of the influence of solid concentration in the input sediment subjected to flocculation and centrifugal sedimentation on the solid concentration in the eluate allows the conclusion that, as in the case of water content examinations, this dependence is represented by straight lines. Hence the decrease in the solid concentration in the eluate is constant in the examined range of solid concentration in the input sediment, and its value depends on the flocculant dose (F52M is more effective).

3.3. VERIFICATION OF EQUATIONS

Equations representing individual parameters of the successive stages of the wastewater pretreatment technology were verified under real condition in the SUPERFISH fish-processing plant. The verification consisted in running the seven series of tests under conditions of technological process at various values of independent parameters of unit processes. In the process of the centrifugal sedimentation we verified two equations: the first representing the water content in the sediment W (2) (with the application of F52M flocculant) and the second for the concentration of solids β (5).

The results obtained and the values calculated using equations are compared in table 8.

Table 8

Comparison of test results with calculations using analytical and empirical equations representing the process of the centrifugal sedimentation

Parameter	Unit	Independent parameters				Equation	Test	Deviation of results
		W_I / β_I	D_F	n	t_R			
Water content W	%	97.90	0.2	3500	7	75.99	73.01	3.9%
		98.68	0.2	3200	7	85.23	85.12	0.1%
		98.08	0.4	2800	7	77.07	76.12	1.2%
		98.28	0.8	2500	7	80.04	74.03	7.5%
		98.07	0.4	3500	7	77.02	76.18	1.1%
		97.87	0.6	3200	7	75.61	75.39	0.3%
		98.32	0.2	2800	7	80.17	80.29	0.1%
Solid concentration β	g/dm^3	21.04	0.2	3500	7	4.16	5.04	17.5%
		13.23	0.2	3200	7	0.98	1.04	5.8%
		19.18	0.4	2800	7	2.37	2.66	10.9%
		17.17	0.8	2500	7	2.21	2.1	5.0%
		19.31	0.4	3500	7	2.56	2.59	1.2%
		21.29	0.6	3200	7	4.24	5.14	17.5%
		16.76	0.2	2800	7	1.61	1.62	0.6%

The differences between the values obtained during the tests and the values calculated from the equations (table 8), are slight (18% at the maximum). They show that the results calculated based on the equations obtained during laboratory tests are consistent with real data also in the case where different values of independent parameters are inserted (within the ranges tested).

4. CONCLUSIONS

The results of investigating the centrifugal sedimentation process allow us to state that this process is efficient in dewatering sediments produced during pretreatment of wastewater from the fish processing. An effectiveness of dewatering is increased by two flocculants. The F52M flocculant appeared to be more effective than Zetag 66.

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ODWADNIANIE OSADÓW SEDYMENTACYJNYCH Z INSTALACJI DO PODCZYSZCZANIA ŚCIEKÓW Z ZAKŁADU PRZETWÓRSTWA RYB W PROCESIE SEDYMENTACJI ODŚRODKOWEJ

Kompleksowy układ podczyszczania ścieków pochodzących z przetwórstwa ryb w Zakładzie Przetwórstwa Ryb SUPERFISH uwzględnia również zagospodarowanie osadów powstających w czasie oczyszczania ścieków. W artykule przedstawiono rezultaty odwadniania osadów w wirówce sedymentacyjnej. Otrzymane wyniki aproksymowano, korzystając z równań i stosując metodę punktu centralnego.

Uzyskane równania poddano weryfikacji. Otrzymane wyniki pokazały, że sedymentacja odśrodkowa jest skuteczna w odwadnianiu osadów, a dodatek flokulantów (w szczególności F52M) poprawia skuteczność procesu odwadniania.