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EXPANDED POLYSTYRENE FILTERS WITH INCREASING LAYER OF SUSPENDED SEDIMENT IN WATER SOFTENING TECHNOLOGIES

Вапнування – найбільш поширений метод реагентного пом'якшення води. Існуючі споруди працюють зі значно нижчою продуктивністю від проектної. Запропоновано застосовувати метод вапнування на пінополістирольних фільтрах із зростаючим шаром завислого осаду для пом'якшення води. Порівняно ефективність в лабораторних та виробничих умовах, наведено рівняння, яке пов'язує видалення кальцію та магнію.

Ключові слова: пом'якшення води, метод вапнування, шар завислого осаду, пінополістирольне завантаження, іони кальцію та магнію.

Известкование – наиболее распространенный метод реагентного умягчения воды. Продуктивность существующих сооружений значительно ниже проектной. Предложено использовать метод известкования на пенополистирольных фильтрах с растущим слоем взвешенного осадка для умягчения воды. Сравнено эффективность в лабораторных и производственных условиях, приведено уравнение, связывающее удаление кальция и магния.

Ключевые слова: умягчение воды, метод известкования, слой взвешенного осадка, пенополистирольная загрузка, ионы кальция и магния.

Liming is the most spread reagent water softening method. Existing edifices work with much lower productivity combined with designed. We offer to use liming method on expanded polystyrene filters with increasing layer of suspended sediment for water softening. Here are also compared effectiveness in laboratory and industrial conditions, presented equation what connects calcium and magnesium removal.

Key words: water softening, liming method, suspended sediment layer, expanded polystyrene filling, calcium and magnesium ions.

Water hardness is due to multivalent metallic ions, primarily calcium and magnesium. Hard water is generally not harmful to human health; however; it can cause scaling problems in domestic and especially in industrial systems [1, 4]. In water treatment practice a number of methods of water treatment with reagents are used for the purpose of association contained cations – calcium and

magnesium – in low soluble compounds, which are removed later from the water by precipitation and filtration.

Liming and lime-soda ash are the most spread ones [2, 41]. For this may be used upflow clarifier, specifically the sludge-blanket clarifier [3, 10.42]. The sludge blanket clarifiers are solids contact clarifiers with a distinct solids layer that is maintained as a suspended filter through which flow passes. The sludge blanket unit contains a central mixing zone for partial flocculation and a fluidized sludge blanket in the lower portion of the settling zone [4, 226]. As the small, coagulated particles enter the sludge blanket, contact with other particles in the blanket causes flocculation to occur. The floc grows in size and becomes part of the blanket [5, 1]. The section of sludge blanket clarifier type VTI-1000I is represented on Fig. 1

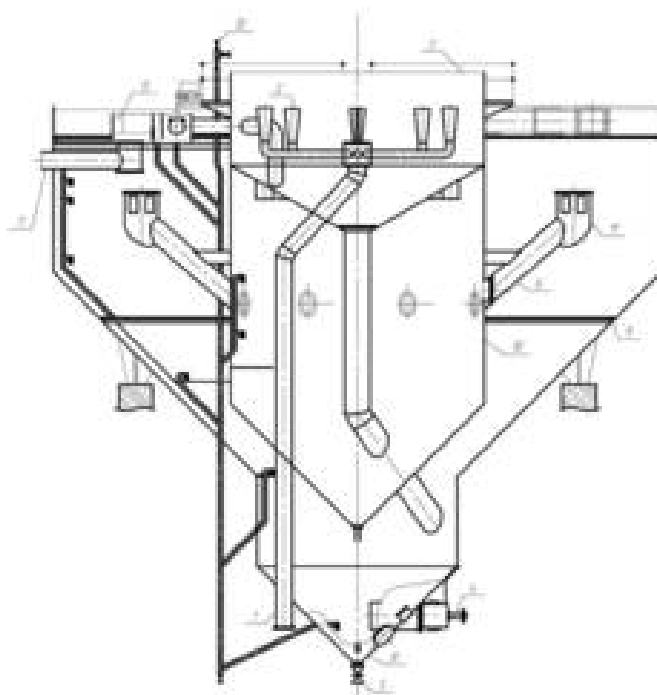


Fig. 1. Clarifier type VTI-1000I: 1 – initial water pipeline; 2 – switchgear; 3 – air separator; 4 – nozzle device; 5 – pipeline for removing coarse particles by purging; 6 – sludge outlet pipeline; 7 – pipeline for removal of mixture: treated main stream water and water which is cleansed of sludge; 8 – sludge box; 9 – horizontal perforated partition; 10 – sludge thickener; 11 – sludge receiving window; 12 – pipeline for cleaning sludge thickener; 13 – receiving switchgear box

This edifice has such disadvantages as quite difficult construction and exploitation. Nowadays existing edifices work with much lower productivity combined with designed. So there is a need in finding new and improving already existing water softening methods and technologies.

In this paper we propose to use liming method on expanded polystyrene filters with increasing layer of suspended sediment for water softening. This type of filter was discovered by professor Valerii Orlov and associate professor Sergii

Martynov at National university of water and environmental engineering, Ukraine. Their research is engaged with using it for water deferrization, but not for water softening [6,43].

We have conducted research of softening process on experimental plant in laboratory and industrial conditions (Fig. 2, 3). During filtering cycles we controlled analytical characteristics of water such as: pH, total hardness alkalinity and also filtering rate, pressure losses. Also we discovered characteristics of suspended sediment layer.

Experimental research process is the following. Water mixes with lime in the contact tube and then passes firstly through a layer of suspended sediment which is performed gradually increasing, and after – floating expanded polystyrene backfill [7, 1].

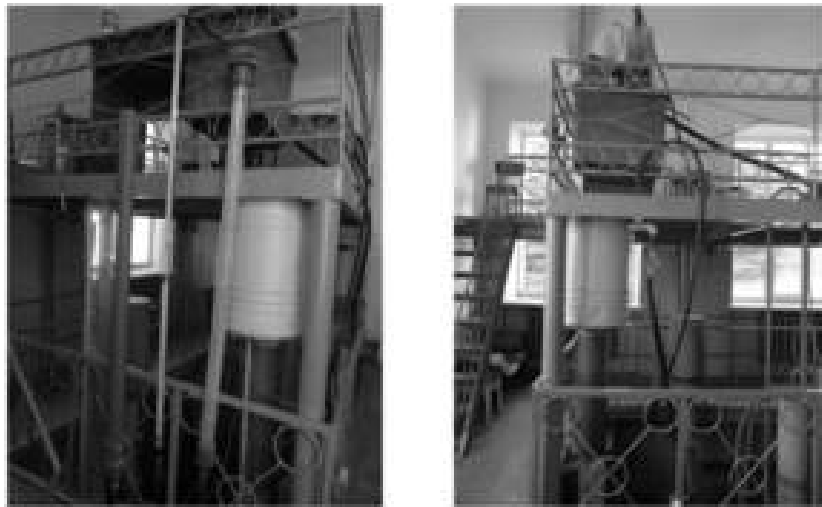


Fig. 2. Photos of laboratory experimental plant for research of softening process



Fig. 3. Photos of industrial experimental plant for research of softening process

The filtering rate range was between 2,5 and 4,5 m³/hour. In laboratory conditions we served tap water on plant with such characteristics: total hardness – 5,8 mmol/dm³, alkalinity – 6,10 mmol/dm³, pH – 7,40. As reagent we used slaked lime OP-1 ISO B V.2.7-90-99 ("Ferezi", Lviv), what we prepared directly in laboratory, and received maximum effect 83 % (decreasing of total water hardness from 6,0 to 1,0 mmol/dm³). In industrial conditions we served river water with such characteristics: total hardness – 7,1 mmol/dm³, alkalinity – 4,8 mmol/dm³, pH – 8,10, used lime from lime preparation workshop with concentration of calcium hydrate 4 % and received maximum effect 56 % (decreasing of total water hardness from 7,0 to 3,0 mmol/dm³).

The difference of the results of total hardness and alkalinity removal effectiveness in laboratory and industrial conditions are represented in Table 1.

Table 1

Effectiveness of total hardness and alkalinity removal during filtering cycle in laboratory and industrial conditions

Hours of filtering cycle	Effectiveness of total hardness removal, parts of the unit		Effectiveness of alkalinity removal, parts of the unit	
	laboratory	industrial	laboratory	industrial
1	0,66	0,49	0,65	0,69
2	0,68	0,56	0,63	0,84
3	0,63	0,54	0,71	0,77
4	0,70	0,36	0,70	0,61
5	0,73	0,46	0,76	0,77
6	0,71	0,56	0,71	0,84
7	0,74	0,33	0,63	0,55
8	0,70		0,66	
9	0,66		0,70	

Considering equations (7), (8), (9), (10) due to [8, 168], compatible solubility product of calcium carbonate and magnesium hydroxide can be written as equation (1):

$$SP = \beta_1 \beta_2 \beta_3 \beta_4 \cdot f_I f_{II} \cdot X_p Y_p Z_p W_p. \quad (1)$$

where β_1, β_2 – ratio of total content of calcium and carbonate to total content with products of their hydrolysis; β_3, β_4 – ratio of total content of magnesium and hydroxide to total content with products of their hydrolysis; f_I, f_{II} – activity coefficients of mono- and divalent ions; X_p, Y_p, Z_p, W_p – general content of calcium, carbonate, magnesium, hydroxide and their hydrolysis products.

In saturated solution concentration of calcium, carbonate, magnesium, hydroxide in g-ion/l, are equal, that's why concentration each of them is equal to

compatible solubility of calcium carbonate and magnesium hydroxide in g-mol/l. It is presented by equation (2):

$$X_p = Y_p = Z_p = W_p = C_{CaCO_3 + Mg(OH)_2} = \sqrt{\frac{SP}{\beta_1 \beta_2 \beta_3 \beta_4 \cdot f_I f_{II}}} \quad (2)$$

If we put under equation (2) in equations (5) and (6) [8, 168; 9, 309], will get equation (3), what connects effectiveness of calcium and magnesium removal:

$$\alpha_s = 1 - \frac{1}{XZ} \cdot C_{CaCO_3 - Mg(OH)_2} \quad (3)$$

Calculated maximal effect of calcium and magnesium compatible removal depending on different temperatures presented in Table 2.

Table 2

Maximal effect of calcium and magnesium compatible removal depending on different temperature

Temperature, °C	pH	Maximal effect of calcium and magnesium removal, parts of the unit, due to concentration in initial water		
		4,1/1,7 mmol/dm ³	4,55/1,85 mmol/dm ³	5,0/2,0 mmol/dm ³
0	9,7	0,38	0,66	0,72
10	9,7	0,78	0,88	0,9
25	9,6	0,86	0,91	0,92
50	9,6	0,93	0,96	0,97
75	9,6	0,97	0,98	0,99

We also discovered characteristics of suspended sediment layer due to method presented by Kurgaev [9, 23]. Samples were taken to several glass cylinders, filling them with a layer of water with sediment to different heights of 100 to 400-600 mm. After this, we observed the settling of sediment until the moment of stabilization of the upper boundary position of sediment. After measuring the final height of the sediment we find the solid phase content by weight in these samples. On (Fig. 4a, b, c) it's represented the change of height of suspended sediment sample at the beginning and in time of measuring.

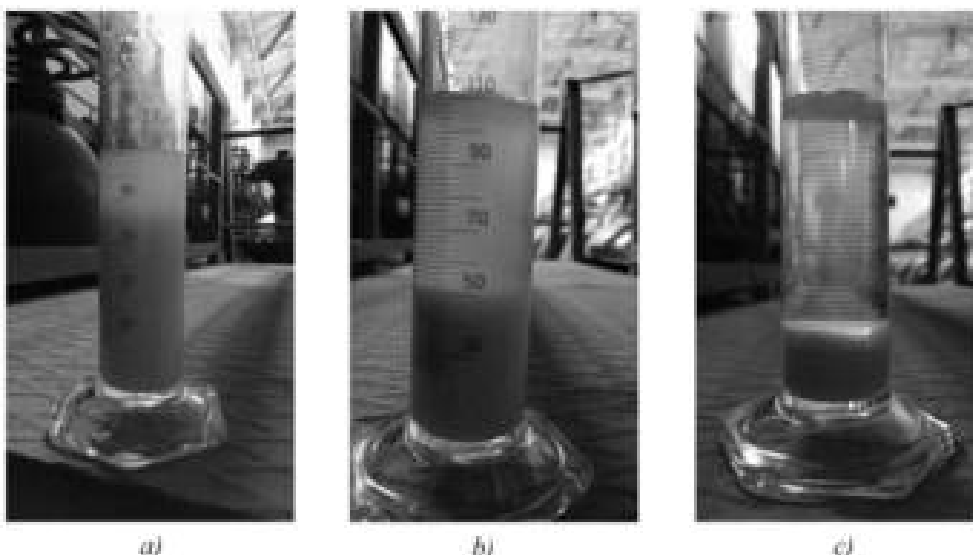


Fig. 4. Change of height of suspended sediment sample: a) at the beginning; b) and c) in time

Calculated values of suspended sediment layer characteristics are represented in Table. 3.

Table 3

Characteristics of suspended sediment layer due to calcium carbonate and magnesium hydroxide particles

Characteristic, units of measurement	Value		
Height of sample, sm / time, hour	50 sm/ 11.0	50 sm/ 12.0	50 sm/ 15.0
Solid phase mass, g	0,158	0,174	0,276
Specific concentration, g/sm ³	0,0821	0,0905	0,1435
Sedimentation rate, sm/s	0,0116	0,0133	0,0145
Solid phase content by weight in volume unit of unsaturated sediment, g/sm ³	0,0008	0,0009	0,0014
Density of unscathed flake-like suspension, g/sm ³	1,00052/ 1,00048	1,00057/ 1,00053	1,00088/ 1,00082
Value that characterizes the ratio of the volume of water, that is included in the cells of the suspension flakes, to the volume of the solid phase in these flakes	3285,6/ 2920,4	2983,4/ 2651,8	1927,5/ 1713,2
Ratio of water content and solid phase by mass	1216	1104	713
Equivalent diameter, sm	0,99/ 1,03	1,01/ 1,05	0,85/ 0,88

Research of presented method – liming on expanded polystyrene filters with increasing layer of suspended sediment, shows positive reducing effect of water total hardness and alkalinity. Applying of it allows to improve existing water softening technological scheme trough simplifying – excluding clarifiers with suspended sediment; to make it more simple in exploitation for staff; for building new edifices it requires smaller buildings size, what saves space; is more energy saving, because of excluding using pumps for backwash.

Equation (3) connects effectiveness of calcium and magnesium removal and allows to find pH level for the most optimal compatible effectiveness for different temperature modes. Characteristics of suspended sediment layer due to different particles helps to discover process technology better.

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