IOP Conf. Series: Materials Science and Engineering **262** (2017) 012221 doi:10.1088/1757-899X/262/1/012221

Technological Aspects of Waterworks Sludge Treatment

M Yu Belkanova, E V Nikolaenko, D A Gevel

Architecture and Construction Institute, South Ural State University, 76, Lenin Avenue, Chelyabinsk 454080, The Russian Federation

E-mail: belkanovami@susu.ru

Abstract. The water yielding capacity of the sludge in water-supply network treatment facilities is determined by the water quality in a water source and its treatment technology. The paper studies the sludge of water-supply network treatment facilities formed in the conditions of low turbidity and average water colour index in the water source. Such sludge has a low water yielding capacity and is subject to conditioning. The paper shows the influence of seasonal variations of turbidity, water colour index and temperature of the feed water on the specific sludge filtration resistance. It considers the specific features of sludge formation in different settling basins influencing its water yielding capacity. It is shown that the washwater return performed at one of the blocks of the facilities increases the feed water turbidity and leads to the formation of the sludge easily susceptible to conditioning. The paper studies the following methods of the reagent sludge treatment: polyacrylamide-based flocculant treatment, joint treatment with flocculant and vermiculite filler, lime treatment. The use of vermiculite allows to reduce the required flocculant dose. The author determines optimum doses of reagents allowing to direct the sludge for further mechanical dewatering after conditioning. It is shown that, when the sludge is processed with lime, the filtrate formed at dewatering can be reused as an alkalifying agent, which will allow one to cut the costs for the acquisition of reagents.

1. Introduction
The problem of waterworks sludge treatment is considered to be one of the least elaborated, most technically challenging and expensive. The amount and the composition of the waterworks sludge depend on the quality of the feed water in the water source, the dose and the type of the applied coagulants and other reagents, the treatment flow chart and design features of the facilities, where the sludge is formed [1-6].

2. Main part
The paper studies the sludge formed at Chelyabinsk water-supply network treatment facilities. The samples were collected from the Shershnyovskoye reservoir, which water has a low turbidity and which colour index varies from average to high. To evaluate the water quality the information on the dynamics of the turbidity, water colour index and temperature variation in the reservoir shown in figures 1 and 2 was gathered in different periods of 2016.

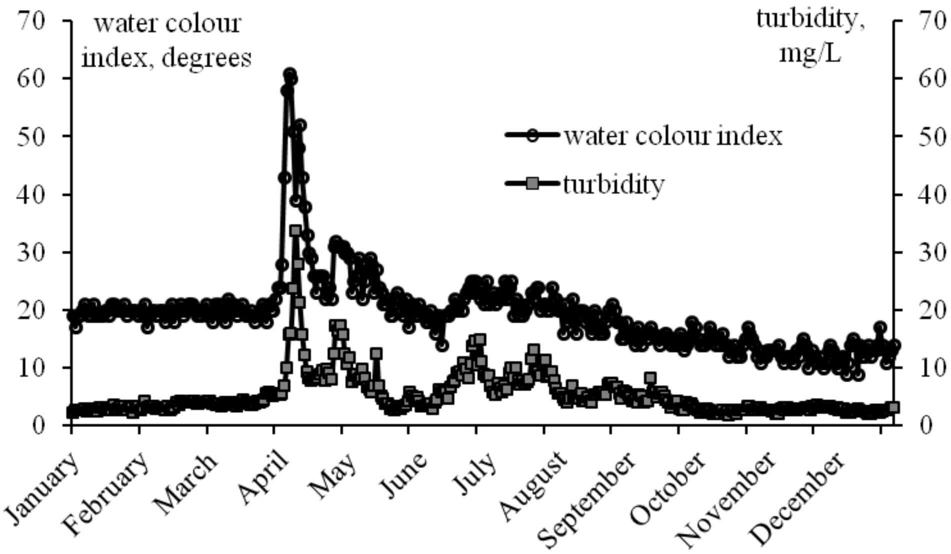

Figure 1. The water colour index and turbidity of the Shershnyovskoye reservoir, 2016.

Seasonal variations of the water quality in the water source lead to the changes of the reagent water treatment mode. In different periods of the year, the following reagents were used at Chelyabinsk water-supply network treatment facilities: coagulants (aluminium sulphate; aluminium oxychloride), flocculants (FL-4540; AN-905), potassium permanganate, building lime [7].

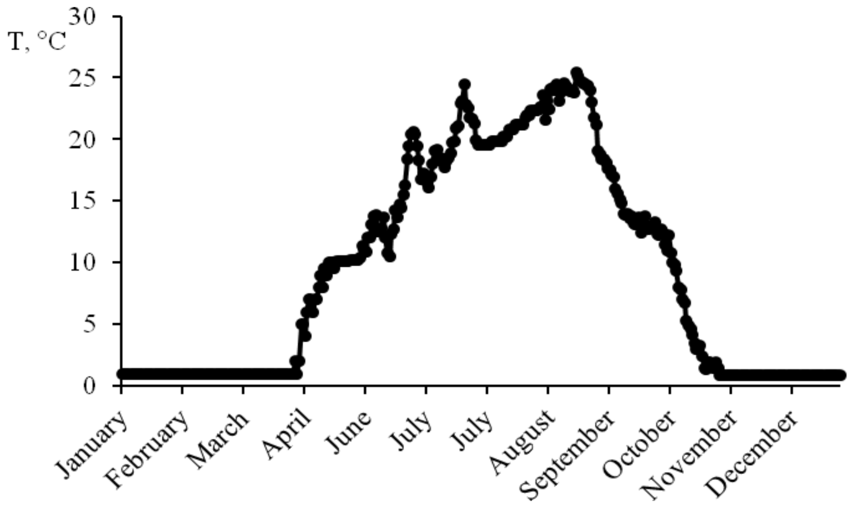

Figure 2. Water temperature of the Shershnyovskoye reservoir, 2016.

Sludge is formed at water-supply network treatment facilities at three blocks throughout the implementation of the two-level water treatment scheme: settling basins – high-rate filters. The elementary and particle sludge composition is studied in the works [8,9].

Sludge is formed in horizontal and double-deck settling basins [7] differing by design features and sludge settling and accumulation conditions. In the double-deck settling basin the sludge settling and accumulation are separated: the first deck is a structurally reserved sludge accumulation area, the lower deck is used to create the conditions for the formation of the unhindered settling and clarification area. The suspended floc layer of the coagulated suspended solid is formed in the area of the water flow deflection from the lower to the upper deck [10]. Such contact coagulation improves hydraulic treatment conditions and intensifies floc formation due to the catalytic influence of the preformed suspended solid. Such intensification is particularly important in case of a low turbidity of the feed water.

In single-deck horizontal settling basins of blocks # 2 and 3, flocculated particles are settled in the water volume, which is displaced horizontally at the water flow speed in the settling basin. In practice, there can appear turbulence in the flow entry area due to the difficulties occurred at the hydraulic vertical flow distribution, local temperature difference, agitations connected with the change of the supply water composition, etc. [11]. The sludge accumulation reduces the working section area of the horizontal settling basin, which results in convection flows washing out the sludge clarification, settling and accumulation areas, and reduces the water clarification efficiency.

Washwater of high-rate filters is returned at one of the three blocks, which allows to increase the feed water turbidity, to create additional nucleating centers of the solid phase and to accelerate the coagulation of admixtures at the low-turbid water treatment, which is vital for the Shershnyovskoye reservoir. Besides, the turbidity increase sharply strengthens the action of flocculants and weights the sludge [10]. The washwater return contributes to the formation of larger fractions in the sludge. The work [12] shows that the increase of the particle size increases the amount of free water, decreases the amount of associated water and, consequently, decreases the specific sludge resistance. In this connection, one can expect an increase of the water yielding capacity of sludge at the washwater return.

For the research, the sludge was collected by seasons: in spring – at the preparation for the flood rise; in summer and autumn. The table contains the main characteristics of the initial sludge. The averaged value of the specific filtration resistance of the sludge collected in summer comprises about $3000 \cdot 10^{10}$ m/kg, and for the sludge of spring and autumn – about $5000 \cdot 10^{10}$ m/kg. At an increase of the feed water temperature the viscosity is decreased, and, consequently, the processes of suspension sedimentation and sludge formation are decelerated in the accumulation area of the settling basin. It leads to a decrease of the specific sludge filtration resistance.

Table. Characteristic of the initial sludge formed in different settling basins

Facility	Date of collection	Moisture content, %	Solid concentration, g/L	Specific filtration resistance, $r \times 10^{10}$, m/kg
Double-deck settling basin, Block #1	06.10.2015	97.80	22.00	6300
	26.03.2016	98.26	17.40	3275
	28.06.2016	95.90	41.10	3841
	18.10.2016	98.74	12.60	7297
Horizontal settling basin, Block # 2	09.03.2016	98.74	12.62	5892
	07.11.2016	97.73	22.70	6066
Horizontal settling basin, Block # 3	09.03.2016	95.76	42.25	6320
	28.06.2016	96.55	34.53	1967
	07.11.2016	97.09	29.10	1546

The washwater return performed in block # 3 increases the feed water turbidity and decreases the specific sludge filtration resistance as compared to the sludge of blocks # 1 and 2. However, the high solid concentration of the sludge (42.25 mg/L) to a greater extent influences the properties of the sludge in block # 3 collected in spring – a more concentrated sludge has a higher filtrate viscosity, which increases the specific filtration resistance.

The sludge in all the blocks, irrespective of the collection season, belongs to non-filtered and requires a pretreatment for an efficient dewatering.

The most widespread sludge treatment method abroad mastered in the experimental-industrial conditions at some Russian stations is its mechanical dewatering with a pre-conditioning using different reagents, such as flocculants or lime [1, 11-19]. The use of fillers allows to decrease the pressurized pore deformation during filtration and the filter cake layer growth on the filter baffle [19].

To study the reagent treatment influence on the water yielding capacity of sludge we used Besfloc polyacrylamide (hereinafter referred to as PAA)-based cation flocculant with the 0.1 % working solution concentration. When the sludge was treated with lime, we used lime milk with the active part concentration of 50 g/L (by CaO). The studies were carried out at a vacuum filtration unit according to the procedure described in [11-12]. The results of the sludge conditioning with lime are presented in figure 3.

The studies have shown that lime introduced in the sludge exercises a dual function: as a chemical agent partially dissolving gel-like aluminum hydroxide and as a filler decreasing the compression index value. This set of actions leads to an improvement of the sludge filtering properties [20]. From out the doses taken, the 20 % DS lime dose turned to be most efficient for the sludge of all the blocks. At such treatment conditions the specific sludge filtration resistance decreased to the level below $500 \cdot 10^{10}$ m/kg, the conditioned sludge belongs to well-filtrated and can be directed for further mechanical treatment. On the other hand, for the sludge of blocks # 2 and # 3 at the 15 % DS lime dose the specific resistance also decreased to the required value, and for block # 1 this dose turned to be inefficient. The sludge of block # 1 is formed in double-deck settling basins, where there apparently appear conditions for its additional structuring and growth of the water adhesion strength. Such technological features create additional difficulties with the treatment of the sludge formed therein.

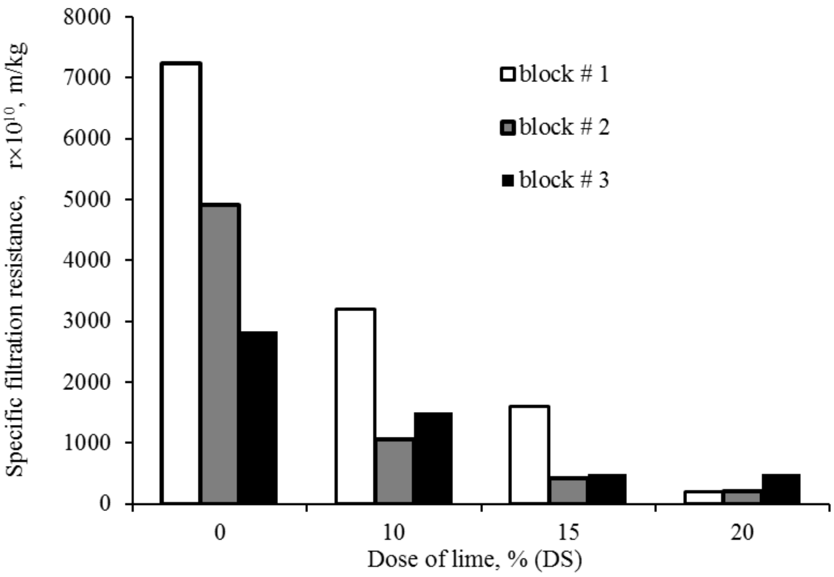

Figure 3. Decrease of the specific filtration resistance depending on the lime dose

At an analysis of the filtrate received at the sludge dewatering in all three blocks, it has been established that the calcium ion concentration therein (from 5 to 15 mg-equ/L) and the pH value (from 8.5 to 10.5) correspond to the analogous values of the alkalifying agent used at water-supply network treatment facilities. The low filtrate turbidity not exceeding 2.5 mg/L allows to use it as a recoverable material.

At the sludge treatment with PAA-based flocculant and a joint use of the flocculant and vermiculite a considerable increase of the water yielding capacity was registered. The PAA doses were varied from 0.1 to 1 %, the vermiculite doses – from 1 to 3 %. Figure 4 shows the specific sludge filtration resistance values at optimum doses of reagents.

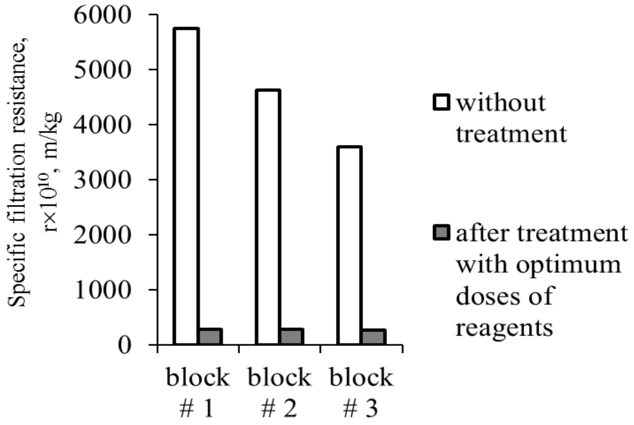

Figure 4. Decrease of the specific sludge filtration resistance after reagent treatment: block # 1 – 0.5 % PAA and 2 % vermiculite; block # 2 – 0.5 % PAA; block # 3 – 0.3 % PAA

The introduction of the flocculant leads to a noticeable discharge of free water from the sludge, a growing viscosity and an increasing inhomogeneity. At the flocculant dose of 1 % and more the viscosity considerably influences the change of the filtrate volume when the specific filtration resistance is determined. The flocculant increases the filtrate transparence: when the sludge was treated with the flocculant (1 %), the filtrate turbidity was decreased from 10.8 mg/L (untreated sludge filtrate) to 0.8 mg/L. The efficiency of the sludge conditioning with the polyacrylamide-based flocculant and the joint treatment with the flocculant and vermiculite can be evaluated by the change of the straight line slope angle in coordinates t/V=f (V), where t – filtration time, V – filtrate volume (figure 5). At an increase of the flocculant concentration from 0.2 to 0.5 % the specific filtration resistance is decreased, and at the 0.5 % concentration it reaches the values admissible for mechanical treatment.

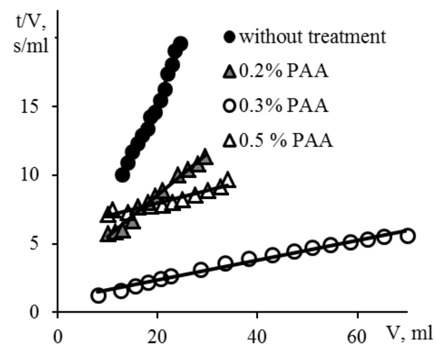

Figure 5. Diagram of building parameter B of the sludge treated by polyacrylamide (% DS PAA)

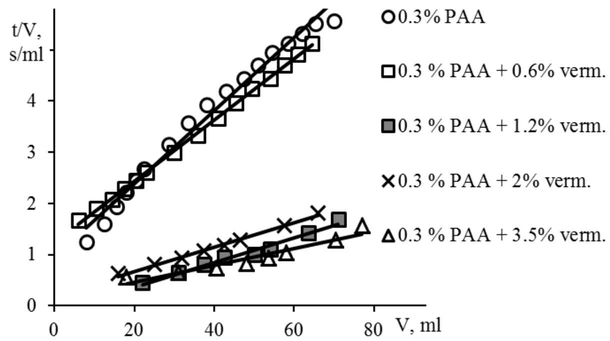

Figure 6. Diagram of building parameter B of the sludge treated by flocculant (% DS PAA) jointly withм (% DS vermiculite)

The sludge treated by flocculant (0.3 %) and vermiculite (0.6 %) is close by the water yield to the sludge treated only by the flocculant (figure 6). The joint sludge treatment with flocculant and vermiculite with the concentration of 1.2 – 3.5 % allows to intensify the water yield of sludge, to decrease the specific filtration resistance in 3 – 4 times as compared to the sludge treated only with flocculant or at a low vermiculite content (0.6 %). The optimum vermiculite dose comprises 1.2 %, its further increase leads to a growth of the specific filtration resistance values.

3. Conclusion

Seasonal changes of the water quality in the surface water source and sludge formation conditions influence its water yielding capacity. Reagent sludge treatment with lime or flocculant with vermiculite filler in optimum doses allows to receive admissible values of the specific sludge filtration

IOP Conf. Series: Materials Science and Engineering **262** (2017) 012221 doi:10.1088/1757-899X/262/1/012221

resistance for its mechanical dewatering. The filtrate formed at the conditioned sludge dewatering can be used as a recoverable material, thus cutting the costs for the acquisition of reagents at water-supply network treatment facilities.

Acknowledgment
The work was supported by Act 211 Government of the Russian Federation, contract № 02.A03.21.0011.

References

[1] Lyubarsky V 1980 *Waterworks Sludge and its Treatment Methods* (Moscow: Stroyizdat) p 129
[2] Babatunde A and Zhao Y 2007 *Crit. Rev. Environ. Sci. Technol.* **37** pp 129–64
[3] Wichmann K and Riehl A 1997 *Wat. Sci. Tech.* **36** pp 43–50
[4] Verrelli D, Dixon D and Scales P 2009 *Colloids and Surfaces A: Physicochem. Eng. Aspects* **348** pp 14–23
[5] Volik Yu, Ternovskaya O and Shevchenko L 1986 *Basic Development Lines of Water Supply, Natural Water Treatment and Sludge Treatment* (Kiev) pp 136–40
[6] Butko B and Lysov V 2010 *Water Supply and Sanitary Engineering* **7** pp 51–4
[7] *Process Regulations for Chelyabinsk Water-Supply Network Treatment Facilities* 2014
[8] Nikolaenko E and Belkanova M 2016 *2th Int Conf on Industrial Engineering* vol 150, ed A A Radionov (Elsevier) pp 2315–20
[9] Nikolaenko E and Belkanova M 2016 *Water Saving, Melioration and Hydrotechnical Facilities as a Basis for Agricultural Clusters Formation in Russia in the XXI Century (Tyumen)* vol 1 (Tyumen: Tyumen State Architecture and Construction University) pp 122–5
[10] Babenkov E 1977 *Coagulant Water Treatment* (Moscow: Nauka) p 356
[11] DEGREMONT 2007 *Technical Water Treatment Handbook* (St.-Petersburg: New Journal) p 1696
[12] Turovsky I 2008 *Wasterwater Sludge. Dewatering and Disinfection* (Moscow: DeLi Print) p 376
[13] Babaev A, Podkovyrov V, Domozhakov D, Arutyunova I and Yagunkov S 2010 *Water Supply and Sanitary Engineering* **10-1** pp 20–26
[14] Podkovyrov V, Zvyagin K, Dmitrieva Yu, Arutyunova I and Yagunkov S C 2011 *Water Supply and Sanitary Engineering* **3** pp 37–43
[15] Kuznetsov V 2015 *Water Supply and Sanitary Engineering* **11** pp 28–33
[16] Nikolaenko E, Belkanova M and Repnikov N 2016 *Prospects of the Construction Complex Development (Astrakhan)* vol 1 (Astrakhan: Astrakhan State Architecture and Construction University) pp 80–6
[17] Yasin E 2010 *Environmental Approval* **5** pp 3–45
[18] Sokolov L, Lebedeva E and Pavlikov D 2010 *Ecology and Industry of Russia* **6** pp 24–7
[19] Zhao Y 2002 *Colloids and Surfaces A: Physicochem. Eng. Aspects* **211** pp 205–12
[20] Draginsky V 2000 *Guidelines on the Compliance with SanPiN 2.1.4.559-96 at Water Stations During Natural Water Treatment* (Moscow: Russian State Committee for Construction) p 78