WASTEWATER SLUDGE CONDITIONING WITH FLOCCULANT-NACL-STRAW TO IMPROVE SLUDGE DEWATERABILITY

ORIGINAL SCIENTIFIC PAPER

Adina Ćosić[1]✉, Franc Andrejaš[1], Mugdin Imamović[2], Amina Kadirić[2]

DOI: 10.5281/zenodo.5520686

RECEIVED 2021-07-08 **ACCEPTED** 2021-08-30

[1] University of Tuzla, Faculty of Technology, Urfeta Vejzagića 8, 75000 Tuzla, Bosnia and Herzegovina
[2] Fabrika Cementa Lukavac d.d., Lukavačkih brigada bb, 75300 Lukavac, Bosnia and Herzegovina
✉ cosicadinaa@gmail.com

ABSTRACT:
One of the major improvement points in wastewater treatment processes is sludge treatment. The effectiveness of existing sludge treatment processes is highly limited due to poor dewaterability and compressibility of sludge. In this paper, a new sludge conditioning method was studied. The results show that combining NaCl and straw powder with commercial flocculant significantly improves sludge dewaterability and reduces moisture content, while increasing heat value. Adding NaCl in 0.25M dosage and 50% straw powder (dried and sieved to 0.125 – 0.063 µm) resulted in significant reduction of specific resistance to filtration and sludge moisture content. The results also suggest that it would be possible to partially substitute the flocculant with less expensive conditioners, which could potentially reduce the cost of sludge dewatering.

KEYWORDS: wastewater, flocculants, sludge

INTRODUCTION

Sludge is an inevitable by-product produced as a result of wastewater treatment processes. On average, sludge takes up around only 1% of treated water [1]. However, sludge management can take up to 60% of total operating costs of the wastewater treatment plant[2]. The high cost of sludge treatment is mainly due to its high water content (>92) and poor dewaterability[3].

For the purpose of sludge dewatering, chemicals such as calcium oxide, iron chloride, aluminum chloride and polyacrylamide are used[4]. However, these chemicals are expensive and reducing the need for these chemicals is economically important.

The aforementioned chemicals significantly reduce the moisture content of sludge and specific restistance to filtration (SRF) by forming larger flocs. However, a lot of the moisture is bound inside the sludge flocs. Thus, disintegrating the flocs before conditioning is key to enhancing sludge dewaterability[5]. It is understood that NaCl sludge condititoning is a cost-effective method of improving sludge dewaterability, with the reported optimal NaCl dosage of 0.25-0.30 mol/l[6, 7]. Furthermore, to improve sludge filter cake compressibility and mechanical strength some physical aids can be used. Zhu et al. reported using rice husk powders as physical conditioner, which lowered the moisture content of sludge filter cake to 62.50% [4]. Using physical conditioners can also increase the heat value of treated sludge, which is important for further sludge treatment i.e. incineration. Many physical conditioners such as lime, gypsum, fly ash and rice husk have been used as physical aids [8, 9, 10, 4]. However, currently there are no reports on using straw as a physical conditioner in sludge treatment.

The objective of this paper is to research the effect of straw powders on sludge dewaterability as well as researching the possibility of lowering the needed dosage of commercial flocculant by introducing alternative conditioners.

MATERIALS AND METHODS

Sewage sludge sample was collected from a local wastewater treatment plant in Živinice, Bosnia&Herzegovina. Raw sludge was stored at 4ºC and restored to room temperature before tests. The pH value of raw sludge was 7.16 with an initial moisture content of 94.50%.

NaCl was purchased as an analytical reagent. The flocculant was kindly donated by the wastewater treatment plant in Živinice. The flocculant solution (10 g/l) was prepared and mixed on a jar test apparatus 5 minutes at 80 r/min immediately before tests. Straw was collected from a local dairy cow farm. Prior to the tests, the straw was dried at 105°C, ground in a ball mill and sieved to 0.125 – 0.063 μm. Sludge filtration was conducted using a vacuum pump with a Buchner funnel at 600 mm Hg pressure.

SLUDGE CONDITIONING AND DEWATERING

The samples were as follows:

- Sample 1: Flocculant (10 g/l)
- Sample 2: Flocculant (10 g/l)+ NaCl (0.25M)
- Sample 3: Flocculant (10 g/l) + NaCl (0.25M) + straw (50%)
- Sample 4: Flocculant (10 g/l) + straw (50%).

All chemicals and physical aids were added to 300 ml of sludge in a 800 ml beaker. The prepared flocculant solution was added to the sludge (Sample 1) and mixed on a jar test apparatus for 60 s at 250 r/min, then 5 min at 80 r/min.

The samples containing NaCl (Sample 2 and Sample 3) were mixed for 120 mins at 80 r/min prior to adding the flocculant solution. In case of Sample 3, 50% wheat straw powder was added with NaCl and thus mixed for 120 mins at 80 r/min prior to adding the flocculant solution. After adding the flocculant, samples containing NaCl and NaCl+wheat straw powder were mixed for 60 s at 250 r/min, then 5 min at 80 r/min.

Sample 4 was prepared as follows: 50% straw powder was added to 300 ml sudge in a 800 ml beaker and mixed for 120 mins at 80 r/min. Then, the flocculant solution was added and the sludge was mixed for 60 s at 250 r/min, then 5 min at 80 r/min.

100 ml of each sample was filtered after mixing in a Buchner funnel with blue ribbon filter paper. The filtrate volume was recorded every 30 s for 4 min. Then, time to filter (TTF) was recorded as the time needed to collect 50 ml of filtrate.

ANALYTICAL METHODS

The effectiveness of sludge conditioning was measured in terms of moisture content, specific resistance to filtration (SRF) and net solids yield (Yn). Moisture content of sludge filter cake as well as moisture content of conditioned sludge before filtration was determined on a KERN moisture analyser.

The SRF of sludge was determined using the methods described by Coakley and Jones [11]. SRF is calculated by Eq (1),

$$SRF = 2\ \frac{pA2b}{\mu c} \qquad (1)$$

where p is pressure (g/cm$^{2)}$, A is filtration area (cm^2), b is the slope calculated from the plot t/V vs. V (s/cm^6), μ is filtrate viscosity (P) and c is solids content (g/ml).

The Yn of sludge was calculated as described by Rehbun et al. [12]. Yn was calculated by Eq (2),

$$Yn = F\ \left(2\frac{pc}{\mu tSRF}\right)^{1/2} \qquad (2)$$

where p is pressure (g/cm^3), c is solids content (g/ml), μ is filtrate viscosity (P), SRF is calculated from Eq. (1) and F is a correctional factor calculated from Eq. (3),

$$F = \frac{SS\ original}{SS\ original + SS\ conditioner} \qquad (3)$$

where $SS_{original}$ is the original sludge solids (g/l) and $SS_{conditioner}$ is the conditioner solids (g/l).

Heat value and chloride and mercury contents of samples were also determined on an IKA calorimeter and Metronohm titrator.

RESULTS AND DISCUSSION

Sewage sludge was conditioned by single and combined processes described in section 2. and were as follows: flocculant conditioning with flocculant dosage of 10 g/l and 6 min total reaction time; flocculant-NaCl conditioning with a dosage of 10 g/l flocculant and 0.25M NaCl and 126 min reaction time total; flocculant-NaCl-straw powder conditioning with a dosage of 10 g/l flocculant, 0.25M NaCl and 50% powder straw (0.125 – 0.063 μm) and reaction time 126 min total; flocculant-straw powder conditioning with a dosage of 10 g/l flocculant and 50% powder straw (0.125 – 0.063 μm) with a reaction time of 126 min total.

The effectiveness of different conditioning methods in terms of SRF and moisture content is shown in Table 1, Figure 1. and Figure 2. shows the change of Yn with different conditioners. The SRF of raw sludge was 5.34 x 10^{10} s^2/g with a moisture content of 94.50%. Adding the flocculant decreased the SRF of sludge significantly to 3.59 x 10^{10} s^2/g, the moisture content dropped to 86.21% and the Yn was 7.49x10^{-4} g/cm^{2}s. The flocculant-NaCl sample displayed a further decreased SRF of 3.14 x 10^{10} s^2/g, 84.91% moisture content and the Yn increased to 3.63 x 10^{-3} g/cm^{2}s. In the flocculant-NaCl-straw powder conditioned sample the SRF was further reduced to 2.43 x 10^{10} s^2/g, the moisture content dropped to 79.87% and Yn further increased to 2.16 x 10^{-3} g/cm^{2}s. In the flocculant-straw powder conditioned sample the SRF was 2.73 x 10^{10} s^2/g, 83.78% moisture content and the Yn was 2.18 x 10^{-3} g/cm^{2}s.

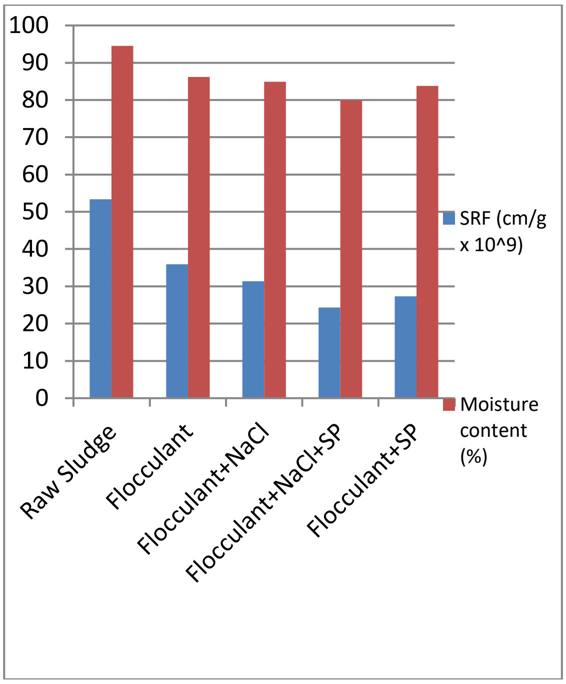

Fig 1. Effectiveness of different conditioning methods on SRF and moisture content of sludge

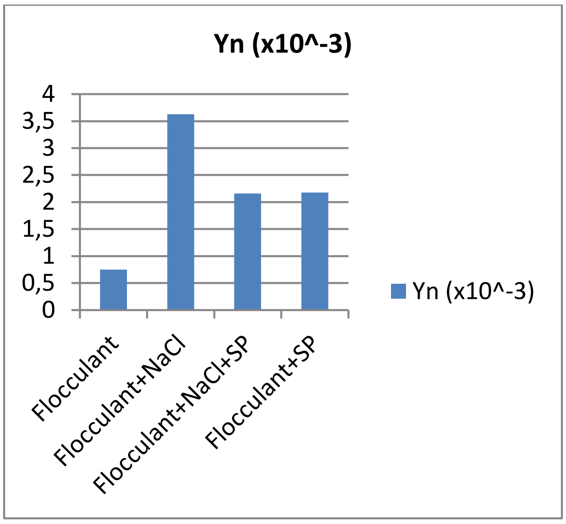

Fig 2. Effect of different conditioners on Yn of sludge.

Heat value of sludge samples conditioned with different conditioners was also considered. Heat values are presented in Table 2. Chloride and mercury contents in all samples were <0.1 and <0.54 respectively, meeting the requirements for incineration.

Table 1. SRF, Yn and moisture content of conditioned sludge

Sample	SRF ($x10^{10}$ s^2/g)	Yn ($x10^{-3}$ g/cm^2s)	Moisture content (%)
1. Flocculant	35.90	0.75	86.21
2. Flocculant + NaCl	31.40	3.63	84.91
3. Flocculant + NaCl + SP	24.30	2.16	79.87
4. Flocculant + SP	27.30	2.18	83.78

Table 2. Heat values of conditioned sludge.

Sample	Heat Value (MJ/kg)	Mercury (mg/kg)	Chlorine (%)
1. Flocculant	15.32	0.54	<0.1
2. Flocculant + NaCl	13.92	<0.54	<0.1
3. Flocculant + NaCl + SP	13.95	<0.54	<0.1
4. Flocculant + SP	16.12	<0.54	<0.1

CONCLUSION

In this paper, different sludge conditioning methods were studied in order to improve sludge dewaterability and lower the moisture content of sludge using alternative conditioners.

The highest SRF and moisture content reduction occured in the Flocculant+NaCl+SP conditioned sample, where SRF was 2.43 x 10^{10} s^2/g and moisture content was 79.87%. Yn was best in the Flocculant+NaCl conditioned sample, at 3.63 x 10^{-3}

g/cm^2s. Heat value was best in the Flocculant+SP conditioned sample, at 16.12 MJ/kg.

SRF, moisture content and Yn of sludge were significantly improved by combining different conditioners, compared to the sample conditioned only with flocculant. This suggests that combined conditioning highly benefits sludge dewaterability. Furthemore, it would also be possible to reduce the amount of flocculant needed by adding alternative conditioners.

REFERENCES

[1] Gurjar, B.R., Tyagi, V.K. (2017) Sludge Management, Taylor & Francis Group, London, UK, CPI Group (UK) Ltd, Croydon, CR0 4YY

[2] Foladori, P., Andreottola, G., Ziglio, G. (2007) Sludge reduction Technologies in Wastewater Treatment Plants, IWA Publishing Alliance House 12 Caxton Street London SW1H 0QS, UK

[3] Parkin, G. F., Owen, W. F. (1986) “Fundamentals of Anaerobic Digestion of Wastewater Sludges.” Journal of Environmental Engineering, ASCE, vol. 112, no. 5, pp. 867–920.

[4] Zhu, C., Li, F., Zuang, P., Ye, J., Lu, P., Wang, H. Combined sludge conditioning with NaCl-cationic polyacrylamide-rice husk powders to improve sludge dewaterability, Powder Technology 336 (2018) 191-198.

[5] Mowla, D., Tran, H., Allen, D.G., A review of the properties of biosludge and its relevance to enhanced dewatering processes, Biomas Bioenergy 58 (2013) 365-378.

[6] Raynaud, M., Vaxelaire, J., Olivier, E., Dieude-Faucel, E., Baudez, J.-C., Compression dewatering of municipal activated sludfge: effects of salt and pH, Water Res 46 (2011) 4448-4459

[7] Cui, Y., Su, H., Chen, Y., Chen, Y., Peng, Y., Mechanism of activated sludge floc disintegration induced by excess addition of NaCl, CLEAN-Soil, Air, Water 43 (2015) 1197-1206.

[8] Zall, J., Galil, N., Rehbun, Skeleton builders for conditioning oily sludge, J. (Water Pollution Control Federation) (1987)699-706.

[9] Zhao, Y. Enhancment of alum sludge dewatering capacity by using gypsum as skeleton builder, Colloids Surf., A Physiochem. Eng. Asp. 211 (2002) 205-212.

[10] Chen, C., Zhang, P., Zeng, G., Deng, J., Zhou, Y., Lu, H., Sewage sludge conditioning with coal fly ash modified by sulfuric acid, Chem. Eng. J. 158 (2010) 616-622.

[11] Coakley, P., Jones, B.R.S., Vacuum Sludge Filtration: I. Interpretation of Results by the Concept of Specific Resistance, Sewage and Industrial Wastes, Vol. 28, No. 8 (1956), pp. 963-976.

[12] Rehbun, M., Zall, J., Galil, N., Net Sludge Solids Yield as an Expression of Filterability for Conditioner Optimization, Journal (Water Pollution Control Federation), Vol. 61, No. 1 (1989), pp. 52-54...