# Conditioning of waste sludge from biological wastewater treatment plant from gikil

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ISSN 2712-1267 UDC: 628.3.034.2:628.336.3 https://doi.org/10.7251/JCTE2203033Z Original scientific paper

Paper received: 21 Oct 2022 Paper accepted: 21 Dec 2022 Paper available from 30 Dec 2022 at https://glasnik.tf.unibl.org/

Keywords: waste sludge, conditioning, settling, flocculant, specific filtration resistance.

Sludge generated in wastewater treatment processes must be treated in an adequate manner, and therefore disposed of in an environmentally friendly manner. The biggest obstacle to the efficient use of sludge is the high water content, therefore the development of methods to accelerate the sludge dewatering process is particularly important. For the purposes of the research, the waste sludge created in the process of purifying ammoniaphenol wastewater in the GIKIL factory was used. Sludge conditioning was performed by adding a commercial flocculant (0.1 % solution) in combination with pyrophyllite, kaolin clay and shredded cardboard. According to earlier research, the volume of waste sludge with the addition of a suitable flocculant could be reduced by more than 5 times compared to the initial amount, leaving behind a large amount of separated water that can be returned to the process. The results show that the addition of commercial flocculant in the amount of 0.8 % gives the best results (reduction of sludge volume by 78.8 %). A lower percentage was found in samples with a mixture of flocculants with pyrophyllite (78 %) and kaolin (77.6 %), while the combination of flocculants with waste cardboard was ineffective (64.4 %). Addition of flocculant to waste sludge resulted in a decrease in specific filtration resistance (1.15x10<sup>7</sup> s<sup>2</sup>/g). A decrease in specific resistance was also observed in flocculant/kaolin clay (0.8x10<sup>7</sup> s<sup>2</sup>/g) and flocculant/cardboard (1.09x10<sup>7</sup> s<sup>2</sup>/g) samples. Sludge conditioning also resulted in a reduction of suspended solids in the neonate compared to settled raw sludge without additives.

### INTRODUCTION

In addition to purified water, waste sludge also appears in wastewater treatment devices. The efficiency of each device is evaluated by the quality of the purified water, but also by the efficiency of the sludge treatment that is separated in the purification process (Chen et al., 2010; Kuglarz et al., 2008). Increasing the level of wastewater treatment increases the amount of separated sludge, and its processing and permanent removal is the main problem in wastewater treatment devices (Feng et al., 2009). Although the sludge produced during wastewater treatment is a by-product, it is not useless. A number of sludge treatment technologies are well developed, but many of them are still under development (Lee & Liu, 2000). Since the biggest obstacle to the efficient use of waste sludge is the high water content, the development of methods for improving the sludge dewatering process is particularly important (Bien et al., 2021).

The sludge produced in the process of ammonia-phenol wastewater purification in the GIKIL (Global Ispat Koksna Industrija Lukavac) factory is characterized as hazardous waste and needs to be specially processed in order to turn it into an inert waste material. Several different methods of waste sludge processing are known, such as dehydration, aerobic and anaerobic stabilization, thickening, thermal decomposition, etc., and the products of such treatments that are obtained can be used as a source of energy, as fertilizer for land reclamation purposes, but stabilized waste sludge can also be disposed of as non-hazardous waste at the communal waste dump (Foladori et al., 2007).

When it comes to the sludge from the ammonia-phenol waste water treatment plant at the GIKIL factory, the content of organic matter (nitrogen and phosphorus) is present in high concentrations, and according to previous research, the sludge from GIKIL waste water treatment plant is not burdened with heavy metals. However, the presence of microorganisms in the sludge, as well as the presence of phenol, ammonia, thiocyanate and cyanide, is an obstacle to the use of sludge without prior treatment (Tomar et al., 2022). An additional difficulty is that large amounts of waste

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sludge with an extremely low content of dry matter are generated daily. In order to reduce the amount of waste material generated in this way and to achieve the inertness of this type of waste, it is necessary to apply methods of physical and chemical conditioning (Benitez et al., 1994). Sludge conditioning is a preparatory process used to thicken solids and separate water.

In this work, conditioning methods using certain minerals and chemical compounds that will speed up the process of coagulation of solids and release of absorbed water were examined, and the procedure of mechanical separation of the remaining liquid phase was carried out.

# MATERIALS AND METHODS

# **Experiment setup**

For the purposes of the research, waste sludge from a wastewater treatment plant with a capacity of  $50 \text{ m}^3/\text{h}$  installed in the coke industry GIKIL, Lukavac, Bosnia and Herzegovina was used. Sludge was collected from the pool intended for the disposal of excess sludge. In order to ensure the necessary test conditions, the raw sludge was stored at a temperature of 4 °C and it was warmed to room temperature before testing.

For sludge conditioning, flocculant, pyrophyllite slate, kaolin clay and waste cardboard were added. The flocculant was donated from the Živinice wastewater treatment plant (Bosnia and Herzegovina). A solution of flocculant (PE) with a concentration of 1 g/L was prepared and mixed on the Jar test apparatus for a period of 10 minutes at 100 rpm immediately before the test. Mechanically crushed pyrophyllite shale (PF) was obtained from the deposit "Parsovići" Konjic (Bosnia and Herzegovina). The pyrophyllite shale was sieved to a granulation of 0-100  $\mu$ m. Kaolin clay (KC) was purchased as an analytical reagent. The collected waste cardboard (CB) was dried at 105 °C and then ground in a ball mill. The mixing of waste sludge with chemical additives was carried out on the Jar - test apparatus for a certain period of time (Figure 1.). Sludge filtration was carried out using a vacuum pump with a Buchner funnel, while the pressure change was monitored. Sludge sedimentation was carried out in measuring vessels with a volume of 250 mL.

All of the formed samples (Table 1.) contained the same volume of waste sludge (350 mL). The waste sludge was transferred into 600 mL glasses. The initial sample (S0) without added chemicals and physical additives was used as a blank sample. The prepared flocculant solution was added to the sludge (sample S1) and the sample was mixed on a Jar test for 60 sec at 250 rpm, then 10 min at 100 rpm. Samples to which solid additives were added, i.e., samples containing



Figure 1. Mixing of waste sludge samples with added chemicals

Table 1. Formed sludge samples with reagent addition

Sample designation	Waste sluge volume (mL)	PE (mL)	PF (g)	KC (g)	CB (g)
SO	350	-	-	-	-
S1	350	2	-	-	-
S2	350	2	2.5	-	-
S3	350	2	-	2	-
S4	350	2	-	-	2
S5	350	2	2.5	2	-
\$6	350	2	2.5	-	2
S7	350	2	-	2	2

pyrophyllite, kaolin clay and cardboard were mixed for 30 minutes at 100 rpm before adding the flocculant solution. After adding the flocculant, the samples were mixed for 60 s at 250 rpm, then for another 10 min at 100 rpm. After mixing the samples, 100 mL of each sample was filtered in a Buchner funnel with blue strip filter paper. The filtrate volume was recorded every 30 sec. The time required to collect 50 mL of filtrate was recorded. The remaining amount of mixed samples was transferred into measuring cylinders of 250 mL, and the height of the settled sludge was recorded after 5, 10, 60 and 120 minutes.

# **Analytical methods**

The efficiency of sludge conditioning was measured by determining the specific resistance to filtration (SRF). In order to determine the SRF, filtrate volume, filtration time, filtration pressure, filter surface, density of the initial sample and filtrate, and the moisture content of the filter cake, as well as the moisture content of the conditioned samples before filtration, were measured.

Experimentally, determination of specific filtration resistance was done by using Buchner's vacuum apparatus (Figure 2.) and calculated according to relation (1) (Benitez et al., 1994; Rebhun et al., 2016).

$$SRF = 2\frac{PA^2b}{\mu c} \tag{1}$$

where *P* is the pressure (g/cm<sup>2</sup>), *A* is the surface of the filter (cm<sup>2</sup>), *b* is the slope of the *t*/V curve vs. V (s/cm<sup>6</sup>),  $\mu$  is the viscosity of the filtrate (g/cms)) and *c* is the concentration of dry matter remaining on the filter per unit volume of the filtrate (g/cm<sup>3</sup>).



Figure 2. Scheme of vacuum filtration process in laboratory conditions (Wojcik et al., 2017)

As the main objective of sludge conditioning is to improve yield, it is preferable to express filterability as yield (Yn). The specific filtration resistance is mathematically directly related to the yield of dry matter. Sludge yield Yn was calculated according to the relation described by Rebhun (2016). Yn is calculated according to relation (2).

$$Yn = F\left[\frac{2Pc}{\mu tSRF}\right] \tag{2}$$

where *P* is the pressure (g/cm<sup>2</sup>), *c* is the concentration of dry matter (g/cm<sup>3</sup>),  $\mu$  is the viscosity of the filtrate (g/cms), *SRF* is the specific resistance to filtration (s<sup>2</sup>/g) and *F* is the correction factor calculated according to relation (3).

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

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

# **RESULTS AND DISCUSSION**

Waste sludge from the plant for the biological treatment of ammonia-phenol wastewater was conditioned

individually and by combined processes described in the chapter Materials and Methods. Raw waste sludge was used as a blank sample, sludge conditioned with the addition of flocculant in the amount of 2 mL of 0.1 % flocculant solution had a total reaction time of 11 minutes, while the other prepared samples (shown in Table 1.) with or without the addition of flocculant and with the addition of pyrophyllite, kaolin clay and cardboard had a total reaction time of 41 minutes. The effectiveness of different conditioning methods in terms of SRF, dry matter content, and yield are shown in Table 2. The change in SRF and Yn using different sludge conditioners are shown in Figures 3 and 4.

Table 2. The SRF, Yn and dry matter content of conditioned sludge

Sample designation	SRF (x10 <sup>7</sup> s <sup>2</sup> /g)	Yn (x10 <sup>-2</sup> g/cm <sup>2</sup> s)	Solids content %
SO	2.21	1.23	0.67
S1	1.15	2.35	0.97
S2	2.40	1.12	1.50
S3	0.80	3.28	0.70
S4	1.09	2.35	0.95
S5	1.95	1.38	1.73
\$6	2.18	1.20	1.27
S7	2.83	0.953	1.86



Figure 3. Effect of different conditioning methods on sludge SRF



Figure 4. Effect of different conditioners on Yn sludge

The SRF of the raw sludge was  $2.21 \times 10^7 \text{ s}^2/\text{g}$  with a dry matter content of 0.67 %. Adding flocculant (S1) significantly reduced the SRF value to 1.15x10<sup>7</sup> s<sup>2</sup>/g, and the dry matter content increased to 0.97 %, while the yield value also increased to  $2.35 \times 10^{-2}$  g/cm<sup>2</sup>s. The combination of flocculant and kaolin clay showed an additional decrease in the SRF value of the sludge to 0.8x10<sup>7</sup> s<sup>2</sup>/g, and Yn was 3.28x10<sup>-2</sup> g/cm<sup>2</sup>s. Sample S4 showed a decrease in SRF to a value of  $1.09 \times 10^7 \, \text{s}^2/\text{g}$ , with a dry matter content of 0.95 % and Yn amounting to 2.35x10<sup>-2</sup> g/cm<sup>2</sup>s. Samples S5 (SRF=1.95x10<sup>7</sup> s<sup>2</sup>/g) and S6 (SRF=2.18x10<sup>7</sup> s<sup>2</sup>/g) had lower SRF compared to the untreated raw sludge sample. The value of Yn for sample S5 was slightly higher (1.38x10<sup>-2</sup> g/cm<sup>2</sup>s), while for sample S6 it was lower compared to S0, and was 1.20x10<sup>-2</sup> g/cm<sup>2</sup>s. Higher SRF values were observed in samples S2 and S7 and were  $2.40 \times 10^7 \text{ s}^2/\text{g}$ and 2.83x10<sup>7</sup>s<sup>2</sup>/g, retrospectively, while the values for Yn were significantly lower (S2=1.12x10<sup>-2</sup> g/cm<sup>2</sup>s and S7=0.953x10<sup>-2</sup> g/cm<sup>2</sup>s) are compared to the values obtained for untreated raw sludge.

The remaining amount of sludge was subjected to the sludge settling process in measuring cylinders with a volume of 250 mL. The height of the formed precipitate after 5, 10, 60 and 120 minutes was recorded. The obtained results are shown in table 3. After separating the liquid and solid phases, obtained by conditioning the sludge, the determination of suspended matter (SM) in the neonate was started. The results obtained from this analysis are shown in table 4. In sample SO, the smallest amount of precipitate was recorded (44 mL), while the content of suspended substances remaining in the neonate was 530 mg/L. The best results were obtained in sample S1, where the sediment height was 53 mL, and the content of suspended matter was 58 mg/L. The approximate height of the precipitate was also recorded in samples S2 (55 mL) and S3 (56 mL), but in these samples the SM content increased (94 mg/L and 168 mg/L, retrospectively) compared to sample S1 (58 mg/L).

## CONCLUSION

In this paper, different methods of conditioning waste sludge using alternative conditioners were examined with the aim of improving the filtration and dewatering process. The greatest reduction in SRF and the greatest increase in yield was observed in sample S3, i.e. with the combination of flocculant and kaolin clay, where SRF was  $0.8 \times 10^7 \text{ s}^2/\text{g}$  and Yn  $3.28 \times 10^{-2} \text{ g/cm}^2\text{s}$ . Also, a significant decrease in SRF occurred in sample S1 ( $1.15 \times 10^7 \text{ s}^2/\text{g}$ ) and S4 ( $1.09 \times 10^7 \text{ s}^2/\text{g}$ ), and the value of Yn was the same for both tested samples and amounted to  $2.35 \times 10^{-2} \text{ g/cm}^2\text{s}$ . The SRF and Yn of the sludge as well as the dry matter content of the filtered sludge were improved by the

Table 3. Height of sediment in a certain time interval				
Sample designation	Time (min) /Sediment height (mL)			
	5 min	10 min	5 min	120 min
SO	86	74	50	44
S1	104	82	56	53
S2	106	84	57	55
S3	162	112	66	56
S4	160	130	92	89
S5	188	148	76	62
S6	130	120	84	82
S7	178	130	84	74

Table 4. Values of SM in neonates of conditioned/settled waste sludge

Sample designation	SM (mg/L)		
SO	530		
S1	58		
S2	94		
S3	168		
S4	108		
S5	184		
	154		
S7	212		

addition of flocculants. However, much better results were obtained with a combination of flocculants and different conditioners, which indicates that combined sludge conditioning with the addition of flocculants and readily available conditioners provides great benefits in the sludge dewatering process. In this way, the amount of added flocculant could be reduced by adding and using different conditioners. When it comes to sedimentation of sludge with the addition of flocculants and conditioners, the best results were shown by the sample where only flocculants were added, and slightly lower values of sediment height and content of suspended matter were also recorded in cases with a combination of flocculants and other conditioners, which opens up the possibility of further research and determining the optimal amounts of flocculants and conditioners to achieve better results.

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