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AEROBIC DIGESTION OF POST-COAGULATION SLUDGE

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Abstract

An increasingly higher number of water treatment plants (WTP) are currently searching for a technology that would make it possible to disposal post-coagulation sludge produced by water treatment processes. Due to their substantial content of organic compounds, some tests were conducted to see how such sludge can be stabilized in aerobic conditions. Post-coagulation sludge supplied by water treatment plant was tested used. Post-coagulation sludge result from carbon and backwash water of contact filter and the wastewater produced when primary settling tanks are cleaned. The efficacy of the process depended on the properties of sludge and the duration of the process. Post-coagulation sludge by WTP showed a relatively constant percentage of organic matter (39.5% Total Solids – TS). In aerobic digestion the organic matter reduction rate amounted, on average, to 4-22%, depending on the duration of the process. Aerobic digestion conducted in less than 12 days allowed for a small reduction in organic matter (4.0-13.2%). But when the process was extended more than 23 days it ensured the reduction in content of organic compounds by about 18% and allowed to obtain sludge characterized by earthy scent and not showing a tendency to putrefy.

Streszczenie

Obecnie coraz więcej przedsiębiorstw wodociągowych poszukuje technologii pozwalającej na unieszkodliwianie osadów pokoagulacyjnych powstających w procesach oczyszczania wody. Z uwagi na znaczną zawartość w nich związków organicznych przeprowadzono badania ich stabilizacji w warunkach tlenowych. Do badań wykorzystano osady pokoagulacyjne z zakładu produkcji wody (ZPW), powstające w wyniku oczyszczania popłuczyn z filtrów węglowych, filtrów kontaktowych oraz ścieków z czyszczenia osadników. Efektywność stabilizacji zależała od właściwości osadów oraz czasu trwania procesu. Osady pokagulacyjne z ZPW charakteryzowały się w miarę stałym udziałem masy organicznej wynoszącym około 39.5% sm. Podczas stabilizacji tlenowej uzyskiwano redukcję masy organicznej od 4% do 22% w zależności od czasu trwania procesu. Stabilizacja prowadzona w czasie krótszym od 12 dni pozwalała na niewielką redukcję masy organicznej (4.0-13.2%). Natomiast wydłużenie czasu procesu powyżej 23 dni zapewniało obniżenie zawartości związków organicznych o około 18% oraz pozwalało na uzyskanie osadów charakteryzujących się ziemistym zapachem i niewykazujących tendencji do zagniwania.

Keywords: **Post-coagulation sludge; Aerobic digestion; Reduction of volatile solids.**

1. INTRODUCTION

Post-coagulation sludge is generated by the treatment of surface water or backwash water of filter. It has an amorphous or formless structure. The amorphous structure is mainly built of metal hydroxides that are precipitated from the aluminium and iron coagulants used for coagulation. As a result of dissociation and hydrolysis, coagulants that are dosed into water form numerous hydro-complexes, which during association

and adsorption combine with coagulated impurities and flocculate as flocs. The properties of post-coagulation sludge depend on the technology employed and the composition of intake water [1]. Depending on the season of the year, this sludge shows very high hydration levels from 98.7 to 99.8%, and a variable content of organic substances ranging from 45 to 64% TS. When temperatures are high, post-coagulation sludge tends to putrefy, which involves the build-up of unpleasant odours [2]. A vegetable smell that occurs from time to time may suggest a high proportion of phytoplankton in such sludge. This proportion grows significantly when water blooms in the tank [2, 3]. Similar to wastewater treatment plant sludge, this sludge should, therefore, be stabilized to prevent the formation of unpleasant odours and reduce the volume of organic substances [4]. Hence, research is required to find effective ways of stabilizing post-coagulation sludge and determining achievable levels of its disposal.

One of the common methods of stabilization sewage sludge is aerobic digestion. This process is used in case of sludge susceptible to methane fermentation, which contain toxic substances [5-8]. The process involves aerobic biochemical decomposition of organic substances contained in the sludge under conditions of substrate starvation. During the process of aeration oxidation only micro-organic compounds are bio-available. The most of organic compounds (2/3 of it) is embedded in the biomass as a result of metabolic reaction. The remaining 1/3 is converted to final products – mainly CO_2, H_2O, and NH_3. Process of self-oxidation (known as endogenous respiration) begins when the depletion of organic matter [7, 9]. As a result of decrease in the quantity of organic compounds, the sludge becomes odorless.

The purpose of the presented research was to determine to what extent it is reasonably practicable to ensure effective stabilization of post-coagulation sludge during aerobic conditions.

2. METHODOLOGY AND SCOPE OF THE INVESTIGATIONS

The subject of the investigations was the post-coagulation sludge supplied by water treatment plant. Post-coagulation sludge was sampled from the accelerator in which process sewage is treated using aluminium sulphate. This sludge includes carbon and backwash water of contact filter, as well as the sewage resulting from the cleaning of primary settling tanks. The treated sludge is recycled to raw water, and the sludge disposed to the sludge storage tank. Subsequently, the sludge is occasionally dewatered in the belt press installation [10].

Total solids (TS), volatile solids (VS) and capillary suction time (CST) were determined for the tested sludge, both before and after digestion. Analysis was conducted in accordance with the existing standards: PN-EN 12880 [11] and PN-EN 12879 [12]. The CST was measured using a special gauge consisting of two separate components: an acrylic filtration unit with electrodes and a timer. The CST measurement helps to determine how fast liquid is stripped from hydrated sludge based on the operating principle of the capillary suction forces of Whatman filter paper 17 [13]. The lower the CST value, the more easily the tested sludge gives off its water component, thus showing a higher tendency towards dewatering.

The laboratory investigations of aerobic digestion were conducted in reactor with a capacity of 2 dm^3, with aeration system with compressed air. The air was introduced by a porous ceramic diffuser, and also interfere, aeration reactor contents. Aeration intensity was selected so as to maintain the dissolved oxygen concentration above 2 mg O_2/dm^3. Indicator of progress in the stabilization process was the degree of aerobic decomposition of organic substances assessed as loss of organic matter. In any season 4 series of research were conducted. The total duration of the aerobic digestion process in order to systematize the results was divided into periods. Results obtained in less than 11 days assigned to the first period of stabilization, the second period was a time trial from 12 to 23 days, while above 23 days – the third period.

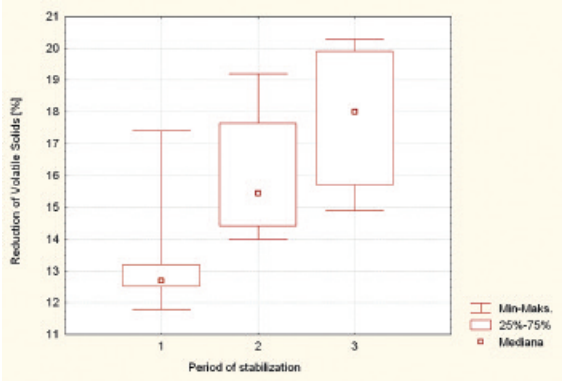

Figure 1.
Reduction of Volatile Solids – winter

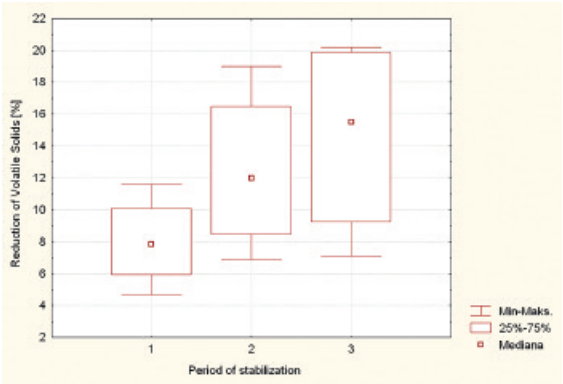

Figure 2.
Reduction of Volatile Solids – spring

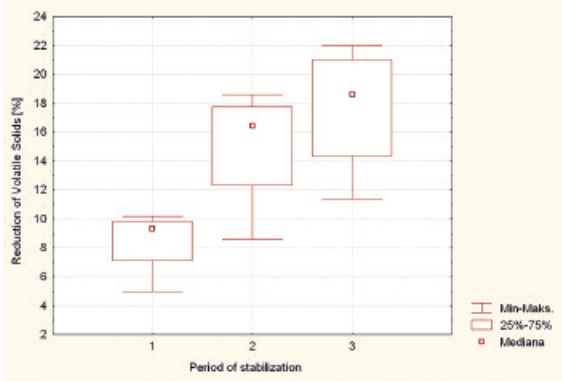

Figure 3.
Reduction of Volatile Solids – summer

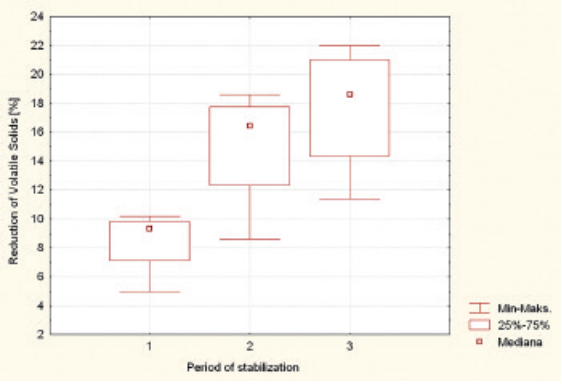

Figure 4.
Reduction of Volatile Solids – autumn

3. DISCUSSION OF INVESTIGATIONS RESULTS

The results obtained for a series of studies conducted during the winter are shown in Table 1. Post-coagulation sludge before stabilization process was characterized by low reactivity of 5.6 - 6.6. The share of volatile solids - VS (defined as loss on ignition) in the post-coagulation sludge was 35.6 - 49.0% TS. During the stabilization process carried out under aerobic conditions in the test sludge obtained a reduction of organic solids (Fig. 1). In the first period a reduction of volatile solids loss from 11.8-17.4% was obtained, while in the second and third period respectively 14.0-19.2% and 14.9-20.3%. It was found that the degree of mineralization was dependent on the duration of the process.

Results from studies conducted in the spring are shown in Table 2. Downloaded post-coagulation sludge characterized by volatile solids content of 34.4-48.7% TS. As a result of biochemical changes in the stabilization process content of organic matter has been reduced. Reduction of volatile solids was obtained from 4.7% in the first period to 20.2% in the third period of stabilization (Fig. 2).

Post-coagulation sludge during the summer was characterized by organic matter ranging from 38.5% to 42.3% TS (Table 3). As a result of biochemical changes occurring during the process, as in previous series of investigations, a reduction in organic matter content was been noted (Fig. 3). The loss of volatile solids ranged from 5% (5th day) to 22% in 40th day process.

The last series of investigations was performed for the aerobic digestion of sludge collected in the autumn (Table 4). Studies post-coagulation sludge was characterized by different contents of volatile solids in the range from 38.3% to 50.4% TS. Stabilization process has allowed for the reduction content of volatile solids in post-coagulation sludge (Fig. 4). Demonstrated that with prolonged aeration time, volatile solids reduction increased from 4%

Table 1.
Setting-up of the results - winter

Months	Period of aerobic digestion	Day of aerobic digestion	pH index	Concentration of oxygen in reactor	Total solids (TS)	Volatile solids (VS)	Reduction of TS	Reduction of VS	CST
		day	pH	[mg O_2 /L]	g/kg	% TS	%	%	seconds
XII	0	0	6.60	-	7.80	49.0	-	-	48
	1	7	7.15	8.0	7.42	45.2	4.5	11.8	53
	2	14	7.45	8.5	7.28	43.8	6.7	16.1	58
	3	30	7.65	8.5	7.16	42.7	8.2	19.5	64
I	0	0	6.38	-	6.43	43.7	-	-	35
	1	7	7.39	8.5	6.08	38.2	5.4	17.4	56
	2	14	7.16	8.0	6.04	37.6	6.1	19.2	61
	3	40	7.03	8.1	6.02	37.2	6.4	20.3	94
II	0	0	5.92	-	8.76	36.0	-	-	40
	1	10	6.54	9.1	8.45	32.5	3.5	12.7	64
	2	21	6.61	11.6	8.42	32.2	3.9	14.0	79
	3	40	6.82	9.6	8.39	31.9	4.2	14.9	84
III	0	0	5.60	-	11.10	35.6	-	-	50
	1	10	6.66	5.8	10.76	32.6	3.1	12.5	62
	2	25	6.92	7.8	10.68	31.9	3.8	14.8	75
	3	45	6.95	7.0	10.62	31.5	4.3	16.5	78

Table 2.
Setting-up of the results –spring

Months	Period of aerobic digestion	Day of aerobic digestion	pH index	Concentration of oxygen in reactor	Total solids (TS)	Volatile solids (VS)	Reduction of TS	Reduction of VS	CST
		day	pH	[mg O_2 /L]	g/kg	% TS	%	%	seconds
III	0	0	6.45	-	14.30	34.4	-	-	60
	1	7	6.65	8.0	14.13	33.2	1.2	4.7	67
	2	14	6.71	8.4	14.08	32.5	1.5	6.9	72
	3	30	6.68	8.8	14.05	32.2	1.7	7.1	75
IV	0	0	6.42	-	5.80	48.7	-	-	25
	1	7	6.56	6.4	5.62	46.2	3.1	7.1	31
	2	14	6.61	7.2	5.57	45.3	4.0	10.0	43
	3	30	6.60	7.6	5.54	44.8	4.5	11.4	61
V	0	0	6.54	-	21.9	44.9	-	-	74
	1	5	6.76	5.2	20.8	41.8	5.0	11.6	78
	2	15	6.46	5.3	20.2	39.4	7.8	19.0	83
	3	40	6.53	5.3	20.1	39.0	8.2	20.2	96
VI	0	0	6.21	-	26.8	39.7	-	-	82
	1	5	6.74	3.9	26.13	37.2	2.5	8.6	75
	2	19	6.34	3.3	25.7	35.6	4.1	14.0	95
	3	40	6.54	4.5	25.3	33.8	5.6	19.6	111

(first period) to 18.8% (third period).

Effectiveness of the stabilization process depended on the characteristics of sludge and the duration of the aeration process. Post-coagulation with water treatment plant was characterized as stable volatile solids (VS) throughout the year. In winter and summer, the average content of volatile solids was about 39.5% of TS. The process of aerobic digestion allowed for the reduction of organic substances, whose average loss in the first period of the process (up to 11 days) amounted to 12.7% in the second (12-23 days) 15.5% and around 18% in the third period (more than 23 days). In spring, the average content of volatile solids in the post-coagulation sludge prior to trial was approximately 42.2% of TS. Due to biochemical changes, sludge showed a decrease in VS

Table 3.
Setting-up of the results – summer

Months	Period of aerobic digestion	Day of aerobic digestion	pH index	Concentration of oxygen in reactor	Total solids (TS)	Volatile solids (VS)	Reduction of TS	Reduction of VS	CST
		day	pH	[mg O_2 /L]	g/kg	% TS	%	%	seconds
VI	0	0	6.46	-	13.10	39.2	-	-	33
	1	7	6.84	4.4	12.70	36.6	3.1	9.5	39
	2	14	6.95	5.6	12.37	34.5	5.6	16.9	45
	3	30	6.98	6.7	12.26	33.5	6.4	20.0	62
VII	0	0	6.57	-	15.10	39.1	-	-	45
	1	5	6.82	3.9	14.60	36.3	3.3	10.2	48
	2	16	7.02	4.2	14.20	33.8	6.0	18.6	50
	3	40	7.12	4.7	14.10	32.6	6.6	22.0	52
VIII	0	0	6.49	-	17.80	38.5	-	-	53
	1	5	6.84	3.4	17.50	37.2	1.7	5.0	62
	2	21	7.00	4.5	17.30	36.2	2.8	8.6	67
	3	40	6.98	4.2	17.15	35.4	3.6	11.4	73
IX	0	0	6.64	-	15.10	36.5	-	-	88
	1	7	6.75	6.4	14.60	34.1	3.3	9.6	95
	2	14	6.82	6.5	14.10	31.8	6.6	18.7	101
	3	35	6.94	7.1	14.08	31.7	6.7	19.1	114

Table 4.
Setting-up of the results – autumn

Months	Period of aerobic digestion	Day of aerobic digestion	pH index	Concentration of oxygen in reactor	Total solids (TS)	Volatile solids (VS)	Reduction of TS	Reduction of VS	CST
		day	pH	[mg O_2 /L]	g/kg	% TS	%	%	seconds
IX	0	0	6.84	-	16.90	50.4	-	-	560
	1	7	6.92	6.5	16.30	48.5	3.6	7.0	612
	2	14	7.15	7.2	15.55	46.0	8.0	17.5	664
	3	35	7.23	7.8	15.50	44.5	8.3	18.8	695
X	0	0	6.53	-	20.40	38.3	-	-	146
	1	7	7.14	6.2	20.10	37.3	1.5	4.0	152
	2	14	7.22	8.8	19.90	36.4	2.5	7.3	155
	3	35	7.29	8.6	19.71	35.5	3.4	10.4	160
XI	0	0	6.74	-	11.50	39.4	-	-	75
	1	7	7.24	9.0	11.20	37.7	2.6	6.8	77
	2	14	7.31	9.4	11.13	37.1	3.2	8.8	81
	3	35	7.53	9.6	11.07	36.8	3.7	10.2	83
XII	0	0	6.56	-	10.70	41.4	-	-	43
	1	5	7.26	9.5	10.54	40.2	1.5	4.3	46
	2	14	7.24	8.4	10.38	39.0	3.0	8.6	48
	3	35	7.22	8.3	10.18	37.5	4.9	13.8	52

content in the different periods of the process – 7.9%, 12% and 15.5%. It was observed that the aerobic digestion process of post-coagulation sludge run in less than 12 days allowed for a small reduction of volatile solids (4-13.2%). Extension of the duration of the process ensured obtaining better results in the decrease of the organic compounds (7.1-22%). Moreover, sludge was characterized by earthy scent and did not show a tendency to putrefy. The highest loss of organic mass amounting to achieved 22% was during the summer after 40 days aeration.

The studies also identified the impact of the aerobic digestion process on sludge filtration properties. It was observed that the sludge after the stabilization process was characterized by worse filter properties. With the increase in aeration time the CTS increased,

an indication of reduced speed in putting water sludge dewatering process and pointed to the dewatering of filtration properties of stabilized sludge.

4. SUMMARY

The growing eutrophication of surface waters deteriorates the quality of treatable water. This requires more powerful treatment processes, which produce relatively large volumes of organic substances. Keeping sludge in drying beds involves putrefaction and the build-up of unpleasant odours. Accordingly, the introduction of sludge stabilization may become a necessity in the future.

The investigations were conducted to identify the potential for the aerobic digestion of post-coagulation sludge in order to obtain sludge with a reduced content of organic substances.

According to the Environmental Protection Agency of the United States stabilization of the degree of reduction depends on the content of organic matter in the stabilization process. According to this criterion, the loss of volatile solids should be at least 38% [14-16]. According to other authors [17-20] reduction in content of organic matter in the sludge during the aerobic digestion rate of 30% is sufficient to fully stabilize sewage sludge. By contrast, according to the stability criterion included in the Polish law [21, 22] municipal sewage sludge is considered to be stabilized if they have undergone treatment processes that reduce tendency to putrefy, they do not emit nuisance odors to the environment and do not endanger your health. Taking into account the results obtained during analyzing the aerobic digestion of post-coagulation sludge from water treatment plant, as well as the criteria showed above, it can be stated that this process is inefficient. Obtained in the process the reduction of organic matter was relatively low (below 30%). However, by adopting the criterion of stability in the Waste Act and the criterion of the European Union, requirement for stabilization of sewage sludge, which reduces the burden caused by the emission of odors, has been reached. In conclusion, the aerobic digestion process prevents putrefy of post-coagulation sludge in tanks storage and ensures that post-coagulation sludge is not burdensome aroma.

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