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USE OF TALC FOR FILAMENTOUS BULKING CONTROL IN EFFLUENT TREATMENT PLANT

ABSTRACT

One of the main existing operational problems in activated sludge effluent treatment processes is the poor sedimentation of the biological sludge in the secondary clarifiers. This poor settleability of the sludge is, generally, associated with excessive growth of filamentous bacteria in the bioreactor causing sludge filamentous bulking. In Brazil, many pulp and paper mills have faced problems related to sludge filamentous bulking in their effluent treatment plants experiencing a significant reduction in COD and BOD removal efficiency and a loss of suspended solids in the treated effluent. The addition of talc to increase floc density for the control of filamentous bulking has been studied. The objective of this study was to test the use of talc for the control of filamentous bulking. The bio-sludge used was obtained from a recycling paper mill and had an abundance of filamentous bacteria Type 021N. The experiment consisted of five bioreactors operating batch wise with sludge age of ten days. Different talc applications were used: 0%, 25%, 50%, 75% and 100% in relation to the total suspended solids in the aeration tank. The following analyses were carried out to monitor the system: suspended solids, sludge volumetric index (SVI) and chemical oxygen demand. Successive additions of talc contributed for the reduction of IVL. Dosages of 75% and 100% showed to be most efficient to improve settleability of the sludge. The presence of talc did not interfere with biological activity of the sludge. However, it was observed an increase of the total suspended solid concentration in the aeration tank. The addition of talc had a temporary effect on sludge settleability, so it was necessary to add repeatedly talc in the reactor in order to maintain a low sludge volumetric index.

PALAVRAS-CHAVES: Talc; Sludge Settling Ability; Sludge Bulking; Activated Sludge.

USO DE TALCO PARA O CONTROLE DE VOLUME FILAMENTOSA NA ESTAÇÃO DE TRATAMENTO DE EFLUENTES

RESUMO

Um dos principais problemas operacionais existentes nos processos de tratamento de lamas activadas é o efluente pobre sedimentação do lodo biológico nos clarificadores secundários. Esta fraca sedimentação do lodo é, geralmente, associada a um crescimento excessivo de bactérias filamentosas no bioreactor causando lamas filamentosa de volume. No Brasil, muitas fábricas de pasta e papel têm enfrentado problemas relacionados às lamas filamentosa de volume nas suas estações de tratamento de efluentes que experimentam uma redução significativa da eficiência de remoção de COD e BOD e uma perda de sólidos em suspensão no efluente tratado. A adição de talco para aumentar a densidade dos flocos para o controlo de volume filamentosos foi estudado. O objetivo deste estudo foi testar o uso de talco para o controle de volume filamentosos. O bio-lodo utilizado foi obtido a partir de uma fábrica de papel reciclagem e tinha uma abundância de bactérias filamentosas Tipo 021N. O experimento consistiu de cinco biorreatores lote sábio com idade de lodo de dez dias de funcionamento. Foram utilizados diferentes aplicações de talco: 0%, 25%, 50%, 75% e 100% em relação ao total de sólidos em suspensão no tanque de arejamento. As seguintes análises foram realizadas para monitorar o sistema: sólidos suspensos, índice volumétrico de lodo (SVI) e demanda química de oxigênio. Adições sucessivas de talco contribuiu para a redução de IVL. As dosagens de 75% e 100% mostrou ser mais eficiente para melhorar a sedimentação da lama. A presença de talco não interferir com a actividade biológica do lodo. No entanto, observou-se um aumento da concentração total de sólidos em suspensão no tanque de arejamento. A adição de talco teve um efeito temporário de lamas de sedimentação, por isso foi necessário adicionar repetidamente talco no reactor a fim de manter um baixo índice de lodo volumétrico.

KEYWORDS: Talco; Sludge Colonização Capacidade; Sludge Bulking; Lodo Ativado.

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INTRODUCTION

Pulp and paper mill effluents are rich in organic matter and are normally treated with biological processes prior to discharge into a receiving body of water. Activated sludge is by far the most used treatment of pulp and paper mill wastewater worldwide (POKHREL and VIRARAGHAVAN, 2004; AGRIDIOTIS et al., 2006). It is basically composed of an aerobic bioreactor followed by clarifiers where the sludge settles and is recycled back into the reactor, while the overflow (treated effluent) is discharged (HENZE et al., 2008).

Oxidation of the organic matter along with biological growth occurs in the bioreactor where a mixture of microorganisms composed mainly of bacteria, protozoa and rotifers is kept and compose the so-called bio-sludge. An essential feature of the biological growth is the capacity of the microorganisms to form flocks that can be subsequently separated by sedimentation in the clarifier units (VON SPERLING, 2011).

The flock is a heterogeneous structure composed of microorganisms and organic matter. The conditions for flocculation of the microorganisms are still not completely understood (PACHECO and PESSÔA, 2009). However, it is hypothesized that filamentous microorganisms perform as the backbone of the flock (macrostructure) whereas other bacteria aggregate to form the flock (SANT'ANNA JÚNIOR, 2011).

A general problem in activated sludge plants is the poor sedimentation of the sludge causing sludge losses and consequently low efficiency of the treatment plant. One particular problem associated to the sludge's poor settling ability is the excessive growth of filamentous bacteria causing the so-called *filamentous bulking*. In this condition, the sludge becomes cloudy and bulky and has a low settling capacity, causing significant loss of microorganisms that are washed out, thus deteriorating the quality of the treated effluent (JENKINS et al., 2003).

Several studies are evaluating the causes of sludge bulking in order to provide information that can help treatment plant operation teams to make changes in some of the used conditions and avoid the problem. Normally, this problem's solution requires the identification of the filamentous microorganisms present in the sludge, the literature search for its ideal growth conditions and finally the experimental changes of these conditions in the bioreactor to achieve the inhibition of their excessive growth (JENKINS et al., 2003). This approach is adequate, but it requires the participation of specialists who are not normally available in many plants.

Sometimes the problem becomes so severe that other measurements are necessary to control the sludge losses, at least temporarily. The use of biocides, flocculants or other chemicals to help controlling the sludge losses has been proposed in the literature. Researchers have studied the use of talc to increase the flock density and improve sludge settling ability (MAMAIS et al., 2011).

Although some studies (GRAJA et al., 1998; PIIRTOLA, et al., 1999; PIIRTOLA, et al., 1999; SEKA, et al., 2000; AGRIDIOTIS et al., 2006) show a significant influence of agents lastrantes – among them the use of talc – in control of '*bulking*' filamentous, by reducing the sludge volume index (SVI), the number of papers devoted to this topic is still very low, same world, and this situation is even more significant for Brazilian conditions. Furthermore, there is a lack of information about the optimal dosage and its effect on the microbiological population of effluent treatment. The basic function of adding ballasting agent the reactor in a biological wastewater treatment by activated sludge is to increase the density and size of the flake biological improving sedimentation of sludge in the settling unit (MAMAIS et al., 2011).

The objective of this study was to test the use of talc for the control of filamentous bulking in an activated sludge plant of recycled paper mill. It evaluated the best talc application rate and its effects on the efficiency of the treatment plant.

THEORETICALLY REVIEW

Experimental

The experiments were composed of five sequential batch reactors (SBR). The feeding effluent was collected in an OCC (old corrugated cardboard) mill after primary clarifier. The following parameters were measured to characterize the effluent: pH, electrical conductivity (EC), chemical oxygen demand (COD), biochemical oxygen demand (BOD), color, suspended solids, dissolved solids, chloride, hardness, total nitrogen and phosphorus. All analyses were carried out according to the Standard Methods for Examination of Water and Wastewater (APHA, 2005).

The talc used in this research was provided by Xilolite S/A. They were all composed of hydrated magnesium silicate ($3.MgO_4.SiO_2.H_2O$) and produced in the mines of Brumado, BA, Brazil. Table 1 presents the physicochemical characteristics of the talc.

Table 1: Physicochemical properties of the talc used.

Physicochemical characteristics	Talc
pH (10%)	9.0
Moisture (% maximum)	1.00
Oil Absorption (%)	51
Apparent density (g/cm $^{-3}$)	0.90
Compacted Density (g/cm $^{-3}$)	1.60
Specific area (cm^2 g^{-1})	9.000
Brightness (min %)	94
Particle size (mesh)	#325

Four different concentrations of talc were used in relation to the total mixed liquor suspended solids in the aeration tank (MLSS). In Table 2 the treatments used in this step are represented.

Table 2: Treatments to be performed with the talc that presented the best SVI reduction.

Treatments	Talc/MLSS
T1	0%
T2	25%
T3	50%
T4	75%

T5	100%

The bio-sludge was obtained from an activated sludge treatment plant in an OCC (old corrugated cardboard) mill where the effluent was also used. Samples were used wastewater final OCC collected in the channel effluent after primary treatment and before entering the biological treatment. The inoculum used was the aerobic sludge treatment plant effluent by conventional activated sludge of the industry where they were collected wastewater.

As an experimental strategy it was sought to assess the effect of successive talc additions on the treatment system, with solid control through the maintenance of the sludge age (θc) at ten days, without, however, considering the concentration of total suspended solids in the aeration tank (MLSS). At this stage, three successive talc applications were made with a minimum of 10 days interval between each application.

The bioreactors were composed of five PVC containers with 3,000 ml capacity and a useful volume of 2,000 ml, equipped with air diffusers that were enough for the mechanical agitation and to supply the oxygen needed for the effluents aerobic treatment. The bioreactors were kept in a controlled temperature (35ºC) using a digital thermostat and heaters. Five bioreactors were used, one for treatment without adding talc (control) and the other four for treatments with talc addition in the proportions (talc/MLSS) presented in Table 2.

The duration of each treatment cycle was 24 hours, distributed as 21 hours of filling/reaction and 3 hours of sedimentation/settling. The sludge age was maintained at ten days. The dissolved oxygen (DO) was maintained above 2.0 mg L^{-1}, the pH of the feeding effluent was adjusted to the range of neutrality (6.8-7.2) and the food/microorganism ratio (F/M) was maintained between 0.2 and 0.3 kg BOD_5 kg VSS d^{-1}. As a source of nutrients in the effluent was added input of laboratory systems, nitrogen as urea – $(NH_2)_2CO$ - and monobasic sodium – $(NaH_2PO_4.H_2O)$ - as a source of phosphorus, according to the ratio of BOD: N: P ratios equal to 100:5:1.

The microbiological control was accomplished through sludge samples analyzed by light microscopy and direct phase contrast in increases of 100, 200 and 400X. Microscopic observations were also conducted to assess the interaction of fresh silt and talc.

The identification of microorganisms microscopic observations was performed with the sludge according to the dichotomous key to determine the kind available in Jenkins et al. (2003). The technique allows to observe the shape of the filaments and cells and the relationship thereof with the flakes and the diameter and length of action of cells and filaments.

Experiments were conducted and monitored in laboratory scale for 90 consecutive days, and were collected 30 observations – which features three repetitions, ten days (equivalent to sludge age) in a completely randomized – for each of the treatments in order to evaluate the effect of talc on the control of filamentous swelling. The efficiency of treatments and settling sludge were determined by means of COD removal of wastewater and SVI, respectively.

Data obtained during the implementation phase of the experiment were tested for normality, homogeneity of variances and grip, using the Shapiro-Wilk test and Chi-square Statoft available in the software Statistica. Because of the observation of the data distribution does not possess normal obtou by the transformation of the sample data, analyzes it using parametric statistics.

RESULTS

Table 3 presents the average values for the physicochemical characteristics of the effluent during the execution of the experiment in eight samples.

Table 3: Physicochemical characterization of the effluent during the execution of the experiment.

Parameters	Unit	n	Values
Total COD		60	3.065 ± 427
Soluble COD		60	2.427 ± 363
Total BOD_5			2.892 ± 183
Soluble BOD_5			2.476 ± 123
Color	mg l^{-1}		264 ± 21
Chlorides		12	95 ± 11
Total Hardness			776 ± 24
Total N			0.70 ± 0.05
Total P			1.41 ± 0.03
pH	-	60	5.4 ± 1.7
Electric conductivity	µS cm^{-1}	60	2.4 ± 0.26

n = number of samples end ± Standard deviation.

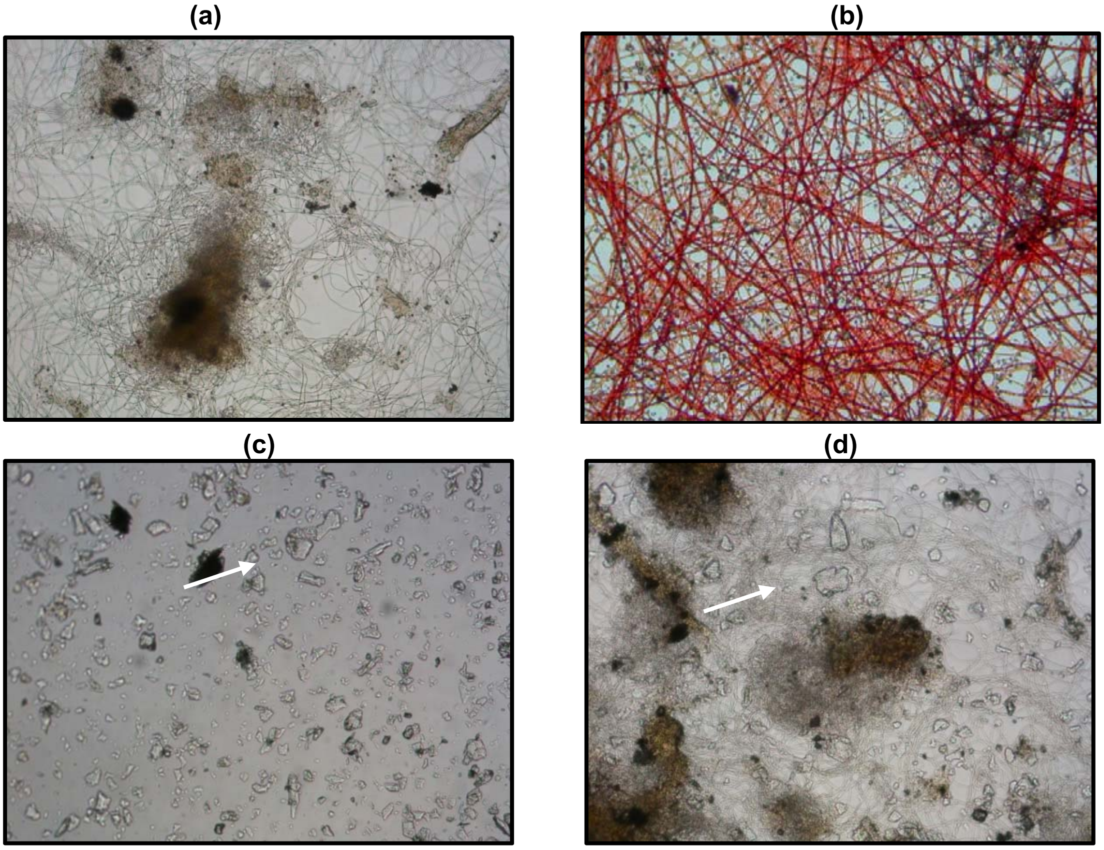
The filamentous bacteria present in abundance is the *Type 021N* (Fig 1a-b), which is a commonly found bacterium in the sludge of biological treatments of effluents from paper mills (LOURES, 2007; SOUSA, 2008).

Figure 1 shows the biological sludge microphotographs in conjunction with the treatments with talc addition. Figure 1. (c) shows a microphotograph of talc in a magnification of 100X where its particles can be easily observed. Figure 1 (d) show the phase-contrast microphotographs the five treatments. The excessive concentration of filamentous bacteria in the biological sludge can be observed in all treatments.

The bacterium *Type 021N* characterized by forming bridges between the flakes, making it impossible to approach each other, hindering sedimentation of the sludge. As a result, the sludge blanket in the secondary sedimentation remains upward, which causes large masses of suspended solids in the treated effluent. Due to the difficulty of interaction between the flakes caused by this species, the swelling becomes very aggressive and excessive.

As Jenkins et al. (2003) and Henze et al. (2008) the growth of this organism is associated with several factors, such as nutrient deficiency, particularly nitrogen and phosphorus, the presence of easily biodegradable substrates, mainly volatile fatty acids and short chain sugars simple and septicidade the effluent in the presence of sulfide .

It can be verified in Figure 1 (d) that the talc particles clump in the biological flock, strengthening its structure and increasing its weight, so as to facilitate its sedimentation and thus demonstrating to act as a ballasting agent. Consequently, there is a drop in the SVI values in the treatments in which the talc is present.



According to Bidault et al. (1997), Graja et al. (1998) and Clauss et al. (1999), this hydrophobic aggregation of the talc particles to the biological flock is due to the presence of exopolysaccharides (EPS) within its matrix. The EPS are composed of various substances such as proteins, nucleic acids and lipids presenting hydrophobic characteristics.

To qualitatively assess the effect of successive talc additions to the biological system regarding the improvement of sludge settling ability, the variance of the obtained SVI averages in each treatment was analyzed and is presented in the ANOVA Table (Table 4). According to these results, there is at least a contrast between the treatment's averages, statistically different from zero, at 1% probability. Thus, the averages of the treatments were compared pairwise by the *Tukey* test at 5% of significance. The SVI average results obtained for the treatments in each of the steps are presented in Table 5.

Table 4: Summary of the analysis of variance (ANOVA) for the treatments where successive talc applications were made in the biological reactor

Source of Variation	Degrees of freedom	Average square	Calculated F
Treatments	4	65712,4750	66,69*
Applications	2	7179,8523	7,29
Treatments x Applications	8	688,3239	0,7
Residues	125	985,3476	
Total	139		
CV (%)	19,61		

* Significant by the F test at 1% probability; CV = Coefficient of Variation.

Table 5: Comparison between overall SVI averages from each treatment and applications in the experimental sets in which successive talc applications were made in the biological reactor.

Applications	**Treatments**				
	T1	**T2**	**T3**	**T4**	**T5**
1	233.9	199.1	166.7	147.3	125.0
2	221.6	193.0	161.8	119.9	104.8
3	202.7	172.0	140.5	110.5	96.5
Overall average**	219.4**a**	188.0**b**	156.3**c**	125.9**d**	108.7**d**

** Overall SVI average followed by the same letter do not differ between each other in the level of 5% probability, by the Tukey test.

Analyzing the SVI data set, it is possible to verify that the control treatment (T1) without talc application, presented the largest overall value for the SVI, featuring an sludge with poor settling ability and statistically confirming that the addition of talc significantly improves the sludge settling ability.

According to the results shown in Table 5 and the regression equations presented in Table 6, it appears that the treatments in which talc was added experience a high rate of growth, ie higher the slope, resulting in a significant increase SVI with the passage of time, thereby revealing a temporary effect of talc in controlling filamentous bulking sludge. A statistically significant difference in the settling ability was observed as a result from the increasing talc concentrations used in relation to the total mixed liquor suspended solids (MLSS), i.e., the overall SVI values are inversely proportional to the talc concentration applied.

Reductions in the SVI values of 14.3% and 28.7% were verified in the T2 and T3 treatments respectively, when compared to the control treatment. However, when analyzing the absolute value of this index, it may be affirmed that such settling ability improvements are not significant to the effluent biological system treatment and are actually further from being ideal.

The best sludge settling results were obtained in the treatments with the higher talc concentrations used, where the SVI reductions compared to the control treatment were 42.7% and 50.5% for the T4 and T5 treatments, respectively. The overall SVI average values are statistically equal in these two treatments.

Table 6: Adjusted equations for the lines as a function of the SVI treatment time for first applying talc.

Treatments	**Adjusted equations *y = ax+b**	R^2	**Confidence interval (IC)****
T1	y = 5,0744x + 213,59	0,3925	(-2,1625) – (12, 3768)
T2	y = 7,6248x + 168,57	0,8645	(4, 076) – (11,0668)
T3	y = 8,8573x + 131,31	0,7717	(3,3732) – (14, 3410)
T4	y = 8,827x + 111,99	0,7953	(3,6321) – (14,0107)
T5	y = 8,034x + 99,842	0,7221	(7,8540) – (15,3574)

* y = the sludge volume index (SVI) = ex cycles (days) ** 95% likelihood that the average slope is between the IC.

Although the short term effect on the settling improvement has been observed through the use of talc for around five to seven days, the talc has proved to be an efficient ballasting agent, increasing the weight and the density of the biological flock. It could be used as a corrective measure in emergency situations under severe sludge bulking conditions, avoiding sludge losses in the clarifiers.

This timeframe (5-7 days) can be sufficient to correct the causes that favor the overgrowth of filamentous bacteria or to create favorable conditions for the growth of forming flocks bacteria.

The ANOVA test was used for the analysis of variance on the COD removal efficiency average values from the treatments and in each of the three successive talc applications (Table 7). This analysis was useful in the evaluation of the effect of the influence of the use of talc on the biological activity and therefore in the removal efficiency of organic matter.

Table 7: Summary of the analysis of variance (ANOVA) for the treatments in which successive talc applications were made in the biological reactor.

Source of Variation	Degrees of freedom	Average square	Calculated F
Treatment	4	0.6587	1.22^{ns}
Applications	2	8.3607	15.54
Treatments x Applications	8	0.7825	1.45
Residue	125	0.5381	
Total	139		
CV (%)	0.77		

ns = non significant by the F test at 1% probability; CV = Coefficient of Variation.

According to the results shown in Table 6, there were no statistically significant differences at 1% of probability between the COD removal averages from the treatments. The results presented in Table 8 show that there were no differences on COD removal and homogeneity in the data could be observed. Thus, it can be inferred that, statistically, the same efficiency in the removal of organic matter occurred in all five treatments and therefore no negative effect on COD removal related to the application of talc was observed. These results prove that talc act as an inert factor in the system. Very high COD removal efficiencies were obtained due to the biodegradability characteristics of this type of effluent. These values of COD removal efficiency are similar to the results of studies reported by Pokhrel and Viraraghavan (2004) due to the high biodegradability of the organic matter from the paper industry effluent recycled activated sludge processes can reach values removal efficiency of organic matter in terms of COD greater than 93%.

Table 8: Comparison between the overall averages from the DQO removal efficiency in each of the treatments with successive talc applications in the experimental sets.

Applications	Treatments				
	T1	**T2**	**T3**	**T4**	**T5**
1	94.2	94.3	94.4	94.6	94.8
2	95.6	95.6	95.3	95.2	95.0
3	95.6	95.1	95.0	95.0	94.8
Overall Average^{ns}	95.1	95.0	94.9	94.9	94.9

ns = not significant at 1% probability for the F test.

As results obtained by Seka et al. (2000) and Agridiotis, et al. (2006), it was found that besides being insoluble and improve the balance hydrophobicity / hydrophilicity, talc does not affect the treatment efficiency, which proves its compatibility with the biomass.

CONCLUSIONS

Based on the results obtained, it was possible to conclude that: A short-term effect of talc on improving settling ability of filamentous bulking sludge was observed and the results indicated that a new application of talc is necessary after the period of five to seven days in order to control the filamentous bulking.

The best performances regarding improvement of sludge settling capacity were obtained in the treatments with the higher talc concentrations in relation to the MLSS, with SVI reductions in relation to the control treatment of 42.7% and 50.5% for the T4 (75% talc) and T5 (100% talc), respectively. The overall SVI average values are statistically equal in these last two treatments.It was statistically proved that, qualitatively, there was no effect from the talc addition on the efficiency of COD removal between the control treatment (T1) and the other treatments with addition of increased talc concentrations (T2, T3, T4 and T5). This, efficiency exceeded 94% on all treatments.

The use of talc demonstrated to be an efficient ballasting agent, although large amounts had to be applied to control bulking sludge losses in the secondary clarifiers. Therefore it is suggested that talc could be used as a corrective measure, only in emergency situations with severe bulking conditions. We thank FAPEMIG (Fundação de Amparo à Pesquisa do Estado de Minas Gerais) for the financial support and scholarship that helped us to carry out the experiments. The CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico) provided the PQ fellowship to C. M. Silva and GM fellowship to H. A. V. Rossoni. This work was also supported by Xilolite Ltda.

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