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Effect of Activated Sludge Preservation on Its Adsorption Capacity in Treatment of Wastewater

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Abstract

Adsorption by activated sludge which plays a significant role in substrate removal has received a lot of recognition. A number of studies have been conducted into understanding this mechanism. However, the impact of activated sludge preservation on the adsorption capacity test results has not been documented. Live activated sludge is usually preserved after sampling to maintain the original sludge characteristics in order not to alter its adsorption capacity. Preservation of the sludge is relevant when the sludge has to be transported over long distances before adsorption experiments can be conducted. This paper seeks to present the effects of preservation of activated sludge on its adsorption capacity. The preservation methods considered were pre-aeration and cold-storage of the sludge. Sludge samples were pre-aerated for periods of 4 and 24 hours at room temperature and some were stored at 4°C for 6 hours. Adsorption batch experiments were then carried out on both fresh and preserved activated sludge samples. Glucose was used as an external substrate in these experiments. The results revealed a difference between the adsorption capacity of the fresh and preserved sludge samples. Sludge pre-aeration increased the adsorption capacity of the sludge. There was however, no significant difference in the adsorption capacities for 4h and 24h pre-aerated sludge samples. Adsorption capacity of the 6h cold-stored activated sludge was poor compared to that of the fresh sludge.

Keywords: Activated sludge, Activated sludge preservation, Adsorption capacity, Glucose

1. Introduction

Adsorption is a mechanism by which substrates are rapidly attached onto the surface of activated sludge flocs. This concept of instantaneous uptake of substrates immediately after contact between activated sludge and wastewater was first introduced by Eikelboom (1982). The adsorption process is one of principal methods resulting in an efficient removal of organic pollutants from wastewater. The adsorptive capacity of the sludge depends largely on the surface characteristics of the flocs which include the size, surface area and surface charge (Tan and Chua, 1997). This attribute of the activated sludge has led to modifications in the conventional wastewater treatment plant (wwtp). Such modifications include the contact stabilisation process (Ullrich and Smith, 1951) and the inclusion of a selector system (Chudoba et al., 1973) in the wwtp to prevent sludge bulking.

Due to the important role of adsorption in substrate removal, numerous studies have been carried out on the measurement of adsorption capacity of activated sludge to enhance understanding and improve upon operations of the wwtp. Most of these studies used dried activated sludge (Aksu, 2000, Chowdhury and Molligan, 2011, Lawson et al., 1984, Ajaykumar et al., 2009, Selvakumar and Hsieh, 1987), dead activated sludge (Ren and et al., 2011, Zhao et al., 2007, Dobbs et al., 1995) or washed live activated sludge (Clara et al., 2004, Espaza-Soto and Westerhoff, 2002, Leung et al., 2001) as adsorbents.

Studies on adsorption capacity of live activated sludge can be extended to better elucidate pollutant removal from wastewater. Live activated sludge is usually preserved after sampling to maintain the original sludge characteristics in order not to alter the adsorption capacity of the sludge. Preservation of the sludge is particularly relevant when it has to be transported over long distances which prolongs the period between the time of sampling and the adsorption batch experiment. Two main methods of sludge preservation have been to either aerate the sludge at room temperature or store it at 4°C. The impact of activated sludge preservation on the

adsorption capacity test results has not been documented. This paper presents the effect of these two methods of sludge preservation on adsorption capacity of activated sludge.

2. Materials and Methods

2.1 Biomass

Activated sludge samples were collected from the aeration tank of a biological phosphorus elimination and pre-denitrification wastewater treatment plant of size 500,000 population equivalent in Germany. Some portions of the freshly sampled activated sludge were used in the adsorption batch experiments immediately upon arrival at the laboratory. Fresh sludge samples that were neither pre-aerated nor stored cold are termed in this paper as 0h pre-aerated or 0h cold-stored sludge. Some of the remaining sludge samples were aerated at room temperature and some portions were also stored in a refrigerator at 4^0C. Adsorption batch tests were carried out on these samples after 4 and 24 hours of pre-aeration and after 6 hour cold-storage of the sludge. The temperature of the cold sludge was allowed to rise to 20^0C in the reactors before the experiment was conducted. Sludge loads of 1gCOD/gTS and 0.3gCOD/gTS were used in the batch tests with pre-aerated sludge and cold-stored sludge respectively.

2.2 Preparations of Solutions

In these experiments, glucose was used as substrate since it is a readily biodegradable substrate and yields high adsorption capacity with the activated sludge (Phan, 2005). 200mL volume of glucose was used. Stock concentrations of 35gCOD/L and 10gCOD/L of glucose were used in the experiments with pre-aerated and cold-stored sludge respectively. To hamper nitrification during the experiments, allythiourea (ATU) was added.

2.3 Experimental Set-up

A diagram of the experimental set up is shown in Figure 1. The arrangement consists of four reactors with 2L capacity each placed on magnetic stir plates. Magnetic stirrers were put in each reactor to ensure homogenous mixing of the reactor contents. Dissolved oxygen (DO) probes were fitted to the reactors to detect the oxygen concentration of the reactor contents. The temperature was maintained at 20^0C and the pH was kept between 7 and 8. The experiments were carried out in the laboratory of the Institute of Sanitary Engineering and Waste Management (ISAH), Leibniz University of Hanover, Germany.

2.4 Adsorption Batch Experiment

The adsorption batch test method used in this study was developed by Phan (2004). Samples of the sludge mixed liquor were first poured into each reactor. 4ml ATU was then added. Samples of the sludge were then taken for chemical oxygen demand (COD) tests. 200mL volume of glucose solutions were then poured into each reactor with the exception of that for the blank test. The reactor contents were then aerated and the oxygen uptake rates were recorded automatically. Samples were then taken from each reactor after 2, 5, 10, 20, 40 and 60 minutes. Each sample taken was filtered and the supernatant was analysed for COD using the Lange cuvette test method. Total solids (TS) concentration test (according to DIN 38414 S 2) was also carried out at the end of the experiment. COD tests were run on the glucose stock solutions to ascertain the actual concentration used.

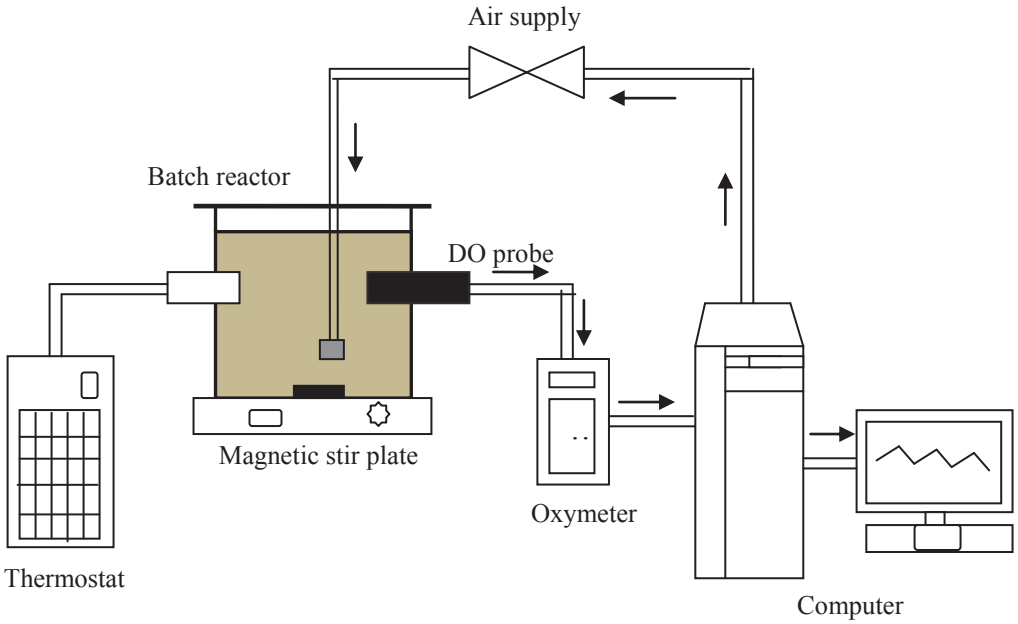

Figure 1. A Diagram of the Experimental Set up

2.5 Analysis of Results

2.5.1 Determination of Respired COD Substrate

The amount of the soluble COD substrate respired by the activated sludge is obtained from the oxygen uptake rate of the sludge. It was calculated using equation 1 (Ekama et al. 1986).

$$Ss, i = \left[\frac{1}{(1-Y_H)}\right] \Delta O, i \qquad (1)$$

Where,

Ss, i (mg COD/L) is the respired COD up to time i

ΔO, i (mg O/ L) is the concentration of oxygen utilized up to time i

Y_H (mg COD/mg COD) is the yield coefficient of heterotrophs. It has a value of 0.67.

2.5.2 Determination of Total Eliminated Substrate

The computation of the total eliminated substrate is based on the concentrations of soluble COD that were measured during the batch experiment. It was estimated from the formula given in Equation 2 (Prendl, 1997).

$$S_{Eli,i} = \frac{(COD_{sub} - COD_{meas,i}) \times V_{sub} - (COD_{meas,i} - COD_{sludge}) \times V_{sludge}}{(V_{sub} + V_{sludge})} \qquad (2)$$

Where,

$S_{Eli,i}$ (mg COD/L) is the total substrate eliminated up to time i

COD_{sub} (mg COD/L) is the dissolved COD concentration of substrate used

COD_{sludge} (mg COD/L) is the dissolved COD concentration of activated sludge sample

$COD_{meas,i}$ (mg COD/L) is the dissolved COD concentration of the mixed liquor sample measured during the test at time i

V_{sub} (L) is the volume of substrate

V_{sludge} (L) is the volume of activated sludge used in the tests

2.5.3 Determination of Adsorption Capacity

The amount of substrate adsorbed is the difference between the total eliminated substrate and the respired COD substrate. The formula is given in Equation 3.

$$S_{ads,i} = S_{Eli,i} - S_{S,i} \qquad (3)$$

Where,

$S_{ads,i}$ (mg COD/L) is the adsorbed COD up to time i

Thus adsorption rate and adsorption capacity can be calculated according to Equation 4 and 5 respectively.

$$Q_{ads,j} = \frac{\Delta S_{ads,ij}}{\Delta t \times TS \times 1000} \quad (4)$$

$$\rho_{ads,i} = \frac{\Delta S_{ads,j}}{TS \times 1000} \quad (5)$$

Where,

$Q_{ads,j}$ [(g COD/(g TS*h)] is the substrate adsorption rate between time i and j

$P_{ads,j}$ [(g COD/g TS] is the substrate adsorption capacity at time j

$\Delta S_{ads,ij}$ (mg COD/L) is the substrate adsorbed between time i and j

Δt (h) is the time difference between times i and j.

3. Results and Discussion

3.1 Instantaneous Nature of Adsorption

The adsorptive capacity of activated sludge to rapidly remove substrates immediately after contact is made with the glucose substrate can be observed in the adsorption rate and capacity curves shown in Figures 2 and 3 respectively. After two minutes of contact, the adsorption rate reached its peak and then decreased gradually. The gradual decrease depicts the insubstantial amount of substrate adsorption with time. The decrease in the adsorption rate of the sludge after two minutes is due to the few active adsorptive sites remaining on the sludge flocs after the rapid substrate uptake.

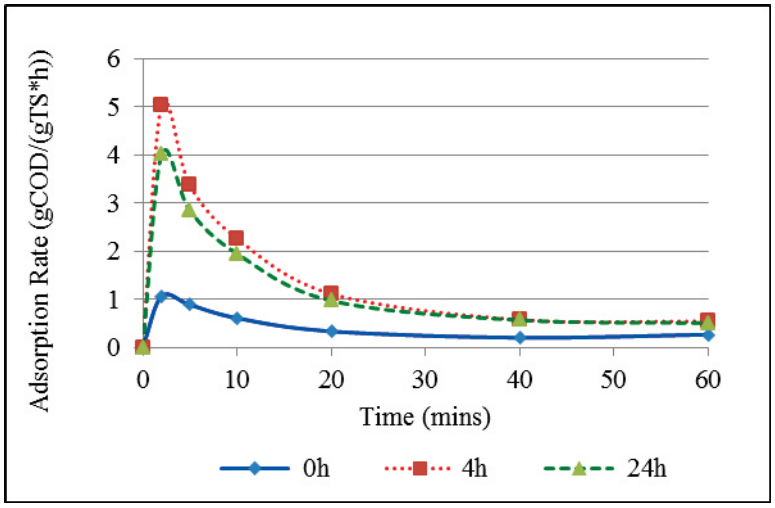

Figure 2. Adsorption rate curves for 0h, 4h and 24h pre-aerated activated sludge (sludge load of 1gCOD/gTS)

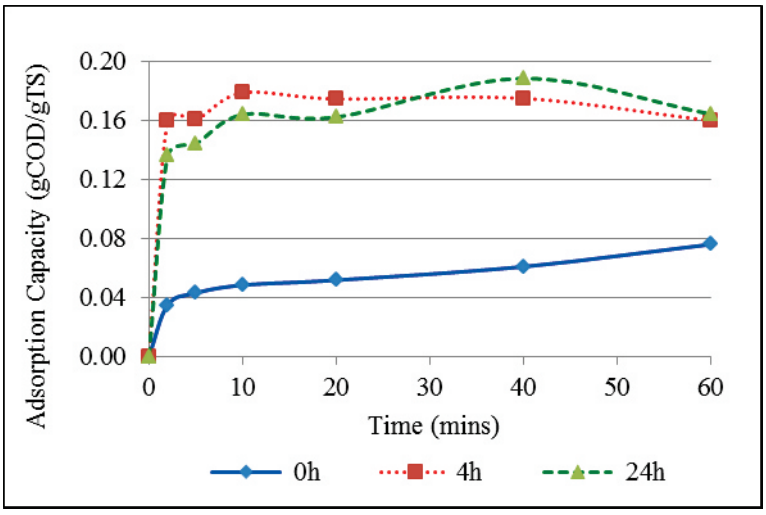

Figure 3. Adsorption capacity curves for 0h, 4h and 24h pre-aerated activated sludge (sludge load of 1gCOD/gTS).

3.2 Effect of Sludge Pre-Aeration on Adsorption Capacity

From Figure 2, the adsorption rate after 2 minutes contact time for non-preaerated sludge (that is 0h pre-aerated sludge) was 1.07gCOD/(gTS*h). There was a significant increase in the adsorption rate to 5.03 and 4.01gCOD/(gTS*h) after 4 and 24 hours of pre-aeration respectively (Figure 2). During the 4h and 24h pre-aeration period the already adsorbed substrate on the sludge were utilised by the sludge. This created more free adsorptive sites on the surface of the sludge flocs which enhanced the adsorption of the glucose substrate. This phenomenon explains the increase in adsorption capacity after sludge pre-aeration. This concept of enhancing substrate adsorption by initial pre-aeration of the activated sludge is applied in the contact stabilisation process for wastewater treatment. The difference in the adsorption rate after 4h and 24h pre-aeration was however, negligible. This shows that prolonging the pre-aeration period beyond 4h does not yield a significant increase in the adsorption rate.

3.3 Effect of Cold-Storage of Sludge on Adsorption Capacity

The adsorption rates and capacities curves (Figures 4 and 5) illustrate that the fresh activated sludge adsorbed the substrate better when it was not subjected to cold-storage (0h cold-storage). An adsorption rate of 0.32gCOD/(gTS*h) was reached after 2 minutes contact time. This rate is lower than that obtained by 0h pre-aerated sludge of 1.07gCOD/(gTS*h) because of the lower sludge load of 0.3gCOD/gTS used in the cold-storage experiment. A sludge load of 1gCOD/gTS was used in the experiments with the pre-aerated sludge. This signifies that the higher the substrate concentration the higher the amount of substrates adsorbed onto each gram of the activated sludge flocs. Thus, a higher sludge load results in a higher adsorption capacity (Phan, 2005, Chowdhury and Molligan, 2011).

The adsorption capacity results obtained within the first 5 minutes for the 6h cold-stored sludge were negative as seen in Figures 4 and 5. It is possible that desorption might have occurred. Due to the initial negative adsorption results for the 6h cold-stored sludge, a lower adsorption capacity of 0.015gCOD/gTS was obtained after 60 minutes contact time compared to that of the 0h cold-stored sludge of 0.03gCOD/gTS. One probable reason for the negative adsorption capacities at the start of the test is the competition between already adsorbed COD and the glucose molecules for adsorptive sites on sludge flocs. Adsorption is known to increase with low temperatures (Ren et al. 2011). It is probable that during the 6h cold- storage, most of the COD (soluble and colloidal organic substrates) in the sludge mixed liquor adsorbed onto the sludge flocs. However, due to the low temperatures, the adsorbed COD was metabolised at a lower rate. Thus, the surface of the sludge flocs became loaded with the adsorbed organic substances (Reed, 1970). During the adsorption test, these already adsorbed substrates compete with glucose for adsorption sites on the sludge flocs. Thus the initial negative adsorption results recorded might be due to the release of the already adsorbed COD from the surface of the sludge flocs. These results revealed that cold storage of activated sludge alters the adsorption capacity of the sludge when glucose was used as substrate.

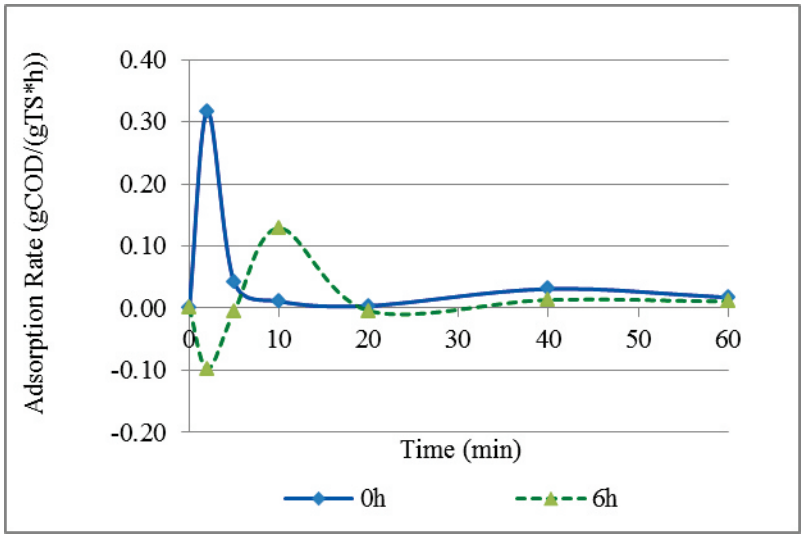

Figure 4. Adsorption rate curves for 0h and 6h cold-stored activated sludge (sludge load of 0.3gCOD/gTS)

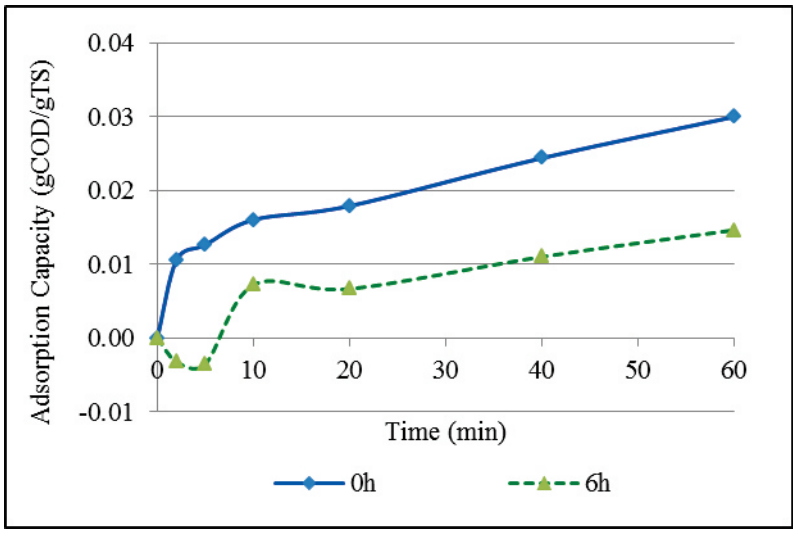

Figure 5. Adsorption capacity curves for 0h and 6h cold-stored activated sludge (sludge load of 0.3gCOD/gTS)

4 Conclusion

In this paper, the effect of activated sludge preservation on adsorption capacity batch test results has been presented. The two main methods of sludge preservation studied were pre-aeration and cold-storage at 4°C. The results revealed that both forms of preservation impact the adsorption capacity of the sludge. Whilst pre-aeration of the sludge improved the adsorption capacity of the activated sludge, cold-storage resulted in lower adsorption potential of the sludge to glucose. Pre-aeration of the sludge for about 4 hours before subsequent contact is made with substrate improves the adsorption capacity of the sludge. Preferably, adsorption experiments should be performed on freshly sampled live activated sludge immediately upon reaching the laboratory. If the sampled sludge however, should be kept cold it is recommended they should be stored in small volumes for effective cooling to reduce their biological activity. This research work is supposed to serve as a foundation for further studies into activated sludge preservation effects on its adsorption capacity. Additional research could also focus on assessing the effect of activated sludge preservation using real wastewater as substrate.

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