Journal of Water Process Engineering 4 (2014) 137–142

Contents lists available at ScienceDirect

Journal of Water Process Engineering

journal homepage: www.elsevier.com/locate/jwpe

Utilisation of turbidity as an indicator for biochemical and chemical oxygen demand

Le Anh Tu Nguyen*, Andrew James Ward, David Lewis

School of Chemical Engineering, The University of Adelaide, Adelaide, SA 5000, Australia

ARTICLE INFO

Article history:
Received 21 April 2014
Received in revised form
25 September 2014
Accepted 28 September 2014
Available online 25 October 2014

Keywords:
Turbidity
Management tools
Biochemical oxygen demands
Chemical oxygen demands
Advanced integrated wastewater ponds

ABSTRACT

The objective for this paper was to develop a high throughput methodology to determine chemical oxygen demand (COD), five-day biochemical oxygen demand (BOD_5) and other water quality parameters via turbidity measurements of the treated effluent that has residual suspended microalgae. This methodology has twin applicability and can be utilised in wastewater management scenarios as well as pond management for the aquaculture and biofuel microalgae pond management applications. The final results indicated high correlations of turbidity with most of the studied standard parameters with the exception of BOD_5. This paper also suggested that COD is a more reliable method than BOD_5 in measuring the effluent from AIWPS®.

1. Introduction

Frequent monitoring of effluent from wastewater treatment plants is essential for public safety. Advanced Integrated Wastewater Pond Systems (AIWPS®), which exploit microalgae for nutrient removal in municipal wastewater with the added benefit of carbon dioxide absorption and mitigation, are not exceptions. Monitoring, however, creates burdens on these systems as they are often designed for small operating flows and monitoring adds further delays in time and management of the wastewater plant. A management tool is, thus, required for rapid estimation and detection of desired monitoring parameters. A fast and reliable parameter is needed as an input measurement. While some significant parameters such as 5-day Biochemical Oxygen demand (BOD_5) need a period of six working days or 3 h for Chemical Oxygen Demand (COD) testing, the turbidity parameter is a highly probable candidate as less than 5 min is required for its analysis. Turbidity reflects the high recorded residual suspended microalgae conditions in the effluent in which AIWPS® experience.

The focus of this paper is, therefore, to initiate the development of a management tool by utilising turbidity of the treated effluent with residual suspended microalgae. This simple indicator can be then correlated with a number of different parameters which are implicated under the current US EPA and South Australian EPA guidelines. Number of cells, total solids and volatile solids, 5-day BOD_5 and COD are the five parameters which were investigated for correlation with turbidity in this study.

1.1. AIWPS® system

A natural wastewater treatment system namely AIWPS® would provide answers to current industry challenges. The AIWPS® in which microalgae plays a key role in nutrient removal, carbon dioxide uptake and extra dissolved oxygen production is a simple upgrade from the Waste Stabilisation Pond (WSP). The system is a series of four ponds in order of Advanced Facultative Pond (AFP), High Rate Pond (HRP), Algal Setting Pond (ASP), and the final Maturation Pond (MP) [1]. While the AIWPS® has three times lower operating and maintenance cost than conventional wastewater treatment systems, only high rate ponds are currently applied in the regional Australian wastewater treatment facility (WWTF) [2].

In AIWPS®, ponds are highly integrated with one another in order to remove chemical oxygen demand, nutrients, pathogens and toxicants. The AFP with additional in-pond digesters promotes methane fermentation, disinfection, nutrient removal and odour control. The consumption of carbon dioxide from the microalgal photosynthesis in the facultative ponds upgrades methane from in pond digesters to 84% methane in the captured biogas [3]. Thus,

* Corresponding author at: 685 Lower North East Road, Paradise, SA 5075, Australia. Tel.: +61 403 195 427.
E-mail addresses: latn90@gmail.com, l.a.tu.nguyen@gmail.com (L.A.T. Nguyen).

http://dx.doi.org/10.1016/j.jwpe.2014.09.009
2214-7144/

electrical generation from captured Biogas is feasible. Unlike the AFP, in the HRP, the interaction between microalgae and aerobic bacteria is more profound [3]. The purpose of the algae is to provide extra dissolved oxygen for bacteria to breakdown BOD. Meanwhile, bacteria supply carbon dioxide and nutrient to promote the growth of those algae [2]. ASPs, however, have a primary focus on algae removal under gravity as the main driving force in order to meet required effluent quality management [4].

1.2. Microalgae involvement in AIWPS® system

The implication of microalgae in AIWPS® starts from the need to provide a system with sustainable energy consumption in order to compete in pollutant removal of conventional wastewater treatment [4] and later, Abdel-Raouf et al. [5] have pointed out that the photosynthetic capability of microalgae and the adsorption of nutrients namely nitrogen and phosphorus are of particular interest. In fact, the growth of microalgae increases dissolved oxygen which in turn encourages bacterial growth in order to maintain BOD removal as well as removing nutrients at the same time.

In general, the growth and species of microalgae that are present in the pond depend on the environment and location of the pond. Most microalgae species are classified under either Chlorophytes (green algae) or Cyanobacteria (blue-green algae). A study [5] found that eight most common species in natural microalgae populations were Chlorella, Ankistrodesmus, Euglena, Chlamydomonas, Oscillatoria, Micractinium and Golenkinia. In particular, in high rate ponds, under the mixing influence of paddle wheels, Scenedesmus and Micractinium are the two most common colonial microalgal species [2].

Microalgae also contribute to the removal of carbon dioxide which indirectly removes *E. coli*. In term of carbon dioxide, Singh and Ahluwalia [6] insist microalgae can both collect carbon dioxide (CO_2) from the atmosphere and water soluble carbon sources, in wastewater. While standard atmospheric conditions exist, which contains CO_2 at a level of 0.0387% (v/v) could not support the entire microalgae population. Thus, the main sources of carbon and specifically carbon dioxide for microalgae to undergo photosynthesis depend on bacteria during BOD breakdown processes in wastewater treatment ponds [4]. Furthermore, under rapid demand of dissolved CO_2, microalgae indirectly increase the pH value of the wastewater present in the pond to greater than 10. Under influence of microalgae, *E. coli* was efficiently removed with the recorded effluent from maturation pond at 10 MPN/100 mL, which met the US EPA guidelines for water reuse.

1.3. Limitation of AIWPS®

Even though, AIWPS® have benefits in WWT, management concerns are needed to be addressed. The first concern is the removal of total suspended solid (TSS). The primary reason is the addition of microalgae in suspension over the entire system and HRP in particular. While the impact of microalgae on nutrient removal and their tolerances with wastewater composition have been well investigated [5,7], there is limited data in regard to the effect of the high concentration of suspended microalgae in effluent.

1.4. Effectiveness of turbidity as an indicator

While, turbidity is a measure of water clarity, this parameter is an integrated measurement of suspended and dissolved particulates in the water. The methodology of measuring turbidity utilises the reflection of light that passes through the water without being scattered and absorbed. The measurements of light scattering are usually quantified and reported in nephelometric turbidity units (NTU) [8]. Under the requirement of US EPA and Australian and New Zealand Guidelines of Fresh and Marine Water Quality, the average discharge turbidity is to be lower than 2 NTU over a 24-h period. In addition, the instantaneous measurement should never exceed 5 NTU. The recommended turbidity should be met prior to disinfection. Currently, based on United State Environmental Protection Agency (2012) [9] use of turbidity as an indicator for total suspended solids is used in the State of Florida, US, Turbidity metres are also employed as a measure of system performance.

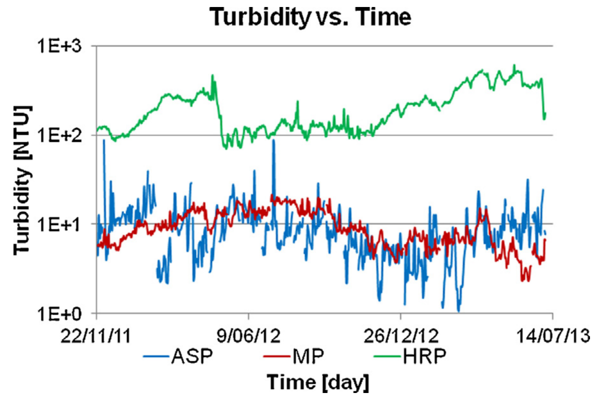

Fig. 1. Turbidity NTU measured in HRP, ASP and MP in the Delhi AIWPS® WWTF.

2. Materials and methods

2.1. Test samples

Due to the unavailability of colonial microalgae samples from an actual Advanced Integrated Pond System, water samples with a single suspended marine microalgae species (*Tetraselmis sp.*) were utilised as a sample proxy. *Tetraselmis sp.* was chosen as it is a conventional aquaculture feed utilised by the aquaculture industry [10,11] and is also utilised in the production of biofuel [12] and illustrates the twin applicability of these techniques use in other algae pond management scenarios. Under the unique growth condition in the laboratory, salt was added to the mixture at a concentration of 7.00% which was twice the concentration of natural seawater. High salinity was used for culture of this species as outlined in Fong Sing et al. [12] which details the commercial culture of this species.

The tests commenced after the *Tetraselmis sp.* growth medium provided a turbidity reading of higher than 418 NTU utilising the Hach 2100N Turbidimeter, which correspond to the average reading from high rate ponds in the Delhi AIWPS® WWTF during the highest recorded period between 20/03/13 and 20/06/13 (Fig. 1). Since this study purpose is to establish correlation in a wide range of turbidity which observed in a AIWPS®. The choice of average turbidity during highest recorded period is therefore necessary to limit the highest end value with lowest end recorded at 0 NTU. Tests were conducted in triplicate under minimum of five different turbidity values in order to establish regression models for the number of cells, total solids, volatile solid, COD and BOD_5 water quality parameters.

2.2. Cell counts

Since *Tetraselmis sp.* is considered as unicellular, direct counts are considered the best technique in examining the number of algal cells. From the previous five sets of test samples, 5 mL aliquots of well mixed sample were extracted for analysis. In order to limit microalgal cells mobility, three drops of lugol's solution were added to sample vials to kill and immobilise the cells. The sample vials containing the sample were shaken vigorously to homogenise