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Reuse of car wash wastewater by chemical coagulation and membrane bioreactor treatment processes

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ABSTRACT

Car wash wastewater contains significant concentrations of contaminants such as nutrients, organics, particulate matter, sand, oil, grease, diesel detergents and so on. A range of treatment processes such as a membrane bioreactor (MBR), coagulation and ozonation were investigated to treat car wash wastewater. Ozonation was effective in removing the chemicals and suspended solids; the removal efficiency was greater than the coagulation process. Once the MBR system was acclimatised, 100% of suspended solids, 99.2% of COD, 97.3% of TOC and 41% of ammonia were removed. This study demonstrates that MBR is a potentially promising treatment system for recycling car wash wastewater which could be reused in the same car wash station.

1. Introduction

Water recycling provides a great opportunity to conserve one of our natural resources that is essential for the survival of mankind. Reducing wastewater and being able to reuse it as resource is critical in light of long term droughts. There are currently more than 17.6 million motor vehicles registered in Australia (Australian Bureau of Statistics, 2014). All these vehicles need to be washed frequently, either by a household car wash or by a commercial car wash service. The latter is a recent industry which is gaining popularity due to its positive environmental impacts, comparing it with the household car wash method. Car wash facilities usually have two types of services (automatic and self-serve wash). Generally, 200 L of water are used in automatic wash every time a car is washed; and from 40 to 50 kL in a self-serve wash. Thus, car wash requires a big volume of water and also it generates a significant volume of wastewater containing various types of pollutants. Most of the time, the car wash wastewater is discharged into sewer systems without any treatment. For example, up to 10,000 L of wastewater a day can be generated at a commercial car wash station in Geelong, Australia. This equates to in excess of 3.5 million litres per annum of wastewater which is disposed of rather than recycled. If this is extrapolated across the more than 10,000 car wash facilities in Australia, it would represent over 35 billion litres of wastewater per annum. The current water price for businesses supplied by Barwon Water in the Geelong region is approximately AUD$2.21 per kilolitre. With a total volume of thirty-five billion litres of wastewater being produced by car washes Australia wide each year, the total value of the wastewater disposed of through the sewerage system is around AUD$77.35 million.

Chemical, biological and membrane processes have been widely used in treating various kinds of industrial and municipal wastewater. Sabur et al. (2012) used coagulation processes for treating a textile wastewater and found that the removal efficiency of COD, total dissolved solids and turbidity was 90%, 74% and 93%, respectively. Amuda and Amoo (2007) reported that coagulation was capable of removing 73%, 95% and 97% of chemical oxygen demand (COD), total phosphorus (TP) and total suspended solids (TSS), respectively, from beverage industrial wastewater. Moreover, membrane bioreactor (MBR) was highly effective in reducing the contaminants from industrial wastewater. Hosseinzadeh et al. (2013) found that MBR led to a removal of 75%, 98% and 74% removal of COD, TSS and total nitrogen (TN), respectively, from industrial town wastewater. Cheng et al. (2015) studied the effect of

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MBR treatment for antibiotic wastewater treatment and found that MBR could remove 92.5% of BOD, 96% of COD, 81.5% of suspended solids and more than 99.9% of selected antibiotics such as imipenem and cilastatin. Another study by Friha et al. (2014) found that aerobic submerged MBR could effectively treat the cosmetic wastewater with a removal of 98.13% of anionic surfactant and 83.73% of COD. However, only a few studies have investigated car wash wastewater treatment with the aim of producing reusable effluent. The car wash wastewater was extremely murky and the presence of suspended solids was noticeable. Rubio and Zaneti (2009) found that flocculation column-flotation treatment could effectively reduce the turbidity and colour (>90% and 75%, respectively) from cash wash wastewater.

Lau et al. (2013) found that ultrafiltration and nanofiltration for car wash water reclamation effectively reduced COD, TDS and turbidity. Kiran et al. (2015) compared the efficiency of modified polyethersulfone and cellulose acetate membranes in the treatment of carwash effluent using ultrafiltration and found that the modified membranes performed better at removing COD, turbidity and maintaining stable flux than commercial polyethersulfone (PES) membrane. However, it is important to consider the costs of implementation, operation and maintenance along with the efficiency of the treatment process. Compared to conventional treatment technologies, MBR appears to be suitable for the removal of all types of contaminants present in cash wash effluent since it has the ability to meet high permeate quality and small space requirement. Small footprint for space is required due to its limited availability in a car wash station and high effluent quality is required in order to reuse in washing cars. The objective of this research was to investigate the impact of different treatment processes including MBR, coagulation and ozonation in treating car wash wastewater.

2. Materials and methods

2.1. Sample collection

The feed water was collected from Grovedale car wash in Geelong, Australia. Car wash wastewater pre-treated in an oil and grease separator was employed for this study. Samples were stored at 4 °C and brought back to room temperature (22 ± 2 °C) prior to all tests.

2.2. Treatment processes

2.2.1. MBR setup

The schematic of the laboratory-scale MBR experimental setup is shown in Fig. 1. The system was constructed with five tanks including a 10 L feed tank, two 6 L anoxic reactors (AR1 and AR2), a 10 L aerobic membrane bioreactor (AMBR) and a 10 L permeate tank. In order to increase the surface area within the anoxic reactors to encourage bacterial growth, 75 polypropylene bio-balls (40 mm nominal diameter and 450 m^2/m^3 of specific surface area) supplied by All Round Aquatics, Australia were placed in each anoxic reactor. A hollow fibre hydrophilic polyethersulfone (H-PES) membrane module (pore size of 0.1 μm and effective membrane area of 0.032 m^2) from SENUOFIL Co., China was placed in the aerobic reactor. Hereafter, the entire system will be referred to as MBR system and the aerobic reactor with the membrane module will be referred to as AMBR. The MBR system used activated sludge during the acclimatisation process for over 4 weeks, which was collected from the Anglesea Wastewater Reclamation Plant situated closer to Geelong, Australia. Once the system was acclimatized with synthetic wastewater ($C_6H_{12}O_6$ 710 mg/L, CH_3COONH_4 200 mg/L, $NaHCO_3$ 750 mg/L, NH_4Cl 30 mg/L, KH_2PO_4 30 mg/L, K_2HPO_4 60 mg/L, $MgSO_4.7H_2O$ 50 mg/L, $CaCl_2.2H_2O$ 30 mg/L, NaCl 30 mg/L), different ratios of carwash wastewater and synthetic wastewater were used as feed for the MBR process. Finally, 100% carwash effluent was used and the performance of MBR system under this condition is reported in this study.

2.2.2. Coagulation and ozonation treatment

Coagulation was performed with a laboratory jar test apparatus (Phipps and Bird, PB-700). Alum ($Al_2(SO_4)_3.18H_2O$) and Poly-Aluminium Chloride (PACl) coagulants were applied to 2 L car wash wastewater samples. Samples were mixed at 300 rpm for 5 min and then mixed at 30 rpm for 30 min; samples were allowed to settle for 30 min after which the supernatant was collected for analysis. The doses were 12.5 mL of 10% Alum and 10 mL of 5% PACl per 1 L of carwash wastewater. Both coagulants were tested without pH adjustment. Supernatant from the jar test conducted with 10 mL of 5% PACl per L of wastewater was used for ozonation; the ozone dosage was 10 mg L^{-1} at 15–25 s of exposure.

2.3. Analytical methods

Conductivity, turbidity, dissolved oxygen (DO) and pH and of the water samples were measured using a conductivity meter (WTW LF330), turbidity meter (2100p Hach), and DO meter (WTW oximeter 330), pH meter (WTW pH 330) respectively. Suspended solids concentration was analysed by using pre-dried GF/C filter paper.

Total organic carbon (TOC) and TN concentration were determined using a TOC-L Shimadzu analyzer. COD concentration of the water samples were carried out using Spectroquant COD cell test kit and Thermo-reactor TR-320. The concentration of ammonium, nitrate, nitrite, total phosphorus of the water samples were determined using Merck ammonium test kit (1.00683.0001, analogous to EPA 350.1), nitrate test kit (1.14773.0001), nitrite test kit (1.00690.0001) and phosphate cell test kit (1.14729.0001), respectively. Before these analyses were undertaken, all samples were filtered through 0.45 μm filter.

3. Results and discussion

3.1. Performance of coagulation and ozonation

The characteristics of the car wash effluent before and after coagulation with Alum and PACl are shown in Table 1 (The values are average of two readings with a standard deviation less than ± 1%). The concentration of turbidity and suspended solids of the raw car wash wastewater was 1000 NTU and 4.2 mg/L, respectively. Etchepare et al. (2014) and Lau et al. (2013) reported that the concentration of turbidity of car wash wastewater was 229 and 68.9 to 62.8 NTU, respectively. Clearly, the level of turbidity was significantly higher for this study compared to previous studies because the Geelong region which is surrounded by rural areas where sand, mud, clay and other solids are available in large quantities and could easily get stuck onto the surface and tyres of a car. In addition, samples were mostly taken during the wet season, when turbidity increases because car bodies carry more dirt during that season. The removal efficiency of turbidity by coagulation with alum or PACl was 99.5 and 99.6%, respectively.

The use of PACl as a coagulant resulted in a 65.25% COD removal, a result which could be attributed to the adsorption of organic matter onto flocs and charge neutralization (Duan and Gregory, 2003), as PACl coagulant is positively charged and it adsorbs the negatively charged organic compounds in the coagulation process. There was a further small additional removal of COD (approximately 2%) followed during ozonation. According to Hoigné and