Ammonia-nitrogen removal from urban drainage using modified fresh empty fruit bunches: A case study in Kota Kinabalu, Sabah

L N S Ricky¹, Y Shahril², B Nurmin³, AY Zahrim¹

¹Chemical Engineering Programme, Faculty of Engineering, Universiti Malaysia Sabah, Jalan UMS, 88400 Kota Kinabalu, Sabah, Malaysia
²Medical, Faculty of Medicine and Health Science, Universiti Malaysia Sabah, Jalan UMS, 88400 Kota Kinabalu, Sabah, Malaysia
³Civil Engineering Programme, Faculty of Engineering, Universiti Malaysia Sabah, Jalan UMS, 88400 Kota Kinabalu, Sabah, Malaysia

E-mail: ¹zahrim@ums.edu.my

Abstract. Highly concentration of ammonia nitrogen in urban drainage could pollute the river and give pungent smell. The strong pungent odours that coming out from the urban drainage may degrade the image a city and could possibly reduce the present of tourist. To minimize the presence of pungent odours, the ammonia nitrogen can be removed from the urban drainage by applying proper adsorbent. In this study, an adsorbent produced through chemical modification of fresh empty fruit bunch (EFB) fibers has been carried out. The maximum adsorption capacity is between 0.01-0.60 mg/g. The finding also shows that the retention time is vital when designing ammonia nitrogen filter.

1. Introduction

The common contaminated substances that discharged from urban residential people to the urban drainage with high content of ammonia-nitrogen which released into rivers would diminish the aesthetic values, dirty and kill aquatic life such as fishes and prawns, and destroy marine ecology. Higher concentration of ammonia-nitrogen discharged from urban drainage into the waterways, also known as nitrogen pollution in hydrosphere [1] which contributed to the eutrophication, corrosion and fouling of water bodies like rivers and lakes, increasing the depletion of dissolved oxygen and toxicity to other aquatic organisms [1, 2]. In addition, ammonia-nitrogen in the rivers produced a strong pungent odour smell [3] also reported in Kota Kinabalu, Sabah [4]. The total tourist that visited Sabah in 2004 was 3.065 million visitors as the third largest tourism industry for Sabah [5]. The strong pungent odour that coming out from the urban drainage may degrade the image of the city and could possibly reduce the present of tourist. In general, the prolonged exposure to this pungent odour smell caused respiratory problems, headaches, vomiting, emotional stresses or depression to physical symptoms such as sensory irritation and nausea [6, 7]. To protect the human and environment as well
to sustain the ecotourism, the drainage water with minimum pollutant is considered to be very
important in this regard. From previous studies, there are several techniques to remove ammonia-
nitrogen by using chemical precipitation, membrane filtration, ion exchange, air stripping, sand
filtration, electrodialysis and biological nitrification.

Empty fruit bunch (EFB) fibers suggested had the potential for the removal of ammonia-
nitrogen, nutrient and colour due to its being ecofriendly and abundantly available plant wastes. In
the palm oil mill industry, it was reported that EFB-POME compost contained 1.9 % N, 0.6 % P₂O₅, and
2 % K₂O [8]. Malaysia is one of the world largest palm oil exporters, and about 3.0 million tons of oil
palm empty fruit bunch (EFB) fibers are produced in every year [9]. after the processing of the fruits
in palm oil mill processing, the empty fruit bunch, fibers and shells of oil palm are the primary solid
unwanted wastes [10]. All these wastes are called biomass that produced in the oil palm industry in
Malaysia [11].

Modification of agricultural wastes may break the lignin structure and consequently increase the
ammonia nitrogen removal. Demirak et al.(2015) reported that the modification of the agricultural
wastes by using dilute sodium hydroxide solutions were to improve the penetration of modifying
agents and increase the sorption capacity [12].

2. Materials and Methods

2.1 Biosorbent preparation

The fresh empty fruit bunch (EFB) fibers were collected from Tawau. The parameters of the empty
fruit bunch [13] are summarized in Table 1.

| Parameters          | Shredded EFB |
|---------------------|--------------|
| Moisture (%)        | 24           |
| pH                  | 6.7          |
| C (%)               | 53.0         |
| N (%)               | 0.9          |
| C/N                 | 58.9         |
| COD (mg/L)          | -            |
| BOD (mg/L)          | -            |
| Oil and grease      | -            |
| Total solid (mg/L)  | -            |
| Cellulose (%)       | 52.5         |
| Hemicellulose (%)   | 28.8         |
| Lignin (%)          | 17.1         |

These EFB fibers were washed with tap water to remove the unwanted residual salinity and dirtiness
such as soil-sand and leftover palm oil and waxy impurities. After that, the half clean EFB fibers were
started to shred into small piece and put into a pail and soaked with tap water for repeated 5 times in
30 minutes. Next, these soaked EFB fibers were again washed with distilled water before its dried
under the room temperature for 3 days. Modifications of the EFB fibers were carried out by the
treatment with 10 mM of NaOH for 12 hours in room temperature. Then, the modified fresh EFB
fibers were again washed with distilled water and dried in an oven at 60°C for 48 hours until a constant
weight is obtained. For the preparation and modification of the large scale of modified EFB fibers, tap
water were used instead of distilled water.
2.2 Retention time study for urban drainage water at Kampung Sembulan Lama, Kota Kinabalu, Sabah

A random urban drainage water sampling was collected at Kampung Sembulan Lama (Point 1 to 4). The distance between each point was 100 cm as shown in figure 1. The collected drainage water samples from four points were took back to the laboratory, Faculty Engineering, UMS. The sample of each point was used to determine the retention time by using 7 grams of modified fresh EFB fibers were added into beaker that contained 500 mL drainage water for 120 minutes. The initial reading of ammonia-nitrogen concentration, pH, conductivity and COD for the drainage water was determined as well.

![Figure 1. Schematic diagram of urban drainage system at Kampung Sembulan Lama drainage (Point 1 to 4), Kota Kinabalu, Sabah.](image)

2.3 Analysis

The ammonia-nitrogen concentration contents were analyzed according to the volumetric method based on Nessler method [14]. The Chemical Oxygen Demand (COD) was analyzed by using Spectrophotometer HACH DR 6000. The conductivity and pH were measured by using HI 9811-5 portable meter, Hanna instruments.

3. Results and Discussion

It was found that the ammonia nitrogen content and organic matter (measured as Chemical Oxygen Demands) was insignificantly reduced. It is believed that this happen due to insufficient contact time. Therefore an attempt was made to investigate suitable detention time for removing pollutants especially ammonia-nitrogen.

Table 2 showed the characteristics of urban drainage water for the initial concentration on ammonia-nitrogen, Chemical Oxygen Demand (COD), conductivity and pH.

| Point  | Point 2 | Point 3 | Point 4 |
|--------|---------|---------|---------|
| Initial ammonia-nitrogen concentration (mg/L) | 34.71 | 37.36 | 31.35 | 27.77 |
| COD (mg/L) | 32 | 20 | 41 | 28 |
| Conductivity (μs/cm) | 1930 | 2320 | 570 | 460 |
| pH | 7.1 | 7 | 6.6 | 6.5 |
It appeared that the highest ammonia-nitrogen concentration occurred at point 2 which is 37.36mg/L and the lowest concentration at point 4 is 27.77mg/L. The highest COD was measured at point 3 which is 41 mg/L due to located at the centre of the lagoon area. The COD was diluted when the drainage water flowing out from point 3 to point 1. The conductivity values was observed much higher at points 1 and 2 than points 3 and 4 due to it nearer to the river that connected to the seawater. The conductivity indicates high salinity with present of dissolved ions namely sodium ions and chloride ions [20]. It found that the pH of the drainage water from Kampung Sembulan Lama is in the range from pH 6.5 to 7.1. Ammonia exists in aqueous solution as ammonium ion of the solution which below pH 9.25, the predominant species is \( \text{NH}_4^+ \) [21]. This proved that there is ammonium content inside the urban drainage water at Kampung Sembulan Lama due to its pH of the drainage water is below pH 9.25.

Based on Table 3, the drainage water collected at Kampung Sembulan Lama at different random points, point 1 to point 4. The investigation of the ammonia-nitrogen removal by EFB fibers was conducted by carry out a series batch of biosorption experiments for adsorption capacity.

|                  | Point 1 | Point 2 | Point 3 | Point 4 |
|------------------|---------|---------|---------|---------|
| Adsorption capacity (mg/g) |         |         |         |         |
| (10 min)         | 0.04    | -0.09   | -0.08   | -0.02   |
| (40 min)         | 0.22    | 0.03    | -0.30   | 0.01    |
| (80 min)         | 0.07    | 0.47    | 0.08    | 0.07    |
| (120 min)        | 0.19    | 0.60    | 0.23    | 0.25    |

Most of the ammonia-nitrogen solution removal occurs within a 20 minutes contact time. After 20 minutes, the ammonia uptake by the EFB fibers continued in a much slower rate until reached almost 40 minutes when the equilibrium is reached. The adsorption capacity in minutes 40 was showed 0.22 mg/g, 0.03 mg/g, -0.3mg/g and 0.01mg/g at point 1 to 4. From the table 2, the adsorption capacity showed a negative adsorption capacity due to adsorption was occurred by poor adsorption. The negative adsorption indicated that the adsorption behaviour did not fit on Langmuir approach which leading to negative slopes [15]. Also, negative values adsorption capacity data was not suitable to plot the graphs as no adsorption occurred on that particular time [16]. The inadequacy for the negative values for ammonia of the isotherm model to explain the adsorption process [17].

While in minutes of 120 minutes, the range of adsorption capacity was 0.19 and 0.6 mg/g at point 1 and point 4. The adsorption is reaching the equilibrium state at time of 40 minutes. The adsorption capacity is 0.22 mg/g at point 1 and 0.01 mg/g at point 4 was adsorbed by EFB fibers in the 40 minutes when all the EFB fibers sites vacant and the ammonia-nitrogen concentration gradient was high because of film diffusion onto the external surface of EFB fibers [1]. This is due to the contact time for the EFB fibers to react with the ammonium ions in the urban drainage water. The cation ion from the ammonium ions will interact with the anions from the surface of the lignocellulosic that is negatively charged [1]. At the time reached 120 minutes, it becomes equilibrium in which there is no interaction happened between EFB fibers and ammonium in the drainage water. Beyond that 120 minutes contact time, the adsorption of the ammonia-nitrogen removal is remain approximately constant. Similarity study also had been done by using different biosorbent such as P. oceenica considered a rapid ammonium adsorption process compared to other adsorbents [18]. This can show that the modified EFB fiber for the vacant surfaces were reduced with time increased. The large number of vacant surface sites are available for the sorption is fast at the initial stage and then the
remaining surface sites are difficult to be occupied because the repulsion between the N-NH$_4^+$ on the adsorbent fibers and bulk phase [19].

The retention time for the ammonia-nitrogen removal is at 80 minutes. Davis et al. (2001) suggested that the biological pond containing hardwood mulch and several plant species with retention time of 130 to 250 minutes for removing of several pollutants including ammonia nitrogen. The ammonia nitrogen was reduced to 87% from the initial concentration of 2.4 mg/L [22]. The detention time for ammonia removal was 1.4 to 60.6 days of -86.0 to 96.0 % of long term pollutant for treatment of stormwater runoff by using wetlands [23]. In another study, Ghosh and Gopal (2010) reported that the 77.58 to 99.96 % removal of ammonium nitrogen at retention time of 1-4 days [24]. According to Harmayani and Anwar (2012), the hydraulic retention time was after 60 to 90 minutes for the ammonia (NH$_4^+$) with the initial ammonia concentration of 0.5 to 5.0 mg/L. The maximum NH$_4^+$ biosorption showed by using the sawdust was 137.5 mg/g [17]. Dumont et al. (2014) reported that the average ammonium-N adsorption onto wood residues (G30) was 0.154 mg/g during the first 14 days of submersion. The maximum uptake for the ammonium nitrogen (NH$_4^+$-N) adsorption onto the wood residues (G30) was 0.191 mg/g at constant throughout 60 days [25]. Besides that, Ma et al. (2011) reported that the time needed for the ammonium removal by wheat straw was 240 minutes. The maximum adsorption capacity was 148.7 mg/g with the pH range of 4 to 8 [26].

4. Conclusion

Several past studies have been reviewed and the literatures suggest the potential of modified agricultural wastes for treating the pollutants from urban drainage water. Little knowledge was found for fiber modification for the ammonia-nitrogen removal purpose. Our study found that the filter (modified fresh EFB) retention time is critical during the operation of modified EFB. Besides that, the retention time of minimum eighty minutes is required for effective removal of ammonia-nitrogen from Kota Kinabalu urban drainage water.

5. References

[1] Wahab M A, Jellali S and Jedidi N 2010 *Bioresource Technology* **101** 8606-15
[2] Liu H, Dong Y, Liu Y and Wang H 2010 *Journal of Hazardous Materials* **178** 1132-6
[3] Talaiekhozani A, Bagheri M, Goli A and Talaei Khoozani M R 2016 *Journal of Environmental Management* **170** 186-206
[4] Xiang N J 2013 *Water of life from muddy microbes. Insight Sabah. Kota Kinabalu.*
[5] Charuruks I B 2015 *Sabah tourism board. In: Ministry of Tourism, Culture and Environment, Kota Kinabalu, Sabah.*
[6] Nicell J A 2009 *Atmospheric Environment* **43** 196-206
[7] National Research Council Committee on Odors, 1979 *Ordors from stationary and Mobile Sources. Board on Toxicology and Environmental Hazards, Assembly of Life Sciences. National Research Council, National Academy of Sciences, Washington, DC.*
[8] Zahrim A Y and Asis T 2010 *Malaysia* **71** 11-7
[9] Sajab M S, Chia C H, Zakaria S and Khiew P S 2013 *Bioresource Technology* **128** 571-7
[10] Omar R, Idris A, Yunus R, Khalid K and Aida Isma M I 2011 *Fuel* **90** 1536-44
[11] Ngadi N and Lani N S 2014 *Science & Engineering* **68(5)** 35-9
[12] Demirkak A, KESKİN F, ŞahiN Y and Kalemci V 2015 *Mugla Journal of Science and Technology* **1** 5-12
[13] Baharuddin A S, Wakisaka M, Shirai Y, Abd-Aziz S, Abdul Rahman N A and Hassan M A 2009 *International Journal of Agricultural Research* **4** 69-78
[14] HACH 2012 *DR/2010 Spectrophotometer Procedures Manual, Spectrophotometer Handbook (U.S.A)*
[15] Kiurski J, Adamovic S, Krstic J, Oros I and Vojinovic M M 2011 Adsorption efficiency of low-cost materials in the removal of Zn(II) ions from printing developer ACTA Technica Corviniensis. Bulletin of Engineering.

[16] Adediran G O, Nwosu F O and Adekola F A 2000 Nig. J. Pure & Appl. Sci. 15

[17] Harmayani K D and Anwar A H M F 2012 A International Journal of Environmental Science and Development 3 114-7

[18] Jellali S, Wahab M A, Anane M, Riahi K and Jedidi N 2011 Desalination 270 40-9

[19] Mansuri N, Mody K and Basha S 2014 Internation Journal of Environmental Science and Technology 11 1711-22

[20] Fondriest 2015 Conductivity, Salinity & Total Dissolved Solids.

[21] Suneethan M and Ravindranath K 2012 Der Pharma Chemica 4 214-27

[22] Davis A P, Shokouhian M, Sharma H and Minami C 2001 Water Environment Research 73 5-14

[23] Carleton J N, Grizzard T J, Godrej A N and Post H E 2001 Water Research 35 1552-62

[24] Ghosh D and Gopal B 2010 Ecological Engineering 36 1044-51

[25] Dumont P A, Chadwick D R and Robinson S 2014 Sustainability, Agri, Food and Environmental Research 2 47-67

[26] Ma Z, Li Q, Yue Q, Gao B, Li W, Xu X and Zhong Q 2011 Chemical Engineering Journal 171 1209-17