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Problems of Ammonia and Manganese in Malaysian Drinking Water Treatments

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Abstract: The contamination of ammonia (NH_3-N) and manganese (Mn) in Malaysian rivers exceeding standard limits is a major problem to drinking water treatment plants (DWTPs). High level of NH_3-N and Mn in raw water are due the sewage discharged and effluent from domestic and latex based industry to the river. The NH_3-N and Mn concentrations have been evaluated at four selected DWTPs using the data since the year 2005 to 2009. From the assessment, three DWTPs (DWTP2, DWTP3 and DWTP4) were always received raw water containing high NH_3-N and Mn concentrations. Meanwhile, the raw water at DWTP1 recorded NH_3-N and Mn concentrations were found below the Malaysian regulated limit (Mn < 0.2 mg/L; NH_3-N < 1.5 mg/L). DWTP3 recorded 17 times of shutdown frequency, followed by DWTP2 (9 times) and DWTP4 (8 times) since the year 1998 to 2010 due to high content of NH_3-N. One-way analysis of variance (ANOVA) showed that the significant fluctuation ($p < 0.05$) of NH_3-N concentrations in raw water occurred on the year 2007 and 2009, while significant fluctuation of Mn concentration in raw water was observed on year 2005 and 2008 ($p < 0.05$).

Key words: River contamination · Ammonia removal · Manganese removal · Drinking water treatment · Biological aerated filter

INTRODUCTION

Water is generally known as an important necessity for all activities such as living consumption, industries, agricultural and routinely human activities of drinking, washing and bathing. Clean drinking water is essential to human and other living things. However, the sources of the clean drinking water are contaminated by chemical constituents (organics, inorganics and gases) and physical contaminants (colour, odour and solid) [1, 2]. Inorganic pollutants such as ammonia-nitrogen (NH_3-N) and manganese (Mn) are the main problems in Malaysian drinking water treatment plants (DWTPs). Both pollutants exist in water via naturally creation, domestic and industrial effluents and sludge discharge. Basically, NH_3-N is formed at low concentration through nitrogen mineralization process from organic matters. Once, the drinking water is contaminated by other NH_3-N and Mn sources, the NH_3-N and Mn levels increased to a high concentration exceeding the Malaysian regulated standard limit.

In Malaysia, there are two standards regulated for drinking water quality of raw and treated water. For raw water, the regulated standard limit is acceptable below than 1.5 mg/L for NH_3-N and 0.2 mg/L for Mn [3]. Meanwhile, the acceptable limits for treated water are also below than 1.5 mg/L for NH_3-N and 0.1 mg/L for Mn. As summarized in Table 1, European Communities regulates the maximum allowable concentration for NH_3-N and Mn below than 0.5 mg/L and 0.05 mg/L, respectively. In developed countries like USA and Canada, there are no regulated guidelines for NH_3-N concentration in water because the contaminant was observed low in raw and treated water. However, for developing country such as Malaysia, the limit of NH_3-N is regulated due to the frequent problem of high NH_3-N contamination.

Generally, the presence of NH_3-N caused a problem in taste and odour of water [9], toxicity to aquatic lives, oxygen depletion and occurrence of eutrophication [10]. The contaminant also created hazardous by-products of carcinogenic chloramines when react with chlorine during

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Table 1: Drinking water quality guidelines for NH_3-N and Mn

Countries	NH_3-N (mg/L)	Mn (mg/L)	References
Malaysia	Raw water: ≤ 1.5	Raw water: ≤ 0.2	[3]
	Drinking water: ≤ 1.5	Drinking water: ≤ 0.1	
WHO	Drinking water: ≤ 1.5	Drinking water: ≤ 0.1	[4]
European Communities	Drinking water: ≤ 0.5	Drinking water: ≤ 0.05	[5]
Canada	No guideline	Drinking water: ≤ 0.05	[6]
USA	No guideline	Drinking water: ≤ 0.05	[7]
Australia	Drinking water: ≤ 0.5	Drinking water: ≤ 0.05	[8]

the chlorination process at the final stage of a DWTP process [11]. Moreover, the drinking water containing more than 0.2 mg/L of ammonia would decrease the disinfection efficiency [12, 13]. Mn in drinking water will affect on pipe clogging due to the accumulation and precipitation of Mn^{4+} in water distribution for a long period of time in which consequently resulting in restricted water flow [14]. The Mn concentration over 0.1 mg/L, lead to a bad impact on water discoloration, metallic taste, odor problem, turbidity, biofouling and corrosion, staining of laundry and plumbing fixture [15]. Although, the Mn contamination does not pose a direct health risk, it can cause chronic aesthetic problems for drinking water utilisites [16]. In any DWTP, high NH_3-N concentration may interfere with the manganese filtration process because too much oxygen is consumed by nitrification in which consequently resulting in mouldy, earthy-tasting water [13, 17].

Recently, the raw water for Malaysian DWTPs is frequently reported having contaminated with NH_3-N and Mn. The problems lead to the water shortage for human populations at certain area since the plant has to be shutdown the plant whenever it receives exceeded allowable NH_3-N level. It is because the present Malaysian DWTPs do not have any ability to treat the NH_3-N and Mn simultaneously at high concentrations. This paper presents the evaluation of NH_3-N and Mn levels in raw water at four selected DWTPs. The study is an ongoing research which ultimately aims to investigate the ability of a biological aerated filter (BAF) system in removing NH_3-N and Mn simultaneously from drinking water.

MATERIALS AND METHODS

Raw data was obtained from one of the water treatment operators that is responsible for treated water in Malaysia. The evaluation was carried out at four selected DWTPs starting from January 2005 to December 2009. Due to the "Confidentially and Non-Disclosure" agreement, the selected DWTPs were named as DWTP1, DWTP2, DWTP3 and DWTP4. The intake points for the DWTPs were located at Labu and Langat Rivers (Figure 1). The data has been analyzed using a one-way analysis of variance (ANOVA) to determine the significant fluctuation of NH_3-N and Mn concentrations at the four different DWTPs with interval coefficient of 95% ($p < 0.05$). Statistical calculations were executed using SPSS software for Windows, version 16.0 (SPSS Inc. USA).

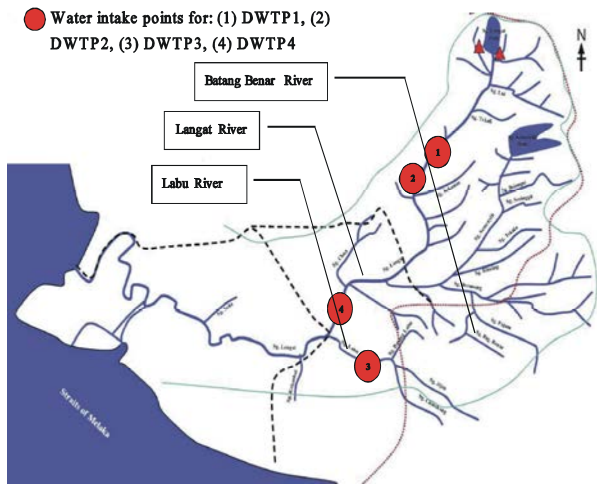

Fig. 1: Location of water intake points

BAF was designed and performed as additional system for Malaysian DWTPs in purpose to remove NH_3-N and Mn simultaneously from drinking water. A laboratory-scale BAF system made of transparent polyvinyl chloride (PVC) was designed with the dimensions of 150 cm height (H) × 16 cm diameter (D) with an effective working volume of 15 L. The BAF design was based on the data correlation of removal performances with BAF dimensions obtained from a previous study [18]. Based on the removal performance [19, 20], it shown that the BAF system could remove NH_3-N and Mn simultaneously from drinking water treatment to below Malaysian regulated limits.

RESULTS AND DISCUSSION

Ammonia Concentrations: Figure 2 shows the levels of NH_3-N concentration in raw water at DWTP1, DWTP2, DWTP3 and DWTP4 since the year 2005 to 2009. From the chart, it was found that only DWTP1 received the raw water containing NH_3-N below the Malaysian regulated limit (< 1.5 mg/L) [3].

Instead, three cases of NH_3-N concentration over the maximum concentration limit (MCL) that were recorded at DWTP2 on August 2005 with 2.51 mg/L, September 2005 with 1.91 mg/L and July 2008 with 2.78 mg/L. At DWTP3, only two cases were recorded on August 2005 (3.19 mg/L) and May 2008 (2.02 mg/L). The most serious cases of NH_3-N contamination in raw water were recorded at DWTP4 with five cases which occurred on January 2005 (2.33 mg/L), March 2005 (3.17 mg/L), September 2005 (2.09 mg/L), August 2009 (2.27 mg/L) and October 2009 (2.03 mg/L).

Moreover, Figure 3 shows the frequency of NH_3-N exceeding limit reported at selected Malaysian rivers [21]. As depicted, Labu and Langat Rivers (Figure 1) that supplied the raw water to DWTP1, DWTP2, DWTP3 and DWTP4 was often contaminated with high NH_3-N concentrations. It can be seen that the NH_3-N concentration exceeding the limit in the selected monitoring rivers occurred at almost every year (from year 2004 to 2009). The most serious contamination was recorded on year 2007 where 27 frequencies of NH_3-N exceeding the regulated limits were reported. Then, followed by 2005 (22 frequencies), 2006 (21 frequencies), 2004 (19 frequencies), 2009 (11 frequencies) and 2008 (10 frequencies). On year 2004 to 2007, NH_3-N concentration that exceeded the regulated limit was observed increased, however, the frequency of exceeding limits decreased on year 2008 and 2009.

Due to high levels of NH_3-N in the raw water, the DWTPs were frequently shutdown because the present DWTPs do not have any effective treatment process to treat the contaminant. High levels of NH_3-N in raw water are due to few factors such as industries, agricultural, sewage treatment and landfill which were located adjacent to the rivers. Wastes from the activities as well as domestic wastes, sewage, latex and leachate [21] which were not properly treated were directly released to the rivers. Ujang [22] reported that low effluent quality of sewage discharged to the rivers was due to the ineffective operation of sewage treatment plant. Moreover, the increasing NH_3-N concentration in raw water was also influenced by illegal industries and garbage disposal along the rivers.

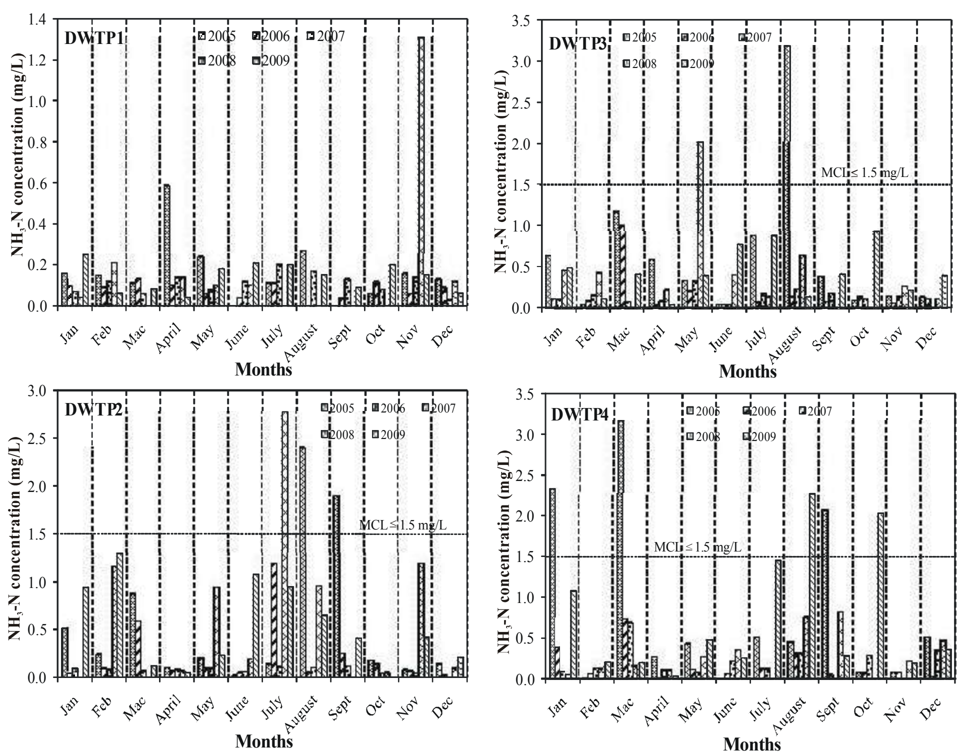

Fig. 2: NH_3-N concentrations in selected DWTPs

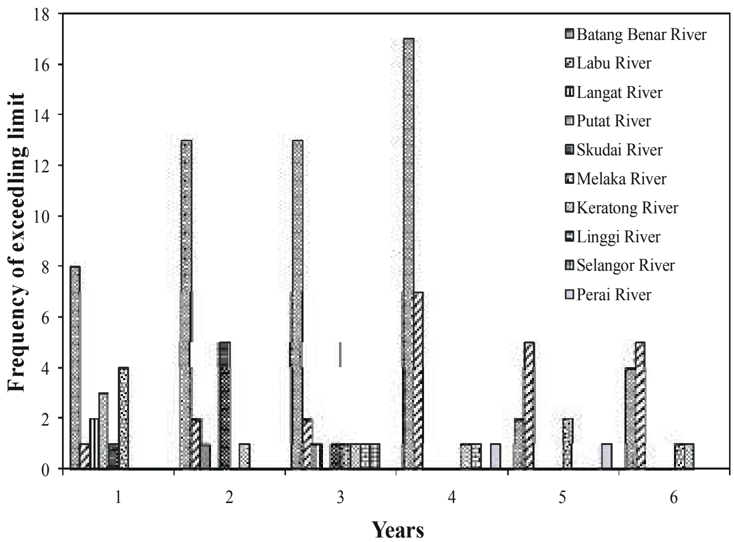

Fig. 3: Frequency of NH_3-N exceeding limit at Malaysian rivers (Source: [16])

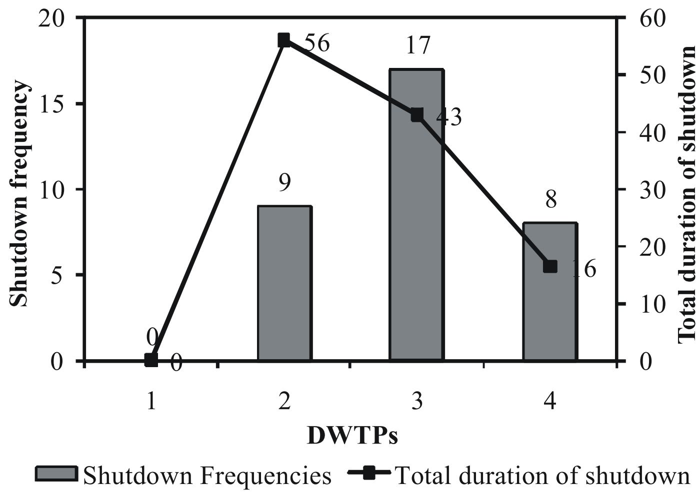

Fig. 4: Frequencies and total duration of plant shutdown

Currently, the only way to decrease the high NH_3-N concentration in raw water was through the dilution process in which it is totally dependent on raining. This method is time consuming and not reliable since the whether condition cannot be predicted for continuous occurrence of NH_3-N dilution. Figure 4 depicts the shutdown frequency of DWTPs since the year 1998 to 2010. The most frequent plant shutdown occurred at DWTP3 with 17 times, following by DWTP2 (9 times) and DWTP4 (8 times). Despite, the shutdown frequency of DWTP2 is less than DWTP3, its total duration of shutdown is much longer with 1340 hours (56 days). Moreover, in the year 2009, the longest shutdown duration was recorded on July with 870 h (36 days) shutdown (DWTP3).

Manganese Concentrations: The Malaysian standard limits for Mn standard in raw water and drinking water were 0.2 mg/L and 0.1 mg/L [3], respectively. Figure 5 shows the Mn concentrations in raw water at DWTP1, DWTP2, DWTP3 and DWTP4 along the year 2005 to 2009. Similar with NH_3-N concentration, the Mn level at DWTP1 was below the regulated standard limit. Four cases of high Mn level were recorded at DWTP2 which occurred on August 2005 (0.27 mg/L), July 2008 (0.49 mg/L), June 2009 (0.25 mg/L), September 2009 (0.29 mg/L) and December 2009 (0.31 mg/L). At DWTP3, the highest Mn concentration was recorded on zSeptember 2005 (0.39 mg/L), March 2006 (0.23 mg/l), May 2008 (0.44 mg/L), March 2009 (0.22 mg/L) and February 2010 (0.31 mg/L). Despite, other months at DWTP3 that recorded the Mn concentration below the standard limit,

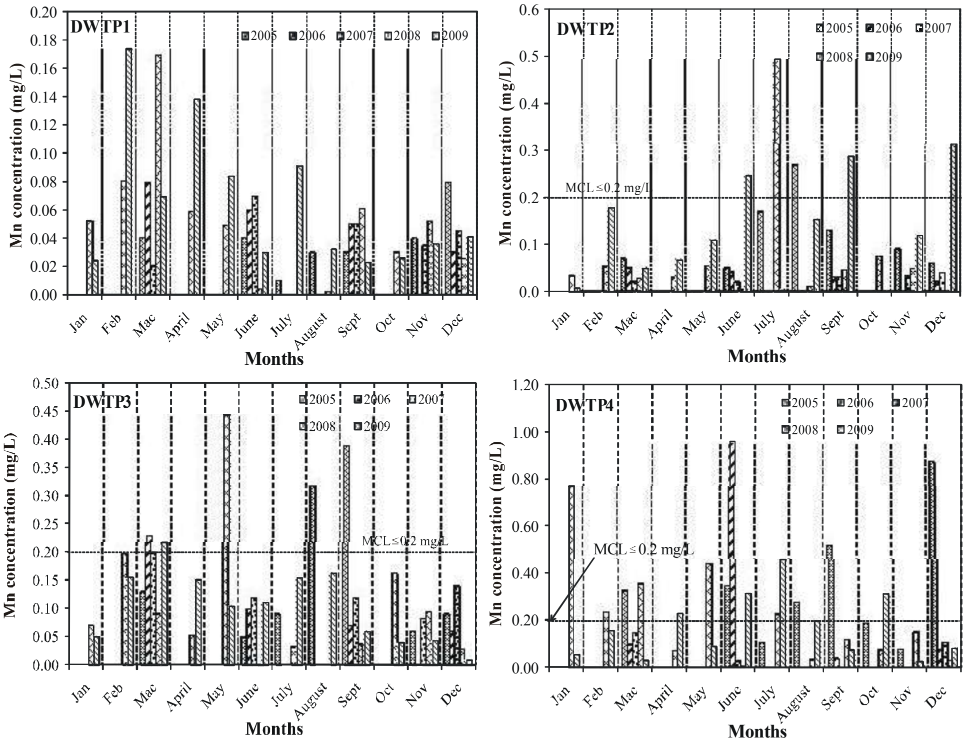

Fig. 5: Mn contamination levels in selected DWTPs

Table 2: ANOVA of NH_3-N and Mn fluctuations

Contaminants	Years	Lowest (mg/L)	Highest (mg/L)	*F*-values	Significance (p < 0.05)
NH_3-N	2005	0.02	3.17	1.46	0.24
	2006	0.02	1.19	0.73	0.54
	2007	0.01	0.70	3.24	0.03
	2008	0.01	2.78	1.45	0.24
	2009	0.02	2.27	3.33	0.03
Mn	2005	0.00	0.88	3.89	0.02
	2006	0.00	0.96	0.92	0.44
	2007	0.00	0.20	2.02	0.12
	2008	0.08	0.77	2.92	0.04
	2009	0.02	0.46	2.43	0.08

the Mn concentrations were almost approaching to 0.2 mg/L. When the Mn presence in water for a long period of time, the oxidation will occur in which consequently yields an accumulation of manganese oxide (MnO_2) in the form of black colour. The contaminant will cause problem on water distribution system as well as in pipe clogging problem.

The most critical Mn concentration in raw water was observed at DWTP4. Fifteen cases of Mn concentration were recorded as exceeding the standard limit since the year 2005 to 2009. The highest Mn concentration in rivers was detected on June 2009 with 0.96 mg/L, following by December 2005 (0.88 mg/L) and January 2008 (0.77 mg/L). The Mn contamination is caused by industries as well as tanneries, metal processing and mining and agricultural activities which were all located adjacent to Langat and Labu Rivers (Figure 1).

Statistical Evaluation: Statistical analysis of ANOVA was performed for four DWTPs (DWTP1, DWTP2, DWTP3 and DWTP4) along year 2005 to 2009 in order to evaluate the most fluctuation of NH_3-N and Mn concentrations. The results were listed in Table 2. One-way ANOVA resulted that the fluctuation of NH_3-N concentration among the four DWTPs, occurred on year 2007 and 2009 ($p < 0.05$). The lowest and highest NH_3-N concentrations has been recorded as 0.02 mg/L and

0.70 mg/L (2007) and 0.02 mg/L and 2.27 mg/L (2009), respectively. However, on the year 2005, 2006 and 2008, the NH_3-N concentrations at the fours DWTPs were not much fluctuated ($p > 0.05$). In contrast to NH_3-N, the significant difference of Mn fluctuation was observed on the year 2005 and 2008 with F-values of 3.89 and 2.92, respectively. The lowest and highest Mn concentrations were recorded as 0 and 0.88 mg/L on year 2005 and 0.08 and 0.77 mg/L on year 2008, respectively. These NH_3-N and Mn fluctuations showed that improper treatment of domestic and latex effluent or sewage before being released to the rivers.

CONCLUSIONS

The concentration of NH_3-N and Mn in raw water during the year 2005 to 2009 at four selected Malaysian DWTPs showed that both contaminants were in fluctuated condition. Along the study period, many cases of high NH_3-N and Mn concentrations exceeding the Malaysian standard regulated limits in raw water were reported. The main sources of contaminated raw water by NH_3-N and Mn were due the sewage discharged, domestic and latex effluent to the river. The high levels of both contaminants cause the frequent shutdown of DWTPs for some period until its levels naturally decreased to below standard limits. It was because the current Malaysian DWTPs does not have any dedicated treatment process to remove the NH_3-N and Mn simultaneously. The shutdown of DWTPs consequently caused disturbance on human routine activities, industries and agricultural works due to periodically water shortage. Thus, a study should be carried out to find out an economical drinking water treatment system as an additional system in the existing DWTPs specifically for simultaneous NH_3-N and Mn removals.

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