CHAPTER 4

A REVIEW: CHARACTERISTICS OF LAKE WATER AND THEIR TREATMENT, SPECIFICALLY ON AMMONIACAL NITROGEN (AN) REMOVAL

Safwan Miswan[1], Rafidah Hamdan[1,2] and Nur Adila Ab. Aziz,[1,2]*

[1]Faculty of Civil Engineering and Built Environment,
Universiti Tun Hussein Onn Malaysia, Batu Pahat, 86400 Johor, Malaysia.

[2] Micropollutant Research Centre (MPRC)
Faculty of Civil Engineering and Built Environment,
Universiti Tun Hussein Onn Malaysia, Batu Pahat, 86400 Johor, Malaysia.
*Corresponding Email: rafidahh@uthm.edu.my

4.1 INTRODUCTION

This chapter presents about lake water in Malaysia and studies on previous studies about characteristics of lake water. The standard also explained in this chapter such National water quality standards for Malaysia (NWQS), Water Quality Index (WQI) and Parameters of water quality standard based on Environmental Protection Agency (EPA). Besides, this chapter also reviews on treatment, specifically on ammoniacal nitrogen (AN) removal by previous studies.

4.2 LAKE WATER IN MALAYSIA AND WATER QUALITY PARAMETER STANDARD

A lake is an enclosed body of water (usually freshwater) of considerable size, surrounded by land with no direct access to sea except with a river or stream that feeds or drains the lake [1]. Lakes are considered lentic systems or standing water compared to rivers which are lotic systems or flowing water. Generally, lakes have in-flowing and out-flowing water which makes them complex. Lakes have three main characteristics which make them so unique; long water retention time and complex response dynamics and integrating nature of water body [2]. Lake may occur anywhere within a river basin as natural or man-made lakes.

Natural lakes consist of wetlands, marshes, estuarine lakes, or naturally occurring lakes whereas man-made lakes can be referred as reservoirs, retention pond, ex-mining pond, recreational lakes [3] or as urban landscape elements. Generally, lakes are important source of freshwater which account for only a very small part of around 0.01 percent of the global amount of water [4]. Table 4.1 shows the number of lakes and reservoirs based on states in Malaysia. The highest number of lakes is from Selangor, 15 lakes and followed by Johor, 13 lakes but in terms of the total area of the lake in dominance by the Terengganu state which is 370.80 km^2. This shows that Malaysia is a country rich in water resources and needs to be carefully protected to maintain water quality of lakes and reservoirs for avoid unnecessary problem occur.

Table 4.1: Lakes and reservoirs based on states in Malaysia [3]

State	Number of lakes	Area (km^2)	Volume (mm^2)
Perlis	2	13.33	40.00
Kedah	7	95.03	1637.76
Perak	11	284.68	6766.50
Selangor	15	11.38	511.32
Pahang	10	96.69	355.71
Kelantan	4	11.34	76.80
Johor	13	84.22	940.02
Labuan	3	0.50	5.40
Melaka	4	8.75	81.30

Table 4.1: (Continued)

State	Number of lakes	Area (km^2)	Volume (mm^2)
Negeri Sembilan	5	2.25	182.33
Penang	4	0.94	47.20
Sabah	5	1.81	29.61
Sarawak	4	97.08	6080.00
Terengganu	2	370.80	13600.00
Putrajaya	1	7.50	45.00
Total	90	1094.89	30398.95

Lakes in Malaysia, natural or artificial, have multiple functions. Almost 90% of the nation's water supply comes from the lake and reservoirs [5]. Lakes and reservoirs serve as the source of water for domestic, industrial and agriculture; hydroelectric power generation; flood mitigation, navigation and recreation [6]. They are also home to a variety of biological species and freshwater fish industry, such as the Bukit Merah Lake in Perak is believed to be the only origin of its natural habitat for the exotic species, Malayan Gold Arowana, Scleropages formosus where this could cost up to USD 15,000-USD 25,000 per fish in the market for a full-grown adult [3].

Natural lakes in Malaysia include wetlands such as Bera Lake and Chini Lake in Pahang, and Dayang Bunting Lake in Langkawi Island, In addition to ox-bow lake such as Paya Gungor in Pahang and Logan Bunut in Sarawak [6]. Among the artificial lakes or reservoirs include Kenyir Lake in Terengganu, Pergau in Kelantan, Batang Ai and Bakunin Sarawak, Temenggor in Perak as well as Pedu and Muda in Kedah [6]. Therefore, the purpose inventory of lakes and reservoir in Malaysia are focusing in water supply, irrigation, hydropower, flood control, reclamation, silt retention, natural, and ex-mining pool.

There are few comprehensive inventories on all lakes in Malaysia. A preliminary assessment showed that there were over 90 lakes in Malaysia which covered and area of over 100,000 ha and contained more than 30 billion cubic meters of water [6]. Table 4.1 shows the lake inventory based on states in Malaysia [3]. This list of lakes inventory was not incomplete; however, including ox-bow lakes and ex-mining ponds over the nation. It was estimated that there were approximately more than 4000 ex-mining ponds in the country with area of 16,000 ha. Besides, the inventory excluded new hydroelectric projects like Bakun Dam in Sarawak. Bakun Dam alone has 695 km^2 of reservoir surface areas with gross storage volume of 44 billion cubic meters [7].

Generally, lakes can function as thermal structures, habitats for organisms and support food chain also playing an important role as nutrient providers to aquatic life [8]. Lake water in Malaysia is one of the surface water sources which play an important role as basic water resources as water is needed for the whole life of human beings and associated activities [9][10]. As time changes, development and population have increased the number of pollutants released into water bodies and deteriorate the quality and ecological system. Lakes also affected by the change come from anthropology or natural factors [9]. Lake is important as part of water resources both in quality and quantity of water as water also needs by various human sector such drinking water supply and irrigation [11].

Other than WQI scales, monitoring of the water quality also can be based on Interim National Water Quality Standards (INWQS) for Malaysia [12], also ecological model methods for water quality prediction [13]. WQI scales provide straightforward measures by making collection data into single index value which denotes the water quality condition level. In Malaysia, guidelines of WQI are enrolled by Department of Environment of Malaysia (DOE) based on six major parameters which are dissolved oxygen (DO), pH value, biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solid (TSS) and ammoniacal nitrogen (AN). Through the classification according to DOE, water will be grouped as ‘clean’, ‘slightly polluted’ and ‘polluted’ if the standards comply within the range of 81 to 100%, 60 to 80% and 0 to 59%, respectively.

As there are few national standards or guidelines upon lake water, classification on water assessment for the lake water mostly are based on DOE’s WQI standards as the lake water are associated as surface water [3]. Focus on this chapter is looking on the trending of water characteristics in several lakes also the use of lakes from Malaysia spectrum.

Table 4.2: National water quality standards for Malaysia [12]

Parameter	Class						
	Unit	**I**	**IIA**	**IIB**	**III**	**IV**	**V**
pH		6.5-8.5	6-9	6-9	5-9	5-9	-
DO	mg/L	7	5-7	5-7	3-5	<3	<1
BOD	mg/L	1	3	3	6	12	>12
COD	mg/L	10	25	25	50	100	>100
SS	mg/L	25	50	50	150	300	300
AN	mg/L	0.1	0.3	0.3	0.9	2.7	>2.7

Note :

Class I	Conservation of natural environment Water supply – Practically no treatment necessary Fishery I – Very sensitive aquatic species
Class IIA	Water supply II – Conventional treatment required Fishery II – Sensitive aquatic species
Class IIB	Recreational use with body contact
Class III	Water supply Extensive treatment required
Fishery III	Common of economic value and tolerant species; livestock drinking
Class IV	Irrigation
Class V	None of the above

Table 4.3: Water quality classification based on Water Quality Index (WQI) [12]

Water Quality Index	Index range		
	Clean	**Slightly Polluted**	**Polluted**
Biochemical Oxygen Demand (BOD)	91-100	80-90	0-79
Ammoniacal Nitrogen (AN)	92-100	71-91	0-70
Suspended Solids (SS)	76-100	70-75	0-69
Water Quality Index (WQI)	81-100	60-80	0-59

Reflecting from the water quality assessment, the quality will provide a lake status before taking into consideration for any use purpose. Table 4.2, Table 4.3 and Table 4.4 show some parameters for surface water quality that made by National water quality standards for Malaysia (INWQS), Water Quality Index (WQI) and Environmental Protection Agency (EPA).

Table 4.4: Parameters of water quality standard based on Environmental Protection Agency [12]

Parameter	Standard value
pH	8.5
DO (mg/L)	10
Temperature (^oC)	25
BOD (mg/L)	40
COD(mg/L)	7
TSS (mg/L)	50
Turbidity (NTU)	50
Ammoniacal nitrogen (mg/L)	1.5
Nitrite (mg/L)	0.03
Nitrate (mg/L)	10

Several researchers have investigated the characteristics of lake water in the Malaysia region as shown in Table 4.5. Daud & Syazwani [14] examined the characteristics of Engineering and Serumpun Lake at Universiti Putra Malaysia (UPM) and revealed different characteristics of each lake water even with same pollution sources including agricultural activities and domestic sources. Engineering lake has 7.2, 13.09 NTU, 78.33 mg/L, 212.4 mg/L, 60 mg/L, 0.37 mg/L and 0.77mg/L of pH, turbidity, BOD, COD, TSS, AN and DO were respectively. Meanwhile, Serumpun Lake has 7.3, 13.86 NTU, 212.63 mg/L, 66.1 mg/L, 0.42 mg/L and 0.84 mg/L which was little bit higher for pH, turbidity, COD, TSS, AN and DO respectively. However, based on Water Quality Index (WQI), these lakes were polluted for Engineering and Serumpun lakes, respectively. Both lakes were classified as Class IV and the water is suitable for irrigation uses only.

Table 4.5: Characteristics of lake water by previous studies in Malaysia

Parameter	[14]	[14]	[11]	[15])
	Engineering Lake	**Serumpun Lake**	**Cempaka Lake**	**Sembrong Lake**
pH	7.2	7.3	6.9	8.2
Turbidity	13.09 NTU	13.86 NTU	NR	NR
BOD	78.33 mg/L	48.6 mg/L	0.97	11.9
COD	212.4 mg/L	212.63 mg/L	22.17	33.07
TSS	60 mg/L	66.1 mg/L	6.75±2.50	54.33
TN	NR	NR	NR	NR
TP	NR	NR	NR	1.39
AN	0.37 mg/L	0.42 mg/L	2.46±0.32	1.91
DO	0.77 mg/L	0.84 mg/L	3.2 mg/L	8.18
SO_4	NR	NR	18.58±0.46	NR
NO_2	NR	NR	0.19±0.12	NR
NO_3	NR	NR	1.17±0.10	NR

Gasim et al., [11] claimed that the Cempaka Lake, Bandar Baru Bangi, Selangor, Malaysia was classified moderately polluted due to urban activities based on WQI. The results for pH, BOD, COD, TSS, AN, DO, SO4, NO2 and NO3 were 6.9, 0.97 mg/L, 22.17 mg/L, 6.75±2.50 mg/L, 2.46±0.32 mg/L, 3.2 mg/L 18.52±0.46 mg/L, 0.19±0.12 mg/L and 1.17±0.10 mg/L respectively. Sharip et al., [15] had conducted a study on lake water characteristics in Sembrong Lake, Batu Pahat, Johor. The study found that the lake was slightly polluted according to WQI. The problem occurred because the lake water was surrounded by 84 % agriculture activities. The Sembrong Lake water samples have 8.2, 11.9 mg/L, 33.07 mg/L, 54.33 mg/L, 1.39 mg/L, 1.91 mg/L and 8.18 mg/L of pH, BOD, COD, TSS, TP, AN and DO, respectively.

In Malaysia, water quality of a lake can be influenced by external inputs entering the lake from the watershed as well as the in-lake ecosystem, nutrients cycling and internal loading. External inputs can be organic and inorganic pollutants as well as nutrients which cause deterioration of water quality from point and non-point sources. Nutrient input from point sources is relatively easy to determine and well characterized because it is concentrated and sampling is easy [16]. Meanwhile, input from nonpoint sources is more difficult, but broad ranges of nutrient loss rates from different types of land uses are known [17]. Point sources include discharge from domestic and municipal wastewater, agricultural effluents including applied of fertilizers and industrial wastewaters whereas non-point sources include urban/storm water runoff, agricultural runoff, septic tank overflow and construction sites runoff [18].

Excessive input of nutrients such as phosphorus and nitrogen into the lakes will lead to eutrophication. Agricultural and urban uses lead to the greatest degree of runoff, with human population density in a watershed demonstrating a significant positive correlation to nitrogen and phosphorus runoff [19]. Eutrophication is the process by which a water body becomes uncontrollably rich and abundant in aquatic plants such as algae and aquatic macrophytes (water weeds) due to plant nutrients enrichment, especially phosphorus and nitrogen as dissolved solutes and as compounds bound to organic and inorganic matters from natural and anthropogenic sources [3]. Eutrophication will induce an undesirable disturbance to the balance of organisms present in the water and to the quality of water. According to Huang et al., [3] stated that 56 lakes or 62% of the 90 lakes evaluated were eutrophic while 34 lakes or 38% were mesotrophic. These lakes were assessed based on the Tropic State Index (TSI) values, computed adopting the land use and TP relationships. Therefore, steps are needed to solve the deterioration of water quality.

4.3 CONVENTIONAL NITROGEN, AMMONIA AND NITRATE REMOVAL TECHNOLOGIES

The latest available nitrogen removal technologies can be categorized into physiochemical or biological means. There are six types of physiochemical technologies and seven types of biological technologies listed in the literature. The advantages and limitations of each technology are described in Table 4.6. According to Gupta et al., [20], ion-exchange, adsorption and biological technology are among the most frequently studied technologies for wastewater treatment of ammonium ions. However, these technologies are costly in terms of production, operation and maintenance since they require chemical reagents or complementary facilities [21].

Table 4.6: The advantages and disadvantages of nitrogen removal technologies

Process	Nitrogen removal technologies	Advantages	Disadvantages	Result	Reference
Physicochemical	Ammonia air stripping	Treatment of wastewater with high ammonium concentration Simple operation and effective	High cost of ammonia recovery Icing of the lower packing strata in freezing conditions	69% for ammonia removal	[22]
	Ammonia precipitation as struvite	Able to treat concentrated wastewater (digested sludge liquor, landfill leachate)	The cost of adding magnesium salts is the major economic constraint Struvite precipitation can be influenced by impurities such as calcium	82% for ammonia removal	[3]
	Ion exchange process	Highly efficient and simple process Good control of effluent quality No sensitivity in fluctuation in NH_4^+ influent concentration	High cationic concentration (potassium, calcium, sodium, magnesium) of the solution will reduce ammonium removal capability	87% of ammonium removal	[23]
	Adsorption	Effective and economic method Flexibility in design and operation	Only applicable to wastewater with low AN content Regenerations process is not available for all types of adsorbents	82% of ammonia nitrogen removal	[24]

Table 4.6: (Continued)

Biological	Nitrification and denitrification	Environmental friendly and cost-effective	May become complicated when applied to industrial wastewater due to the varied characteristics Slow	Approximately 100% of total nitrate removal	[26]
	Simultaneous nitrification and denitrification (SND)	Low biomass yield during anaerobic growth Effective in maintaining a neutral pH level in the reactor	Requirement of advanced bioreactors which have adjustable aerobics, buffer and anoxic zone with liquid circulation	75% of total nitrogen removal	[27]
	Autotrophic denitrification	Less sludge production Low biomass build-up	Wastewaters have a very low concentration of biodegradable organic material that requires addition of an electron donor substrate	98±0.4% of nitrogen removal	

4.4 CONCLUSION

Overall, this chapter can give some information about several water quality studies in Malaysia. This chapter also provide standards that applied in previous studies such as NWQS, WQI and EPA. Furthermore, the critical review on treatment of water that focuses on ammonia nitrogen removal have been discussed in this chapter.

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