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Chapter 3

Quality of Water Resources in Malaysia

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1. Introduction

The rapid urbanisation and growth of the population has led to both the ever increasing demand forwater consumption and in tandem the levels of water pollution in Malaysia. Rapid development has produced great amounts of human wastes, including domestic, industrial, commercial and transportation wastes which inevitably ends up in the water bodies. A large number of rivers are so polluted that in some, the consequences are to the extent that the rivers cannot be rehabilitate. Consequently, access to clean and safe water supply has become a tremendous challenge for the water authorities to surmount. Recognizing this, conservative water quality monitoring programs and sustainable use of water are promoted. The major pollutants in Malaysian's rivers and lakes are Biochemical Oxygen Demand (BOD), Ammoniacal Nitrogen (NH3-N) and Suspended Solids (SS). High BOD is contributed largely by untreated or partially treated sewage from manufacturing andagro-based industries. The main sources of NH3-N are domestic sewage, livestock farming and other liquid organic waste products, whilst the sources for SS are mostly earthworks and land clearing activities which the removal is generally achieved through the use of sedimentation and/or water filters. The pollution in rivers and lakes has made it necessary for the water providers to take measures toward securing a stable supply of tap water and supplying potable water. On the other hand, the main contaminants of the marine waters in the country are mainly suspended solids, Escherichia coli, and oil and grease, whilst for groundwater are solid waste landfills, radioactive landfill, etc.

2. River water

River water quality and pollution control need to be addressed urgently since 98 percent of the total water use originates from the rivers. 70% of the water resources in the country are for the agricultural industry.As river water pollution increases, concentrations of the existing pollutants increase. Consequently, it increases water 'quantity scarcity' since good quality water available for use decreases and higher water treatment costs due to the presence of new pollutants. Moreover, the ecological health of the water bodies and the surrounding eco-systems degrade, affecting aquatic lives and habitat, and recreational activities.

2.1. River water quality and status

The Department of Environment (DOE) uses Water Quality Index (WQI) and National Water Quality Standards for Malaysia (NWQS) to evaluate the status of the river water quality [1]. The WQI introduced by DOE is being practiced in Malaysia for about 25 years and serves as the basis for the assessment of environment water quality, while NWQS classifies the beneficial uses of the watercourse based on WQI. In 2012, nine rivers within the Klang River Basin under River of Life Project were added to the national river water quality monitoring programme. The river water quality was assessed based on a total of 5,083 samples taken from a total of 473 rivers. Out of 473 rivers monitored, 278 (59 percent) were found to be clean, 161 (34 percent) slightly polluted and 34 (7 percent) polluted [1]. Figure 1 shows the river water quality trend for 2005-2012.

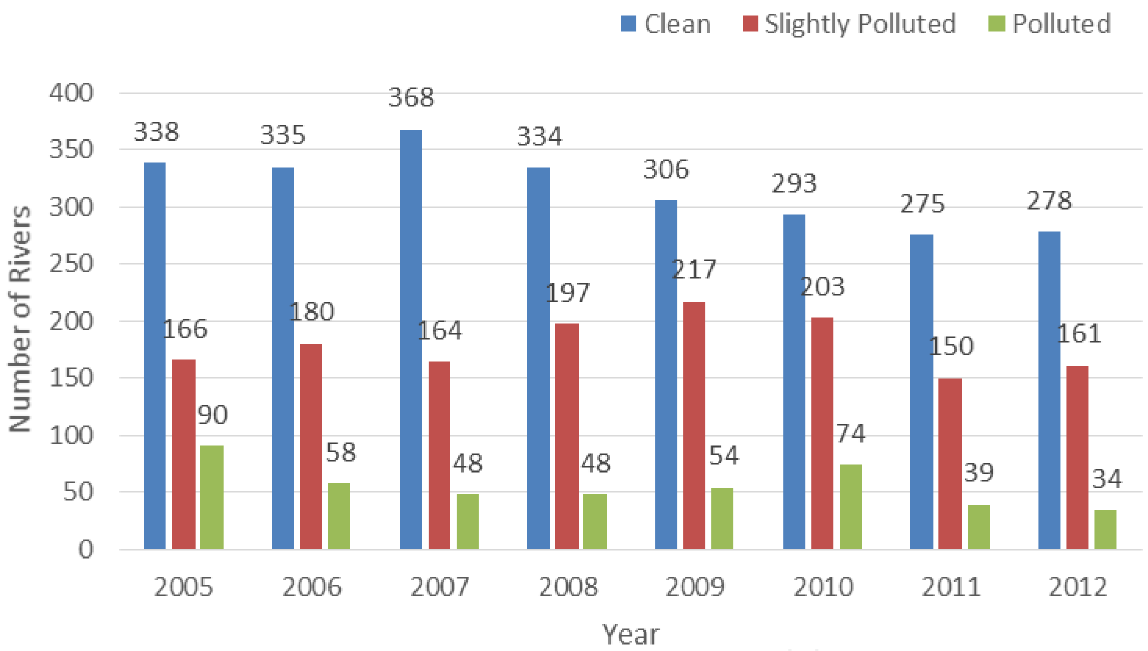

Figure 1. River water quality trend for 2005-2012 [1]

In 2012, 34 rivers were categorized as being polluted, as shown in Figure 1. Out of these, 19 rivers were classified as Class III, 14 rivers as Class IV and one river as Class V. Classification of level pollution by individual pollutant follows the standard set by DOE, as shown in Table 1. Construction activities such as earthworks and land clearing appear to be the main contributor for the sources of SS, whilst the sources for BOD and NH3-N were mostly from agro-based industries and livestock farming, respectively. Pollution of river by untreated or partially treated sewage was also indicated in term of BOD and NH3-N. Besides pollution from organic

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pollutant, inorganic pollutant especially heavy metals also another crucial contribution. Mercury (Hg), Arsenic (As), Cadmium (Cd), Chromium (Cr), Plumbum (Pb), and Zinc (Zn) were analyzed. All Pb, Cd and Zn data were within the Class IIB limits of the NWQS. Meanwhile, 99.97 percent of the data for Cr were within the Class IIB limits of the NWQS followed by Hg (99.96 percent) and As (99.68 percent) [1].

Parameter	Unit	Class				
		I	II	III	IV	V
Ammoniacal Nitrogen	mg/l	< 0.1	- 0.3	0.3 - 0.9	0.9 - 2.7	> 2.7
Biochemical Oxygen Demand	mg/l	< 1	1– 3	3 - 6	6 – 12	> 12
Chemical Oxygen Demand	mg/l	< 10	10 – 25	25 – 50	50 – 100	> 100
Dissolved Oxygen	mg/l	> 7	5 – 7	3 - 5	1 - 3	< 1
pH	-	> 7	6 - 7	5 - 6	< 5	> 5
Total Suspended Solid	mg/l	< 25	25 - 50	50 - 150	150 - 300	> 300
WQI	-	< 92.7	76.5 - 92.7	51.9 - 76.5	31.0 - 51.9	> 31.0

Table 1. DOE Water Quality Index Classification [1]

According to the National Water Quality Standards, surface water quality could be gradually improved/upgraded to a better water class based on the standard values of 72 parameters in 6 water use classes. Tables 2 and 3 illustrate the water classes and uses and the DOE Water Quality Classification based on WQI, respectively.

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

Table 2. Water Classes and Uses [1]

Sub Index & Water Quality Index	Index Range		
	Clean	Slightly Polluted	Polluted
Biochemical Oxygen Demand(BOD)	91 - 100	80 - 90	0 - 79
Ammoniacal Nitrogen(NH3-N)	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

Table 3. DOE Water Quality Classification based on Water Quality Index [1]

2.2. River water pollution

The sources of water pollution can be categorized as point sources and non-point sources. Point sources of pollution are referred to the sources with discharges entering water body at specific locations such as discharges from industries, sewage treatment plants and animal farms, while non-point sources do not have specific discharge point such as surface run-off.In 2012, 1,662,329 water pollution point sources were identified, which comprised of 4,595 manufacturing industries, 9,883 sewage treatment plants (not including individual and communal septic tanks), 754 animal farm (pig farming), 508 agro-based industries, 865 wet markets and 192,710 food services establishments[1].

According to [1], there were three parameters of pollutant loading that have significant impact on the river quality, which include BOD, SS and NH3-N. The estimated BOD load of 848 tons per day in 2012 had decreased by 39 percent compared to 2011 (1,394 tons per day). On the other hand, the estimated SS load was 1383 tons per day, while the estimatedNH3-N load was 232 tons per day, in 2012. Based on the monitoring results in 2012by DOE [1], in terms of river basin basis, Klang River Basin received the highest BOD Load (142 tons per day), followed by Perak River Basin (State of Perak) 114 tons per day, Sarawak River Basin (State of Sarawak) 30 tons per day, Jawi River Basin (State of Pulau Pinang) 26 tons per dayand Muar River Basin (State of Johor) 24 tons per day. Klang River Basin also received the highest SS Load (360 tons per day) and NH3-N load (37 tons per day) among the river basins in Malaysia.

3. Lakes and reservoirs

A lake is an enclosed body of water (usually freshwater) with considerable size, totally surrounded by land with no direct access to sea except with a river or stream that feeds or drains the lake [3, 4]. Lakes are considered lentic systems or standing water compared to rivers which are lotic systems or flowing water [5]. Generally, lakes have in-flowing and out-flowing water which makes them complex [5]. Lakes have 3 main characteristics which make them so unique: long water retention time and complex response dynamics and integrating nature of water body [6]. Lake may occur anywhere within a river basin as natural or man-made lakes [4, 7]. 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 [8] or as urban landscape elements. Generally, lakes are important source of freshwater which account only the very small part of around 0.01 percent of the global amount of water [7].

State	Number	Area (km^2)	Volume (Mm^3)
Perlis	2	13.33	40.00
Kedah	7	95.03	1,637.76
Perak	11	284.68	6,766.50
Selangor	15	11.38	511.32
Pahang	10	94.69	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
Negeri Sembilan	5	2.25	182.33
Penang	4	0.94	47.20
Sabah	5	1.81	29.61
Sarawak	4	97.08	6,080.00
Terengganu	2	370.80	13,600.00
Putrajaya	1	7.50	45.00
Total	**90**	**1,094.89**	**30,398.95**

Table 4. Lakes and reservoirs based on states in Malaysia [8].

Lakes in Malaysia, natural or artificial, have multiple functions. Almost 90 percent of the nation's water supply comes from the lakes and reservoirs [8]. Lakes and reservoirs serves as the source of water for domestic, industrial and agriculture; hydroelectric power generation; flood mitigation, navigation and recreation [8, 9]. They are also home to a variety of biological species and freshwater fish industry [9], i.e. 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 fish could cost up to USD 15,000 – USD 25,000 per fish in the market for a full grown adult [10]. Natural lakes in Malaysia include wetlands like Bera Lake and Chini Lake in Pahang, and Dayang Bunting Lake in Langkawi, in addition to ox-bow lakes such as Paya Bungor in Pahang and Logan Bunut in Sarawak [8, 9]. Among the artificial lakes or reservoirs include Kenyir Lake in Terengganu, Pergau in Kelantan, Batang Ai and Bakunin Sarawak, Temenggorin Perak as well as Pedu and Muda in Kedah [8, 9].

There is no comprehensive inventory on all lakes in Malaysia [8, 9]. A preliminary assessment showed that there were over 90 lakes in Malaysia which covered an area of over 100,000 ha and contained more than 30 billion cubic meters of water [8, 9]. Table 4shows the lake inventory based on states in Malaysia [8]. This list of lakes inventory did not, however include ox-bow lakes and ex-mining ponds over the nation. It was estimated that there were approximately more than 4,000 ex-tin mining ponds in the country with area of 16,000 ha [8]. Besides, the inventory excluded new hydroelectric projects like Bakun Dam in Sarawak [8].Bakun Dam alone has 695 km^2 of reservoir surface area with gross storage volume of 44 billion cubic meters [11].

3.1. Pollution and eutrophication of lakes and reservoirs

In Malaysia, water quality of a lake or reservoir can be influenced by external inputs entering the lake or reservoir 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. Point sources include discharge from domestic and municipal wastewater, agricultural effluents and industrial wastewaters whereas non-point sources includes urban/stormwater runoff, agricultural runoff, septic tank overflow and construction sites runoff. Excessive input of nutrients such as phosphorus and nitrogen into the lakes and reservoirs will lead to eutrophication. Eutrophication is the process by which a water body becomes uncontrollably rich and abundance in aquatic plants such as algae and aquatic macrophytes (water weeds) [12] due to plant nutrients enrichment, especially phosphorus and nitrogen as dissolved solutes and as compounds bound to organic and inorganic matters [13] from natural and anthropogenic sources [12]. Eutrophication will induce an undesirable disturbance to the balance of organisms present in the water and to the quality of water.

According to adesk study on the Status of Eutrophication of Lakes in Malaysia by National Hydraulic Research Institute of Malaysia, NAHRIM [14], 56 lakes or 62 percent of the 90 lakes and reservoirs evaluated were eutrophic while 34 lakes or 38 percent were mesotophic. These lakes were assessed based on the Trophic State Index (TSI) values, computed adopting the landuse and TP relationships. The lakes and reservoirs were graded as good, medium or bad based on allowable nutrient loadings which were corresponded to Carlson's TSI values. Lakes graded as good had TSI values of less than 37.4 whereas TSI values exceeded 47.4 were graded as bad. TSI is not the same as a water quality index. The terms 'good', 'medium' or 'bad' refers to the state of lake in respect to its biological productivity and not 'good water quality', slightly polluted water' or 'polluted water' as detailed in the water quality index. However, if the lakes are confirmed to be eutrophic, steps are needed to tackle the deterioration of water quality. Table 5shows all 90 lakes and reservoirs inventoried in Malaysia with their TSI values and lake status [14-15].

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Name/ State/ Federal Territory	River System	Purpose	Area (km^2)	Storage capacity (Mm^3)	TSI			Lake Status
					LU	Chl a	TP	
State: Perak								
Air Kuning (Perak)	Sg. Ranting/ Sg. Perak	W	n.a.	1.8	60.30	n.a.	n.a.	B
Bersia	Sg. Perak	H, F	5.7	70	60.30	n.a.	n.a.	B
Bukit Merah	Sg. Kurau	I, W	41	75	60.30	n.a.	n.a.	B
Chenderoh	Sg. Perak	H, F	25	95.4	75.44	n.a.	n.a.	B
Gopeng	Sg. Gopeng/ Sg. Perak	SR	n.a.	n.a.	50.00	n.a.	n.a.	B
Jor	Batang Padang/ Sg. Perak	H	0.5	3.9	60.30	n.a.	n.a.	B
Kenering	Sg. Perak	H, F	60	352	60.30	n.a.	n.a.	B
Mahang	Sg. Mahang/ Sg. Perak	H	0.1	0.4	50.00	n.a.	n.a.	B
Temenggor	Sg. Perak	H, F	152	6168	45.85	n.a.	n.a.	M
Kinta	Sg. Kinta/ Sg. Perak	Exm	n.a.	n.a.	68.24	n.a.	n.a.	B
TasikRaban	Sg. Perak	Re	0.375	n.a.	75.44	n.a.	n.a.	B
State: Selangor								
Air Kuning (Selangor)	Sg. Air Kuning/ Sg. Damansara	Re	0.04	0.06	45.85	n.a.	n.a.	M
Batu	Sg. Kelang	F, W	2.5	36	45.85	n.a.	n.a.	M
Klang Gates	Sg. Kelang	W, F	2.25	28.51	45.85	n.a.	n.a.	M
Langat	Sg. Langat	W	1.75	35.49	45.85	n.a.	n.a.	M
Meru	Sg. Subang	W	1	3.5	50.00	n.a.	n.a.	B
Semenyih	Sg. Langat	W	2.5	62.6	45.85	n.a.	n.a.	M
Sungai Baru	Sg. Baru/ Sg. Klang	Re	0.05	0.15	45.85	n.a.	n.a.	M
Sungai Tinggi	Sg. Tinggi/ Sg. Selangor	W	n.a.	107.5	45.85	n.a.	n.a.	M
Sg. Selangor	Sg. Selangor	W	n.a.	235	45.85	n.a.	n.a.	M
Tasik The Mines	Sg. Kuyoh/ Sg. Kelang	Exm, Re	n.a.	n.a.	60.30	n.a.	n.a.	B
TasikTitiwangsa	Sg. Bunus/ Sg. Kelang	Re	0.125	n.a.	-	42.43	n.a.	M

Name/ State/ Federal Territory	River System	Purpose	Area (km^2)	Storage capacity (Mm^3)	TSI			Lake Status
					LU	Chl a	TP	
TasikKundang	Sg. Kundang/ Sg. Selangor	Re	n.a.	n.a.	60.30	n.a.	n.a.	B
TasikAman	Sg. Kelang	Re	0.0224	n.a.	-	91.82	n.a.	B
Damansara	Sg. Damansara	W	0.04	0.009	64.15	n.a.	n.a.	B
Sg. Batu	Sg. Batu	F, W	1.1	2.5	69.39	n.a.	n.a.	B
State: Pahang								
Anak Endau	Sg. Anak Endau	I, W	7.2	38	45.85	n.a.	n.a.	M
Pontian	Sg. Pontian	I, W	20	40	60.30	n.a.	n.a.	B
RepasBaru	Sg. Rengas/ Sg. Pahang	SR	0.05	0.4	68.24	n.a.	n.a.	B
Repas Lama	Sg. Bentong/ Sg. Pahang	SR	n.a.	n.a.	68.24	n.a.	n.a.	B
Sultan Abu Bakar	Sg. Sempam/ Sg. Perak	H	0.5	6.7	68.24	n.a.	n.a.	B
Chereh Dam	Sg. Chereh/ Sg. Kuantan	W	54	250	45.85	n.a.	n.a.	M
TasikChini	Sg. Pahang	N	2	2	68.24	n.a.	n.a.	B
TasikBera	Sg. Bera/ Sg. Pahang	N	6	0.61	68.24	n.a.	n.a.	B
UluLepar	Sg. Lepar/ Sg. Pahang	N	4.69	18	60.30	n.a.	n.a.	B
Bintau	Sg. Kertau/ Sg. Pahang	N	0.25	n.a.	68.24	n.a.	n.a.	B
State: Kelantan								
Bukit Kuang	Sg. Kuang/ Sg. Kelantan	I, W	4.04	14.3	68.24	n.a.	n.a.	B
Pergau (Kuala Yong)	Sg. Pergau	H, F	4.3	62.5	45.85	n.a.	n.a.	M
RantauPanjang	Sg. Golok	W	3	n.a.	75.44	n.a.	n.a.	B
State: Johor								
Bekok	Sg. BatuPahant	F, W	8.75	32	75.44	n.a.	n.a.	B
Congkok	Sg. Tenglu	W	0.5	0.954	45.85	n.a.	n.a.	M
GunongLedang	Sg. Muar	W	0.75	0.3	45.85	n.a.	n.a.	M

Name/ State/ Federal Territory	River System	Purpose	Area (km²)	Storage capacity (Mm³)	TSI			Lake Status
					LU	Chl a	TP	
Juaseh	Sg. Juaseh/ Sg. Muar	W	n.a.	33.2	55.03	n.a.	n.a.	B
Labong	Sg. Endau	I, W	4.25	11.54	45.85	n.a.	n.a.	M
Layang (Lower)	Sg. Layang/ Sg. Johor	W	n.a.	11.63	68.24	n.a.	n.a.	B
Layang (Upper)	Sg. Layang/ Sg. Johor	W	n.a.	45	-	n.a.	100.00	B
Lebam	Sg. Lebam	W	n.a.	3.1	-	n.a.	95.95	B
Linggiu	Sg. Linggiu/ Sg. Johor	W	50	772	-	n.a.	57.73	B
Machap	Sg. Benut	F, W	9.09	12.3	75.44	n.a.	n.a.	B
Sembrong	Sg. BatuPahat	F, W	8.5	18	68.24	n.a.	n.a.	B
Pontian Kecil	Sg. Pulai	W	1.75	n.a.	45.85	n.a.	n.a.	M
PulaiBesar	Sg. Pulai	W	0.625	n.a.	45.85	n.a.	n.a.	M
State: Kedah								
Ahning	Sg. Ahning/ Sg. PdgTerap	W, I	n.a.	275	50.00	n.a.	n.a.	B
Malut	Sg. Malut	W	0.5	7.16	50.00	n.a.	n.a.	B
Muda	Sg. Muda	I	26	120	45.85	n.a.	n.a.	M
Padang Saga	Sg. Ulu Melaka	I, W	0.05	0.2	50.00	n.a.	n.a.	B
Pedu	Sg. Kedah	I	65	860	55.03	n.a.	n.a.	B
Dayang Bunting	Sg. Dayang Bunting	N	0.375	n.a.	45.85	n.a.	n.a.	M
Beris	Sg. Beris/ Sg. Muda	W	13.7	1224	50.00	n.a.	n.a.	B
Federal Territory: Labuan								
Bukit Kuda	Sg. Bangat	W	n.a.	4.78	60.30	n.a.	n.a.	B
Kerupang	Sg. Kerupang	W	n.a.	0.21	60.30	n.a.	n.a.	B
Pagar	Sg. Pagar	W	n.a.	0.41	60.30	n.a.	n.a.	B
State: Melaka								
Air Keruh	Sg. Melaka	Re	0.5	n.a.	60.30	n.a.	n.a.	B
Asahan	Sg. Kesang	W	0.75	0.7	50.00	n.a.	n.a.	B
Durian Tunggal	Sg. Melaka	W	3.5	32.6	75.44	n.a.	n.a.	B

Name/ State/ Federal Territory	River System	Purpose	Area (km^2)	Storage capacity (Mm^3)	TSI			Lake Status
					LU	Chl a	TP	
Jus	Sg. Batang Melaka	W	4	48	68.24	n.a.	n.a.	B
State: Negeri Sembilan								
Kelinci	Sg. Kelinchi/ Sg. Pahang	W	n.a.	50	50.00	n.a.	n.a.	B
Pedas	Sg. Beringin/ Sg. Linggi	W	n.a.	0.525	50.00	n.a.	n.a.	B
Sungai Terip	Sg. Terip/ Sg. Linggi	W, I	2.25	48	-	n.a.	62.9	B
Upper Muar	Sg. Muar/ Sg. Pahang	W	n.a.	53	50.00	n.a.	n.a.	B
Gemencheh	Sg. Gemencheh/ Sg. Muar	W	n.a.	30.8	55.03	n.a.	n.a.	B
State: Pulau Pinang								
Air Hitam	Sg. Air Hitam/ Sg. Pinang	W	0.25	2.6	45.85	n.a.	n.a.	M
Mengkuang	Sg. Mengkuang/ Kulim/ Perai	W	0.625	23.6	75.44	n.a.	n.a.	B
TelukBahang	Sg. TelukBahang	W	n.a.	21	45.85	n.a.	n.a.	M
Bukit Pancur	Sg. Kecil/ Sg. Kerian	N	0.061	n.a.	45.85	n.a.	n.a.	M
State: Perlis								
TimahTasoh	Sg. Perlis	I, W, F	13.33	40	-	n.a.	56.6	B
TasikMelati	Sg. Perlis	Re	n.a.	n.a.	50.00	n.a.	n.a.	B
State: Sabah								
Babagon	Sg. Babagon	W	n.a.	21.5	45.85	n.a.	n.a.	M
Pinangsoo	n.a.	W	n.a.	0.24	45.85	n.a.	n.a.	M
Sepagaya	Sg. Silibukan	W	n.a.	2.5	45.85	n.a.	n.a.	M
Tenom	Sg. Pedas	H	n.a.	4.7	45.85	n.a.	n.a.	M
Timbangan	Sg. Kalumpang	W	n.a.	0.67	45.85	n.a.	n.a.	M
Ox-bow	Sg. Kinabatangan	N	n.a.	n.a.	45.85	n.a.	n.a.	M
State: Sarawak								
Batang Ai	Sg. Batang Ai	H	n.a.	2800	45.85	n.a.	n.a.	M
Sika (Bintulu)	Sg. Sika	W	n.a.	3280	45.85	n.a.	n.a.	M

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Name/ State/ Federal Territory	River System	Purpose	Area (km^2)	Storage capacity (Mm^3)	TSI			Lake Status
					LU	Chl a	TP	
LoaganBunut	Sg. Tera	N	n.a.	n.a.	45.85	n.a.	n.a.	M
TasikBiru	Sg. Sarawak	Exm	n.a.	n.a.	45.85	n.a.	n.a.	M
State: Terengganu								
Kenyir	Sg. Terengganu	H, F	369	13600	-	-	73.5	B
Puteri/ Bukit Besi	Sg. Paka	Exm, Re	1.8	n.a.	60.30	n.a.	n.a.	B
Federal Territory: Putrajaya								
TasikPutrajaya	Sg. Chua/ Sg. Langat	Re	7.5	45	-	27.07	60.6	M

Notes: W – Water supply; I – Irrigation; H – Hydropower; F – Flood Control; Re – Reclamation; SR – Silt Retention; N – Natural; Exm – Ex-Mining Pool; LU – Land Use (%);Chl a – Chlorophyll a; TP – Total Phosphorus; G – Good; M – Medium; B – Bad.

Table 5. Inventory of Lakes and Reservoirs in Malaysia [14-15].

3.2. Lake and reservoir water quality standards

In Malaysia, there is no specific national standard or index for lake water quality as of year 2014. Since lakes are located within a river basin (although lakes have their own lake basins), water quality standards and classification used are of surface water. Normally, analysis on lake water quality is executed based on the DOE's WQI classification as shown in Table 1 [1], DOE Water Quality Classification based on Water Quality Index as shown in Table 3 [1] and National Water Quality Standards for Malaysia [1]. Although there is no standards and index for lakes in Malaysia, Putrajaya has developed its own standards as stated in Table 6 [17].

Parameter	Unit	Standards
pH		6.5 – 9.0
Temperature	°C	30°C, Normal ±
Colour	TUC	150
Conductivity	μS/cm	1000
Hardness	mg/l	250
Turbidity	NTU	50
Transparency (Secchi)	m	0.6
Taste	-	No Objectionable Taste
Odour	-	No Objectionable Odour

Parameter	**Unit**	**Standards**
Floatables	-	No Visible Floatables
Chlorphyll-a	μg/l	0.7
Dissolved oxygen (DO)	mg/l	5 – 7
Biochemical oxygen demand (BOD)	mg/l	3
Chemical oxygen demand (COD)	mg/l	25
Total suspended solid (TSS)	mg/l	150
Ammoniacal nitrogen (AN)	mg/l	0.3
Total Phosphorus (TP)	mg/l	0.05
Nitrate (NO_3-N)	mg/l	7
Nitrite (NO_2-N)	mg/l	0.04
Oil and grease (O&G)	mg/l	1.5
Aluminum	mg/l	<0.05 if pH <6.5 ; <0.1 if pH>6.5
Ammonia	mg/l	0.02 – 0.03
Arsenic	mg/l	0.05
Antimony	mg/l	0.03
Barium	mg/l	1
Beryllium	mg/l	0.004
Boron	mg/l	1
Cadmium	mg/l	0.002
Free chlorine	mg/l	1.5
Chromium, Total	mg/l	0.05
Copper	mg/l	0.02
Cyanide	mg/l	0.02
Iron	mg/l	1
Lead	mg/l	0.05
Manganese	mg/l	0.1
Mercury	mg/l	0.0001
Nickel	mg/l	0.02
Sulphate	mg/l	250
Zinc	mg/l	5

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Parameter	Unit	Standards
Microbiological Constituents		
Faecal coliform	counts/100ml	100
Total coliform	counts/100ml	5000
Salmonella	counts/l	0
Enteroviruses	PFU/l	0
Radioactivity		
Gross-alpha	Bq/l	0.1
Gross-Beta	Bq/l	1
Radium-226	Bq/l	<0.1
Strontium-90	Bq/l	<1
Organics		
Carbon Chloroform Extract	μg/l	500
MBAS/ BAS	μg/l	500
Oil & Grease (Mineral)	μg/l	-
Oil & Grease (Emulsified Edible)	μg/l	-
PCB	μg/l	0.1
Phenol	μg/l	10
Aldrin/ Dieldrin	μg/l	0.02
BHC	μg/l	2
Chlordane	μg/l	0.08
t-DDT	μg/l	0.1
Endosulfan	μg/l	10
Heptachlor/ Epoxide	μg/l	0.05
Lindane	μg/l	2
2,4-D	μg/l	70
2,4,5-T	μg/l	10
2,4,5-TP	μg/l	4
Paraquat	μg/l	10

Table 6. The Putrajaya Ambient Lake Water Quality Standards [17].

Besides WQI, lakes and reservoirs in Malaysia can be classified based on their trophic state calculated using Carlson's TSI involving parameters of chlorophyll-a, phosphorus or Secchi Disk depth. TSI classification of lakes and reservoirs is as shown in Table 7 [18].

TSI	Chla (ug/l)	SD (m)	TP (ug/l)	Attributes
<30	<0.95	>8	<6	Oligotrophy: Clear water, oxygen throughout the year in the hypolimnion
30-40	0.95-2.6	8-4	6-12	Hypolimnia of shallower lakes may become anoxic
40-50	2.6-7.3	4-2	12-24	Mesotrophy: Water moderately clear; increasing probability of hypolimnetic anoxia
50-60	7.3-20	2-1	24-48	Eutrophy: Anoxic hypolimnia, macrophyte problems possible
60-70	20-56	0.5-1	48-96	Blue-green algae dominate, algal scums and macrophyte problems
70-80	56-155	0.25-0.5	96-192	Hypereutrophy: (light limited productivity). Dense algae and macrophytes
>80	>155	<0.25	192-384	Algal scums, few macrophytes

Table 7. Trophic State Index (TSI) classification [18].

3.3. Lakes and reservoirs management

The current management of lakes and reservoirs in Malaysia are fragmented with different management agencies or lake managers, each having different and often competing, sectoral agendas [9]. There is no definite policy on lake management and it is neither binding nor mandatory [19]. As such, series of initiatives have been taken towards sustainable management of lakes and reservoirs in Malaysia. In 2009, Academy of Sciences Malaysia (ASM) together with NAHRIM had embarked on the development of Strategies for the Sustainable Development and Management of Lakes and Reservoirs in Malaysia with emphasis on Integrated Lake Basin Management (ILBM) which was first articulated by the International Lake Environment Committee (ILEC). The Strategy Plan for the Sustainable Management of Lakes and Reservoirs in Malaysia was presented and was endorsed during the 7th National Water Resources Council (NWRC) meeting on 1 November 2012[8, 9].

Besides the development of Strategy Plan, initiative had been taken on the development of Lake Briefs based on the format by ILEC. The main objective of Lake Brief is to assist lake managers and stake holders in preparation for gathering information and data relating to lake sand reservoirs towards the development of effective lake basin management plan based on the context of ILBM. Three series of Lake Briefs have been developed in 2010, 2011 and 2012 involving a total of 26 lakes and reservoirs/dam [9, 20-21]. First series of Lake Brief entitled Managing Lakes and their Basins for Sustainable Use in Malaysia, published in 2010 by ASM with support from NRE and NAHRIM involving eight lakes whereas second and third series of Lake Briefs documented by NAHRIM in 2011 and 2012, involved eight and ten lakes and reservoirs, respectively. Lakes and reservoirs documented in the respective Lake Brief are as exhibited in Table 8 [9, 20-21].

Lake Brief Series I (2010)	Lake Brief Series II (2011)	Lake Brief Series III (2012)
• Bukit Merah, Perak	• TasikBera, Pahang	• Batang Ai, Sarawak
• TasikKenyir, Terengganu	• Paya Indah Wetlands (PIW), Selangor	• Empangan Bukit Kwong, Kelantan
• LoaganBunut, Sarawak	• EmpanganBeris, Sik, Kedah	• Durian Tunggal, Melaka
• TasikPedudanMuda, Kedah	• EmpanganSemberong, BatuPahat, Johor	• Tasik Taiping, Perak
• TasikPutrajayadan Wetlands	• Tasik Ringlet, Cameron Highlands, Pahang	• Tasik FRIM dan Wetlands, Selangor
• TasikChini, Pahang	• EmpanganChenderoh, Perak	• TasikJor, Perak
• TasikTerip, Negeri Sembilan	• EmpanganKlang Gate	• TasikPergau, Kelantan
• TasikTimahTasoh, Perlis	• EmpanganSg. Selangor, Selangor	• Babagon, Sabah
		• TasikSubang, Selangor
		• EmpanganLangat, Selangor

Table 8. List of lakes and reservoirs in Lake Brief reports [9, 20-21].

A systematic approach of lake management plan involving all stakeholders especially community participation to cultivate the sense of ownership should be established and implemented. The successful case of lake management is the Putrajaya Lake and Wetland. Putrajaya has a comprehensive Catchment Development and Management Plan for Putrajaya Lake (CDMPPL) which incorporates various management guidelines and studies, aim to achieve and maintain the high water quality objective set for Putrajaya Lake [22]. The Putrajaya Drainage Master Plan 1996 was developed to preserve the urban ecological values within the wetlands and lake areas and to mitigate the runoff and pollutants exports to external catchments whereas the Putrajaya Integrated Stormwater Management Guidelines set strategies that include stormwater drainage, managing stormwater as a resource, protection of receiving water quality and protection of downstream ecological health [23].

4. Coastal, estuarine and island marine water

Malaysia is one of richest in marine biodiversity in the world where these marine resources are essential contributions to the livelihood and sustenance of its people. Major marine ecosystems in Malaysia include coral reefs, seagrasses, mangroves, mudflats and estuaries [24]. However, these coastal, estuarine and island marine waters are increasingly impacted by pollutants and materials discharged from land-based activities due to urbanization, development and increase in population, resulted in the deterioration of water quality. These threats are generally from point or non-point sources. Point sources of pollutant include sewage and municipal wastewater as well as industrial wastewaters [24]. Non-point sources are runoffs from urban, agriculture, land clearing and construction activities as well as deposition from atmospheric sources. Besides land-based pollution, the marine environment is exposed to threats from the shipping activities, offshore oil and gas exploration and exploitation activities [24].

In Malaysia, the marine water quality is monitored by the Department of Environment (DOE) in Peninsular Malaysia since 1978 and 1985 in Sabah and Sarawak. The aim is to identify the marine water quality status and to determine the degree of pollution from both the land-based sources as well as the sea-based sources that can pose threats to the marine resources which potentially contribute to the stability and diversity of the marine ecosystem [16, 25]. In 2012, there were around 168 coastal and 78 estuary monitoring stations and 76 islands being monitored with a total of 579 samples from coastal, 325 samples from estuary and 190 samples collected from island monitoring stations [3]. Analyses on data were based on the newly developed Marine Water Quality Index (MWQI). As for coastal water quality, only 155 stations of 168 stations were analysed for MWQI [18]. Figure 2illustrates the trend in terms of MWQI for 2010-2012 [3]. It was observed that three stations (1.9 percent) were categorised as excellent, 32 stations (20.6percent) as good, 111 stations (71.6percent) as moderate and nine stations (5.8percent) as poor in year 2012. The number of excellent and good marine water quality stations had decreased, while the stations with moderate water quality had increased [3].

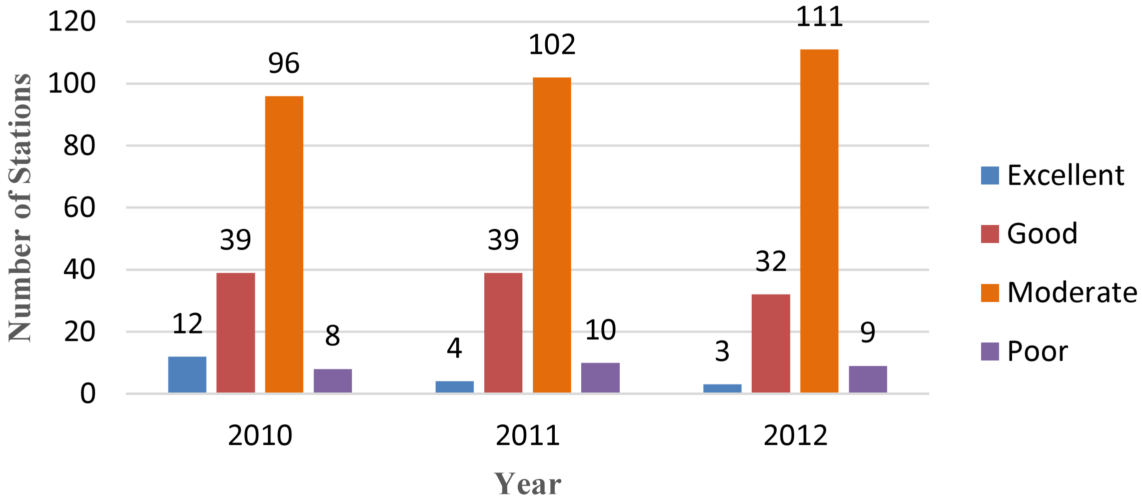

Figure 2. Marine Water Quality Index Trend for Coastal Areas in Malaysia from 2010 to 2012 [3].

Of the 78 estuary stations monitored in 2012, only 69 were analysed for MWQI. The comparison of MWQI trend from 2010 to 2012 in Malaysia is as depicted in Figure 3 [3]. It was observed that there was a slight improvement for the good stations as the good stations had increased from 8.7percent in 2011 to 11.6percent in 2012. Besides, moderate stations showed some decrements from 50 stations in 2011 to 48 stations in 2012, while excellent and poor stations remained the same for 2011-2012 [3].

As for the 76 islands monitored in 2012, 3 islands were classified as development islands, 32 island as resort islands, 29 stations as marine park islands whereas 12 stations were protected

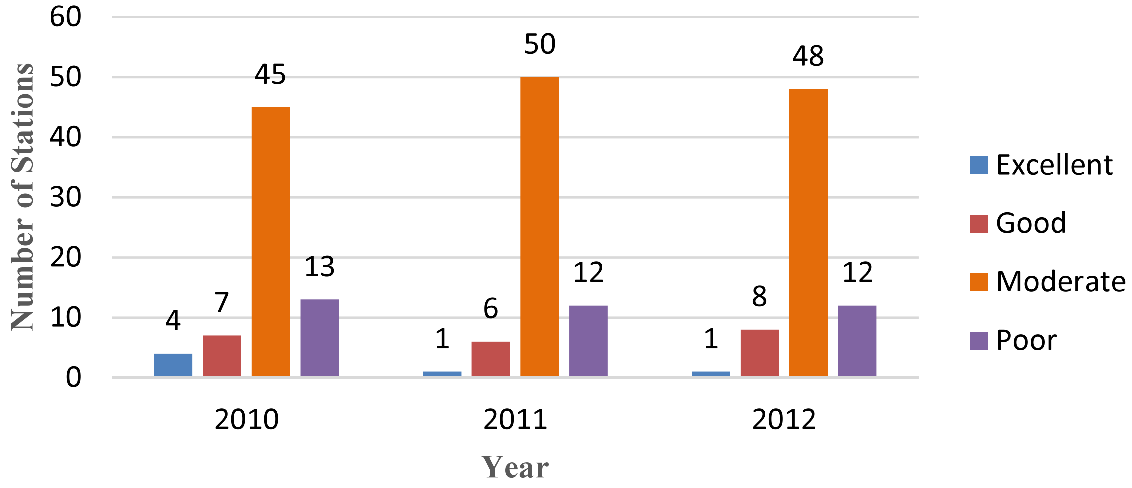

Figure 3. Marine Water Quality Index Trend for Estuary Areas in Malaysia from 2010 to 2012 [3].

islands [3]. Development islands are Labuan Island, Pulau Pinang and Langkawi, resort islands are like Sipadan in Sabah, Dayang Bunting in Kedah and Pangkor in Perak while marine park islands are islands such as PulauPayar in Kedah, Tioman Island in Pahang, Perhentian in Terengganu and Sapi in Sabah. Protected islands are like Pulau Talang-talang Besar in Sarawak, Pulau Arang in Negeri Sembilan, Kukup in Johor and Pulau Panjang in Kelantan [3]. From 76 islands with 93 island stations monitored, 86 were analysed for MWQI [3]. Figure 4 shows the comparison of MWQI for islands in Malaysia between year 2011 and 2012 [3]. It was observed that there is a slight decrement of station with good water quality from 17 stations in 2011 to 13 stations in 2012. 18 stations (20.9percent) in 2012 were categorised as good, while 52 stations (60.5percent) as moderate and were almost the same as recorded in 2011. Stations with poor water quality were very least with only 3 stations in 2012 and 2 stations in 2011 [3].

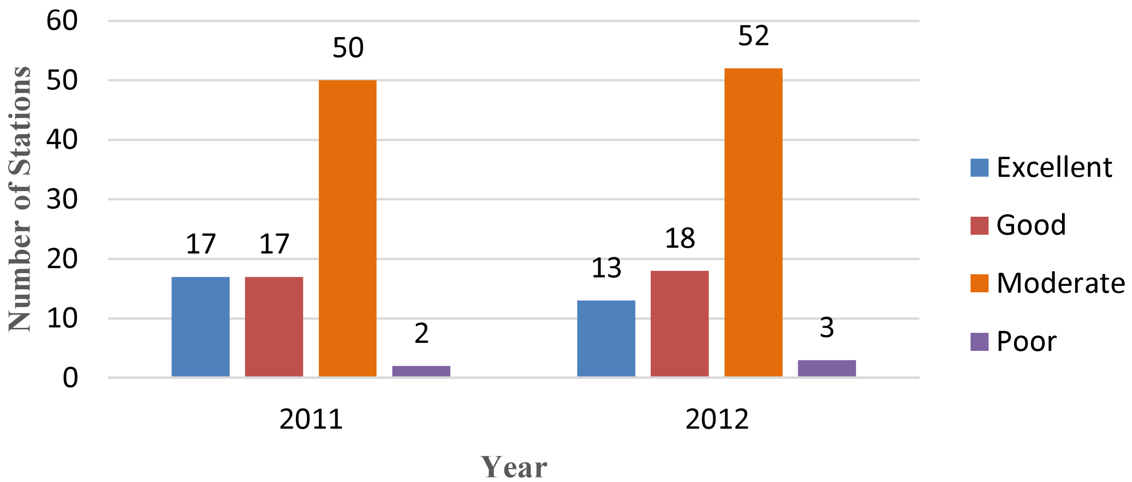

Figure 4. Marine Water Quality Index Trend for Islands (2011 – 2012) [3].

4.1. Marine water quality standards

Water quality at the coastal areas, estuarine and islands are analysed based on the newly developed MWQI by the DOE. The Index is developed based on an opinion poll approach using the Delphi technique involving experts from various group of stakeholders including professionals, practitioners, academicians related to marine water quality management, specialists from marine resource management, marine ecosystems, legislations and regulations, consultants, marine biologist, hydrologist as well as experts from governmental and non-governmental organizations [24]. The MWQI is used as a way to reflect the marine water quality status and category. The index was developed based on seven main parameters consist of dissolved oxygen, DO (0.2), ammonia, NH_3 (0.16), faecal coliform (0.14), total suspended solids, TSS (0.14), Oil and Grease, O&G (0.13), nitrate, NO3 (0.12) and phosphate, PO4 (0.11) with corresponding weightages in parenthesis, reflecting contributions of the respective parameters to the overall water quality [24]. The resulting MWQI is classified into four categories of water quality consisting excellent with index value of 90 – 100, good (80 - <90), moderate (50 - <80) and poor (0 - <50) [24].

Apart from MWQI, Malaysia Marine Water Quality Criteria and Standard (MWQCS) is also developed with four different classes (Class 1, Class 2, Class 3 and Class E) for four different beneficial uses as shown in Table 9 [16, 24]. Class 1 and Class 2 in the MWQCS require MWQI values equal to or greater than 80 and are categorized at least as 'good' water quality [16, 24]. The Class 3 waters of the MWQCS are generally within the moderate category of the MWQI [16, 26]. The application of MWQI to Class E waters requires the samples taken must correspond to a salinity of not less than 25 ppt [24].

Parameter	Class 1	Class 2	Class 3	Class E
Beneficial Uses	Preservation, Marine Protected Areas, Marine Parks	Marine Life, Fisheries, Coral Reefs, Recreational and Mariculture	Ports, Oil & Gas Fields	Mangroves Estuarine & River-mouth Water
Temperature	≤ 2°C increase over maximum ambient	≤ 2°C increase over maximum ambient	≤ 2°C increase over maximum ambient	≤ 2°C increase over maximum ambient
Dissolved oxygen (mg/L)	>80% saturation	5	3	4
Total suspended solid (mg/L)	25 mg/L or ≤ 10% increase in seasonal average, whichever is lower	50mg/L (25 mg/L) or ≤ 10% increase in seasonal average, whichever is lower	100 mg/L or ≤ 10% increase in seasonal average, whichever is lower	100 mg/L or ≤ 30 % increase in seasonal average, whichever is lower
Oil and grease (mg/L)	0.01	0.14	5	0.14
Mercury (μg/L)	0.04	0.16 (0.04)	50	0.5
Cadmium (μg/L)	0.5	2 (3)	10	2
Chromium (VI) (μg/L)	5	10	48	10

Parameter	Class 1	Class 2	Class 3	Class E
Copper (μg/L)	1.3	2.9	10	2.9
Arsenic (III) (μg/L)	3	20 (3)	50	20 (3)
Lead (μg/L)	4.4	8.5	50	8.5
Zinc (μg/L)	15	50	100	50
Cyanide (μg/L)	2	7	20	7
Ammonia (unionized) (μg/L)	35	70	320	70
Nitrite (NO2) (μg/L)	10	55	1,000	55
Nitrate (NO3) (μg/L)	10	60	1,000	60
Phosphate (μg/L)	5	75	670	75
Phenol (μg/L)	1	10	100	10
Tributyltin (TBT) (μg/L)	0.001	0.01	0.05	0.01
Faecal coliform (Human health protection for seafood consumption) – Most Probable Number (MPN)	70 faecal coliform 100mL-1	100 faecal coliform 100mL-1 & (70 faecal coliform 100mL-1)	200 faecal coliform 100mL-1	100 faecal coliform 100mL-1 & (70 faecal coliform 100mL-1)
Polycyclic Aromatic Hydrocarbon (PAHs) (ng/g)	100	200	1000	1000

*IMWQS in parentheses are for coastal and marine water areas where seafood for human consumption is applicable

Table 9. Malaysia Marine Water Quality Criteria and Standards [16, 24].

5. Groundwater

There are the freshwater in rivers, lakes and aquifers, and groundwater resources account for about 99 percent[26]. Despite the abundance of groundwater, it only accounts for 3 percent of total water use for domestic, agricultural, and industrial sectors. Lack of information to indicate groundwater source, perception that the supply is non-sustainable and lack of local expertise on groundwater are factors of under utilization of groundwater resources. Furthermore, leachates from the disposal of waste in landfills pose a threat to human health and environment [27].

On top of that, costly installation of groundwater extraction system, plus readily water supply available to over 90 percent of the communities, groundwater development is said to be ignored. So far groundwater is only extracted through well for domestic use and irrigation in very rural areas. This situation continues until water crisis occurred in 1997. After the water crisis, DOE has taken preliminary steps to explore and determine the quality and distributions of groundwater through the national groundwater-monitoring programme.

5.1. Groundwater wells and quality

By 2012, 107 quality monitoring wells had been established, as shown in Table10[1]. Selection of the sites were done according to the surrounding land uses which were agricultural, urban or suburban, rural, industrial, solid waste landfills, golf courses, radioactive landfill, animal burial areas, municipal water supply and examining areas (gold mine).

Category	Number of Wells
Agricultural Areas	12
Urban/Suburban Areas	11
Industrial Sites	18
Solid Waste Landfills	24
Golf Courses	7
Rural Areas	3
Ex-mining Areas (Gold Mine)	3
Municipal Water Supply	7
Animal Burial Areas	14
Aquaculture Farms	6
Radioactive Landfill	1
Resorts	1
TOTAL	107

Table 10. Number of groundwater wells by land use category [1]

According to [1], 361 water samples were taken from these monitoring wells for the analysis of physical, chemical and biological characteristics. These include total dissolved solids (TDS), pH, temperature, dissolved oxygen and conductivity for physical characteristic; volatile organic compounds (VOCs), pesticides, heavy metals, anions and phenolic compounds for chemical characteristic; and bacteria (coliform) for biological characteristic.The assessment of groundwater quality was based on the percentage of samples exceeded the National Guidelines for Raw Drinking Water Quality 2000 benchmark. In 2012, the results of monitoring showed that all stations were within the benchmark except for arsenics (As), iron (Fe), manganese (Mn), total coliform and phenol. Total coliform was categorized as exceeded the benchmark and in fact were recorded at all stations, followed by phenol, Fe, Mn and As [1].

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5.2. Groundwater quality standard

The Ground Water Quality Standards for Malaysia is still not established, but considering potential of groundwater as an alternative source for surface water, DOE had started the National Groundwater Monitoring Programme to determine the groundwater quality status. The groundwater quality status was determined based on the National Guidelines for Raw DrinkingWater Quality, as shown in Table 11, as the benchmark [1].

Parameter	Symbol	Benchmark
Sulphate	SO4	250 mg/l
Hardness	CaCO3SO	500 mg/l
Nitrate	NO3SO	10 mg/l
Coliform	-	Must not be detected in any 100 ml sample
Manganese	Mn	0.1 mg/l
Chromium	Cr	0.05 mg/l
Zinc	Zn	3 mg/l
Arsenic	As	0.01 mg/l
Selenium	Se	0.01 mg/l
Chloride	Cl	250 mg/l
Phenolics	-	0.002 mg/l
TDS	-	1000 mg/l
Iron	Fe	0.3 mg/l
Copper	Cu	1.0 mg/l
Lead	Pb	0.01 mg/l
Cadmium	Cd	0.003 mg/l
Mercury	Hg	0.001 mg

Table 11. National Guidelines for Raw Drinking Water Quality - revised December 2000 [1]

6. Drinking water

According to [28], Malaysia receives more than 25,000 cubic meters of renewable water per capita annually from its extensive river system that consists of more than 150 rivers. The amount of renewable water that Malaysia receives far exceeds that of many other parts of the world. Thus, over the past 200 years, consumers have the convenience of running water at the turn of a tap.

In Malaysia, the most tapped raw water sources are rivers, which are technically under the jurisdiction of the respective state governments. In the past, conventional treatment systems were employed to treat raw surface water. Typically, this kind of treatment system provides very basic treatment which includes screening, coagulation and flocculation, sand filtration, disinfection (chlorination) and fluoridation. As development becomes more rampant especially industrialization, river water quality becomes seriously deteriorated plus the water characteristic becomes more complex with the existence of new contaminants. At this time, conventional treatment system is not capable to remove these contaminants and as a result they might enter the distribution and supply network. To manage this problem, the Environmental Quality Act, 1974, prescribes more stringent regulatory compliance for wastewater discharging premises located upstream of a water intake point [29]. In spite of this, not all contaminants are covered under the Act, therefore the risk of contamination cannot be totally eradicated.

6.1. Drinking water standard

In 1985, DOE has developed the Drinking Water Quality Standards for Malaysia, as shown in Table 12 below:

Parameter	Group	MALAYSIA STANDARD mg/l (unless otherwise stated)			
		Raw Water		Treated Water	
		Min	Max	Min	Max
Total Coliform	1	0	5000MPN/100 ml	0 in 100 ml	0
E.coli	1	0	5000MPN/100 ml	0 in 100 ml	0
Turbidity	1	0	1000 NTU	0	5 NTU
Color	1	0	300 TCU	0	15 TCU
PH	1	5.50000	9.00000	6.50000	9.00000
Free Residual Chlorine	1	-	-	0.20000	5.00000
Temperature	1	-	-	-	-
Clostridium perfringens (including spores)	1	-	-	0	Absent
Coliform bacteria	1	-	-	-	-
Colony count 22°	1	-	-	-	-
Conductivity	1	-	-	-	-
Enterococci	1	-	-	-	-
Odour	1	-	-	-	-
Taste	1	-	-	-	-

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Parameter	Group	MALAYSIA STANDARD mg/l (unless otherwise stated)			
		Raw Water		Treated Water	
		Min	Max	Min	Max
Oxidisability	1	-	-	-	-
TDS	2	0.00000	1500.00000	0.00000	1000.0000
Chloride	2	0.00000	250.00000	0.00000	250.00000
Ammonia	2	0.00000	1.50000	0.00000	1.50000
Nitrat	2	0.00000	10.00000	0.00000	10.00000
Ferum/Iron	2	0.00000	1.00000	0.00000	0.30000
Fluoride	2	0.00000	1.50000	0.40000	0.60000
Hardness	2	0.00000	500.00000	0.00000	500.00000
Aluminium	2	-	-	0.00000	0.20000
Manganese	2	0.00000	0.20000	0.00000	0.10000
COD	2	0.00000	10.00000	-	-
Anionic Detergent MBAS	2	0.00000	1.00000	0.00000	1.00000
BOD	2	0.00000	6.00000	-	-
Nitrite	2	-	-	-	-
Total organic carbon	2	-	-	-	-
Mercury	3	0.00000	0.00100	0.00000	0.00100
Cadmium	3	0.00000	0.00300	0.00000	0.00300
Arsenic	3	0.00000	0.01000	0.00000	0.01000
Cyanide	3	0.00000	0.07000	0.00000	0.07000
Plumbum/Lead	3	0.00000	0.05000	0.00000	0.01000
Chromium	3	0.00000	0.05000	0.00000	0.05000
Cuprum/Copper	3	0.00000	1.00000	0.00000	1.00000
Zinc	3	0.00000	3.00000	0.00000	3.00000
Natrium/Sodium	3	0.00000	200.00000	0.00000	200.00000
Sulphate	3	0.00000	250.00000	0.00000	250.00000
Selenium	3	0.00000	0.01000	0.00000	0.01000
Argentum	3	0.00000	0.05000	0.00000	0.05000
Magnesium	3	0.00000	150.00000	0.00000	150.00000
Mineral Oil	3	0.00000	0.30000	0.00000	0.30000
Chloroform	3	-	-	0.00000	0.20000

Parameter	Group	MALAYSIA STANDARD mg/l (unless otherwise stated)			
		Raw Water		Treated Water	
		Min	Max	Min	Max
Bromoform	3	-	-	0.00000	0.10000
Dibromoklorometana	3	-	-	0.00000	0.10000
Bromodiklorometana	3	-	-	0.00000	0.06000
Fenol/Phenol	3	0.00000	0.00200	0.00000	0.00200
Antimony	3	-	-	0	0.005
Nickel	3	-	-	0	0.02
Dibromoacetonitrile	3	-	-	0	0.1
Dichloroacetic acid	3	-	-	0	0.05
Dichloroacetonitrile	3	-	-	0	0.09
Trichloroacetic acid	3	-	-	0	0.1
Trichloroacetonitrile	3	-	-	0	0.001
Trihalomethanes - Total	3	-	-	-	-
Aldrin / Dealdrin	4	0.00000	0.00003	0.00000	0.00003
DDT	4	0.00000	0.00200	0.00000	0.00200
Heptachlor &Heptachlor Epoxide	4	0.00000	0.00003	0.00000	0.00003
Methoxychlor	4	0.00000	0.02000	0.00000	0.02000
Lindane	4	0.00000	0.00200	0.00000	0.00200
Chlordane	4	0.00000	0.00020	0.00000	0.00020
Endosulfan	4	0.00000	0.03000	0.00000	0.03000
Hexachlorobenzena	4	0.00000	0.00100	0.00000	0.00100
1,2-dichloroethane	4	-	-	0.00000	0.03000
2,4,5-T	4	-	-	0.00000	0.00900
2,4,6-trichlorophenol	4	-	-	0.00000	0.20000
2,4-D	4	0.00000	0.03000	0.00000	0.03000
2,4-DB	4	-	-	0.00000	0.09000
2,4-dichlorophenol	4	-	-	0.00000	0.09000
Acrylamide	4	-	-	0.00000	0.00050
Alachlor	4	-	-	0.00000	0.02000
Aldicarb	4	-	-	0.00000	0.01000
Benzene	4	-	-	0.00000	0.01000

Parameter	Group	MALAYSIA STANDARD mg/l (unless otherwise stated)			
		Raw Water		Treated Water	
		Min	Max	Min	Max
Carbofuran	4	-	-	0.00000	0.00700
MCPA	4	-	-	0.00000	0.00200
Pendimethalin	4	-	-	0.00000	0.02000
Pentachlorophenol	4	-	-	0.00000	0.00900
Permethrin	4	-	-	0.00000	0.02000
Pesticides	4	-	-	-	-
Pesticides - Total	4	-	-	-	-
Polycyclic aromatic hydrocarbons	4	-	-	-	-
Propanil	4	-	-	0.00000	0.02000
Tetrachloroethene and Trichloroethene	4	-	-	-	-
Vinyl chloride	4	-	-	0.00000	0.00500
Gross alpha (α)	5	0.00000	0.1Bq/l	0.00000	0.1Bq/l
Gross beta (β)	5	0.00000	1.0 Bq/l	0.00000	1.0 Bq/l
Tritium	5	-	-	-	-
Total indicative dose	5	-	-	-	-

Table 12. Drinking Water Quality Standard [2]

6.2. Drinking water treatment technology

In recent years, the pollution in rivers and lakes has become increasingly worse, and it has become necessary to take measures toward securing a stable supply of tap water and supplying good-tasting water. Generally, there are two methods used in water treatment, which are the conventional and non-conventional methods. Conventional method is water treatment which undergoes processes such as coagulation, flocculation, sedimentation, and filtration, as shown in Figure 5, while non-conventional method uses more sophisticated equipment.

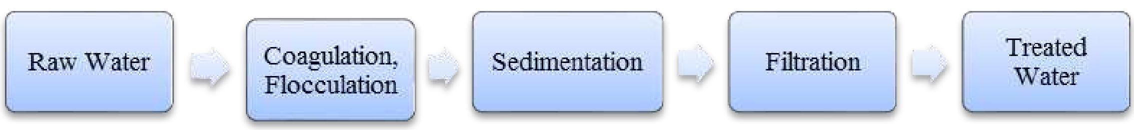

Figure 5. Schematic diagram for conventional treatment plant

In Malaysia, both conventional and non-conventional methods are employed. Generally, if the water is severely contaminated or there is a need for alternative water source, then conventional method is no longer viable for use. At present, Dissolved Air Flotation (DAF) and Actiflo are among the latest conventional technology in use.

In DAF float tank, suspended matter in the feed water is often flocculated with coagulant (such as ferric chloride or aluminum sulfate). These flocculated suspended matters are then floated up to the surface by the adhered bubbles and form a froth layer which is then removed by a skimmer. The froth-free water exits the float tank as the clarified effluent. The tiny bubbles are actually those bubbles that released from the pressure reduction valve when the mixture of clarified effluent and the compressed air are forced to flow through this valve (Figure 6).

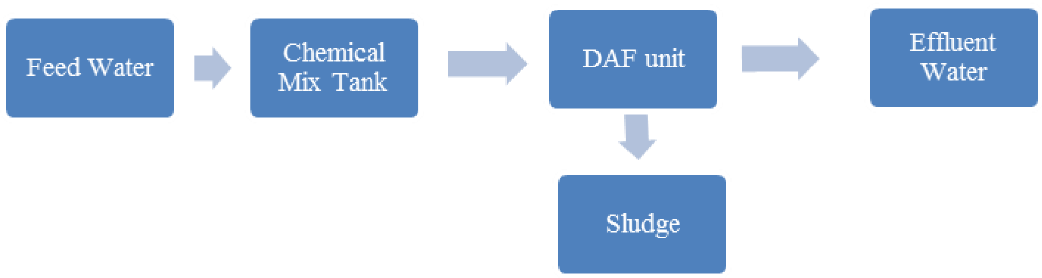

Figure 6. Schematic diagram for DAF technology

One of the non-conventional methods used in Malaysia is membrane technology. Ultrafiltration process in this technology uses membrane modules (Figure 3) as filtration media as compared to sand in conventional filtration plant. At present, one water treatment plant in Bukit Panchor, Pulau Pinang [31] and two plants in Selangor [32] are adopting the application of this membrane technology. Ultrafiltration (UF) is a variety of membrane filtration in which forces like pressure or concentration gradients leads to a separation through a semipermeable membrane. Suspended solids and solutes of high molecular weight are retained in the so-called retentate, while water and low molecular weight solutes pass through the membrane in the permeate. Among the advantages of using the UF technology is, it could produce clean water of high quality, lower operation cost, easily upgradeable system and space reducing compact system.

The progression and development of the water treatment technology are undeniably based on the deteriorating water source quality and current water demand over time resulted from the growth of population and industries. In addition, advancement in water treatment technology minimizes the space usage, increases production yield, more cost effective, and reduced labor.

7. Conclusion

The DOE uses WQI and NWQS to evaluate the status of the river water quality. There is no specific national standard or index for lake water quality analyses for the meantime. Since

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lakes are located within a river basin (although some say lakes have their own lake basins), the water quality standards and classification for rivers are used. On the other hand, the marine water quality is monitored by the DOE in Peninsular Malaysia since 1978, and 1985 in Sabah and Sarawak, with the aim to identify the marine water quality status and to determine the degree of pollution from both the land-based sources as well as the sea. Water quality at the coastal areas, estuarine and islands are analysed based on the newly developed Marine Water Quality Index (MWQI) by the DOE. After the water crisis in 1997, DOE has taken preliminary steps to explore and determine the quality and distributions of groundwater through the national groundwater-monitoring programme. Consequently, DOE had started the National Groundwater Monitoring Programme to determine the groundwater quality status. For drinking water, DOE has developed the Drinking Water Quality Standards for Malaysia since 1985. Selection of water treatment technology depends on the quality of water source. Among the technologies in use in the country are DAF, Actiflo and membrane technology.

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