CHAPTER 5

RESULTS AND DISCUSSIONS

5.1 INTRODUCTION

Measurement of water quality is important to determine the changes in the parameters of water body, as the changes of physical, chemical and biochemical characteristics of water may affect the water's health, and eventually affect the aquatic lives and associated organisms. This can be done through determination of WQI values. If WQI value at a particular water body is low, this shows that there are certain parameters affecting the WQI value. Thus, the specific parameter that lowered WQI value could be identified. However, according to Van Wyk and Scarpa (1999), water quality is not a fixed characteristic of the water. It is very dynamic, changing over time as a result of environmental factors and biological processes.

5.2 WATER QUALITY INDEX (WQI)

The Water Quality Index (WQI) is used to evaluate the river water quality (and also other water bodies including lakes) consisting of parameters such as DO, BOD, COD, TSS, NH_3-N and pH. The WQI serves as a basis for environmental assessment of a watercourse in relation to the pollution load categorization and designation of classes of beneficial uses (DOE, 2006). The classification of WQI was as discussed in the previous chapter and DOE (2006). Table 5.1 shows the WQI values of Paya Indah.

Table 5.1
Water Quality Index values of Paya Indah

Sampling Station	Sampling Weeks						Average	Std. Dev. (±)	Percentage (%)*
	Week 1	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**			
W1	46	45	42	43	61	63	50.0	9.56	19.12
W2	53	60	63	65	66	48	59.2	7.18	12.13
W3	27	26	60	53	54	46	44.2	14.68	33.25
W4	33	34	46	53	57	52	45.7	10.27	22.47
W5	50	47	47	61	78	60	57.2	11.84	20.71
W6	66	73	49	67	**86**	42	**67.2**	12.07	17.97
W7	66	**84**	55	66	**83**	75	**71.5**	11.20	15.68
W8	36	37	46	53	38	48	42.9	6.97	16.25
W9	39	64	59	57	53	46	52.9	9.13	17.28
W10	50	54	46	54	60	55	53.2	4.77	8.98
W11	65	69	57	57	70	58	**62.8**	6.05	9.64
W12	25	40	30	52	55	35	39.4	12.03	30.56
W13	29	43	38	53	56	42	43.5	9.92	22.82
W14	64	62	37	64	64	67	59.8	11.04	18.47
W15	40	46	55	55	61	42	49.9	8.34	16.72

**Percentage of standard deviation against average*

Figure 5.1 shows the weekly WQI values of Paya Indah at each station. From Figure 5.1, it is found that the WQI values at each station fluctuated as the standard deviations of each station were high. Significant fluctuation was observed at Station W3, Station W4, Station W5, Station W12 and Station W13 as the percentage of standard deviation against average are more than 20 percent. It is also observed that only water quality at Station W6 in 5th week, and Station W7 in 2nd week and 5th week could be considered as healthy as their respective WQI values stood within clean range. The water qualities at the remaining stations in the rest of the weeks are mostly polluted, as their WQI values stood within slightly polluted and polluted range.

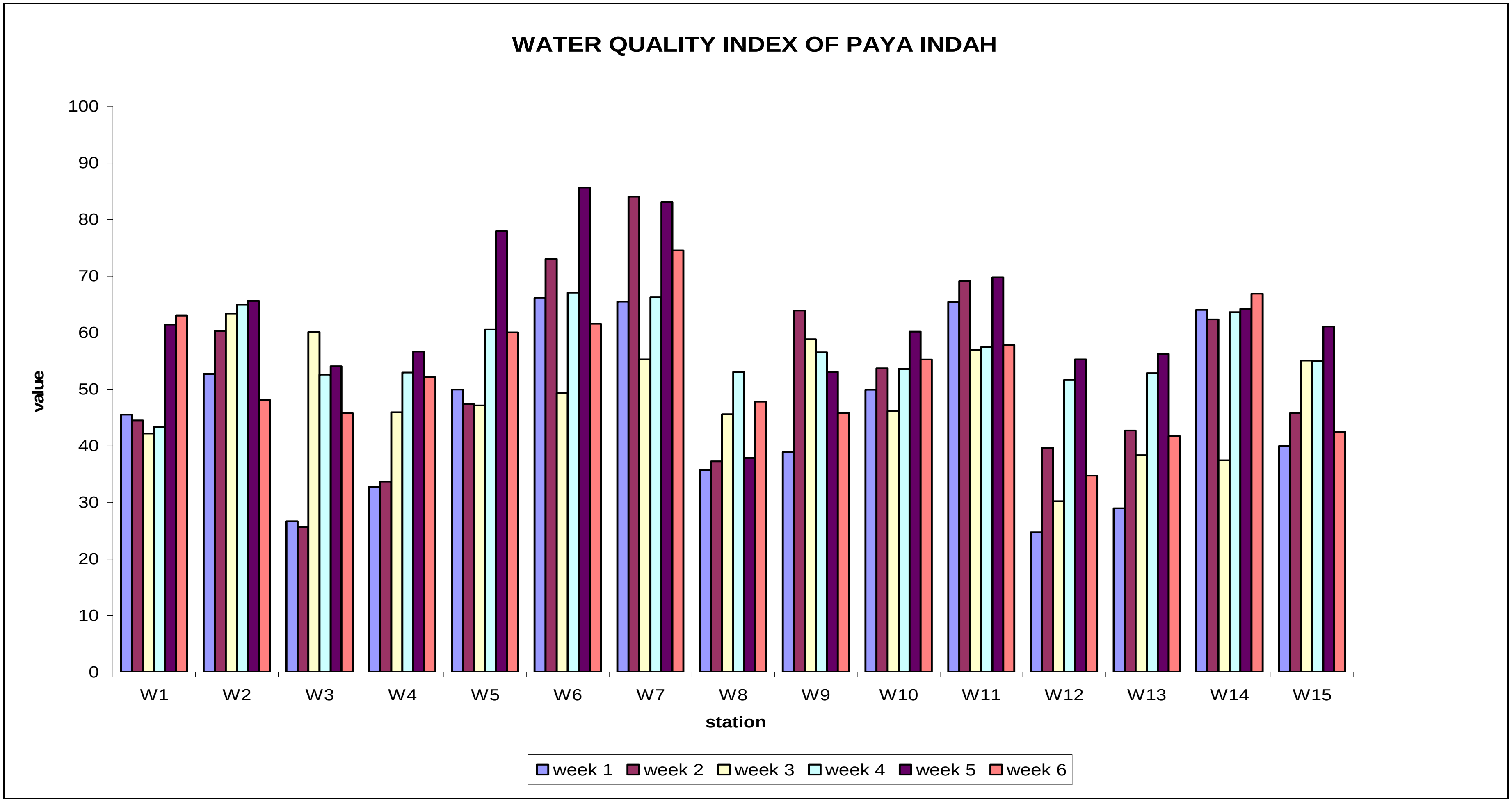

Figure 5.1: Weekly WQI values of Paya Indah at each station

When averaged, only Station W6, Station W7 and Station W11 were slightly cleaner than the remaining stations as their WQI values stood within slightly polluted range. This has been indicated in Figure 5.2 as their peaks exceed the polluted line.

As explained in Chapter 3, Station W3 represent the Visitor Lake, and like Station W9 (Main Lake), Station W10 (Petaling Tin Lake), and Station W15 (Lotus Lake), they represent the major lakes of Paya Indah. From Table 5.1 and Figure 5.1, it was observed that these lakes were considered as polluted as Station W3, Station W9, Station W10 and Station W15 recorded average WQI that stood within the polluted range. CETEC (1996) also recorded low WQI values in their study. Table 5.2 shows comparison of WQI values at these lakes and two canals from CETEC (1996) and this study.

Table 5.2
Comparison of WQI between study in 1996 and 2006-2007

Studies	**CETEC, 1996**		**2006 – 2007**	
Water Body	**Average WQI**	**Status**	**Average WQI**	**Status**
Canal C2 (Station W1)	48.7	Polluted	50.0	Polluted
Canal C4 (Station W2)	41.5	Polluted	59.2	Polluted
Main Lake (Station W9)	65.5	Slightly Polluted	52.9	Polluted
Visitor Lake (Station W3)	55.1	Polluted	44.2	Polluted
Lotus Lake (Station W15)	70.6	Slightly Polluted	49.9	Polluted
Petaling Tin Lake (Station W10)	72.0	Slightly Polluted	53.2	Polluted

From Table 5.2, it is observed that water quality at all lakes had worsened within 10 – 11 years. From CETEC (1996), low pH, low DO and high Oxygen Demands (BOD and COD) had been identified as the major contributors of low WQI values. High TSS and NH_3-N were occasionally reported by CETEC (1996) of influencing WQI values. Only water quality of both Canal C2 and Canal C4 exhibited slight improvement.

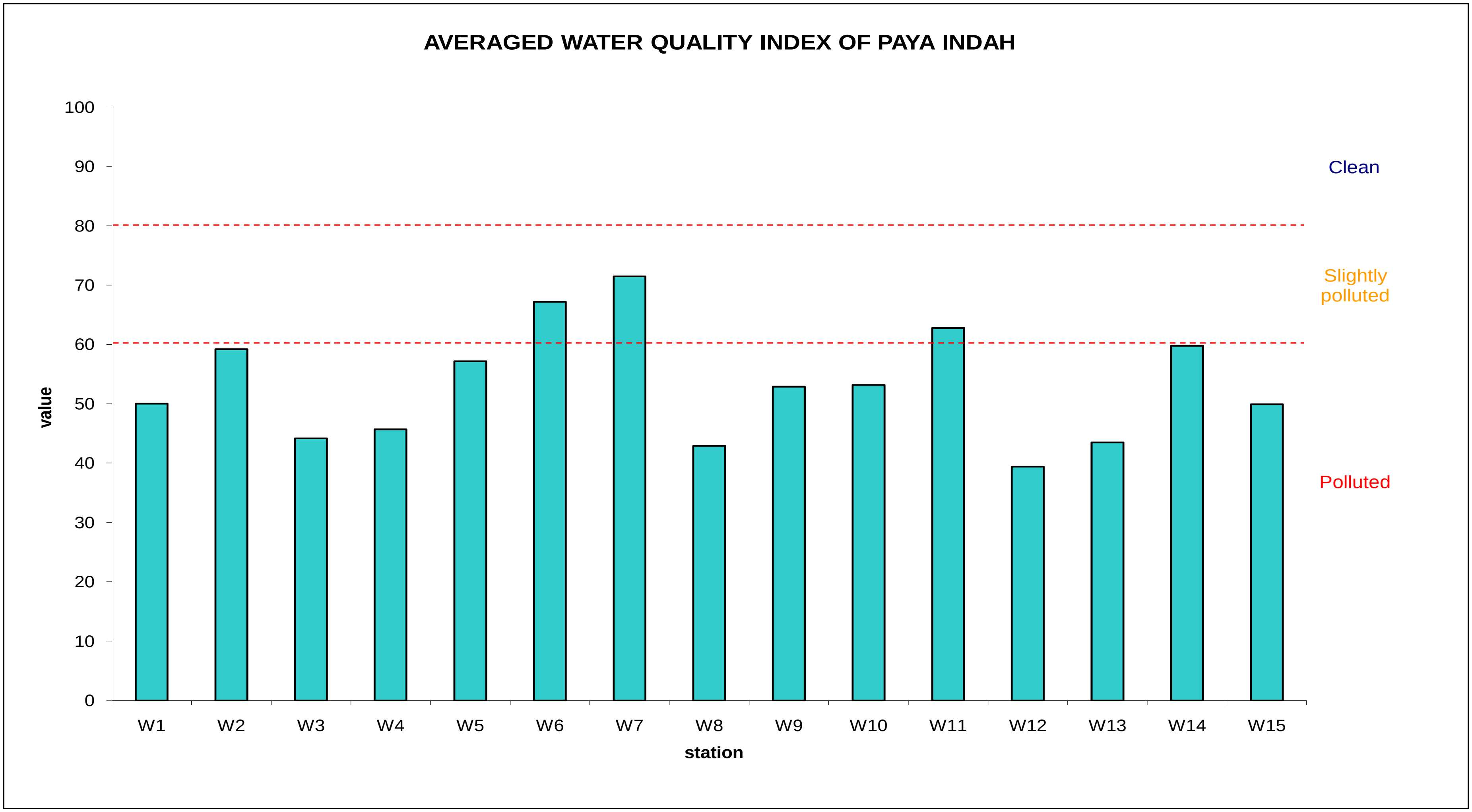

Figure 5.2: Averaged WQI values of Paya Indah at each station

5.3 CRITICAL PARAMETERS

Critical parameters are the major parameters that are frequently used in all water quality studies, monitoring, assessments and analyses. The critical parameters consist of pH, Dissolved Oxygen, Biochemical and Chemical Oxygen Demands, Total Suspended Solids and Ammoniacal Nitrogen. These parameters were also used in WQI calculations as WQI sub-index. Thus, any changes of these parameters' values can influence the WQI values.

5.3.1 pH

The pH can be defined as a description of hydrogen ion (H+) concentration in a solution. It is a way of expressing the hydrogen ion concentration, or more precisely, the hydrogen ion activity (Sawyer et al, 2003). The greater hydrogen ion activity in a solution, the lower is the pH, or simply the solution will be acidic. Alkalinity of the solution occurred when the hydrogen ion activity is lower, and the hydroxide (OH-) ion is greater. The range of pH for acidic solution is 0 – 6 while the range for alkaline solution is 8 – 14. The pH is represented by the following formula.

$$pH = -\log(H^{+})$$
$$pOH = 14 - pH$$

Table 5.3 shows the weekly pH values of Paya Indah.

Table 5.3
pH values of Paya Indah

Sampling Station	**Sampling Weeks**						**Average**	**Std. Dev. (±)**	**Percentage (%)***
	Week 1	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**			
W1	5.0	4.8	4.5	4.8	4.8	5.5	**4.9**	0.34	6.83
W2	4.7	6.6	5.6	4.6	5.2	5.0	5.3	0.74	13.98
W3	5.6	4.5	5.7	4.2	4.2	4.3	**4.8**	0.71	14.87
W4	4.9	4.4	4.9	4.4	4.9	4.9	**4.7**	0.26	5.45
W5	6.4	5.2	6.5	5.9	6.2	7.1	6.1	0.64	10.25
W6	6.3	6.3	6.8	6.0	6.0	6.5	6.3	0.31	4.85
W7	5.9	6.1	6.6	6.0	6.1	6.6	6.2	0.31	4.92
W8	6.4	4.2	6.7	4.3	4.4	4.4	**4.4**	0.17	3.80
W9	4.5	4.7	4.9	4.4	4.5	4.3	**4.6**	0.22	4.76
W10	5.6	5.0	5.3	4.9	4.8	4.6	5.0	0.36	7.18
W11	5.7	5.2	5.5	4.7	5.0	7.0	5.5	0.81	14.66
W12	5.6	5.3	5.5	5.2	5.0	5.3	5.3	0.21	4.02
W13	6.0	6.0	5.7	5.3	5.8	6.0	5.8	0.28	4.75
W14	7.7	5.4	6.9	6.6	6.2	7.2	6.7	0.80	12.06
W15	4.8	5.1	5.2	4.6	5.7	4.4	**4.9**	0.47	9.42

**Percentage of standard deviation against average*

From Figure 5.3, low pH had been observed at Station W1, Station W2, Station W3, Station W4, Station W8, Station W9, Station W10 and Station W15, as the peaks of these stations were below 5.0 in some weeks. Moreover, Station W4, Station W8 and Station W9 recorded pH values below 5.0 in all weeks. The pH below 5.0 indicates acidic conditions and considered to be unhealthy, and fall within Class V of INWQS.

The fluctuations of weekly pH values at each station were considered as not significant, as the percentage of standard deviation of pH at each station are less than 20 percent. Occasionally, pH value of more than 7.0 was observed. Averaged pH values as shown in Figure 5.4 shows six (6) out of 15 stations (Station W1, Station W3, Station W4, Station W8, Station W9 and Station W15) were below Class III of INWQS.

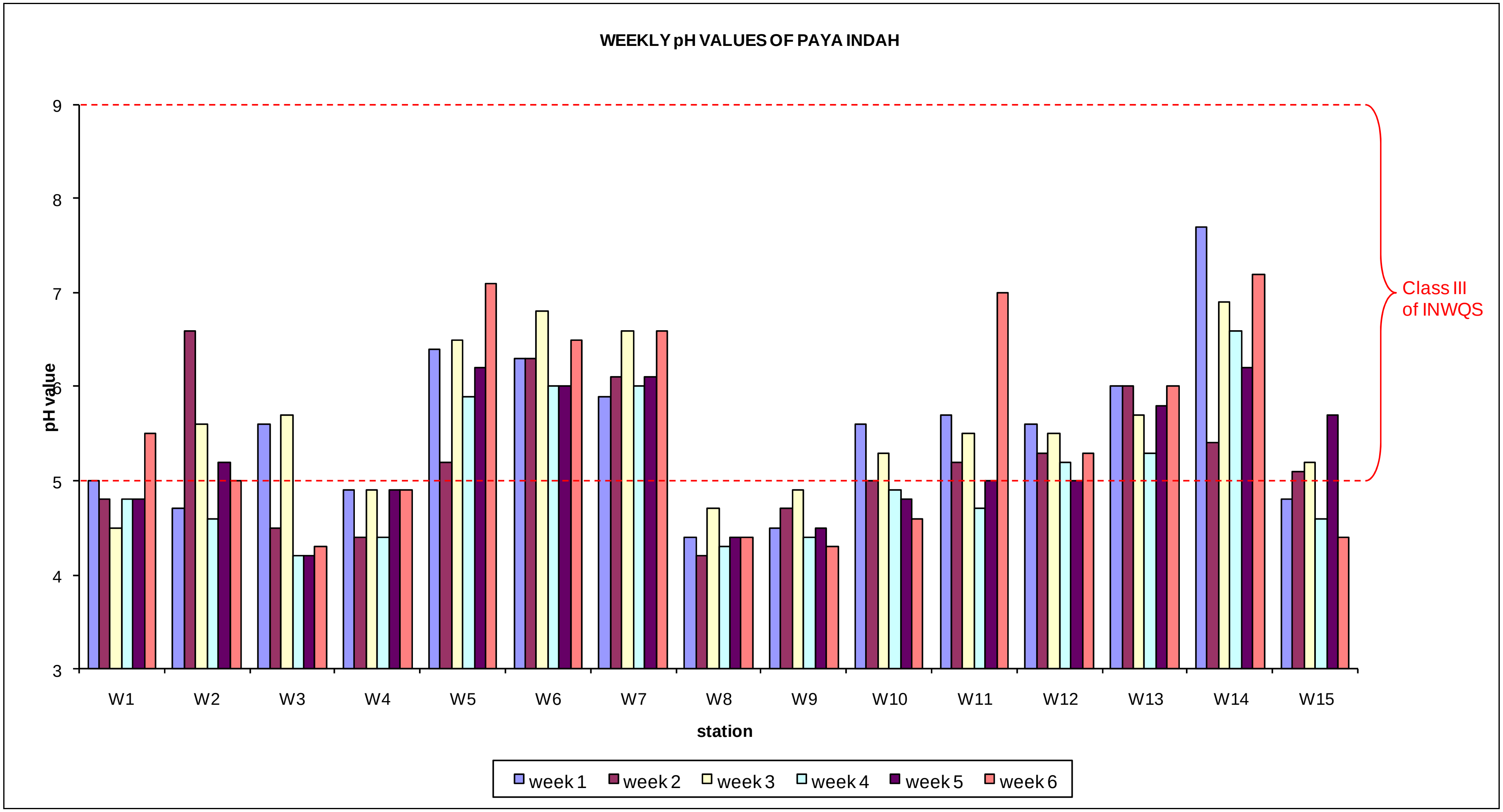

Figure 5.3: Weekly pH values of Paya Indah at each station

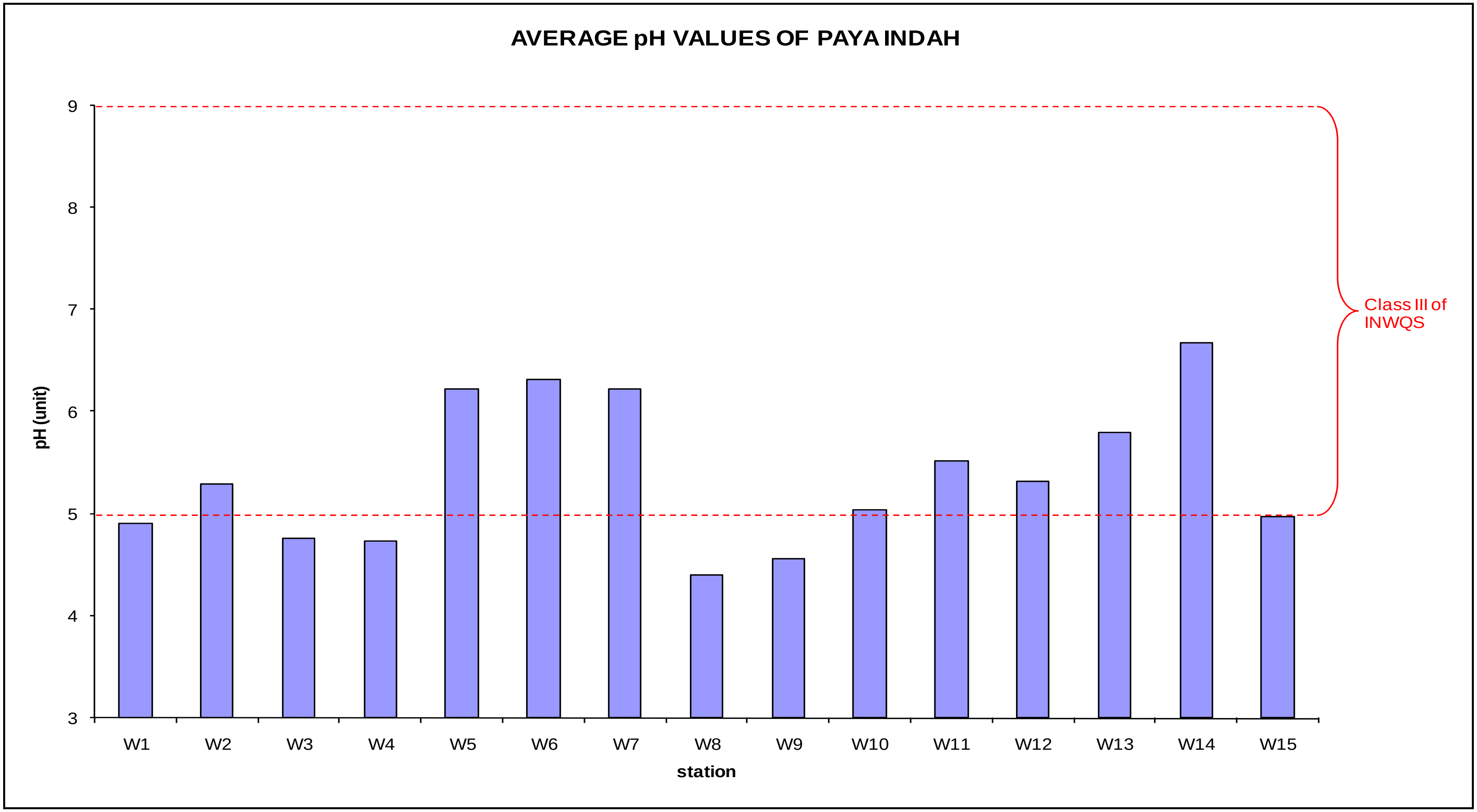

Figure 5.4: Averaged pH values of Paya Indah at each station

Study of acidity at Paya Indah was carried out by CETEC (1996) at six (6) major ponds: Main Lake; Blackwater Lake (Visitor Lake); Petaling Lake (Petaling Tin Lake); Lotus Lake; Blue Lagoon; and New Lake. Three (3) out of six lakes recorded pH values below 5.0, namely Main Lake (4.33 – 4.58), Blackwater Lake (Visitor Lake) (4.26 – 4.94) and Petaling Tin Lake (3.37 – 3.65), while the remaining lakes recorded pH value above 5.0. Therefore those three lakes recorded pH at Class V of INWQS.

The low pH at certain major lakes of Paya Indah may be contributed by several factors such as the natural condition of Paya Indah as half peat swamp and ex-mining area; previous mining activities; and acid rain from adjacent urban area (CETEC, 1996 and DNASB, 2001). Water circulations and regulations of drainage regime also contributed to low pH.

The main source of water at Paya Indah comes from adjacent North Kuala Langat Peat Swamp Forest. As we know, peat forms when plant material, usually in marshy areas, is inhibited from decaying fully by acidic conditions and absence of microbial activity (UNDP, 2006). Therefore, water in peat swamps is generally high in humic substance (humus and humic acid) that give a typically dark brown to black colour to the water (UNDP, 2006). The humic substances may be also tannin and lignin from waterlogged decomposition process. Zulkafli and Zahari (1997) also carried out water quality survey simultaneously with their fish survey. According to their water quality survey, four (4) out of nine (9) lakes recorded pH value below 5.0, which are Visitor Lake, Main Lake, Driftwood Lake and Chalet Lake. The dark brownish-reddish colour of water body of Canal C2 (Plate 5.1), Canal C4 (Plate 5.2) and Visitor Lake (Plate 5.3 and Plate 5.4) were enough to indicate that pH value of Paya Indah is lowered by peat swamp.

Plate 5.1: Water at Station W1 in dark-brown colour indicates the presence of humus and humic acid. Slow water movement observed here

Plate 5.2: Condition of water body at Station W2 with the sheen on the surface indicates the presence of discharges from nearby palm oil mill

Plate 5.3: Water condition in Visitor Lake, in dark-brown colour indicates the presence of humus and humic acid. The water was stagnant here

Plate 5.4: A shallow pond beside Visitor Lake, as its water in dark-brown colour that indicates acidic condition of Paya Indah water body. The water flow at this area was stagnant except at the inlet from crocodile lake

Mining activities also affect pH values of Paya Indah, despite mining activities ceased to exist since 1996. Tin mining is the major mining activity at that time, after iron and clay for brick manufacturing. According to CETEC (1996), the water in the mining pond was reported to have become more acidic during mining operation. This is because the heavy mineral residues from separation of tin ore during mining process contains as high as 24% of pyrite or iron sulphide (FeS_2). Dredging operations lifts the sediments and the associated pyrite to the land surface thus moving pyrite from its stable reducing environment in the subsurface to an unstable surface environment (CETEC, 1996). Briefly oxidation of FeS_2 will generate acidity (Gleisner et al., 2005), as sulphuric acid (H_2SO_4) produced, as affirmed by Jiang et al. (2007). It should be noted that oxidation of FeS_2 is microbially mediated reaction (Hounslow, 1995). The detail process of FeS_2 oxidation will be discussed later in another subchapter. Production of H_2SO_4 may worsen the readily acidic condition of Paya Indah.

Besides tin mining, clay mining also took place circa 1995, as reported in The News Straits Times (15th October 1997). Continuous clay mining could cause adverse impact to Paya Indah lakes such as peat subsidence because the water would be drained out from Paya Indah. According to the Malaysian Wetland Foundation Chief Executive Officer, Muralee D. Menon in The News Straits Times (15th October 1997), the clay is needed to hold water, otherwise the water will be drained away from Paya Indah. As a result, all mining activities were stopped in 1997, as mentioned in The New Straits Times (15th October 1997) and The Star (unknown date, circa 1996).

Rainwater may also be a potential cause of low pH in Paya Indah, as the rainwater is acidic. It is known that unpolluted rain has a pH of about 5.6 (which is the pH of distilled water in equilibrium with atmospheric carbon dioxide) (Wolff et al., 1988; and

CETEC, 1996). A number of studies show evidence of uncontaminated rainfall having a pH in the range 4.5 – 7.4 (Wolff et al., 1988).

There is little question that such pH values are associated with anthropogenic emissions of sulphur and nitrogen oxides formed during the combustion of fossil fuels (Masters, 1991). Precipitation is normally more acidic than pH 5.6 (Wolff et al., 1988). There is some natural H_2SO_4 and HNO_3 in the atmosphere, and industrial emissions, mainly from fossil fuel combustion, have greatly increased the concentration in some areas (Wolff et al., 1988).

In the field survey, internal water circulations among the major lakes of Paya Indah as in Table 5.2 were observed to be minimally flowing, and some lakes were almost stagnant. The minimal water movement also contributes to the low pH. From the average results, areas with constant and speedy water flow as observed at Station W12 and Station W13 show pH values more of than 5.0. This shows that the pH values could be influenced by speed of the water flow. Thus the constantly flowing water could keep the water pH values at acceptable level. Regulation of Paya Indah drainage system could also improve water pH either by replacement of water with higher pH values or dilution of water to improve pH values. About dilution, CETEC (1996) denoted that a mining company employed dilution techniques using water from adjacent lake to curb the pH problem. However, it depends on the source of water intake, as if the source of water was from Kuala Langat Peat Swamp Forest, the improvement of pH values would be unlikely as the pH of water from Kuala Langat Peat Swamp Forest is already low.

5.3.2 Dissolved Oxygen (DO)

In aquatic system, Dissolved Oxygen (DO) is vital, as oxygen is an absolute requirement for all aerobic organisms. All living organisms are dependent upon oxygen in one form or another to maintain the metabolic process that produce energy for growth and reproduction (Sawyer et al., 2003). Besides, oxygen plays an important role in influencing inorganic chemical reactions, especially in oxidation process.

DO reading is highly dependent on temperature, salinity, biological activity (microbial, primary production) and rate of transfer from the atmosphere (ANZECC and ARMCANZ, 2000). The solubility of atmospheric oxygen in freshwater ranged from 14.6 mg/l at 0^{o}C to about 7 mg/l at 35^{o}C under 1 atm pressure (Sawyer et al., 2003). Thus, it is shown that DO concentration decreased with the increase of temperature.

There are two (2) major sources of dissolved oxygen in an aquatic ecosystem. Exchange from the atmosphere is a main source of oxygen, with the exchange increasing under turbulent conditions (ANZECC and ARMCANZ, 2000). Another source of dissolved oxygen was from the aquatic plants and weeds, as they release the oxygen during photosynthesis process in daytime, but consumes oxygen for normal respiration at night.

The results of DO concentrations of Paya Indah are summarized in Table 5.4. It should be noted that the DO concentration range of Class III of INWQS is between 3.0 mg/l and 5.0 mg/l. However, the DO concentration that is 5.0 mg/l or more, it is a good observation as the water body is still healthy. Thus the DO concentrations were only compared with the minimum limit of Class III of INWQS (3.0 mg/l).

Table 5.4
DO concentrations of Paya Indah in mg/l

Sampling Station	Sampling Weeks Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Average	Std. Dev. (±)	Percent age (%)
W1	1.17	0.66	1.70	0.85	0.85	0.64	0.98	0.40	**41.05**
W2	3.07	3.48	3.30	2.40	2.76	2.43	2.91	0.45	15.50
W3	0.68	1.28	1.63	1.49	1.39	1.58	1.34	0.35	**25.95**
W4	0.94	0.79	2.05	0.88	0.90	0.54	1.02	0.53	**51.76**
W5	0.82	2.21	3.06	2.27	3.50	3.16	2.50	0.97	**38.76**
W6	0.79	2.92	3.21	1.92	6.77	3.91	3.25	2.04	**62.63**
W7	0.71	5.18	2.67	1.58	4.81	3.52	3.08	1.77	**57.44**
W8	0.78	0.58	0.42	1.15	0.54	3.36	1.14	1.12	**98.22**
W9	2.69	4.82	1.99	2.47	3.42	2.54	2.99	1.01	**33.79**
W10	3.78	4.88	3.20	2.84	4.14	3.59	3.74	0.72	19.23
W11	2.55	4.76	2.53	2.13	3.71	3.01	3.12	0.97	**31.13**
W12	0.78	2.19	1.58	1.24	2.14	1.99	1.65	0.56	**33.97**
W13	2.05	2.07	1.52	1.21	2.54	1.95	1.89	0.47	**24.63**
W14	3.55	4.64	3.32	4.03	3.89	5.47	4.15	0.79	19.01
W15	0.79	1.72	0.90	1.02	1.14	1.51	1.18	0.36	**30.75**

As shown in Figure 5.5, most of the stations recorded DO concentrations below 5.00 mg/l, with the lowest DO concentration at 0.42 mg/l, recorded at Station W8 in week 6, indicating an unhealthy water quality of Paya Indah. This DO concentration was extremely low and only organisms that are able to tolerate such DO concentration could live, e.g. hardy fish species like catfish (*Clarias* sp.), perch (*Anabas testudineus*) or tilapia (*Oreochromis* sp.). Thus it does not comply with Class III of INWQS, and could be categorized in Class V of INWQS. When the weekly DO concentrations were averaged, only Station W6, Station W7, Station W9, Station W10, Station W11 and Station W14 exhibited healthy DO concentrations that are above minimum range of Class III of INWQS. The position of the peaks at the following stations can be observed clearer in Figure 5.6. Calculation on percentage of standard deviation against average found that only Station W2, Station W10 and Station W14 did not have significant fluctuations. The remaining stations show significant fluctuations as the percentages of standard deviation against average at each station were more than 20%. Therefore it is found that DO concentration is very dynamic and it changes each week.

Low DO concentrations may be caused by certain factors. Decomposition process of organic material by detritus may be absent, although the peat soil is abundant with organic material. This is because the decomposition of organic material in peat swamp occurs in fully acidic condition as addressed by UNDP (2006) before. Regulations of Paya Indah drainage system also is one of the factors that influence DO concentration. This could happen when water with lower DO concentration is flushed out from the area and it is replenished with the water with higher DO concentration. It depends on the source of water, and the DO enrichment methods used to increase oxygen absorbing surface area from the air such as direct aeration, fountain or cascade dam.

Oxidation of pyrite or iron sulphide (FeS_2) can also be related with low DO concentration, as large amount of oxygen were occupied for FeS_2 oxidation. A type of microbe, namely *Acidithiobacillus Ferrooxidans* has been identified by Gleisner et al. (2005) and Jiang et al. (2007) as one of the microbes that mediated oxidation of FeS_2. Study by Gleisner et al. (2005) affirms that this microbe oxidize FeS_2 with the presence of DO.

The colouration of water body of Paya Indah as addressed before may be one of the factors of low DO concentration. This situation may reduce light penetration into the water body. The light is required by aquatic plants that submerged in the water to perform photosynthesis. During photosynthesis process, oxygen will be released and carbon dioxide will be absorbed. When there is minimal light penetration, the photosynthesis process shall be limited, thus fewer DO released.

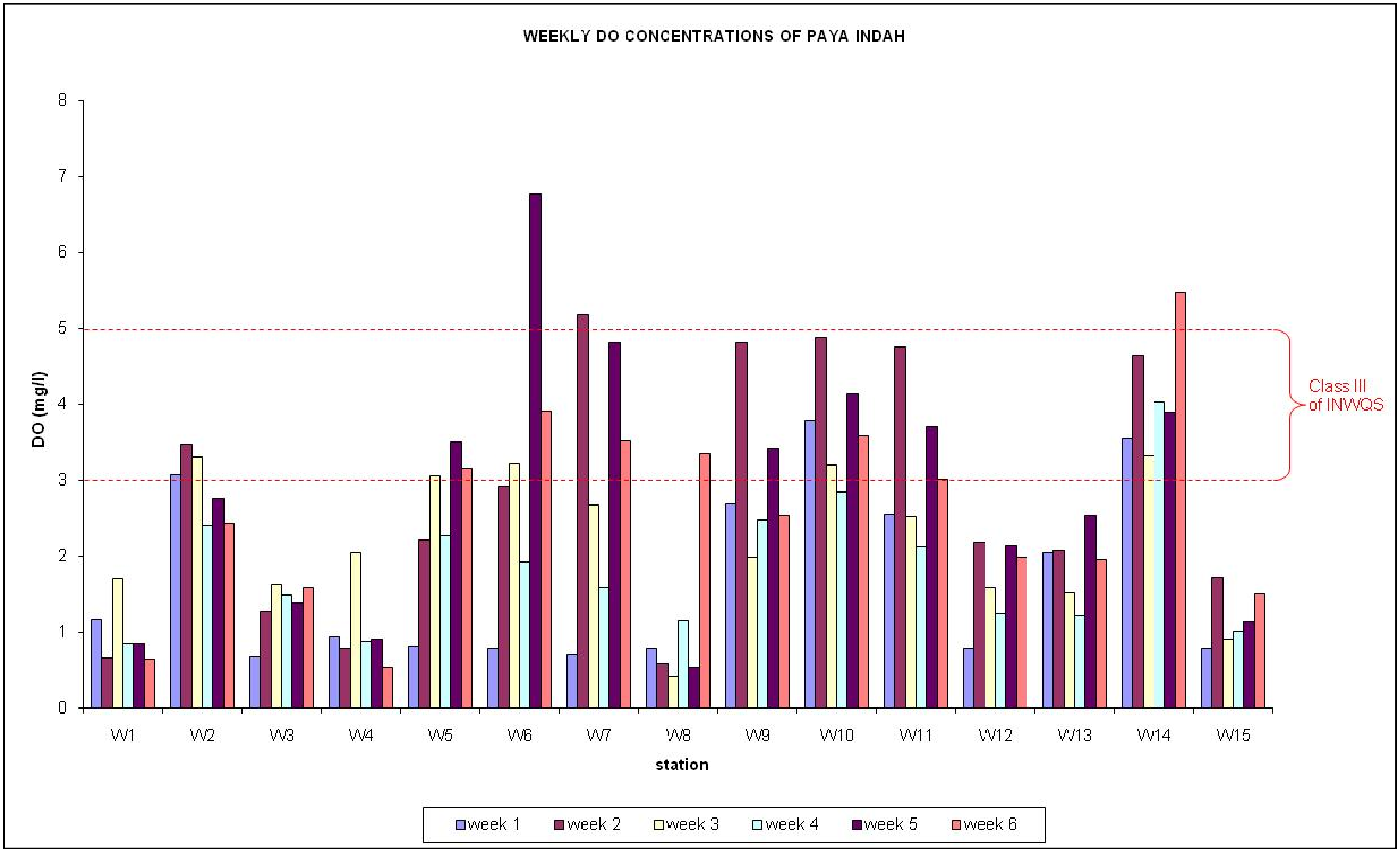

Figure 5.5: Weekly DO concentrations of Paya Indah at each station

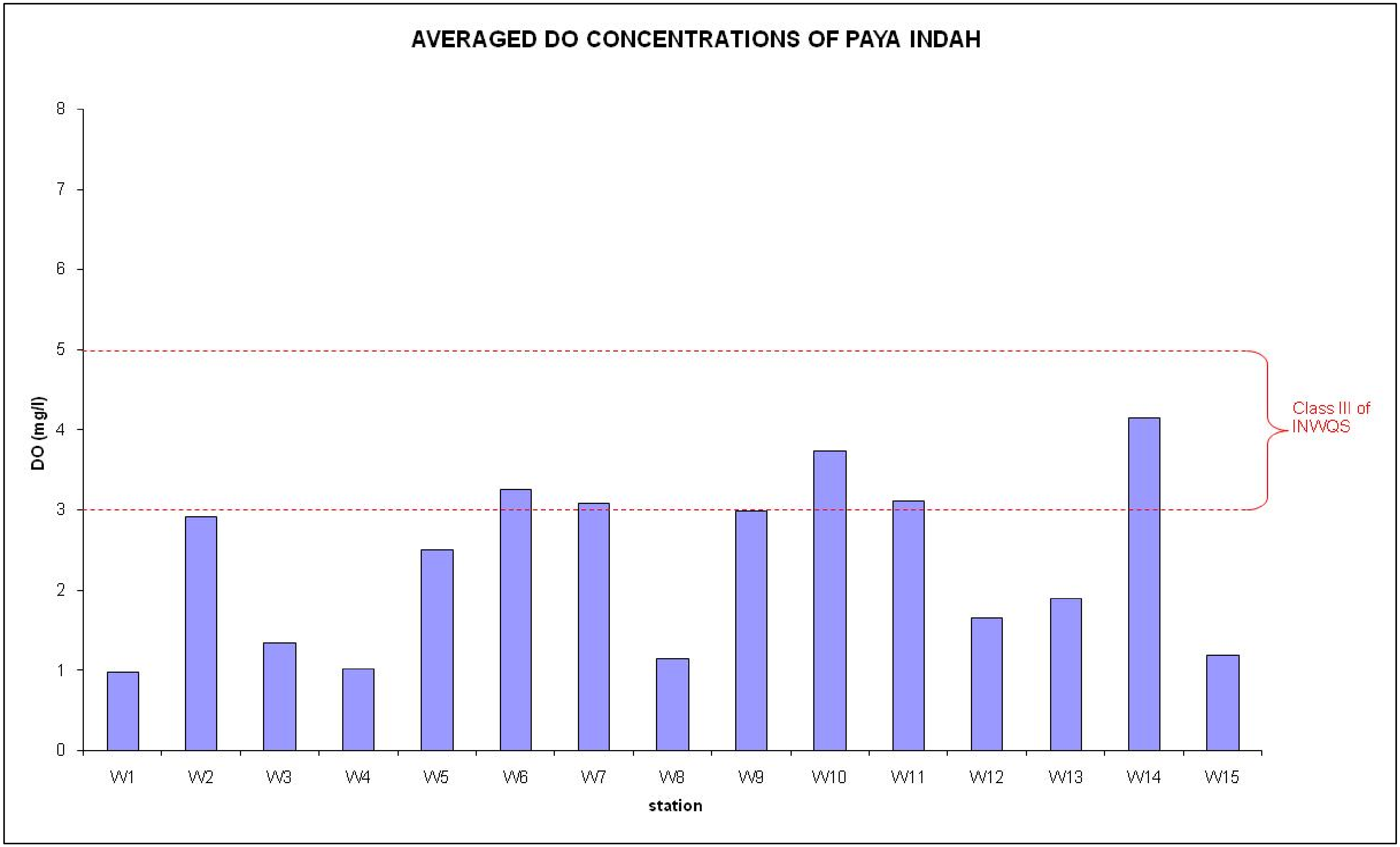

Figure 5.6: Averaged DO concentrations of Paya Indah at each station

Low DO concentrations can results in adverse effects on many aquatic organisms (fishes, invertebrates and microorganisms) which depend upon oxygen for efficient functioning (ANZECC and ARMCANZ, 2000). Moreover, according to ANZECC and ARMCANZ (2000) again, at reduced DO concentrations it is known that many toxic compounds become increasingly toxic. The increasing toxicity of these toxic compounds may threaten not only the ecosystems, but also the human health.

5.3.3 Biochemical Oxygen Demand (BOD)

Biochemical Oxygen Demand (BOD) is usually defined as the amount of oxygen required by bacteria while stabilizing decomposable organic matter under aerobic conditions (Sawyer et al., 2003). Therefore, BOD is an indicator of the amount of the organic matter presence in the water body. Healthy water has a BOD value of 2 mg/l or less.

Table 5.5
Weekly BOD values in mg/l of Paya Indah

Sampling Station	**Sampling Weeks**						**Average**	**Std. Dev. (±)**	**Percent age (%)**
	Week 1	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**			
W1	5	<2	<2	4	3	2	3.5	1.29	36.89
W2	3	<2	2	3	4	33	9.0	13.44	149.28
W3	17	<2	3	6	5	5	7.2	5.59	77.58
W4	9	4	3	6	4	4	5.0	2.19	43.82
W5	4	2	<2	5	2	2	3.0	1.41	47.14
W6	4	2	<2	3	3	2	2.8	0.84	29.88
W7	4	2	<2	3	2	2	2.6	0.89	34.40
W8	8	5	5	6	5	4	5.5	1.38	25.06
W9	9	<2	4	6	7	2	5.6	2.70	48.25
W10	<2	7	<2	<2	<2	<2	7.0	NA	NA
W11	4	2	2	4	2	<2	2.8	1.10	39.12
W12	<2	<2	<2	<2	<2	<2	NA	NA	NA
W13	<2	<2	<2	<2	<2	<2	NA	NA	NA
W14	2	<2	<2	<2	<2	<2	2.0	NA	NA
W15	7	3	6	6	4	3	4.8	1.72	35.64

The weekly results of BOD by stations are summarized in Table 5.5 above. It should be noted that the BOD value below 2 mg/l is considered as not detected, as it is below detection limit. The maximum limit of BOD value under Class III of INWQS had been set to be 6 mg/l.

Referring to Figure 5.7, most of the BOD values were healthy as their peaks were located between Class I and Class III of INWQS. Only some BOD values exceeding Class III of INWQS were occasionally recorded, and stood at Class V of INWQS. According to the weekly BOD values, BOD values at Station W12, Station W13 and Station W14 were below detection limit. Each station exhibited fluctuation of BOD values at each week. The highest BOD value was recorded at Station W2 in the 6^{th} week (33 mg/l). This is because during the sampling, the water at Station W2 was murky due to heavy downpour. Most of the weeks recorded BOD values well below Class III of INWQS. When BOD values of each station were averaged, Station W2, Station W3 and Station W10 recorded BOD values exceeding Class III of INWQS. Therefore, the averaged BOD values at these stations stood at Class IV of INWQS. However BOD value of Station W2 in the 6^{th} week influences the average BOD values with high standard deviation (±13.44). The average BOD value of Station W2 was 9.0 mg/l, and situated at Class IV of INWQS.

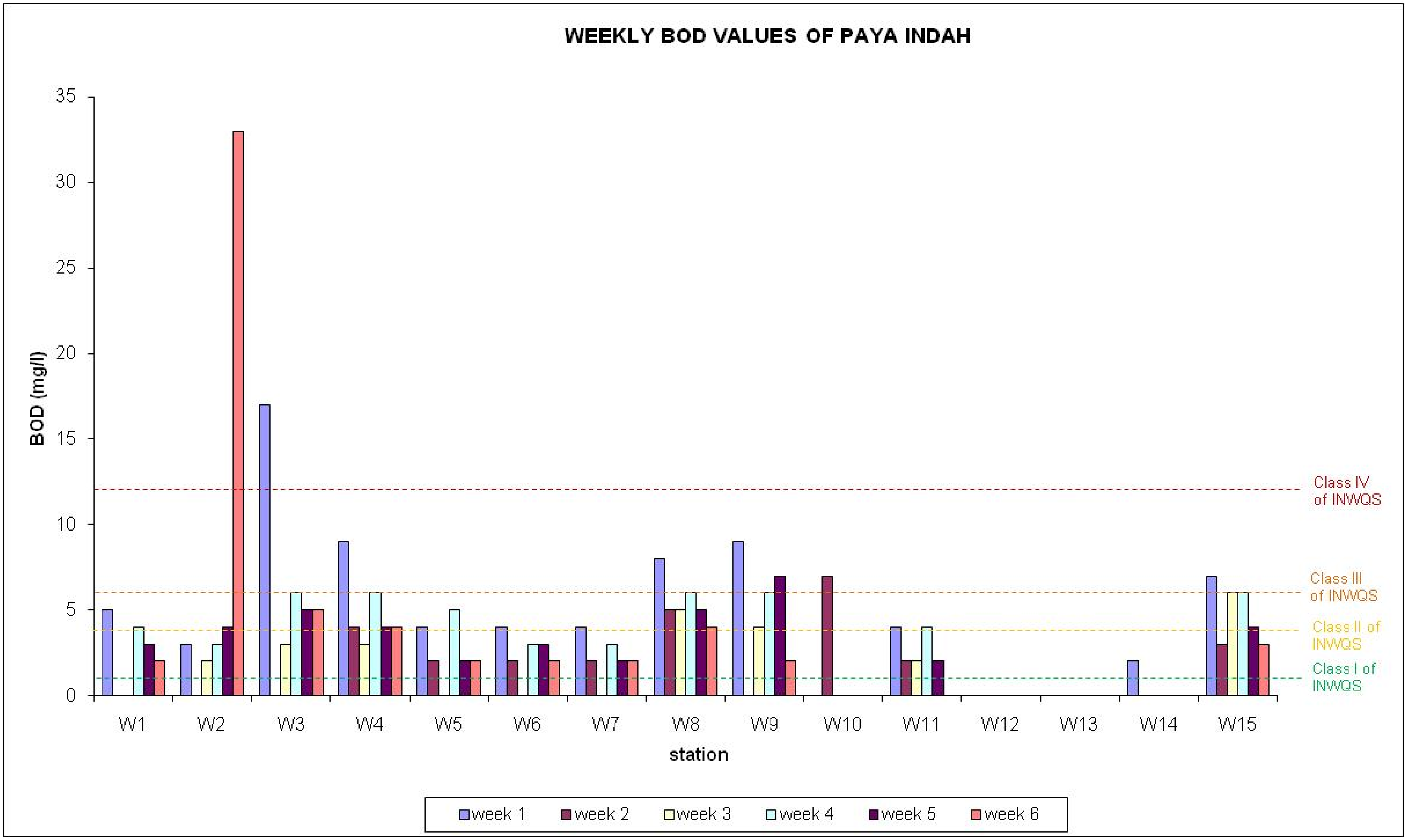

Figure 5.7: Weekly BOD values of Paya Indah at each station

It is also assumed that the significant fluctuations of BOD values at all stations were observed because the percentages of standard deviations against average at all stations were more than 20%. This was exceptional to Station W10, Station W12, Station W13 and Station W14 because these stations recorded BOD values below detection limit at most of the weeks, therefore the standard deviation at these stations could not be calculated.

Low BOD values with low DO concentrations recorded at certain stations at Paya Indah may indicate that the presence of microbial activities at Paya Indah may be minimal. This is due to the decomposition process is fully in acidic conditions and microbial activities are absent (UNDP, 2006). This is because the microbes including detritus may find it difficult to adapt with low acidic condition. Thus the BOD values may be applicable to the consumption of DO by aquatic plants.

Conditions of water flow in the stream can also influence the values of BOD, depending on the flow speed and frequency. This had happened to the interconnection streams between Paddy Lake and Perch Lake (Station W13) (Plate 5.5), and between Perch Lake and Marsh Lake (Station W14) (Plate 5.6). Despite these area having low DO, the BOD is also low and healthy. This is because when these streams flow constantly at very fast speed, the currents carry along the organic matters, thus they couldn’t settle down to the bottom. As a result, microbial process on decomposing organic material would be disrupted by the fast current. It should be noted that decomposition process can only occur when the organic matter settled down at the bottom due to slow current or stagnant water.

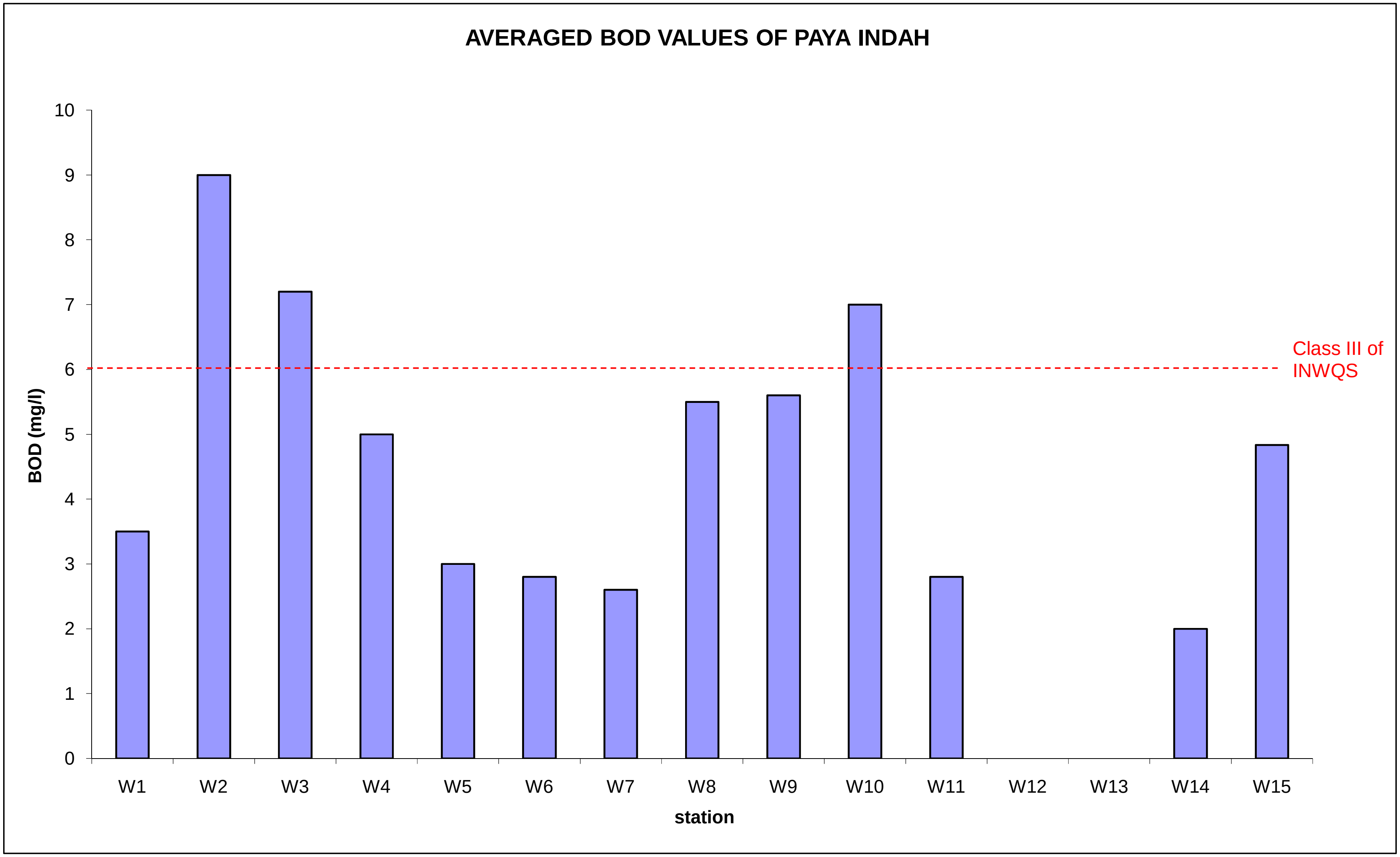

Figure 5.8: Averaged BOD values of Paya Indah at each station

Plate 5.5: Interconnection channel between Paddy Lake and Perch Lake is constantly flowing

Plate 5.6: Interconnection channel between Perch Lake and Marsh Lake is constantly flowing

Heavy downpour can also cause high BOD value. This is because the occurrence of heavy downpour from the upstream carries plenty of mud and silt to the downstream. This mud and silt may contain high organic matter, thus high amount of DO is required by microbes to stabilize the decomposition process of these organic materials. This happened at Canal C4 in Week 6th, as addressed before. In normal condition, BOD values of Canal C4 were acceptable, as the BOD values in the remaining weeks were well below Class III of INWQS.

There are also few of non-point sources of high BOD degrading substances such as downfalls from agricultural activities, industrial downfalls, sewage treatment plant discharge, and untreated leachate from solid wastes disposal facilities, as identified by CTI and OYO (2001). These could happen through infiltration of these substances into the drainage systems and groundwater aquifer within Paya Indah vicinity.

Agricultural activities may also have the possibility to influence the BOD values of Paya Indah, especially from ranching or cultivation activities. This is because the discharge from cultivation facilities could infiltrate drainage and groundwater systems within Paya Indah and adjacent peat swamp and ex-mining pond. It is also observed during the field survey that there are vegetable farming activities within Paya Indah vicinity by farmers and local residents. The location of industrial estates and cultivation facilities (pig farms, poultry farms and cattle farms) within Paya Indah vicinity are as shown in Figure 5.9.

Industrial downfalls may come from the adjacent factories and industrial estates. Wastewaters discharged by the industrial operations are in some cases among the worst sources of water pollution (Laws, 1993). Although the nature of the pollutants associated with these wastewaters differs greatly from one industry to another, in almost all cases the problems are caused by one or a combination of the following conditions in the wastewater: 1. high BOD; 2. high concentration of suspended solids; and 3. presence of toxic substances (Laws, 1993). Studies carried out by CTI and OYO (2001) discover that there are 30 industrial estates with 337 factories located in the Langat Basin (as at 1997 provided by Malaysian Industrial Development Authority, MIDA). Out of 30 industrial estates, only Olak Lempit Industrial Park were the nearest, which is located less than 1 km from Paya Indah. Location of Olak Lempit Industrial Park is shown in Figure 5.9.

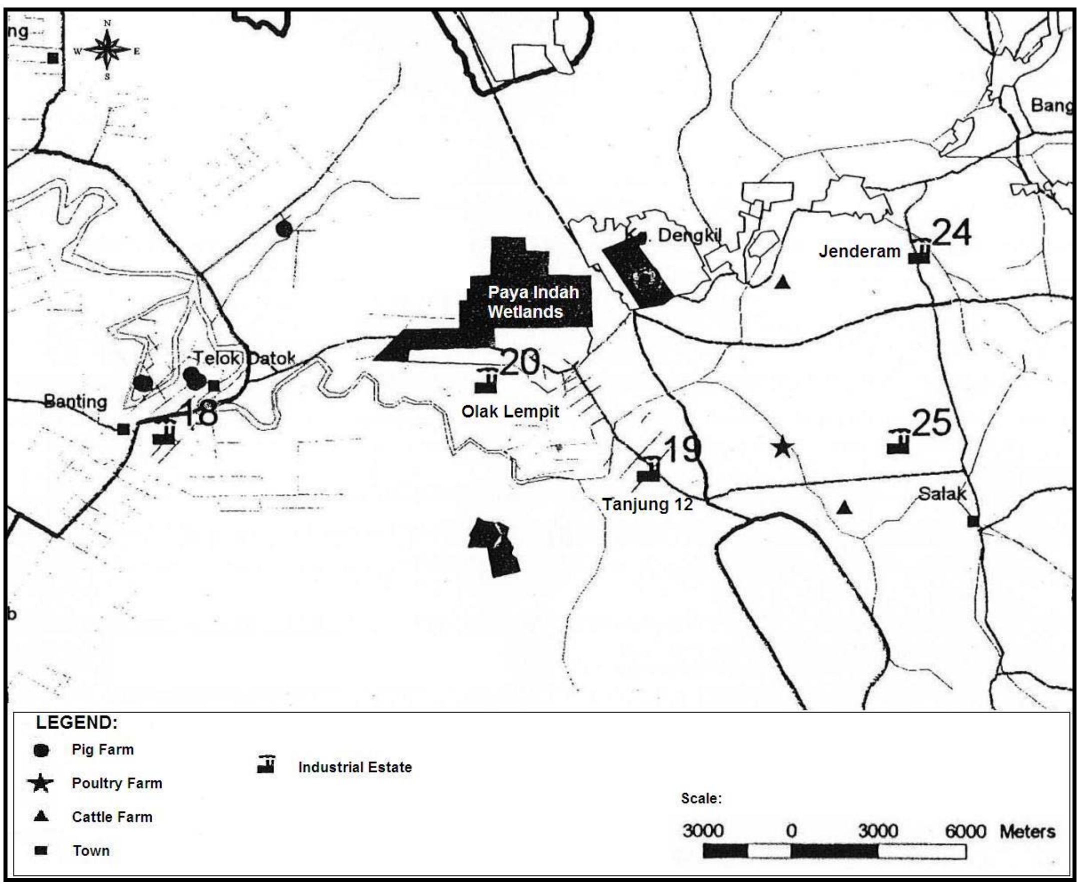

Figure 5.9: Locations of industrial estates, pig farms, poultry farms and cattle farms within Paya Indah vicinity
Source: CTI and OYO, 2001

Besides these industrial estates, field survey during sampling period observed an oil palm extraction mill that was close to Canal C4, as depicted in Plate 5.7. Besides, there is also a palm oil refinery, which is less than 1 km from Paya Indah vicinity. Palm oil mill effluent (POME) and palm oil refinery effluent (PORE) are the obvious examples of industrial or agricultural downfall that are high in oxygen demands, including BOD. As denoted by Ma and Abdul Halim (1991), POME has 100 times polluting capability compared to domestic sewage. During the field survey, Station W2 constantly produced palm-oil-like odour and a thin sheen on its surfaces, and these were suspected to be coming from the nearby palm oil mill and refinery. However, it is observed from the BOD results that with exception of Week 6^{th}, Station W2 (Canal C4) exhibit acceptable BOD values.

Plate 5.7: Palm oil extraction mill near Canal C4

Discharges from sewage treatment plants may potentially degrade water quality, as it has high load of BOD and NH_3-N (CTI and OYO, 2001) before treatment. However, BOD results indicated that there is no proof to relate the sewage treatment discharge with Paya Indah water quality, as the discharges from the sewage treatment plants might be efficiently managed by the Indah Water Consortium (IWK). The nearest sewage treatment plant was located by CTI and OYO (2001) at Olak Lempit, less than 1 km from Paya Indah. This is because before discharge into any water body, the sewage was treated to comply with Standard B of Environmental Quality (Sewage and Industrial Effluents) Regulations 1979 under Environmental Quality Act 1974. The locations of sewage treatment plants within 5 km radius of Paya Indah vicinity, as well as location of solid wastes landfill sites are shown in Figure 5.10. However, the possibility of untreated sewage to infiltrate the groundwater systems may be ever present.

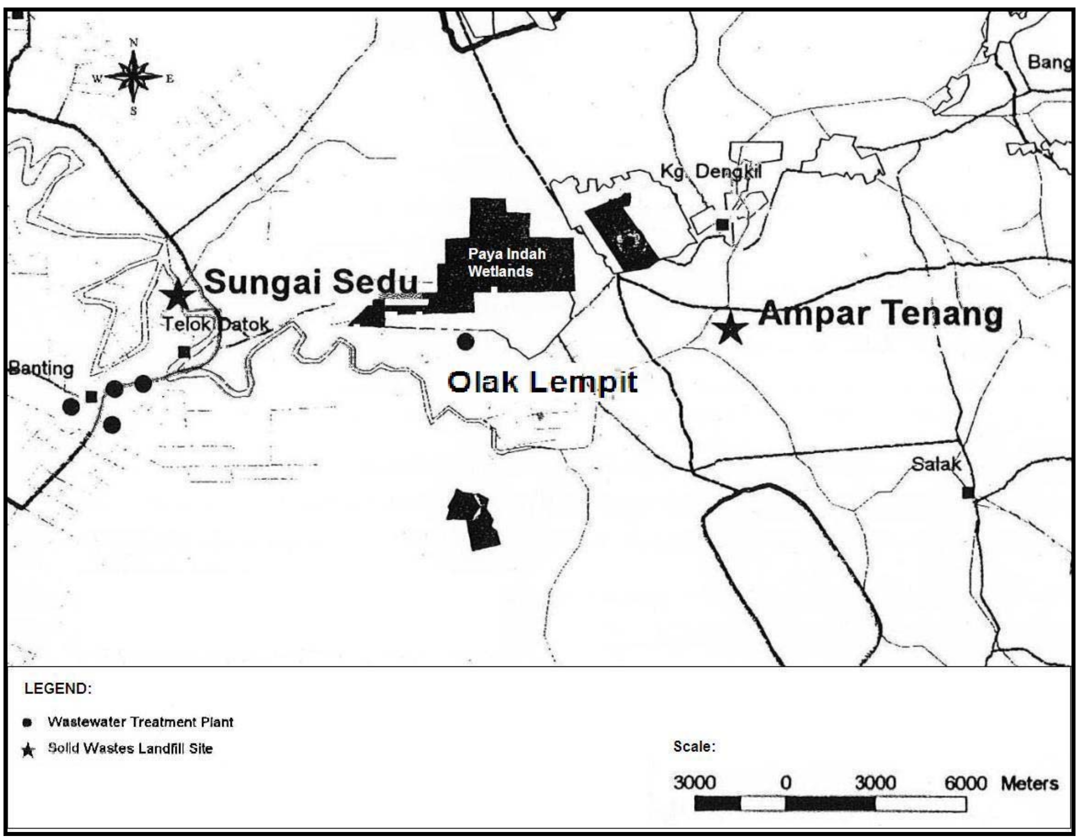

Figure 5.10: Locations sewage treatment plants and solid wastes landfill sites within Paya Indah vicinity
Source: CTI and OYO, 2001

5.3.4 Chemical Oxygen Demand (COD)

Chemical Oxygen Demand (COD) is defined as the amount of oxygen required to degrade the chemical compounds in the water body, especially in oxidation process. COD values are generally higher than BOD values. This is because COD provide a more complete oxidation of both organic and inorganic compounds in the water body, therefore providing a higher estimate of oxygen consumption rates. High COD values indicate that the water body is polluted by chemical compounds. The results of COD test can be obtained faster than BOD test. This is because BOD test uses incubation method that requires 5 days to complete, but the BOD values obtained only represent 60 – 80% of the ultimate BOD value. However COD values could be obtained after 3 hours, by using close-reflux test. Weekly COD values are summarized in Table 5.6 and depicted in Figure 5.13, while averaged COD values are depicted in Figure 5.12. It should be noted that the maximum limit of COD value under Class III of INWQS is 50 mg/l.

Table 5.6
Weekly COD values (mg/l) of Paya Indah

Sampling Station	Sampling Weeks						Average	Std. Dev. (±)	Percent age (%)
	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6			
W1	49	39	60	44	42	51	47.5	7.56	15.91
W2	26	30	61	28	60	97	50.3	27.89	55.41
W3	104	86	115	86	92	101	97.3	11.45	11.76
W4	85	91	116	87	78	85	90.3	13.26	14.68
W5	43	74	58	50	34	50	51.5	13.65	26.50
W6	34	34	60	41	49	43	43.5	9.89	22.75
W7	33	32	49	42	31	44	38.5	7.50	19.49
W8	103	100	124	95	92	102	102.7	11.27	10.98
W9	132	12	113	92	144	93	97.7	46.80	47.92
W10	12	78	38	19	21	34	33.7	23.79	70.66
W11	35	46	53	36	34	30	39.0	8.67	22.24
W12	8	14	16	14	9	24	14.2	5.74	40.53
W13	7	12	29	10	6	9	12.2	8.52	70.02
W14	9	29	32	25	20	24	24.8	5.04	20.28
W15	14	79	111	83	77	8	84.7	13.43	15.86

From weekly COD values, Station W3, Station W4, Station W8, Station W9 and Station W15 recorded COD values exceeding Class III of INWQS in all weeks. The remaining stations recorded COD values well below Class III of INWQS either in all weeks or only certain weeks recorded COD values slightly exceeding Class III of INWQS. When the weekly COD values were averaged according to stations, same situations were observed with Station W2 and Station W5 recording COD values slightly higher than Class III of INWQS. Significant fluctuation of COD values were found at Station W2, Station W5, Station W6, Station W9, Station W10, Station W11, Station W12, Station W13 and Station W14 as their percentages of standard deviation against average were more than 20 percent. The remaining station shows no significant fluctuation.

Oxidation of pyrite (FeS_2) had been identified as a main cause of high COD values, as pyrite were present from previous mining activity, especially tin mining. This is because oxygen was extensively used to oxidize pyrite to produce iron sulphate and sulphuric acid, but the details of this process will be discussed in another chapter. As the point source of COD degradation is mainly from the previous mining activities, the non-point sources of COD degrading substance is almost the same like that of BOD degrading substances such as industrial downfalls, sewage treatment plant discharge, downfalls from agricultural activities and untreated leachate from solid wastes disposal facilities. This could happen in the same way as mentioned in BOD subchapter. If these substances could cause high BOD, the COD could be much higher. POME is an obvious example of pollutants with high COD and BOD. Since, COD results at Station W2 shows less significant of COD values with contamination of POME.

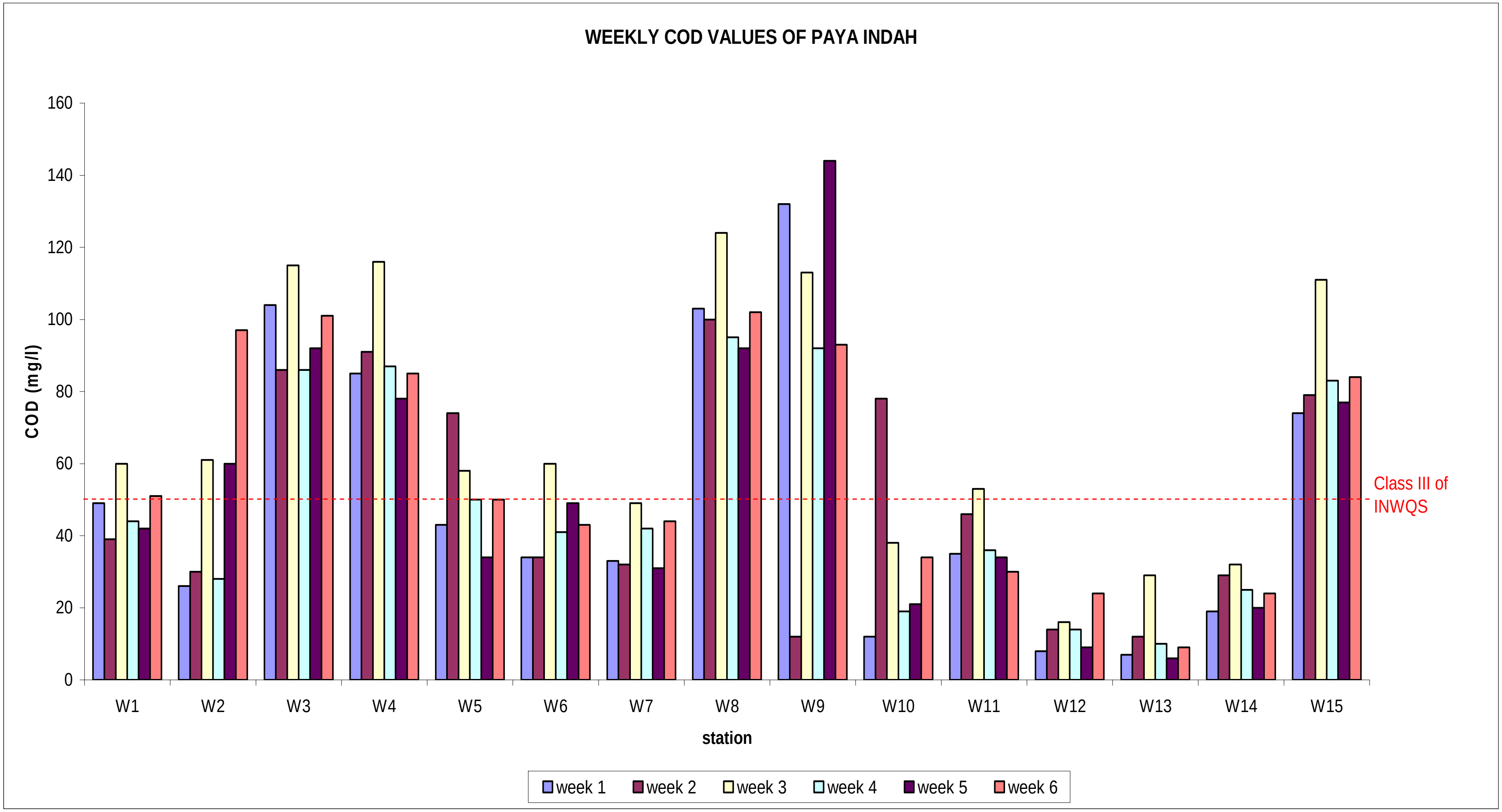

Figure 5.11: Weekly COD values of Paya Indah at each station

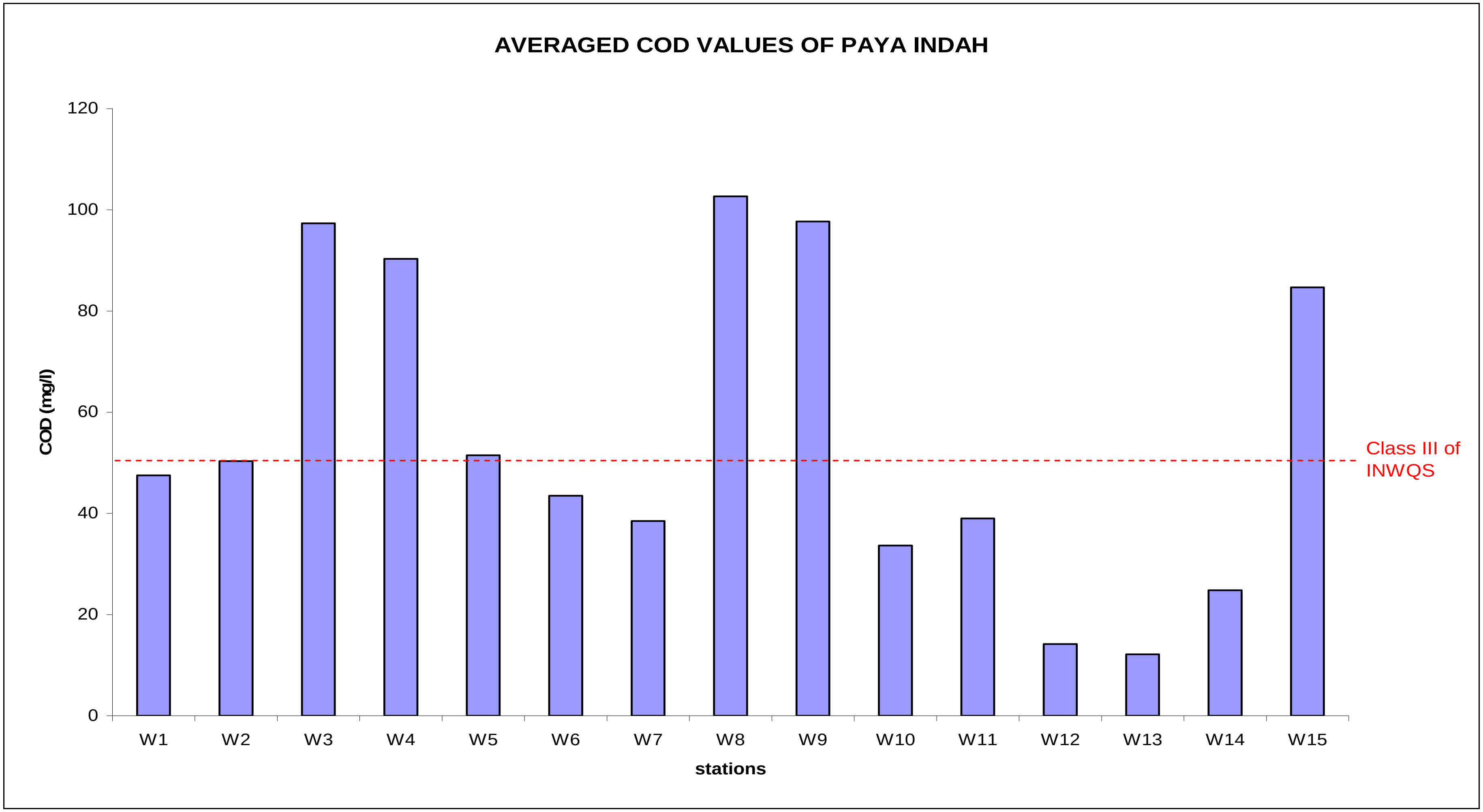

Figure 5.12: Averaged COD values of Paya Indah at each station

5.3.5 Total Suspended Solids (TSS)

Total Solids can be divided into two components, which are Total Dissolved Solids (TDS) and Total Suspended Solids (TSS). TSS includes particles suspended in the water body that cannot pass through a filter. The solids consisted of suspended clay, silt, organic matter, planktons or detritus. An increase in TSS may cause adverse effects on aquatic ecosystem such as increased temperature of water body that eventually reduce DO concentrations. TSS will also block the sunlight to penetrate into the water body. This may cause interruption of photosynthesis process by submerged aquatic plants. TSS also may suffocate the aquatic lives, especially fish by clogging their gills, lowering the resistance to disease and lowering growth rate. TSS is obviously associated with turbidity, as the water body become more turbid with the increase of TSS values.

The results of Total Suspended Solids (TSS) are summarized in Table 5.7 below. It should be noted that the maximum limit of TSS value under Class III of INWQS is 150 mg/l, and the TSS value below detection limit is <2 mg/l.

It was found that only certain stations recorded TSS higher than Class III of INWQS, as shown in Figure 5.13. The high values were found at Station W2 in 3rd week, Station W9 in 5th week, and Station W11 at 2nd week, 3rd week and 4th week. Despite the TSS of each week at each station fluctuated significantly as all stations show percentages of standard deviation against average of more than 20 percent, the average TSS for the stations were well below Class III of INWQS, as shown in Figure 5.14.

Table 5.7
Weekly TSS values (mg/l) of Paya Indah

Sampling Station	**Sampling Weeks**						**Average**	**Std. Dev. (±)**	**Percent age (%)**
	Week 1	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**			
W1	4	4	18	<2	4	7	7.4	6.1	81.98
W2	28	23	201	14	14	63	57.2	72.8	127.27
W3	21	4	17	12	2	4	10.0	7.9	78.74
W4	86	124	38	8	9	16	46.8	47.9	102.21
W5	19	25	39	120	8	6	36.2	42.8	118.34
W6	22	25	28	12	16	32	22.5	7.5	33.23
W7	22	15	14	4	3	3	14.0	6.2	44.03
W8	3	2	5	3	<2	4	3.4	1.1	33.53
W9	68	33	5	11	152	5	45.7	57.4	125.70
W10	6	33	59	4	3	3	18.0	23.2	129.00
W11	86	305	254	171	66	24	151.0	111.6	73.93
W12	4	<2	<2	2	2	<2	2.7	1.2	43.30
W13	3	<2	37	2	3	<2	11.3	17.2	152.65
W14	2	2	<2	3	2	2	2.2	0.4	20.33
W15	4	8	6	3	7	4	5.3	2.0	36.87

Colouration of the Visitor Lake, Lotus Lake, Main Lake and the inflowing canals at Paya Indah may not be caused by high TSS, but it may have been caused by the presence of tannin from decomposition of organic matter in the Kuala Langat peat swamp forest. High TSS values at Station W11 may due to the churns of the bottom of Perch Lake during water sampling procedure, as this lake was observed to be shallow (approximately ±15 cm depth). Thus it is indicated that TSS may not be a cause of water quality degradation of Paya Indah.

There are numerous factors that contribute to the increases of TSS values. TSS, as well as turbidity in most rivers, many lakes, and wetlands is highly dependent upon the water flow, with very large increases (of TSS values) noted during flood (ANZECC and ARMCANZ, 2000). In rivers and streams, TSS values generally increased during rainy days, especially heavy downpour. The rainwater increases the water level (that may lead to the flooding event) and the current's velocity, and the high speed flows will carry along the murky water with silts through erosion of riverbank and suspended riverbed material. In stagnant water condition (such as water body at major lakes of Paya Indah), the TSS values vary with turbulence as deposited sediment is resuspended, and they also vary with wind (ANZECC and ARMCANZ, 2000).

According to ANZECC and ARMCANZ (2000), TSS may arise from point sources such as industrial outfalls, industrial wastes (e.g. from pottery and brick making plants), and stormwater drains, but most TSS arises from diffuse land runoff due to soil erosion. This can be related to the clay mining activity which took place circa 1995, as discussed in sub-section 5.3.1. The News Straits Times (15^{th} October 1997) quoted excerpt from Muralee D. Menon:

“Also, there is a lake right next to the clay mining site, and if the land barrier between the two is breached, then all this muck from the mining will spill into the water and we may lose the lake.”

The ‘muck’ may be referred to the murky water from either mining activity or eroded earth bund (land barrier). If these happen, Paya Indah would be severely affected.

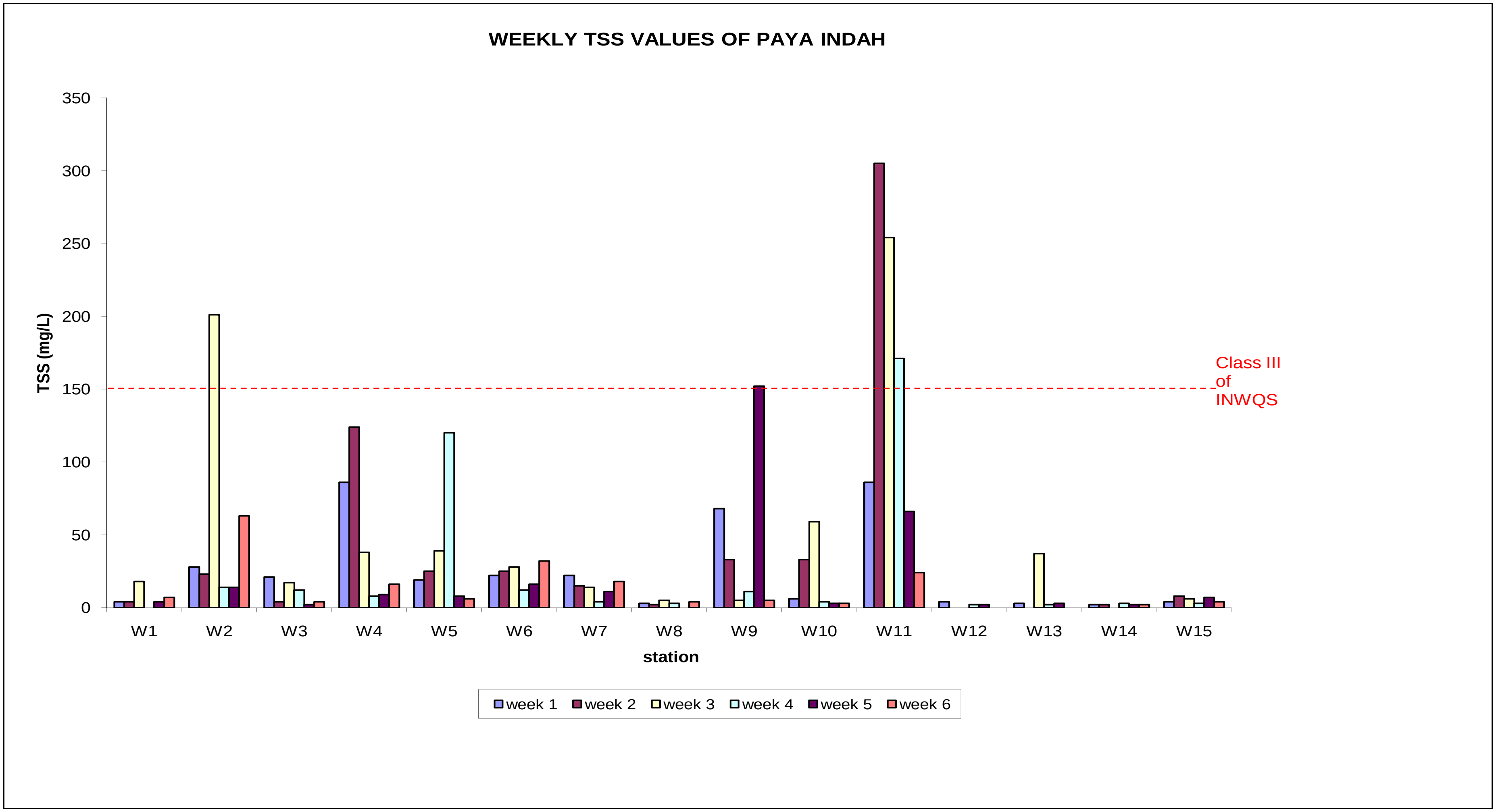

Figure 5.13: Weekly TSS values of Paya Indah at each station

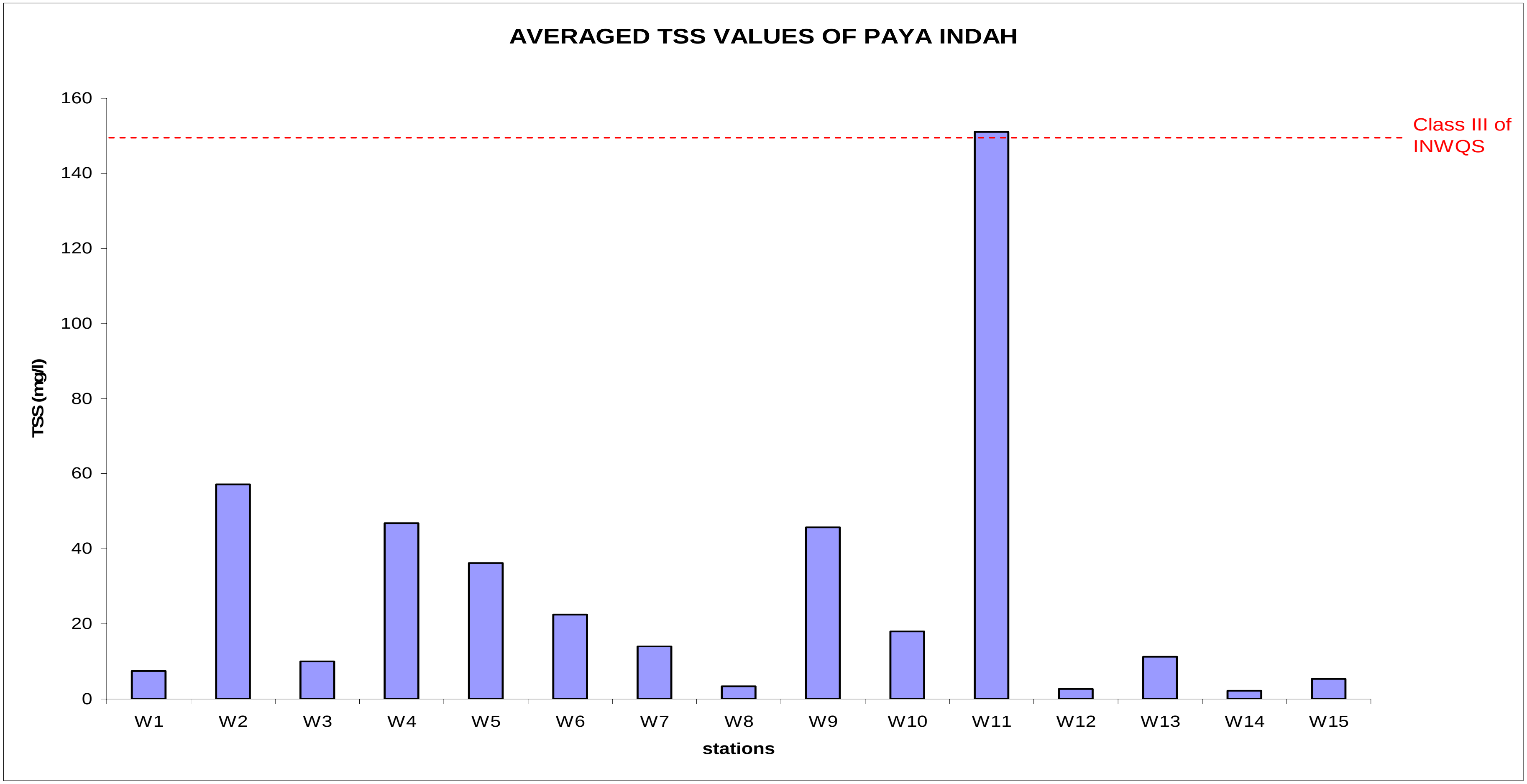

Figure 5.14: Averaged TSS values of Paya Indah at each station

5.3.6 Ammoniacal Nitrogen (NH_3-N)

Nitrogen (N) is an essential nutrient to life on earth. The original N is 78% of the atmosphere, while the remaining percentages comprise Oxygen, Carbon Dioxide and inert gases. N is also available in inorganic forms, which are Ammonia (NH_4), Nitrate (NO_3^-) and Nitrite (NO_2^-). Ammoniacal Nitrogen (NH_3-N) is an indicator to the nutrient content (CETEC, 1996). The level of nutrients would indicate organic pollution especially by manures and municipal sewage (CETEC, 1996).

The results of Ammoniacal Nitrogen (NH_3-N) are summarized in Table 5.8 in weekly basis. The concentration of NH_3-N that is below detection limit (<0.1 mg/l) was considered to be not detected. It should be noted that the maximum limit of NH_3-N concentration under Class III of INWQS is 0.9 mg/l.

Table 5.8
Weekly NH_3-N concentrations (mg/l) of Paya Indah

Sampling Station	**Sampling Weeks**						**Average**	**Std. Dev. (±)**	**Percent age (%)**
	Week 1	**Week 2**	**Week 3**	**Week 4**	**Week 5**	**Week 6**			
W1	0.4	0.9	0.6	1.8	0.6	1.4	1.0	0.54	57.17
W2	0.4	0.5	0.1	1.4	0.4	0.2	0.5	0.46	92.95
W3	1.1	<0.1	0.7	1.2	0.7	<0.1	0.9	0.26	28.43
W4	0.4	<0.1	<0.1	0.7	0.7	0.2	0.5	0.24	48.99
W5	0.7	<0.1	0.7	1.1	0.7	<0.1	0.8	0.20	25.00
W6	0.2	0.8	0.7	1.4	0.6	<0.1	0.7	0.43	58.59
W7	0.2	0.8	0.8	1.7	1.0	0.1	0.8	0.58	75.91
W8	0.6	<0.1	<0.1	0.7	0.6	<0.1	0.6	0.06	9.12
W9	0.3	0.5	0.1	0.8	0.7	<0.1	0.5	0.29	59.66
W10	<0.1	<0.1	3.4	1.2	0.7	0.4	1.4	1.36	95.26
W11	0.8	0.6	0.2	0.8	0.5	0.6	0.6	0.22	38.20
W12	<0.1	0.7	<0.1	0.8	0.4	0.2	0.5	0.28	52.45
W13	<0.1	0.6	<0.1	0.8	0.3	0.1	0.5	0.31	69.09
W14	0.3	1.4	0.1	0.8	0.6	0.3	0.6	0.47	80.71
W15	<0.1	<0.1	0.1	0.5	0.8	<0.1	0.5	0.35	75.25

As depicted in Figure 5.15, NH_3-N concentrations at Paya Indah were observed to be considerably low, as most stations recorded NH_3-N well below Class III of INWQS. Exceeds of Class III of INWQS were occasionally recorded. This indicated that water body of all ponds and canals at Paya Indah were occasionally polluted by NH_3-N.

However fluctuation of weekly NH_3-N at each station is significant since all stations, with exception of Station W8, recorded percentages of standard deviation against average of more than 20 percent. Averaged NH_3-N concentration depicted by Figure 5.16 shows only Station W1, Station W2 and Station W10 exceeds Class III of INWQS. Thus it is shown that the presence of NH3-N in Paya Indah water body is minimal.

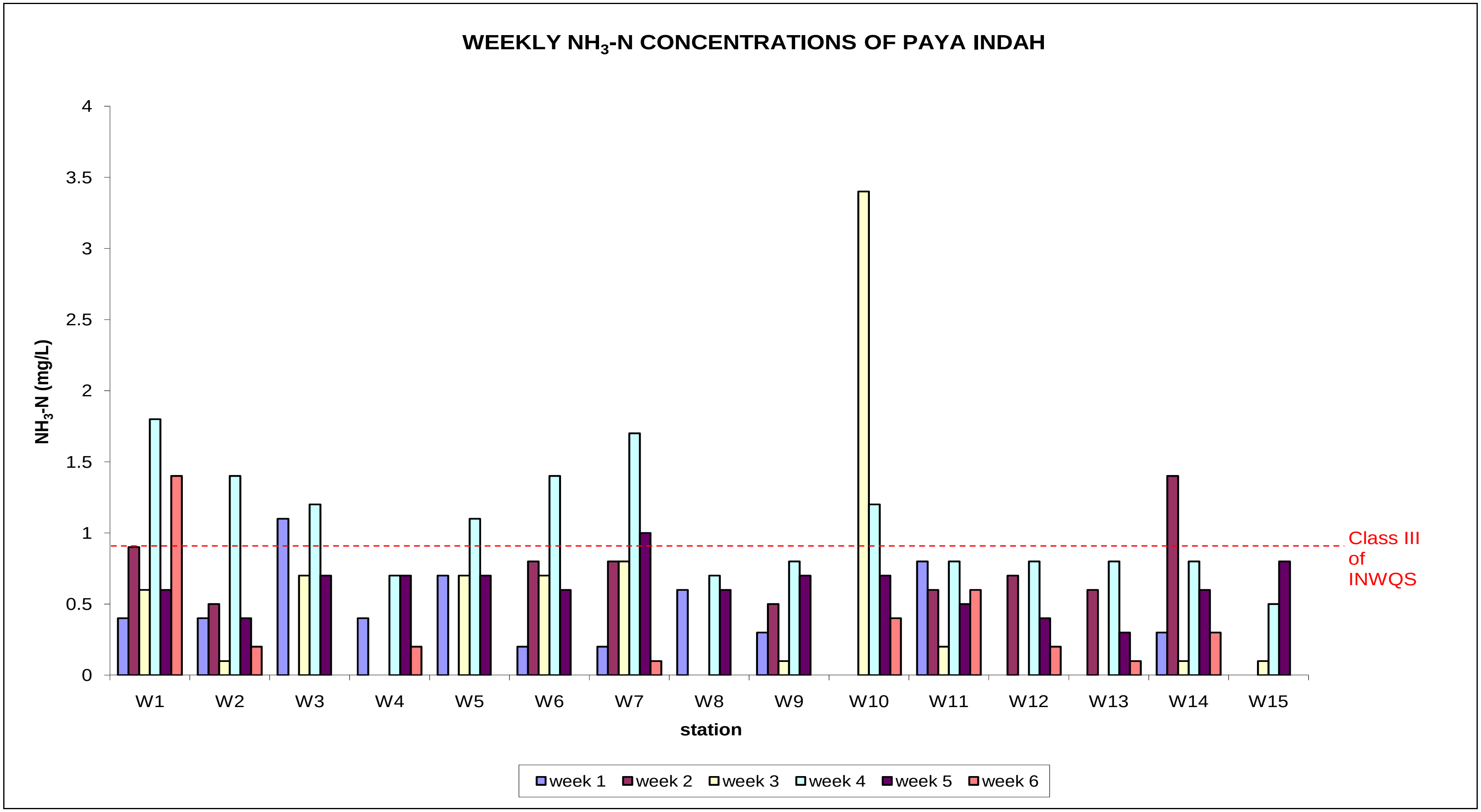

Figure 5.15: Weekly NH3-N concentrations of Paya Indah at each station

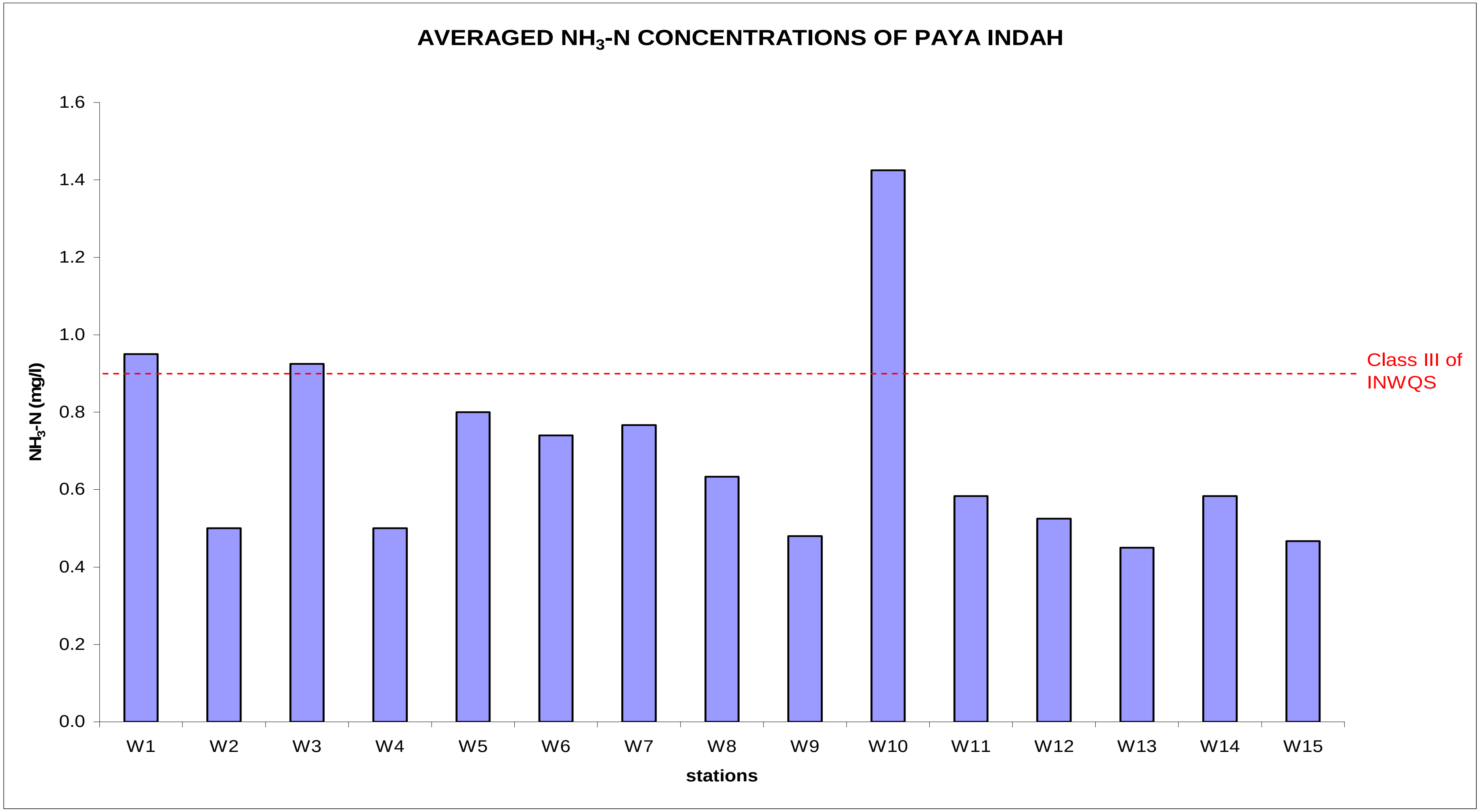

Figure 5.16: Averaged NH_3-N concentrations of Paya Indah at each station

5.4 OTHER PARAMETERS FOR BASELINE DATA

Baseline data collection was done as the data obtained is the benchmark reference to the data collected from monitoring works. This is to determine whether the contamination or pollution on Paya Indah were from the activities, or from external sources, based on the difference between baseline data and monitoring data.

Baseline parameters, other than critical parameters in Sub-chapter 5.3 comprise heavy metals, iron, manganese, other chemical compounds, oil and grease, free chlorine and *E. coli*. Full baseline results are as shown in Appendix 3. However, only iron (Fe), manganese (Mn) and *E. coli* will be thoroughly discussed here. Other parameters will not be discussed as the heavy metals (Mercury (Hg), Cadmium (Cd), total Chromium (Cr), Lead (Pb), Nickel (Ni) and Tin (Sn)) were detected at trace concentration in both baselines. Copper (Cu) and Zinc (Zn) concentrations were still acceptable. Oil and Grease were not detected. Other parameters such as Cyanide (Cn), Arsenic (As), Boron (B), Sulphide (S^{2-}), Total Phosphorus (P) and Free Chlorine (Cl_2) were still under control.

5.4.1 Iron (Fe)

Iron (Fe) is the second most abundant metallic element after Al and the fourth most abundant element (5.63) in the earth's crust. The major ores are haematite (Fe_2O_4), magnetite (Fe_3O_4), limonite (Fe(OH)) and siderite ($FeCO_3$). Fe is also widely distributed as a minor constituent in many other minerals. The element is a vital constituent of plant and mineral life and appears in porphyrins, notably haemoglobin. The pure metal is very reactive chemically and is not often encountered commercially. Iron is usually alloyed with carbon and other metals, collectively known as steel (Mance and Campbell, 1988).

Ferrous Fe^{2+} and ferric Fe^{3+} ions are the primary forms of concern in the aquatic environment. Other forms may be in either organic or inorganic wastewater. The ferrous form Fe^{2+} can persist in water void of dissolved oxygen and usually originates from groundwater or mines that are pumped or drained.

Table 5.9 show full baseline results of Fe. It should be noted that the maximum limit of Fe under Class III of INWQS is 1.00 mg/l.

Table 5.9
Baseline Fe concentrations (mg/l) of Paya Indah

Sampling Station	First Baseline	Second Baseline	Average
W1	1.31	1.32	1.32
W2	1.87	6.55	4.21
W3	2.93	2.94	2.94
W4	4.47	3.85	4.16
W5	5.24	4.63	4.94
W6	4.12	8.64	6.38
W7	4.18	6.00	5.09
W8	2.91	3.91	3.41
W9	3.66	4.89	4.28
W10	0.67	1.40	1.04
W11	1.23	9.18	5.21
W12	1.19	9.89	5.54
W13	0.96	4.74	2.85
W14	1.16	11.98	6.57
W15	3.80	6.94	5.37

In the first baseline, with the exception of Fe concentration at Station W10 (0.67 mg/l) and Station W13 (0.96 mg/l), the remaining stations recorded Fe concentration exceeding Class III of INWQS, thus Fe concentration at these stations stood at Class IV and Class V of INWQS. The highest Fe concentration was recorded at Station W5 (5.24 mg/l) while the lowest Fe concentration was detected at Station W10.

In the second baseline, the Fe concentrations at all stations showed significant increases from the first baseline, with the exception of Station W1, Station W3, Station W4 and Station W5. All Fe concentrations exceeded Class III of INWQS, thus are situated at Class V of INWQS. The highest Fe concentration was recorded at Station W14 (11.98 mg/l), while the lowest Fe concentration was recorded at Station W1 (1.32 mg/l). Graphical result of Fe concentrations is shown in Figure 5.17.

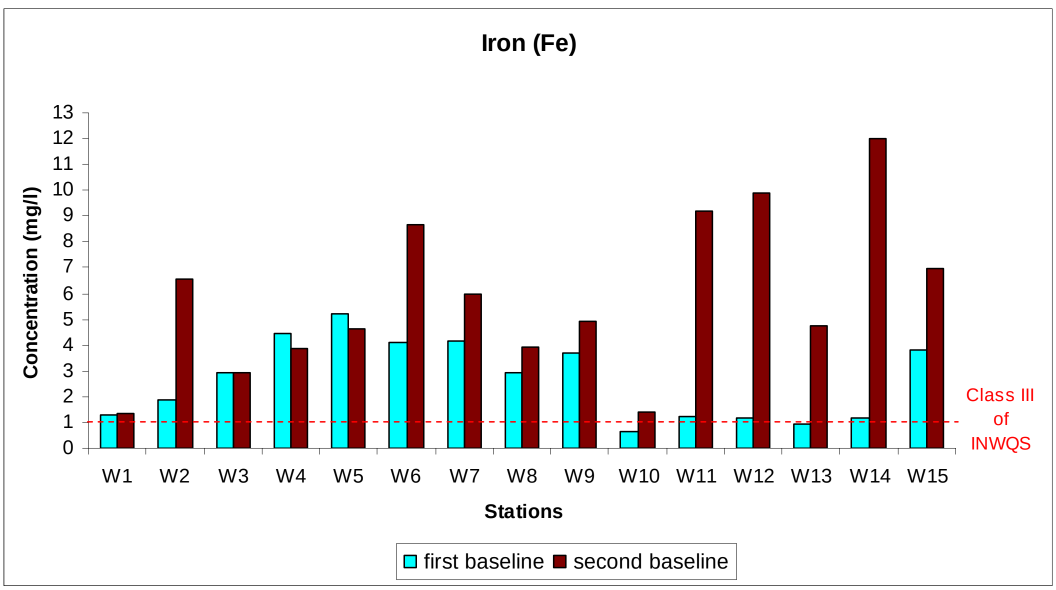

Figure 5.17: Baseline Fe concentration at each station

Table 5.10 shows comparison of average Fe concentrations at selected canals and lakes of Paya Indah.

Table 5.10
Comparison of Fe concentrations at selected canals and lakes of Paya Indah

Canals/Lakes	Average Fe Concentrations	
	1996*	2006/2007
Canal C2	2.70	1.32
Canal C4	2.10	4.21
Lotus Lake	1.97	6.57
Petaling Tin Lake	1.12	1.04
Visitor Lake	3.45	2.94
Main Lake	3.02	4.28

**Source: CETEC, 1996*

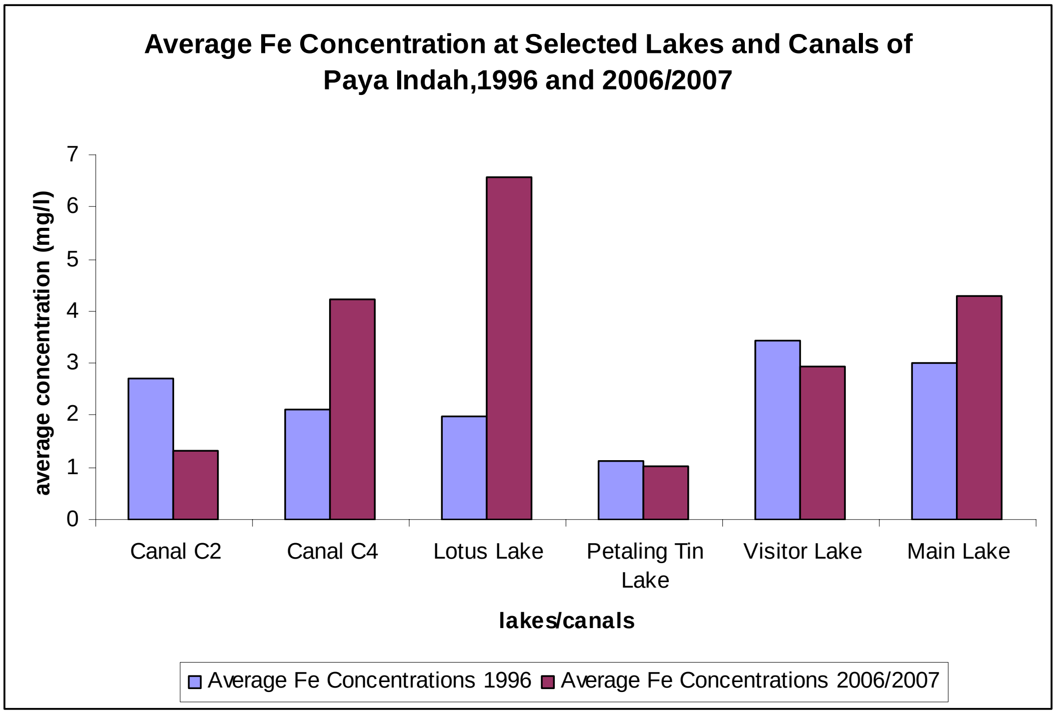

Figure 5.18: Comparison of average Fe concentrations at selected canals and lakes of Paya Indah

As shown in Figure 5.18, it is observed that average Fe concentrations at Canal C4, Lotus Lake and Main Lake show an increase from 1996 to 2006/2007. The average Fe concentrations were from 2.10 mg/l to 4.21 mg/l at Canal C4, from 1.97 mg/l to 4.57 mg/l (Lotus Lake, the highest increase recorded) and from 3.02 mg/l to 4.28 mg/l (Main Lake). This indicated significant increase of Fe content in Paya Indah. Meanwhile Canal C2, Petaling Tin Lake and Visitor Lake show gradual decline of average Fe concentration from 1996 to 2006/2007. Thus it indicated that there were slight improvements of Fe concentrations at Canal C2, Petaling Tin Lake and Visitor Lake, despite the Fe concentrations in these lakes and canal still being higher than Class III of INWQS limit (1.00 mg/l).

The presence of FeS_2 is the main contributor of high concentration of Fe. CETEC (1996), and Zulkafli and Zahari (1997) agreed that the FeS_2 present in the sediment pile at the edge of these pond oxidized on exposure to the air to produce sulphuric acid (H_2SO_4). Oxidation of FeS_2 is microbially mediated reaction (Hounslow, 1995). This could happen where FeS_2 reacts with oxygen and water to release acidity, iron and sulphate (adapted from Zulkafli and Zahari, 1997), by the following equilibrium:

$$2FeS_2 + 2H_2O + 7O_2 \leftrightarrow 2FeSO_4 + 2H_2SO_4$$
$$H_2SO_4 \leftrightarrow 2H^+ + SO_4^{2-}$$

The presence of FeS_2 may come from the tin ore residues, as discussed in sub-section 5.3.1. Sawyer et al. (2003) denotes that Fe may be oxidized with pH below 6.0. Moreover appreciable amount of Fe were available in groundwater, since the depth of Paya Indah were below water table (DNASB, 2001; DNASB et al., 2003). In addition, Fe can form stable complexes with humic substances in water that can be even more resistant to oxidation than inorganic species alone. With the excessive humic substances and acidic condition in peat swamp, oxidation of Fe may be greater.

As far as it is known, humans suffer no harmful effects from drinking waters containing iron (Sawyer et al., 2003). However, excessive Fe concentrations may upset aesthetic value of Paya Indah, with the colouration of water body that perhaps caused by Fe existence.

5.4.2 Manganese (Mn)

Manganese (Mn) is found in abundance in metamorphic and sedimentary rocks and in small amount in igneous rock (Rao and Sastry, 1996). Although Mn in groundwater is generally present in the soluble divalent ionic form because of the absence of oxygen, part of all of the Mn in surface waters (of water from other sources) may be in higher valence state (Ballance, 1996). The presence of Mn, together with Fe may cause nuisance to the water appearance due to the precipitation of both Mn and Fe that might turn the appearance of water body to be dark brown in colour. Therefore, the colouration of water body of Paya Indah might be due to these metals, but with the presence of humic substances, as discussed before. The results of Mn concentrations are shown in Table 5.11.

Table 5.11
Baseline Mn concentrations (mg/l) of Paya Indah

Sampling Station	First Baseline	Second Baseline
W1	0.04	<0.01
W2	0.09	0.06
W3	0.07	<0.01
W4	0.09	<0.01
W5	0.10	<0.01
W6	0.17	0.12
W7	0.20	0.05
W8	0.11	<0.01
W9	0.08	<0.01
W10	0.12	<0.01
W11	0.08	0.12
W12	0.10	0.13
W13	0.10	0.05
W14	0.09	0.12
W15	0.09	0.06

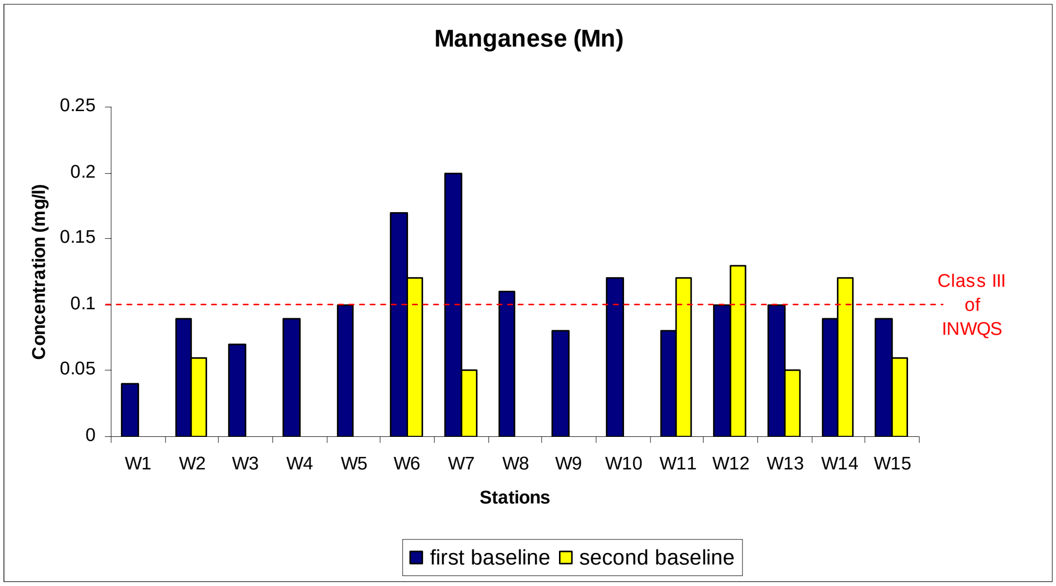

Figure 5.19: Baseline Mn concentrations at each station

As graphically depicted in Figure 5.19, in the first baseline, the stations that recorded Mn concentration greater than Class III of INWQS were Station W6 (0.17 mg/l), Station W7 (0.20 mg/l) and Station W10 (0.12 mg/l). It should be noted that the maximum limit of Mn under Class III of INWQS is 0.10 mg/l, therefore, these stations are situated at Class IV of INWQS. Meanwhile Station W5, Station W12 and Station W13 recorded Mn concentration at par with Class III of INWQS (0.10 mg/l respectively). The remaining stations recorded Mn concentration well below Class III of INWQS. The highest Mn concentration was recorded at Station W7 (0.20 mg/l) while the lowest Fe concentration was detected at Station W1 (0.04 mg/l).

In the second baseline, only Station W11, Station W12 and Station W14 show increases from the first baseline. Station W11 and Station W14 recorded Mn concentrations at 0.12 mg/l respectively, while Station W13 recorded Mn concentration at 0.13 mg/l, the highest Mn concentration recorded. Thus, Station W11, Station W12 and Station W14 exceeded Class III of INWQS, and stood at Class IV of INWQS. Station W6 also recorded Mn concentration at Class IV of INWQS (0.12 mg/l). Station W2, Station W7, Station W13 and Station W15 recorded Mn concentrations well below Class III of INWQS. Station W2 and Station W15 recorded Mn concentrations at 0.06 mg/l respectively, while Mn concentrations at Station W7 and Station W13 stood respectively at 0.05 mg/l. The Mn concentrations at remaining stations were below detection limit (less than 0.01 mg/l).

The source of Mn may come from previous mining activities. Besides tin mining, clay mining also took place circa mid 1990's. Continuous clay mining could cause adverse impact to Paya Indah lakes. According to the Malaysian Wetland Foundation Chief Executive Officer, Muralee D. Menon in The News Straits Times (15^{th} October 1997), the clay is needed to hold water, otherwise it will drain away the water. As a result, all mining activities were stopeed in 1997. The cessation of the mining activities may have helped to reduce the Mn concentration gradually to the present condition.

5.4.3 *Escherichia coli (E. coli)*

Escherichia coli or *E. coli* is a bacterium commonly found in the gut of humans and warm-blooded animals. It is a faecal coliform type bacterium. Faecal coliform bacteria are bacteria associated with human or animal wastes. Most strains of *E. coli* are harmless, but some strains can cause severe food-borne diseases. The 'Enterohaemorrhagic *E. coli*' (EHEC) for example is a strain that causes abdominal cramps, fever, nausea and diarrhoea that may in some cases progress to bloody diarrhoea (haemorrhagic colitis). *E. coli* is mainly transmitted in the food chain through consumption of contaminated foods and unhygienic practices. *E. coli* counts are used to indicate human health risk from harmful microorganisms present in the water. The presence of *E. coli* in the water is a strong indication that recent contamination by black-water, sewage or animal waste has occurred.

The graphical result of *E. coli* is shown in Figure 5.20. It should be noted that the analysis on *E. coli* was not carried out in the first baseline and it was only carried out under second baseline.

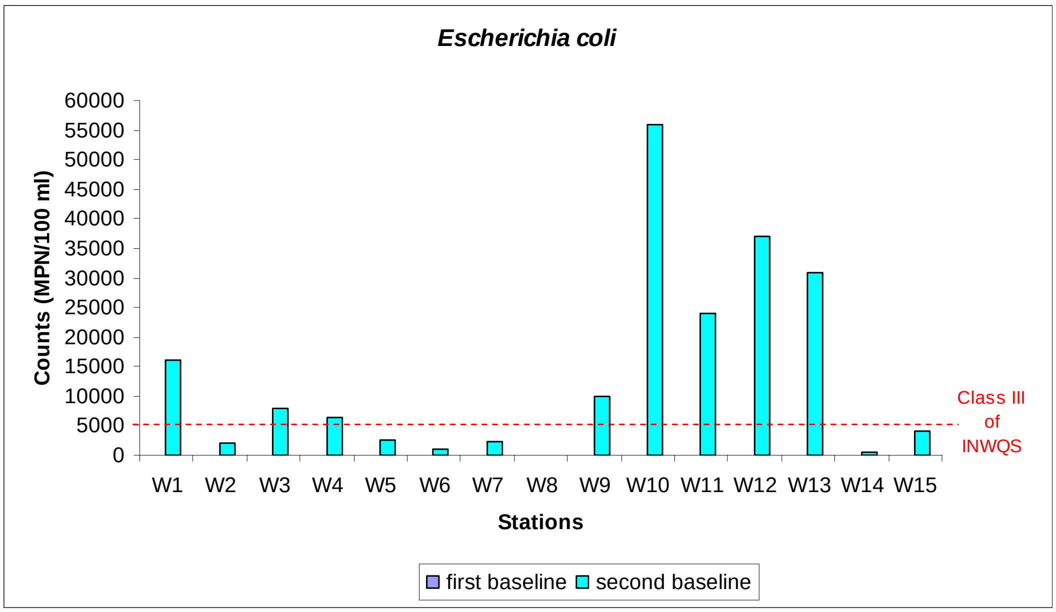

Figure 5.20: Baseline *E. coli* counts of Paya Indah

High *E. coli* counts (that exceeded Class III of INWQS) were observed in Canal C1 (Station W1), Visitor Lake (Station W3), Main Lake (Station W9), Petaling Tin Lake (Station W10), Paddy Lake (Station W11), Perch Lake (Station W12) and Marsh Lake (Station W13). There are many factors that determine the presence of *E. coli* either internally or externally. The internal factors contributing to E. coli presence may be the Hippo and crocodile ponds, the buffaloes and the adjacent National Service camp. Meanwhile the external factors leading to the *E. coli* presence may be the sewerage system of the housing and township areas in Dengkil town, landfills, sewage treatment plants, and ranching of poultry, cattle and swine.

As affirmed by CTI and OYO (2001), depicted in Figure 5.10 from Subchapter 5.3.3 (BOD), three (3) landfill sites had been discovered within the Langat Basin. Ampar Tenang landfill site and Sungai Sedu landfill site were the nearest landfill sites in Paya Indah vicinity. Both landfill sites were commissioned since early 1990-s and still active. Old landfill sites may not have proper waste disposal, e.g. geo lining, and insufficient waste treatment facilities such as leachate collection and treatment facilities, surface water drainage and retention ponds, due to the budget constraints. The effects of leachate on surface water adjacent to a landfill site include biological and chemical depletion of the dissolved oxygen content which could, in turn, lead to the reduction of oxygen-dependent life (Pescod, 1991), and the situation may be worsening with the existing low DO concentration of peat swamp near Paya Indah.

Due to the condition that the water level of Paya Indah being below the water table, the possibility of landfill leachate contamination through groundwater may be higher through seepage from landfill into the groundwater. It is well known that existing landfills in Malaysia are improperly managed before they were taken over by Alam Flora (in Klang Valley), in terms of specification and waste disposal method. Improper landfill (that without bottom protection i.e. geomembrane lining) may cause the leachate seeps into the groundwater. Pescod (1991) denoted that the effects of leachate on groundwater will generally persist for many years, mainly due to the limited amount of dissolved oxygen available and the low rates of dispersion. Once polluted, such groundwater may be unsuitable as a potable water supply for a long time.