Chapter

Seasonal Variability of Groundwater Quality in Kapas Island, Terengganu, Malaysia

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Abstract

The chapter aims to evaluate the groundwater quality levels in Kapas Island, Terengganu, Malaysia during the monsoon changes of the Southwest Monsoon (SWM), Monsoon Transition (MT) and Northeast Monsoon (NEM) in 2018. Four locations were used for groundwater sampling namely, the Kapas Coral Beach Resort, Kapas Beach Chalet, Pak Ya Seaview Chalet, and Kapas Island Resort. Three water samplings at each station for every month in the monsoon. Six parameters of the Malaysian Water Quality Index (WQI), i.e., dissolved oxygen (DO), pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS) and ammoniacal nitrogen (NH_3-N), were used to evaluate the water quality. The findings showed the groundwater quality parameters are in Class I and II. However, according to WQI Malaysia, the water quality status during the three monsoons is slightly polluted. During the SWM, the WQI value was 76 (Class III), the MT was 77 (Class II), and the NEM was WQI 71 (Class III). Given this status, it requires more intensive water treatment as it is not suitable for direct drinking water supply. The implications of the study show that the quality of groundwater in Kapas Island has to improve by the tour operators.

Keywords: water quality index, groundwater, slightly polluted, water treatment, island tourism

1. Introduction

The increase in the population of an area will have an impact on the demand for clean water supply. When the demand for water supply exceeds the capacity, it will lead to a water crisis because the need for water is not only for domestic use but also for various human activities such as industry and agriculture. The main source of water to meet human demand comes from surface water sources such as rivers, ponds and lakes. However, due to increasing demand for water resources, the groundwater resources have been explored on a large scale, especially for drinking water supply [1–4].

The current trend of using groundwater resources as a domestic water supply for humans is no longer uncommon. Polluted river water resources have led the residents or responsible authorities in providing water supply to opt for groundwater resources [5, 6]. Obtaining groundwater resources may not be an obstacle in the plain or continental areas but this situation is slightly exacerbated in island areas. However, groundwater resources are susceptible to water pollution that resulted from human activities such as domestic waste disposal and industrial activities [7]. The main cause of groundwater pollution is due to the disposal of sewage waste from tourism activities, agriculture and residential settlement in an island area [5, 8–10] and at the same time also resulted from natural factors such as the encroachment of saltwater on groundwater or wells nearby the area [11–13].

Groundwater is generally a source of water that is clean and can be easily accessed by building a well and by using pipes and channeling it into the reservoirs. In this case, the lack of freshwater resources particularly in the island area has urged the residents living in the area to have to use this water resource. Therefore, these water resources are specifically for domestic use such as drinking water supply, cooking, bathing and washing. This situation is increasingly affected when the island has been turned into a tourist destination causing the demand for water supply to increase. Therefore, the status of this groundwater quality should also be given special attention so that it is safe to be used by tourists and the local community [7, 8, 14, 15].

Kapas Island in Marang, Terengganu is a less populated area due to its small land area, which is the case with other islands. However, this island has its own charm due to the beauty of its beaches, unpolluted sea and a fascinating marine park. However, the lack of surface water resources such as river water has led local people and operators of resort and chalet for tourism activities to use groundwater resources as the main source of domestic water supply. The major issue is that the condition of these groundwater resources are sometimes unclean, murky and suspended solids are found when channeled to tourist accommodations. Therefore, the purpose of this study is to analyze the quality of groundwater supplied by accommodation operators in Kapas Island to tourists and local residents by using the Water Quality Index (WQI) as set by the Department of Environment (DOE) Malaysia.

2. Study area and methods

2.1 Study area

Kapas Island is located in the district of Marang, Terengganu at latitude 05°13.042′N and longitude 103°15.700′E. Kapas Island was selected as a study area because of its active tourism activities and freshwater resources are highly needed for tourists' domestic use. The Marang district is famous for its Kapas Island and is one of the eight districts in the state of Terengganu. The entire area of Marang district covers a 666.54 km^2 area consisting of six sub-districts, namely Merchang, Pulau Kerengga, Jerung, Rusila, Bukit Payong and Alor Limbat.

Kapas Island is a short distance island located about 6 km away from Marang jetty and is one of the islands in the state of Terengganu (**Figure 1**). The size of Kapas Island is about 1.5 km^2 to 2.5 km^2 and is famous for its clear sea water, white sandy beaches and waving coconut trees, swings along the coast. The island is also quite secluded, away from the hustle and bustle of the mainland and known for its unique marine park in the island area filled with various soft and hard corals, fish, turtles and other interesting marine life making it a mandatory destination for scuba diving and snorkeling activities [16]. The relaxing atmosphere of this island gives comfort to visitors as well as the chances to try

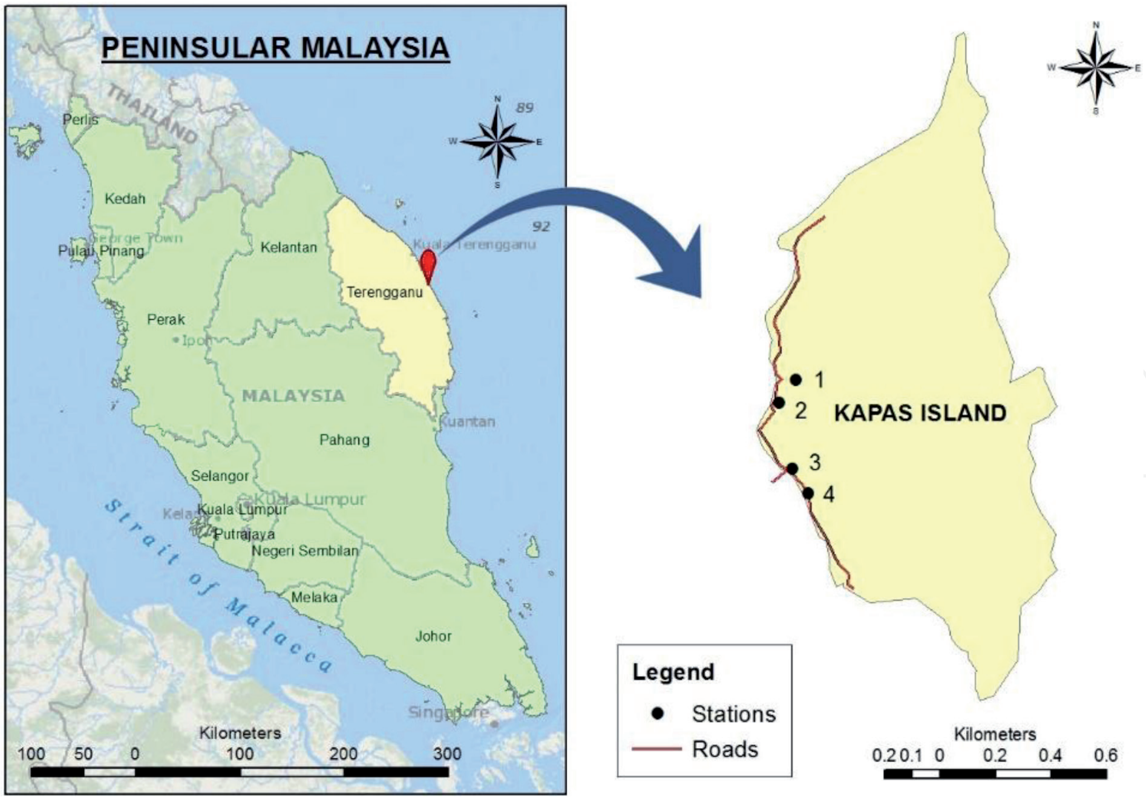


Figure 1.
Groundwater quality sampling station on Kapas Island.

Station	Station name	Latitude	Longitude
1	Kapas Coral Beach Resort	05°13.224′N	103°15.717′E
2	Kapas Beach Chalet	05°13.162′N	103°15.686′E
3	Pak Ya Seaview Chalet	05°13.048′N	103°15.707′E
4	Kapas Island Resort	05°13.004′N	103°15.742′E

Table 1.
The names and positions of groundwater quality observation stations.

out various water activities such as swimming, kayaking, waterboarding, hiking tropical forest tracks and climbing Bukit Singa (Singa Hill). In order to assess the level of groundwater quality in Kapas Island, four sampling locations were determined as shown in **Figure 1** and **Table 1**.

2.2 Study method

Water quality in Malaysia is measured by using the WQI set by the DOE Malaysia. According to Nurfadzlina et al. [17], this index is a measurement to give a comprehensive picture of the status of water quality for an area or water body. Meanwhile, Muhammad Fuad et al. [18] mentions that groundwater quality assessment consists of physical, biological and chemical parameters. In determining the status of groundwater quality in Kapas Island, only six water quality parameters were used as set by the DOE Malaysia in determining the quality status of a water body. The six parameters were pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammoniacal nitrogen (NH_3-N) and suspended solids (SS). In addition, two other parameters were also measured and analyzed, i.e., salinity (SAL) and the total dissolved solids (TDS).

Groundwater sampling in Kapas Island was carried out three times (August, October and November 2018). The three months were chosen to monitor for any possible difference in water quality levels following the season of monsoon winds, especially in Peninsular Malaysia. The observations of the groundwater quality in August represent the Southwest Monsoon winds, October (Monsoon Transition) and November (Northeast Monsoon winds). Sampling activities were carried out at four different locations and groundwater samples were tested in situ using YSI Multiparameter equipment. The parameters tested in situ including pH, SAL, TDS and DO. As for the other parameters, water samples were taken and analyzed ex situ (laboratory analysis), according to the procedure described by the American Public Health Association [19].

A quantitative approach was applied in analyzing the level of groundwater quality in Kapas Island. Descriptive statistics were used to describe the status of groundwater quality whether the observed parameters have exceeded the standards set by the DOE Malaysia. In this regard, the groundwater quality data obtained will be compared with the National Water Quality Standard for Malaysia (NWQSM) (**Table 2**), Water Uses and Classes (**Table 3**), DOE's WQI Classification (**Table 4**) and DOE's WQI Classification based on WQI (**Table 5**). Meanwhile, WQI formulas and calculations are shown in **Table 6**. The groundwater quality data of the four observation stations are presented in the form of tables and diagrams to provide an overall picture of the status of groundwater quality in Kapas Island.

Parameter	Unit	Class					
		I	IIA	IIB	III	IV	V
NH_3-N	mg/l	0.1	0.3	0.3	0.9	2.7	>2.7
BOD	mg/l	1	3	3	6	12	>12
COD	mg/l	10	25	25	50	100	>100
DO	mg/l	7	5–7	5–7	3–5	<3	<1
pH	—	6.5–8.5	6–9	6–9	5–9	5–9	—
Color	TCU	15	150	150	—	—	—
Conductivity	S/cm	1000	1000	—	—	6000	—
Floatables	—	N	N	N	—	—	—
Odor	—	N	N	N	—	—	—
Salinity	%	0.5	1	—	—	2	—
Taste	—	N	N	N	—	—	—
TDS	mg/l	500	1000	—	—	4000	—
TSS	mg/l	25	50	50	150	300	300
Temperature	°C	—	Normal +2°C	—	Normal +2°C	—	—
Turbidity	NTU	5	50	50	—	—	—
Fecal Coliform	count/100 ml	10	100	400	5000 (20000)a	5000 (20000)a	—
Total Coliform	count/100 ml	100	5000	5000	50000	50000	>50000

[a]*Maximum not to be exceeded.*

Table 2.
National water quality standards for Malaysia [20].

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

Table 3.
Classification of water quality and uses [20].

Parameter	Unit	Class				
		I	II	III	IV	V
DO	mg/l	> 7	6–7	3–5	1–3	< 1
pH		> 7	6–7	5–6	< 5	> 5
BOD	mg/l	< 1	1–3	3–6	6–12	> 12
COD	mg/l	< 10	10–25	25–50	50–100	> 100
TSS	mg/l	< 25	25–50	50–150	150–300	> 300
NH_3-N	mg/l	< 0.1	0.1–0.3	0.3–0.9	0.9–2.7	> 2.7
WQI		> 92.7	76.5–92.7	51.9–76.5	31.0–51.9	< 31.0

Table 4.
DOE's WQI classification Malaysia [20].

Sub index & water quality index	Index range		
	Clean	Slightly polluted	Polluted
Biochemical Oxygen Demand (BOD)	91–100	80–90	0–79
Ammoniacal Nitrogen (NH_3-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 5.
Range of water quality index based on WQI [20].

3. Results and discussion

3.1 Groundwater quality based on parameters

Groundwater quality analysis in Kapas Island was done based on eight parameters, namely SAL, TDS, DO, BOD, COD, pH, NH_3-N and TSS. The findings of this study described the value of groundwater quality parameters based on the four designated study areas in addition to comparing the values obtained during the Southwest Monsoon (SWM), monsoon transition (MT) and Northeast Monsoon

WQI Formula	
WQI = (0.22*SIDO) + (0.19*SIBOD) + (0.16*SICOD) + (0.15*SIAN) + (0.16*SISS) + (0.12*SipH) where: SIDO = subindex DO (% saturation) SIBOD = subindex BOD SICOD = subindex COD SIAN = subindex NH_3-N SISS = subindex SS SIpH = subindex pH $0 \leq WQI \leq 100$	
Subindex DO (mg/l)	
SIDO = 0	$x \leq 8$
SIDO = 100	$x \geq 92$
SIDO = −0.395 + 0.030x2–0.00020x3	$8 < x < 92$
Subindex BOD (mg/l)	
SIDOD = 100.4–4.23x	$x \leq 5$
SIDOD = 108* exp.(−0.055x) – 0.1x	$x > 5$
Subindex COD (mg/l)	
SICOD = −1.33x + 99.1	$x \leq 20$
SICOD = 103* exp.(−0.0157x) – 0.04x	$x > 20$
Subindex NH_3-N **(mg/l)**	
SIAN = 100.5 – 105x	$x \leq 0.3$
SIAN = 94 * exp.(−0.573x) – 5 * 1 x – 2 1	$0.3 < x < 4$
SIAN = 0	$x \geq 4$
Subindex SS (mg/l)	
SISS = 97.5 *exp.(−0.00676x) + 0.05x	$x \leq 100$
SISS = 71 *exp.(−0.0061x) - 0.015x	$100 < x < 1000$
SISS = 0	$x \geq 1000$
Subindex pH (mg/l)	
SlpH = 17.2–17.2x + 5.02x2	$x < 5.5$
SlpH = −242 + 95.5x – 6.67x2	$5.5 \leq x < 7$
SlpH = −181 + 82.4x – 6.05x2	$7 \leq x < 8.75$
SlpH = 536 – 77.0x + 2.76x2	$x \geq 8.75$

Table 6.
Water quality calculation formula based on WQI [20].

(NEM). **Figure 2** shows the level of water salinity of the groundwater solution for each sampling station. The salinity difference at each station has a natural factor in the soil cavity during the infiltration process occurring in the area. Observations were made on the total solubility of salts or groundwater salinity in the study area given the position of the observation station are located near the coastlines. It is clear that the salinity value at Station 1 (S1) was at a high position throughout three observations compared to other stations. The values obtained at S1 during the SWM were 1.1% and during the MT (1.09%) and during the NEM (1.17%).

Station 2 (S2) recorded the second highest reading among all observation stations. At S2 during the SWM, it was 0.68% while during the MT it recorded 0.6% and during the NEM it increased to 1.24%. Station 3 (S3) and Station 4 (S4) showed a flat average value between the two stations with the value obtained at S3 during the SWM and the MT was 0.48% and decreased during the NEM to 0.44%. While the readings recorded at Station 4 (S4) during the SWM was 0.48% and increased during the MT to 0.52% and during the NEM obtained a value of 0.51%.

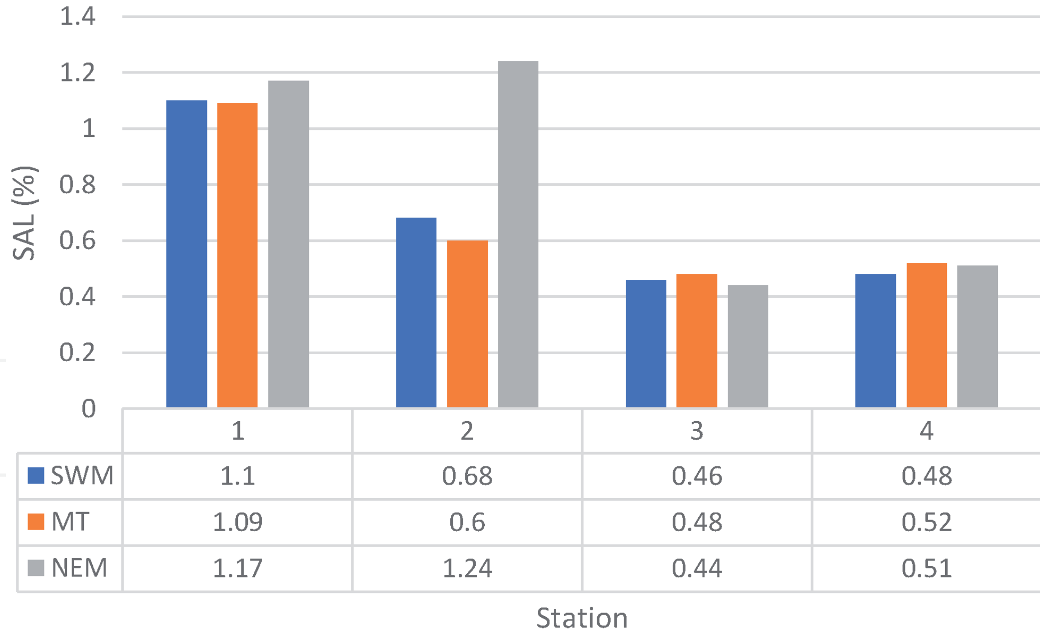


Figure 2.
Value of SAL parameter by station and season.

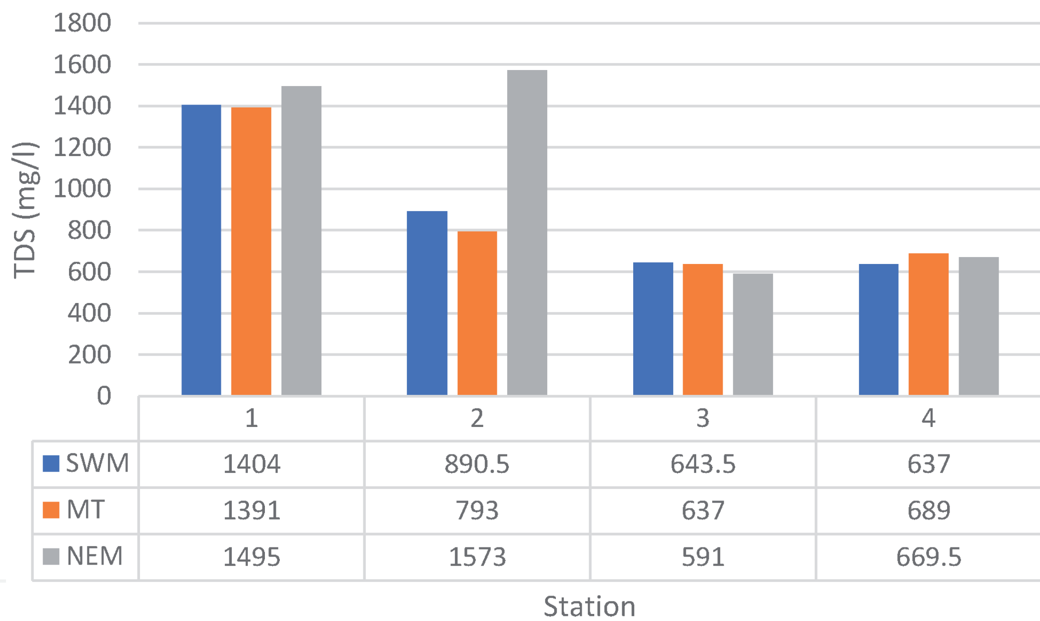


Figure 3.
Value of TDS parameter by station and season.

In the essence, S1 recorded the highest reading of all three observations. This condition may result from seawater penetration into the aquifer system at S1. As pointed by [21], groundwater salinity can also be produced when the boundary between seawater and freshwater moves towards the land due to the leakage of saltwater zones found at the bottom of the aquifer that moves through the joints, fractures or faults. In addition, the locations of S1 and S2 were the closest to the coastlines and this influenced the high SAL value in the area. Overall, the SAL value at all stations exceeded Class I and II but did not exceed Class IV.

Meanwhile, **Figure 3** shows the value of TDS parameters obtained by station and observation by monsoon season in Kapas Island. These different value conditions were also influenced by the SAL content dissolved in groundwater and affected the TDS reading. This study found that the TDS value was in the range of 1573 mg/l and 591 mg/l. Observations showed that the TDS value in the groundwater of the study area was high. NWQSM sets that the TDS for Class II water quality is 1000 mg/l and Class I is 500 mg/l. From the data obtained, the TDS value at S1 was high in all three observations compared to other stations. The values obtained in S1 during the SWM were 1404 mg/l, MT (1391 mg/l) and NEM (1495 mg/l).

Next, S2 recorded the highest reading on the third observation among all other observation stations. At S2 during the SWM, it was only 890.5 mg/l while during the MT it recorded a value of 793 mg/l and during the NEM, it increased to 1573 mg/l. However, S3 and S4 showed a flat horizontal value between the two stations with a small difference in values where S3 during the SWM recorded 643.5 mg/l and during the MT with 637 mg/l and showed a lower value during the NEM with 591 mg/l. While the values obtained in S4 during the SWM (637 mg/l), MT (689 mg/l) and decreased during the NEM (669.5 mg/l).

From the TDS analysis, the TDS was found in abundance at S1 and also showed significant changes at S2 during the NEM. This may be due to the presence of a mineral substance solution dissolved in the water as it is also influenced by SAL which co-exists in the groundwater. The SAL content analysis also increased at S1 and S2. According to Siti Fazilatul Husni et al. [22], this may be due to the rainfall phenomenon which had dissolved more soluble solids while transporting excess sediment and solutions found in the water. Overall, the TDS value at all stations exceeded Class I and II but did not exceed Class IV.

The following discussion is related to the parameters used in determining the WQI for the observation stations. **Figure 4** shows the values of the DO parameter by station and a comparison of different reading values recorded during different monsoon seasons. The study showed that the range of DO content was between 4.68 mg/l to 8.21 mg/l (**Figure 4**). Based on the observations between the stations for the three monsoons showed that there was a change in the DO value between the wet season and the dry season. In fact, the value reading was also constantly increasing from S1 to S4. Starting from the SWM, the analysis obtained showed that the DO value at station S1 which is 7.15 mg/l increased to 8 mg/l at S4. While the value at S2 was 6.77 mg/l and at S3 it was 7.66 mg/l. For observations during the MT, it was found that the DO value at S1 was 6.14 mg/l, increasing to 6.93 mg/l at S2. However, at S3 the DO value decreased to 6.44 mg/l and increased again at S4 which is the highest reading among the stations during the MT with a value of 7.1 mg/l.

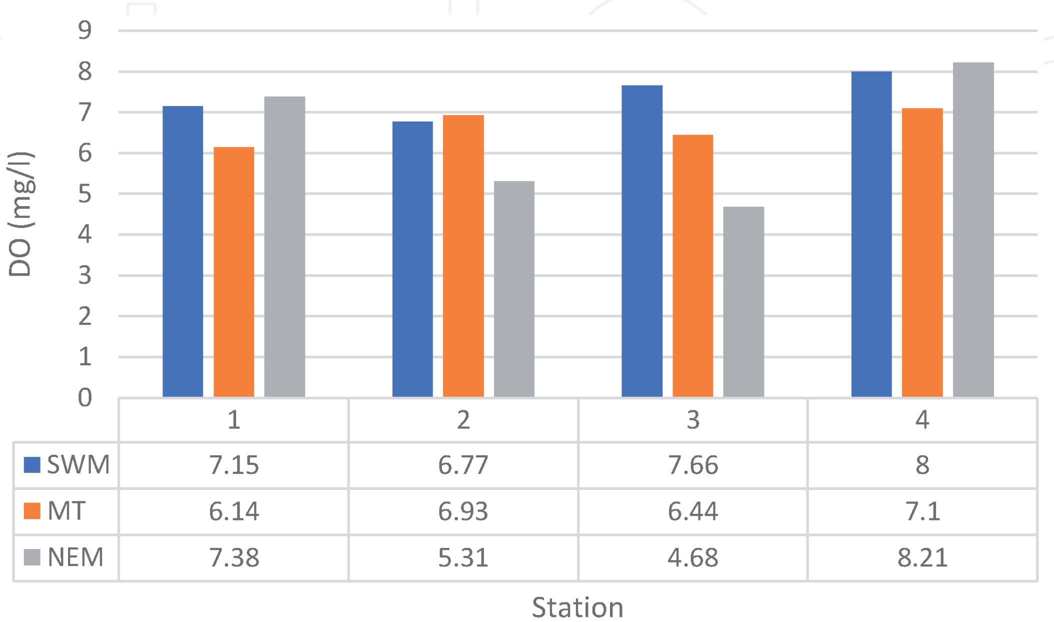
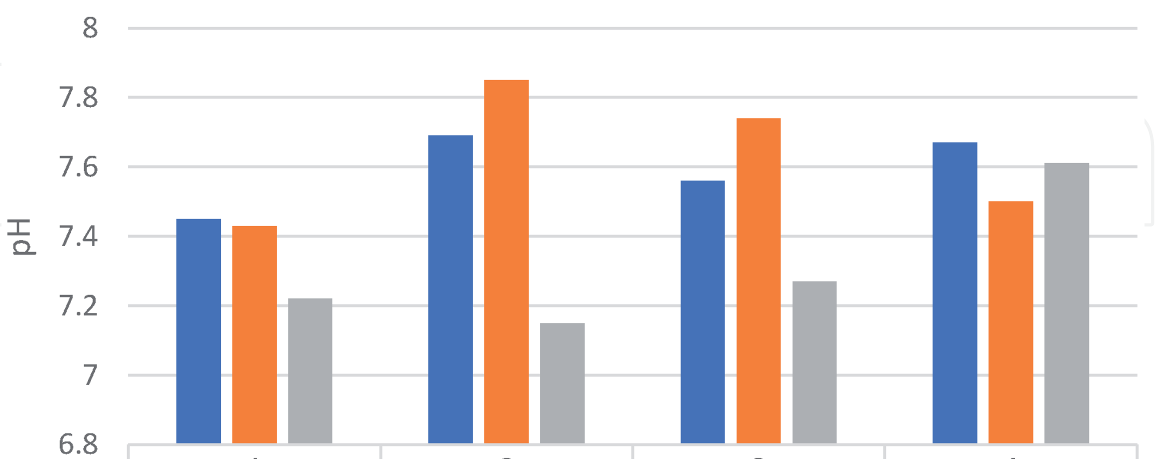


Figure 4.
Value of DO parameter by station and season.

Observations conducted during the NEM showed high-value readings at S1 (7.38 mg/l) and S4 (8.21 mg/l). However, the readings of the DO content decreased at S2 (5.31 mg/l) and decreased to 4.68 mg/l at S3. A low level of DO content can clearly be seen during the NEM at S3 with a value of 4.68 mg/l while the highest DO content was recorded during the same monsoon at S4 which is 8.21 mg/l as there was a heavy rainfall when the observation was made during the NEM. Based on the DO value recorded at all stations, it was found to be in Class I and II except at S3 with a DO value of 4.68 mg/l which is in Class III. It is proven that the rate of DO is dependent on the presence of organic wastes or organic matters that require oxygen causing the level of DO content of the water to be low and it is also influenced by the strength of water convection [23].

Next, the values of the pH parameter were 7.15 to 7.85 (**Table 5**). The results showed that the pH values recorded at all of the observation stations were in Class I as according to the DOE's WQI classification. From the pH values recorded, it showed that the pH of groundwater was in a stable condition for each station according to the monsoon season. High pH readings were recorded at S4 (7.67) during the SWM, NEM (7.61) and MT (7.5). The second highest value recorded was at S2 (7.69) during the NEM and increased to 7.85 during the MT and decreased during the NEM to 7.15. For S3, the MT was high at 7.74 and followed by the value during the SWM (7.56) and decreased during the NEM (7.27). The pH value of 7 obtained showed that the reading is neutral, therefore, the water is neither acidic nor alkaline [24]. While S1 recorded the lowest pH value among all stations during the SWM (7.45), followed by MT (7.43) and the lowest value was during the NEM (7.22). This fluctuation in pH value may be due to the environmental factors of the island as well as the influence of seawater with a higher pH as compared to the pH of freshwater (**Figure 5**) [25].

Figure 6 showed the values of the BOD parameter in Kapas Island that were within the range of 0.38 mg/l to 3.66 mg/l, which was in Class I to III based on the DOE's WQI classification. From the analysis, the differences in BOD readings at all sampling stations during the NEM were the highest compared to other seasons. The data obtained during the NEM at S1 which recorded the highest value of 3.66 mg/l



	1	2	3	4
SWM	7.45	7.69	7.56	7.67
MT	7.43	7.85	7.74	7.5
NEM	7.22	7.15	7.27	7.61

Figure 5.
Value of pH parameter by station and season.

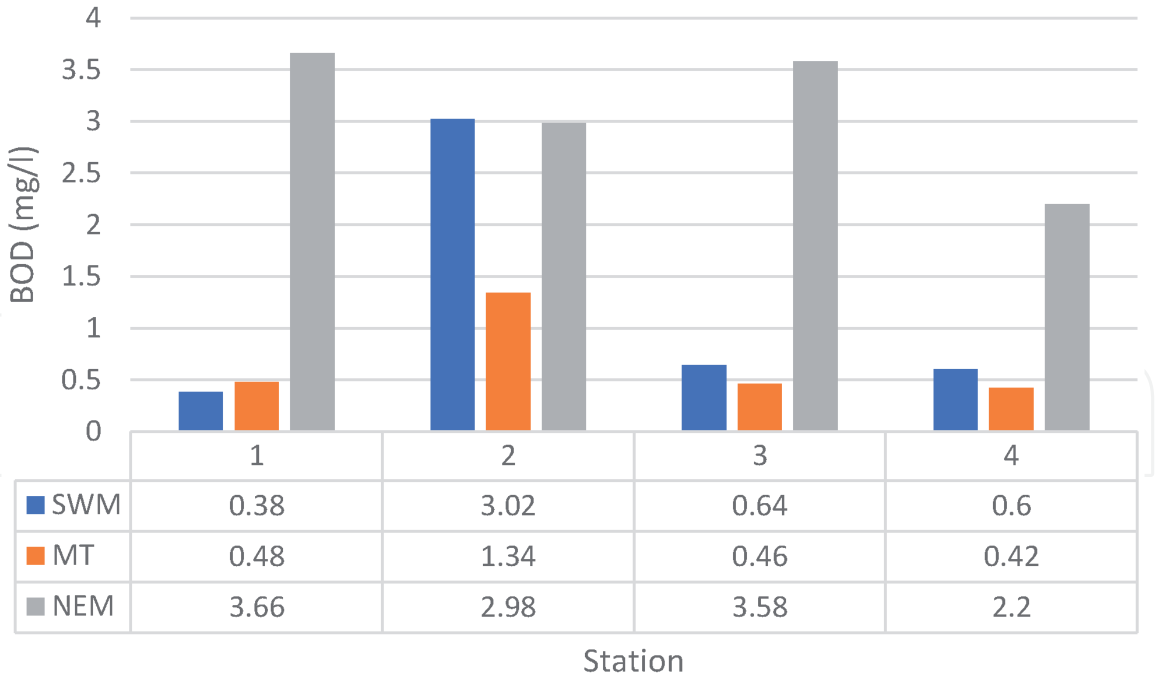


Figure 6.
Value of BOD parameter by station and season.

followed by S3 (3.58 mg/l), S2 (2.98 mg/l) and S4 (2.2 mg/l). During the SWM, all observation stations showed different values and the highest reading of all stations were recorded at S2 with 3.02 mg/l. Meanwhile, the BOD value was recorded as low at S3 (0.64 mg/l), S4 (0.6 mg/l) and S1 (0.38 mg/l). While during the MT, the highest reading values were recorded at S2 (1.34 mg/l) and S1 (0.48 mg/l). The BOD value showed low readings at S3 (0.46 mg/l) and at S4 (0.42 mg/l).

All of the observation stations comparatively showed a high average of BOD values during the NEM. These high BOD values give the impression that there were organic matters that could be broken down by microorganisms and more oxygen was being used because this decomposition process requires oxygen. The high BOD values at all of the stations during the NEM give the impression that the water quality was in Class III based on the DOE's WQI classification. Therefore, the water quality in the area requires further treatment before it can be used and according to Nurfadzlina et al. [17], BOD parameter is used as an indicator for the degree of water pollution. High BOD values indicate that the water tested was in a contaminated status.

Meanwhile, **Figure 7** showed the COD value according to observation station by season. It was found that the COD concentration of the groundwater in the study area appeared to be not polluted with the majority of the analysis showed not-detected value (nd value) or below the WQI classification. During the study period, the values of COD for all observation stations was within the range of 0 mg/l to 2 mg/l (**Figure 7**). Water quality samples for all stations and seasons were in Class I i.e., below 10 mg/l. Class I indicate that the water analyzed is free from organic pollutants especially from sewage.

The COD values obtained according to stations during the SWM at S2 and S3 were not detected with a reading of nd values followed by S1 (0 mg/l) and S4 (1 mg/l). During the MT, all stations showed that the groundwater is currently not contaminated with an nd reading of the analysis. Next, the COD value during the NEM recorded the highest value at S1 which is 2 mg/l followed by S4 (0 mg/l). While at S2 and S3 readings were obtained with an nd status for both stations. With that value, the COD parameter is in Class I where the quality of groundwater in

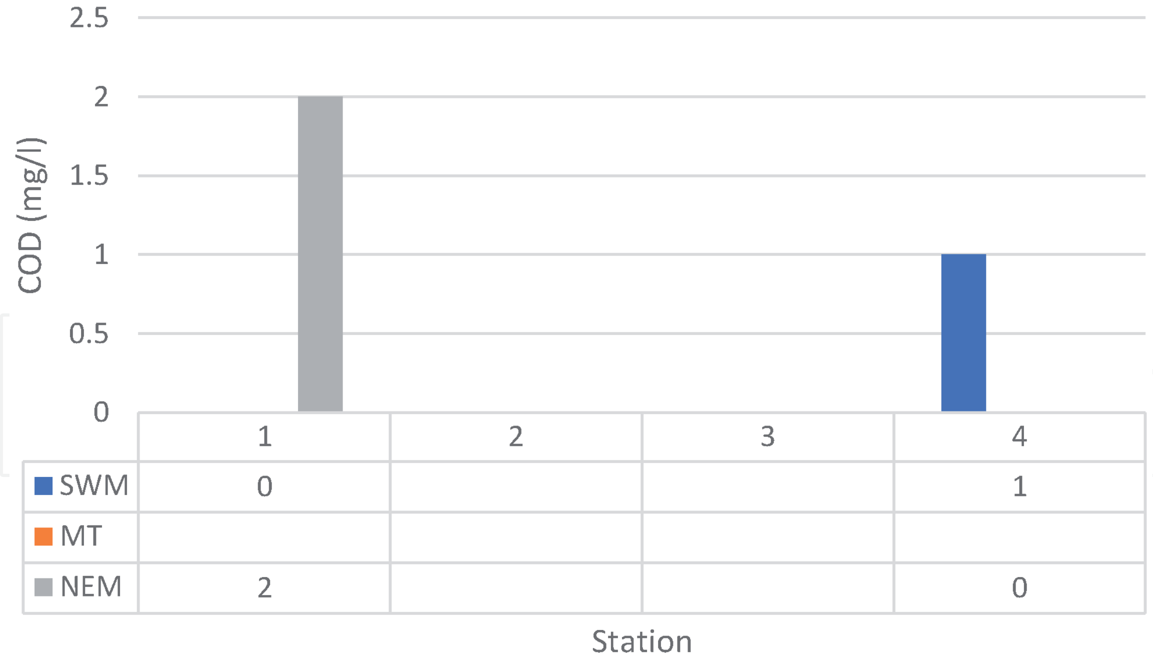


Figure 7.
Value of COD parameter by station and season.

Kapas Island showed no organic pollutants that exist from domestic sewage from residents or tourists. This is due to the widespread usage of COD to determine the concentration of sewage wastes and is used mainly for a mixture of pollutants such as domestic, industrial and biological sewage [25].

Figure 8 shows the readings of the NH_3-N parameter with the NH_3-N concentration for each observation station ranging from 0.01 mg/l to 3.5 mg/l. The majority of the sampling taken and analyzed obtained Class I which is a reading of <0.1 mg/l and only one outlier sample recorded Class V with a reading of 3.5 mg/l as based on the DOE's WQI classification. NH_3-N parameter usually indicates that a body of water has been contaminated by domestic sewage waste, that is, human feces [5, 9].

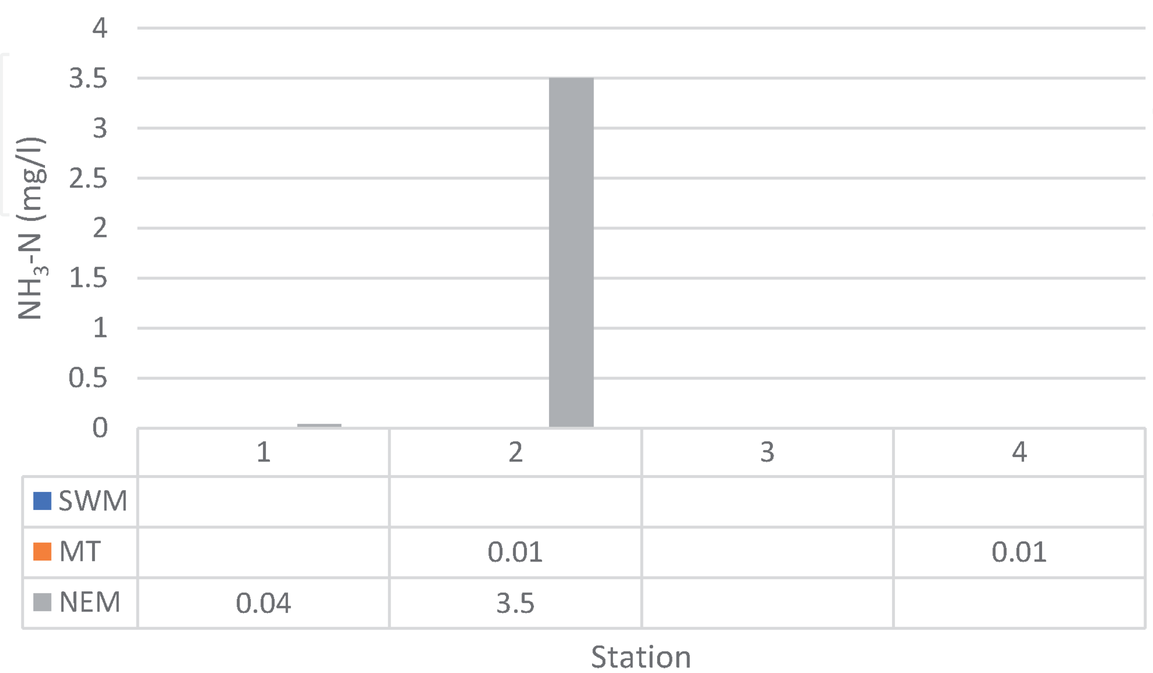


Figure 8.
Value of NH_3-N parameter by station and season.

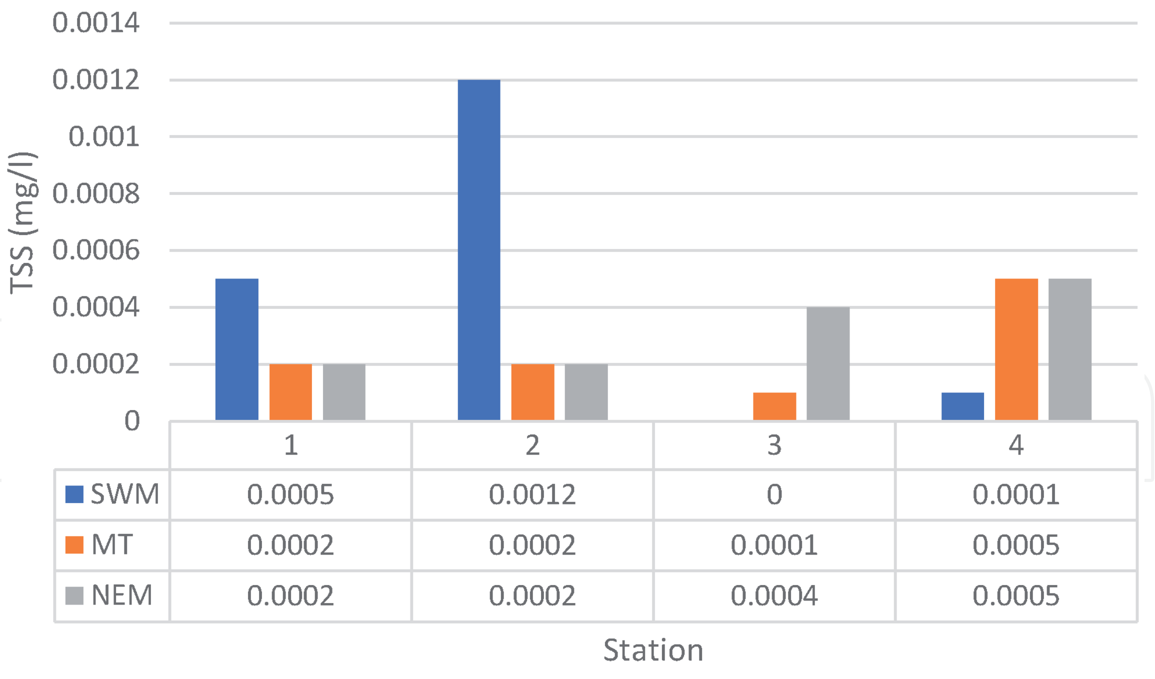


Figure 9.
Value of TSS parameter by station and season.

It is possible that at S2, groundwater had been polluted as a consequence of tourism activities which is sewage waste that was not well managed causing the NH_3-N value to be high in the observations made during the NEM. Nevertheless, the analysis of the study found that the majority of the sample obtained an nd status. During the SWM observation, all stations from S2 to S4 obtained an nd reading while during the MT at S1 and S3 as well as during the NEM at S3 and S4.

Figure 9 showed the laboratory analysis on TSS and found that the values of TSS were within the range of 0–0.0012 mg/l. Based on the DOE's WQI classification, the TSS values for all stations were in Class I which is <25 mg/l. The maximum value recorded was during the SWM at S2 (0.0012 mg/l), followed by S1 (0.0005 mg/l) while at S4 (0.0001 mg/l) and at S3 no TSS was recorded which is 0 mg/l. TSS values were also recorded during the NEM with readings of 0.0005 mg/l at S4 followed by S3 (0.0004 mg/l), S1 (0.0002 mg/l) and S2 (0.0001 mg/l). The average value during the MT was recorded at 0.0005 mg/l at S4 followed by the same values recorded at S1 and S2 which is 0.0002 mg/l as well as at S3 (0.0001 mg/l). The results of this analysis found that the sample obtained through the observations analyzed was water that was not contaminated and also contained less suspended solids.

Furthermore, this situation may be due to the groundwater taken had already gone through suspended solid filtration treatment before the water was being channeled to the tourist accommodation area. The results of the TSS test done in the laboratory may also come from fragments of suspended particles that exist or the condition of contaminated pipeline in the study area because the suspended matter in the water contained inorganic material or organic particles or water-insoluble. Inorganic solids are like clay, silt and other particles in the soil while organic matter includes plant fibers and microorganisms such as algae and bacteria [17].

3.2 Determination of groundwater quality based on DOE's WQI Malaysia

WQI is a very important indicator in knowing the quality status of surface or groundwater. This is carried out to ensure the suitability of water for various purposes such as domestic water supply sources, industrial activities and irrigation in agricultural areas. In this study, DOE's WQI Classification and Water Classes and Uses have been used in determining the status of groundwater quality in Kapas Island. Determination of groundwater WQI in Kapas Island used only six parameters, namely DO, pH, BOD, COD, TSS and NH_3-N. These values of WQI reading are the result of each parameter analyzed based on the WQI formula as shown in **Table 6**. The findings of WQI analysis provided indicators about the current status of groundwater in the study area whether it belongs to Class I (> 92.7), Class II (76.5–92.7), Class III (51.9–76.5), Class IV (31.0–51.9) or Class V (<31.0). Next, based on DOE's Water Quality Classification, groundwater quality status is categorized into three, i.e. clean (81–100), slightly polluted (60–80) and polluted (0–59).

On average, the range of WQI was between 61 to 77, with the majority fell under Class II and III with slightly polluted status (**Table 7** and **Figure 10**). During the SWM, S1 and S3 recorded Class II and S2 and S4 recorded Class III. During the MT, three stations recorded Class II of water quality, namely S1, S3 and S4. Meanwhile, during the NEM, all stations recorded Class III of groundwater quality. Therefore, to be used as a supply of drinking water and other domestic uses, groundwater in this area needs to be treated using conventional and intensive methods. This is for the purpose of providing consumers, especially tourists, with clean water resources. This study is in line with previous studies where an area, especially

Station	SWM			MT			NEM		
	WQI	Class	Status	WQI	Class	Status	WQI	Class	Status
1	77	II	Slightly polluted	77	II	Slightly polluted	73	III	Slightly polluted
2	75	III	Slightly polluted	76	III	Slightly polluted	61	III	Slightly polluted
3	77	II	Slightly polluted	77	II	Slightly polluted	75	III	Slightly polluted
4	76	III	Slightly polluted	77	II	Slightly polluted	76	III	Slightly polluted

Table 7.
WQI values and classes for each groundwater quality observation station in Kapas Island.

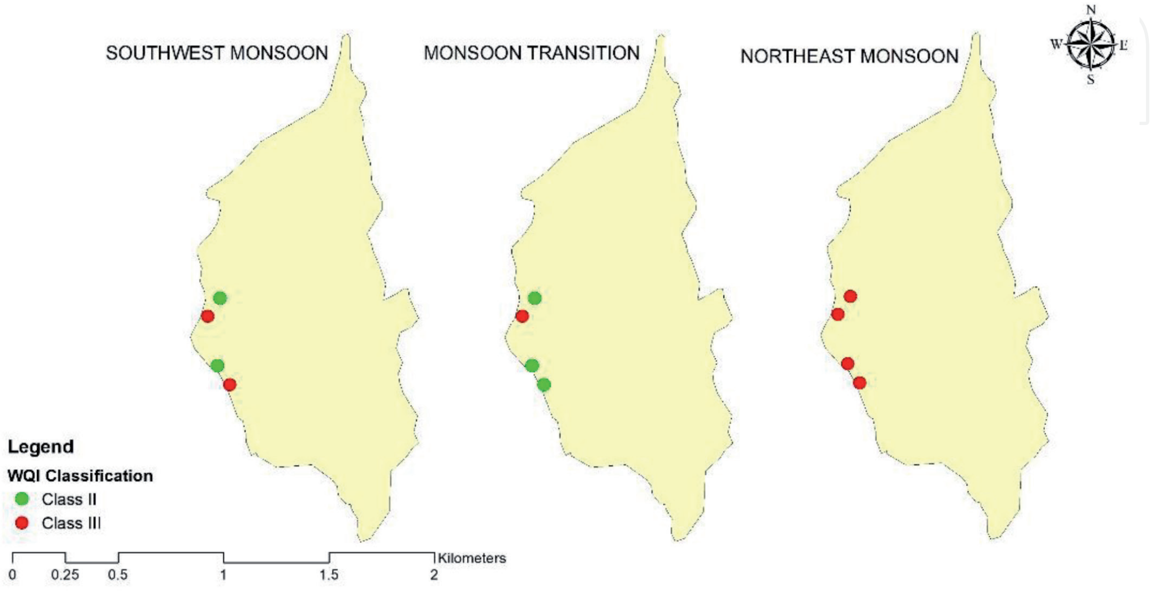


Figure 10.
WQI for observation stations in Kapas Island by season.

in the island area developed for various activities has contributed to the deterioration of groundwater quality [5, 8–9, 13]. Therefore, the values obtained during the NEM for all observation stations in the study area showed relatively the lowest WQI values compared to MT and SWM. This is due to the high concentrations of BOD, COD, TSS and NH_3-N while the low DO value contributed significantly to the deterioration of water quality at all sampling stations taken during the NEM.

4. Conclusion

Groundwater is essential especially in island areas that lack surface water resources. This study which has been conducted in Kapas Island, Marang Terengganu have shown that the groundwater quality was in Class II and III of the slightly polluted status. With the classification obtained, the groundwater in Kapas Island requires conventional treatment for Class II and intensive treatment for Class III. This is because the use of groundwater is not recommended to be directly consumed as drinking water because it contains contaminants from the underground aquifer system during the water pumping process. However, it is still suitable for uses that involve body contact as well as for animal drinks without the need for prior treatment. Therefore, accommodation centers that channel groundwater to be used in tourist accommodation areas should emphasize its use, especially in the process of providing food and beverages to visitors to avoid them from getting sick due to the groundwater.

The determination of WQI status was assessed based on six main parameters that include DO, COD, BOD, SS, NH_3-N and pH tests. Out of six parameters, the parameter with the worst pollution of groundwater quality was the NH_3-N parameter because it exceeded the standard set. The NH_3-N value obtained above this standard was 3.5 mg/l at S2 during the NEM which is in Class V with a highly polluted status. The DO, pH, COD, TSS parameters showed a safe class which is Class I. All stations for DO, pH, COD and TSS parameter tests were below the set standard with an average value of > 7 mg/l for DO, > 7 for pH, < 10 mg/l for COD and < 25 mg/l for TSS. The classification of the obtained parameters was in Class I, so it can be concluded that the groundwater quality in Kapas Island is free from pollution that is for the DO, COD and TSS parameters.

Based on the groundwater quality analysis, it was explained that the status of groundwater quality was safe for external use that included body contact such as bathing, washing, and so on. However, if it is to be used as drinking water and for food preparation, it should be first be given conventional and intensive treatment before use. The lowest WQI value obtained for groundwater quality in Kapas Island was 61%. This value has recorded a Class III of moderately contaminated status but is still safe for external body use and also safe to be used as a drinking source for animals.

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