Seasonal Variation of Irrigation Water Quality in Bachok, Kelantan

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Abstract

Agriculture is dependent on an adequate supply of suitable irrigation water quality. Physicochemical analysis of surface water for irrigation was conducted in Bachok, Kelantan during wet and dry period from July 2021 to December 2022. Surface water sampling points consist of primary, secondary and tertiary irrigation canals supplying water for paddy plantation. This study aimed to evaluate water quality trends in irrigation canals based on physicochemical parameters and discuss its pollution level and irrigation suitability using the Water Quality Index (WQI), National Water Quality Standards (NWQS) and irrigation suitability classification. It was observed that water quality was within NWQS Class IV except DO, Ammoniacal Nitrogen and TSS in locations with intensive aquaculture. ANOVA analysis showed a significant difference between water quality parameters and sampling locations (p<0.05). However seasonal variation in all irrigation canal's water quality was statistically insignificant except for pH. WQI in all sampling points are between 55.86-93.71, which classified into the category of clean and adequate water. Irrigation water suitability index in Bachok are in the range of: SAR (0.31-1.75), MAR (22.75-57.3), SSP (25.9-68.78) and %Na (32.87-69.83). Results showed that half of the water sample in Bachok were slightly polluted and polluted according to WQI. Additionally, MAR and SSP classified 5% and 3% of water samples were unsuitable and unsafe for irrigation. Strategies must be developed to ensure pollution level remains below threshold.

1. Introduction

Water is important for agriculture as the crop needs water to produce desirable yields for human consumption. The agriculture sector is one of the highest users of freshwater resources, accounting for up to 70% of a nation's water resources [1]. Rising demands to produce more food to satisfy the global population are becoming a huge challenge for agriculture as water scarcity is one of the biggest problems facing agriculture irrigation. Water scarcity in developing nations is exacerbated by declining water quality due to inadequate water treatment and pollution control measures failing to keep up with population growth and urbanization. Approximately 30 million hectares of agricultural land, inhabited by over 800 million people, are irrigated with contaminated water [2].

As the largest water user, agriculture causes and suffers from water pollution. Climate, soil physical and chemical qualities, crop salt tolerance, and management approaches affect irrigation water suitability [3]. Water

pollution problems associated with agricultural activity worldwide are salinization and nutrient and pesticide pollution from excessive agrarian input. Salinity impacts approximately 20% of cultivated land worldwide and around 33% of irrigated land [2]. Nutrients from untreated wastewater effluent and agricultural run-off remain the greatest threat as it is estimated that 2250 km³/year of effluent (including cooling water) 330 km³/year of urban wastewater, 660 km³/year of industrial wastewater, and 1,260 km³/year of agricultural drainage are discharged into the environment [1]. Decreasing water quality is a worldwide concern due to the increasing human populations, expanding industrial and agricultural activities, and the potential impact of climate change on the hydrological cycle [4].

Low-quality water originating from municipal, domestic, and industrial wastewater are usually not treated before it was used for irrigating crops. The water has undesirable characteristics such as high sodium content, heavy metal, pathogen-laden, and even consists of emerging pollutants, including microplastics and pharmaceuticals, which remain a growing concern. From an agricultural/rural standpoint, the reduced amount of accessible water for irrigation has resulted in several adverse effects, including diminished food security and decreased incomes for farmers [5].

In Malaysia, agriculture contributes to 64.3% of the total water demand [6] and 55.9% of agriculture water demand was for paddy irrigation [7]. Paddy cultivation is an important economic activity producing food for the expanding population in Malaysia. Compared to other agriculture sectors, paddy cultivation requires a large amount of water usage within its planting period. As water resources are becoming scarcer and water levels in rivers are declining, using wastewater for irrigation becomes a viable alternative for farmers with low access to good quality water.

Water quality for plant irrigation is determined by the water source and standards have been established by water resource agencies in various nations such as the Department of Agriculture and international organizations like Food and Agriculture Organization (FAO). Guidelines assist water users in establishing appropriate threshold values for the physical and chemical properties of water. These values are determined based on criteria such as achieving optimal crop production, crop quality, soil appropriateness, and the preservation of irrigation equipment [8]. In Malaysia, there is no unified national approach for monitoring water and soil pollution, agencies and ministries have separate systems, and fragmented and divided responsibilities where data and knowledge can be lost [9]. Therefore, monitoring irrigation water is crucial for maintaining the sustainability of agricultural yield.

This research aims to investigate water quality for irrigation based on the seasonal variability of physicochemical parameters, irrigation criteria, and the irrigation water quality index (WQI). Data collected is from two seasons of paddy cultivation in Bachok, Kelantan. The insights derived from this research will provide guidance to stakeholders regarding irrigation water use and agricultural policy for sustainable irrigation development in the nation.

2. Methodology

2.1 Study Area Description

Bachok area is located 25 km east of Kota Bharu, Kelantan. The area is dominated by agricultural land and various agriculture activities such as paddy cultivation, fisheries, and livestock farming can be found in the area [10]. Management of paddy cultivation in Bachok falls under Kemubu Agricultural Development Authority (KADA) jurisdiction. Irrigation water was supplied to 8925 ha area of paddy fields [11]. The planting season is divided into two, namely off season (season I) and the main season (season II). Off season planting in KADA is between March and July in the same year which is considered dry period. During this dry period, paddy cultivation is fully dependent on irrigation water. The main planting season for paddy cultivation in KADA is between August to February of the following year. Paddy planting for the main season will not be fully dependent on irrigation due to high rainfall during the monsoon. Source of water originates from Sungai Kelantan and delivered using water pump along primary, secondary and tertiary irrigation canal along the Kemubu Irrigation Scheme. Additional water sources also come from Sungai Kemasin, Sungai Ketereh, and Sungai Semarak [11]. Water samples for this study were collected eleven times from July 2021 to December 2022, during both the off season (July 2021, March 2022, May 2022, July 2022) and main season (August 2021, September 2021, October 2021, December 2021, January 2022, September 2022, December 2022) of the paddy cultivation. The sampling map, pictures and locations of the seven sampling points are shown in Fig. 1 and Table 1.
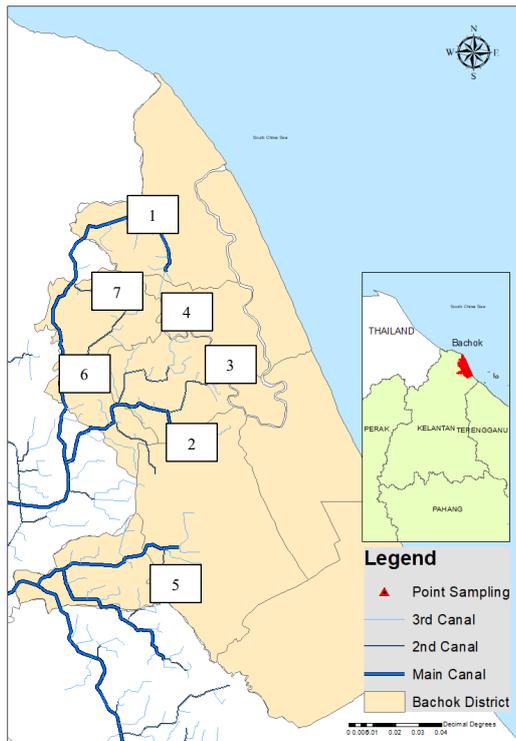
Fig. 1 *Map of sampling points*

Table 1 *GPS of sampling locations*

No	Location	GPS
1.	Banggu Canal (Primary canal, paddy field in surrounding area)	6.107321 N 102.335750 E
2.	Marak Canal (Primary canal, paddy field)	6.010434 N 102.352076 E
3.	KE24-Booster Pump (Sg. Kemasin). (Secondary canal, paddy field, ~5 km to coastal area)	6.043832 N 102.366860 E
4.	Kemasin Lama -KE19 (Sg. Kemasin). (Secondary canal, paddy field, ~8 km to coastal)	6.065119 N 102.347252 E
5.	Lubuk Tembesu (Tertiary canal, paddy field)	5.945814 N 102.345825 E
6.	Peringat Canal (S2PA) (Secondary canal, Sampling points before fish farming activity)	6.039432 N 102.303040 E
7.	Peringat Canal (S2PB) (Secondary canal, sampling points after fish farming activity)	6.071113 N 102.329503 E

2.2 Water Sampling and Analysis

In-situ water quality measurement at the sampling site for pH, temperature, and DO was done using YSI Pro DSS multiparameter and YSI ProODO meter respectively. All sensors were calibrated before analysis. Water sampling for laboratory analysis was done using a long rod water sampler and HDPE bottles. Samples were taken approximately 20 cm from below the surface [12]. Bottles have to be labelled appropriately before water was collected in the field. Water samples were taken in duplicates at each sampling site. Water samples must be promptly transferred to the laboratory in a cooler box filled with ice. Upon arrival at the laboratory, samples were stored in a 4°C chiller. Sampling method was based on guidelines for agriculture water quality management by Department of Agriculture (DOA) [13].

Chemical analysis of water samples involving nutrient Ammoniacal Nitrogen (NH_3-N) and Total Suspended Solids (TSS) were analyzed using spectrophotometer HACH DR 1900. Water samples from the refrigerator must be conditioned at room temperature for two hours before starting the analysis. Nutrient analysis must be performed within 48 hours after sampling. The method for determination of BOD and COD was based on Standard Methods for Examination of Water and Wastewater [14]. Trace metals were analyzed using ICP Inductively Coupled Plasma (ICP) Perkin Elmer Optima 7300 DV. Statistical analysis between water quality parameters in different seasons and sampling points was performed using SPSS version 23.

2.3 Water Quality and Irrigation Suitability Classification

Water Quality Index (WQI) and National Water Quality Standards (NWQS) are the most commonly accepted standards for water quality assessment in Malaysia [15]. Additionally, water for irrigation purposes can also be evaluated using irrigation water suitability classification. The following formulas were used to calculate the WQI, sodium adsorption ratio (SAR), sodium percentage (Na%), soluble sodium percentage (SSP), and magnesium adsorption ratio (MAR) and their categories are described in Table 2.

Table 2 *Water quality index and classification of the water quality guidelines for irrigation purposes*

Index	Equation	Range	Category	
WQI	$(0.22 * SIDO) + (0.19 * SIBOD) + (0.16 * SICOD) + (0.15 * SIAN) + (0.16 * SISS) + (0.12 * SIpH)$	81-100 60-80 <60	Clean Slightly polluted Polluted	[15]
SAR	$SAR = \dfrac{Na^+}{\sqrt{\dfrac{Ca^{2+} + Mg^{2+}}{2}}}$	<10 10-18 18-26 >26	Excellent Good Fairly poor Unsuitable	[16]
SSP	$SSP = [\dfrac{Na^+}{Ca^{2+} + Mg^{2+} + Na^+}] \times 100$	<60 >60	Safe Unsafe	[17]
Sodium percentage (Na%)	$Na\% = [\dfrac{Na^+ + K^+}{Na^+ + Ca^{2+} + Mg^{2+} + K^+}] \times 100$	< 20% (20%–40% 40%–60% 60%–80% 80%	Excellent Good Permissible/Safe Doubtful Unsuitable	[18]
MAR	$MAR = [\dfrac{Mg^{2+}}{Mg^{2+} + Ca^{2+}}] \times 100$	<50 >50	Suitable Unsuitable	[19]

All indices are based on concentration of dissolved anions and cations, expressed in meqL^{-1}.

3. Results and Discussion

Water samples from Bachok irrigation canals were analyzed for physicochemical water quality parameters at seven sampling locations during the off and main season of paddy planting. Table 3 shows average concentrations of water quality parameters in all sampling locations in two seasons of paddy planting. Table 4 shows irrigation water quality characterization in all sampling points and both planting seasons. The percentage of irrigation quality in all water samples were given in Fig. 2(a-e). Graphs include a percentage of WQI, SAR, MAR, SSP and %Na in irrigation water.

3.1 Electrical Conductivity (EC)

Electrical conductivity (EC) is a measurement of dissolved ions in water. EC in sampling locations varies between 7– 139.85 μS/cm as shown in Table 3. Average EC was higher in the wet season (66.76±21.15 μS/cm) compared to the dry season (48.69±36.42 μS/cm). Seasonal fluctuations of rainfall affect the salinity of water utilized for irrigation. Warmer and drier seasons increase the evaporation rate and elevate water salinity due to the ions that are retained after water vaporizes in the atmosphere. On the contrary, higher precipitation during the wetter season reduced salinity by diluting saline concentrations in the water bodies. To maintain optimal crop health throughout the year, farmers have to understand the seasonal pattern and adapt their irrigation techniques to the fluctuating salinity levels. The conductivity level at this concentration is not harmful to rice crops and considered good quality irrigation water as it is below the threshold of 700 μS/cm [8]. EC shows a significant difference between sampling points, however, there is no significant difference between seasons.

3.2 pH

pH is the degree of acidity and alkalinity and a very important parameter for drinking and irrigation usage. Natural waters contain both acid and base substances and biological processes have a tendency to change the levels of either acidity or alkalinity. The interactions among these opposing acidic and basic substances and processes determine pH [20]. Most natural waters have a pH within the 6–9 range. The pH concentrations in the Bachok irrigation canal ranged from 5.89-7.40, with a mean of 6.40±0.33 during the dry season and 6.59±0.32 during the wet season. Water samples taken in the wet period have slightly higher pH values compared to the dry period. It has been found that pH did not vary significantly among sites (*p-value* = 0.273). However, pH varied significantly between seasons (*p* value =0.02). pH in this area was similar to the previous study in Sungai Kelantan [21]. All pH data were within the acceptable limit of NWQS class IV [22] and suitable for irrigation.

Table 3 *Average water quality in irrigation canal during two planting seasons of paddy cultivation*

Parameter	Planting season	1	2	3	4	5	6	7	Mean	Std Dev.	Min	Max	Class IV NWQS
					Sampling points								
EC	Off	52.71	34.8	72.66	47.41	42.67	31.58	57.5	48.69	36.42	7.00	139.85	6000
(µS/cm)	Main	76.98	59.9	73.2	61.87	55.7	45.32	89.62	66.76	21.15	38.18	129.75	
pH	Off	6.44	6.32	6.37	6.31	6.49	6.53	6.35	6.4	0.33	6.05	7.30	5-9
	Main	6.85	6.73	6.42	6.44	6.59	6.58	6.48	6.59	0.32	5.89	7.40	
COD	Off	9.79	4.53	26.55	5.35	6.82	2.50	6.08	8.87	13.38	0	62.5	100
(mg/L)	Main	9.53	2.90	17.24	7.77	2.64	1.67	10.91	7.84	8.38	0	24.3	
Ammonia	Off	0.21	0.14	0.42	0.17	0.23	0.11	1.71	0.43	0.87	0.03	4.60	2.7
(mg/L)	Main	0.21	0.28	0.51	0.28	0.14	0.16	2.39	0.59	1.04	0	5.20	
TSS	Off	18.63	18.88	63.38	16.50	42.67	45.88	106.00	44.63	46.02	8.00	191.5	300
(mg/L)	Main	13.86	29.93	54.93	20.79	27.50	32.50	119.00	43.63	57.38	7.00	373	
DO	Off	4.93	4.88	4.33	4.20	6.93	6.06	3.03	4.83	2.36	0.63	7.64	<3
(mg/L)	Main	3.56	4.45	4.30	3.77	6.05	5.70	3.41	4.36	2.44	0.20	9.18	
BOD	Off	1.64	1.32	1.85	0.93	1.06	0.72	1.14	1.24	0.82	0.11	3.45	12
(mg/L)	Main	1.13	1.09	2.26	0.86	0.90	0.86	2.54	1.41	1.23	0.02	4.93	
Ca	Off	5.13	4.52	6.02	4.44	4.85	5.28	4.62	4.98	2.03	3.01	11.97	NA
(mg/L)	Main	5.07	5.47	3.46	3.67	4.72	3.69	4.01	4.27	1.33	1.92	8.30	
Mg	Off	1.91	1.37	3.73	1.70	1.16	1.33	1.14	1.79	1.18	0.86	6.56	NA
(mg/L)	Main	1.63	1.44	2.04	1.40	1.11	1.00	0.96	1.39	0.55	0.50	3.22	
Na	Off	8.94	6.55	16.57	8.96	5.80	4.48	5.05	8.13	5.39	3.56	30.43	NA
(mg/L)	Main	8.39	6.30	9.16	8.02	5.36	5.04	5.57	6.93	2.64	3.92	14.02	
K	Off	3.75	2.37	4.60	3.39	2.8	3.06	3.61	3.39	1.61	1.25	6.98	NA
(mg/L)	Main	3.64	1.95	2.63	1.92	1.11	1.31	1.96	2.14	1.47	0.71	6.98	

3.3 Chemical Oxygen Demand (COD)

COD was between 0-62.5 mg/L in all sampling points. COD concentration in the off-season was 8.87±13.38 mg/L and the main season was 7.84±8.38 mg/L. There was a statistically significant difference between COD and sampling points. The average COD in irrigation canals falls into Class I NWQS throughout the planting season which was lower compared to results from previous researchers in the Kelantan River basin [23].

3.4 Ammoniacal Nitrogen (AN)

Ammonia is an inorganic substance from untreated sewage, agriculture inputs such as fertilizer, herbicides and pesticides and livestock waste [24]. The decaying process of Ammoniacal Nitrogen by bacteria such as *Nitrosomonas* (ammonia oxidizers) and *Nitrobacter* (nitrite oxidizers) will affect other water quality parameters such as TSS, DO, and BOD [25]. The ammoniacal nitrogen average concentration in the Bachok irrigation canal was between 0-5.20 mg/L. The mean concentration of Ammonia was higher in main season (0.59±1.04 mg/L) compared with the off-season (0.43±0.87 mg/L). Ammonia was correlated with TSS, DO, and BOD. There was no significant difference between seasons. However, ammonia was statistically different between sampling locations. The highest concentration of Ammonia was found in sampling point 7 in both seasons. Intensive aquaculture in this location was one of the main factors of high AN. Aquaculture has the potential to pollute aquatic ecosystems at multiple stages, including during pond construction, pond management, water intake, stocking, nursing, water exchange, sludge discharge, harvesting, and pond emptying [2]. Accumulation of excess nutrients from faeces, residue of feed, and decaying algae were the possible factors contributing to the high ammonia concentration [26].

3.5 Total Suspended Solids (TSS)

Suspended solid is one of the most important water quality parameters for determining a healthy ecosystem for aquatic life. Solids in water column originates from two primary sources: the breakdown and suspension of minerals and organic matter from soils and other geological formations, as well as the decomposition of aquatic microorganisms such as bacteria and algae[20]. The concentration of TSS in the dry season was between 8.00-191.50 mg/L and TSS in the rainy season was between 7.00-373.00 mg/L. TSS was positively correlated with Ammonia and BOD. The maximum concentration of TSS in the wet season was higher than the class IV threshold. These results were similar to Abdul Maulud et al. [27] and Yusoff et al. [28], both explained in their paper that high

rainfall during the wet season was caused by surface runoff and surface erosion in bare ground. The highest TSS was found in sampling point 7 where intensive aquaculture occurs. TSS in irrigation canals can be influenced by fish movement, waste accumulation, and the growth of algae stimulated by nutrient enrichment [29]. High fish stocking density combined with low water flow can also intensify TSS, thereby obstructing irrigation and reducing light penetration, causing adverse impacts on aquatic ecosystems [30]. The average TSS was within class IV DOE classification for both planting seasons and the water was suitable for irrigation. The variation of TSS in all sampling points was statistically significant, however, there is no significant difference between planting seasons.

3.6 Dissolved Oxygen (DO)

The average concentration of DO in this study was between 0.20-9.18 mg/L. DO in dry season (4.83±2.36 mg/L) was higher than wet season (4.36±2.44 mg/L). This finding is similar to Abdul Maulud et al. [27] where DO concentration in the Kelantan River basin was found to be lower in the rainy season. Zhang et al. [31] also found a similar trend with the lower concentration of DO in the rainy season suggesting nonpoint pollution caused by heavy storm runoff during the rainy season as the main reason causing the deterioration of water quality. The average DO in all sampling points was within Class IV NWQS. DO was negatively correlated to ammonia and positively correlated to BOD. DO in irrigation canals is usually affected by physical, chemical, biological and microbiological processes in the surrounding activity [32]. The variation of DO is not significant with planting season and sampling points. There was no significant difference in DO between the two seasons. According to Zhang et al. [31], the reduction of riparian buffer zones, water pollution, and sluice dam operations are contributing to a declining DO concentration and water quality degradation.

3.7 Biochemical Oxygen Demand (BOD)

BOD was found between 0.02-4.93 mg/L in all sampling points. BOD concentration in the dry season was lower compared with the wet season. Zhang et al. [31] and Abdul Maulud et al. [27] observed higher BOD in high rainfall events due to excess runoff and sediment from the surrounding area. Based on DOE classification [22], the average BOD concentration in both seasons was positioned at class I. BOD was correlated with ammonia, TSS, and DO. The variation of BOD between planting seasons was not statistically significant, however there was statistically significant variation among different sampling locations. High concentrations of BOD in water bodies are harmful to aquatic life.

3.8 Calcium (Ca)

Irrigation water naturally contains calcium, however, it does not affect crop growth as long as it is below the threshold. Calcium concentration in the study area ranged between 1.92 and 11.97 mg/L. In the dry season, calcium concentration was between 3.01-11.97 mg/L and in the wet season the calcium level ranged from 1.92-8.3 mg/L. The one-way ANOVA showed no significant difference in calcium levels among the seasons, however there was a significant difference between sampling points. The level of calcium in this study was within the FAO threshold for irrigation [8]. Maharjan et al. [33] explained that calcium concentration in the Miri River is generally low but increased in areas affected by waste dumping and domestic and industrial activity in the surrounding area.

3.9 Magnesium (Mg)

Magnesium is commonly found in natural water originating from the weathering of rocks and is also used in industrial processes. Magnesium concentration recorded in the irrigation canal ranged from 0.5-6.56 mg/L. The average magnesium in the dry season was 1.79±1.18 mg/L and in the wet season, it was 1.39±0.55. The recorded level is low and suitable for irrigation according to Ayers & Westcot[8].

3.10 Sodium (Na)

Sodium is naturally found in water when minerals dissolve, however, it can also originate from municipal sources [34]. Farming becomes challenging when high sodium is present in soil due to its harmful and salinizing effect. Sodium can displace other cations such as calcium on soil colloids thus altering its structure, function, and water management characteristics [35]. However, the impact of sodium from irrigation water is not immediately noticeable in the short term, resulting in significant problems when irrigation is discontinued and land use changes [36]. The sodium level recorded in the Bachok irrigation canal ranged from 3.56-30.43 mg/L. The average Sodium in the dry season (8.13±5.39 mg/L) was higher than wet season (6.93±2.64 mg/L). The level of sodium in irrigation canal was within the accepted value and is not harmful to rice plants according to Ayers & Westcot [8].

3.11 Kalium (K)

Kalium is among the commonly found cations in natural waters and is usually at a low level due to its interactions with soil particles, especially clay minerals [37]. The concentration of kalium in Bachok irrigation water ranged from 0.71-6.98 mg/L. The average concentration in the dry season was 3.39±1.21 mg/L and during wet season the concentration was 2.14±1.47 mg/L which was the acceptable limit of irrigation according to Ayers & Westcot [8].

Table 4 *Irrigation water quality characterization in all sampling points*

Parameter	Planting season	Sampling points							Mean	Std. Dev	Min	Max
		1	2	3	4	5	6	7				
WQI	Off	82.79	86.23	74.06	82.01	87.13	87.45	67.42	80.78	10.39	55.86	91.90
	Main	79.42	83.53	75.18	79.72	90.24	89.21	65.53	79.76	9.97	58.65	93.71
SAR	Off	0.86	0.71	1.26	0.91	0.61	0.48	0.55	0.78	0.31	0.31	1.75
	Main	0.83	0.64	0.95	0.89	0.58	0.61	0.67	0.67	0.24	0.40	1.27
MAR	Off	38.63	33.83	51.43	39.00	28.70	29.9	29.48	36.12	8.08	25.71	57.03
	Main	34.99	30.90	49.45	38.58	27.93	31.1	28.47	34.92	7.70	22.75	56.43
SSP	Off	56.28	52.97	62.69	59.16	48.76	42.52	47.51	52.99	9.15	25.9	68.78
	Main	54.99	47.69	62.25	60.70	48.22	51.95	53.00	54.50	9.20	36.43	70.47
%Na	Off	54.20	50.80	57.83	56.60	48.68	43.88	49.39	51.73	6.57	33.67	61.85
	Main	53.97	45.22	57.48	56.53	44.81	48.81	51.29	51.57	9.27	32.87	69.83

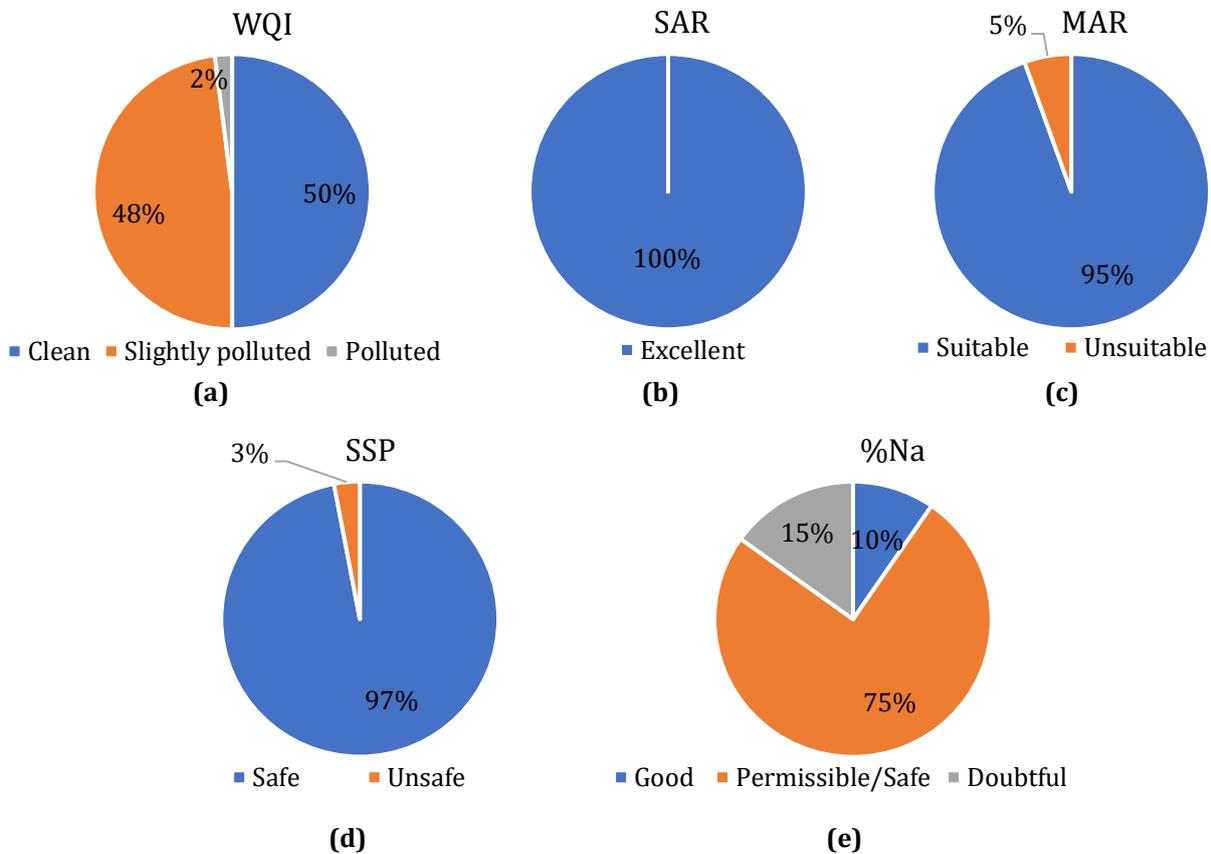**(a)**   **(b)**   **(c)**

(d)   **(e)**

Fig. 2 *Percentage of irrigation quality in all water samples*

3.12 Water Quality Index (WQI)

WQI was used by DOE as an assessment of water pollution in Malaysia. Six parameters were selected and subindex was calculated to derive WQI. The water quality index in all sampling points is between 55.86 and 93.71. A slightly higher average WQI was found during the dry season of 80.78±10.39 compared with the wet season of 79.76±9.97. There was no significant difference between WQI and season, however, WQI was significantly different between

sampling locations. The lowest WQI was found in sampling point 7 and the highest was found in sampling point 5. Previous researchers in the Kelantan River basin also found similar results [38], [23], while Abdul Maulud et al. [27] found that rivers in the Kelantan River basin fall in Class III to IV during different seasons. Fig. 2(a) shows 50% of water samples were clean, followed by 48% of water was slightly polluted and the rest of the sample was considered polluted.

3.13 Sodium Adsorption Ratio (SAR)

The sodium adsorption ratio is a measurement of sodium hazard in irrigation water**.** The ratio of sodium to calcium and magnesium is calculated to determine the level of suitability for irrigation. SAR in all sampling seasons was 0.31-1.75. SAR in both wet and dry seasons were 0.78±0.31 and 0.67±0.24 respectively. Low SAR concentration in all sampling points indicates water is excellent for irrigation [8].

3.14 Magnesium Adsorption Ratio (MAR)

MAR in all seasons is 22.75-57.03. The average MAR in the dry season was 25.71±8.08 which was higher compared with the wet season (22.75±7.7). MAR was significantly difference with sampling points but there was no significant difference with season. The highest MAR was found in sampling point 3 during off season. The high MAR indicates the concentration of Mg ions in water is greater than calcium ions, thus causing clay minerals to absorb Mg ions which could affect the rate of water adsorption in soil [37]. 95% of water samples were suitable for irrigation while the remaining 5% was unsuitable.

3.15 Soluble Sodium Percentage (SSP)

SSP between both dry and wet season range between 25.9-68.78 and 36.43-70.47 respectively. Average SSP was higher in the wet season (54.5±9.2) compared with dry season (52.99±9.15). The highest SSP was found in sampling point 3 in both seasons. SSP was significantly different in sampling location but there was no statistical difference in planting season. SSP in Bachok irrigation canal was safe for irrigation by 97% and only 3% of the total sample was unsafe.

3.16 Percent Sodium (%Na)

Sodium hazard in a term of percent Na is also used to assess irrigation water suitability. Sodium interacts with soil and affects its permeability [18]*.* According to Fipps [39], irrigating water with %Na more than 60% can alter the physical characteristics of the soil due to sodium accumulation. In the Bachok irrigation canal, the %Na in all seasons was between 32.87 and 69.83. Results showed that during dry season, the average %Na was 51.73±6.57, in comparison with a slightly lower average of 51.57±9.27 during the wet season. Percent of Na was significantly different with sampling points but there was no significant difference with season. %Na in all sampling locations was considered suitable for irrigation. A similar result was found in the El Salam Canal by El-Amier et al. [40]. The percentage of Na in all water samples is shown in Fig. 2. All water samples were 10% good, the majority was safe while the remaining 15% was doubtful for irrigation.

Overall, water quality in Bachok district was considered suitable for irrigation except in the area where human activity occurs. The average water quality index in all sampling points was clean except in sampling points 3 and 7 which were slightly polluted. High ammonia and TSS were found in both sampling points which contributes to lower WQI. SAR was excellent in all sampling points and planting seasons. MAR was considered good in all sampling points and seasons except in sampling point 3 during off season. SSP was good in all sampling points except sampling point 3 in both seasons and sampling 4 in the main season. %Na was within the threshold for irrigation in all sampling points and seasons. All irrigation indexes were significantly different between sampling points; however, they were not statistically different between planting seasons. Sampling points 3 and 4's close proximity to the coastal area increases the probability of seawater intrusion, resulting in higher sodium and magnesium concentrations. Anthropogenic activity and surface runoff can also increase magnesium and salt levels in surface water, especially in dry seasons [32]. Additionally, using this water for irrigation will cause a serious threat to soil structure and crop health. Further research can be done to determine the suitable water treatment to prevent severe sodium hazards and environmental pollution.

4. Conclusions

Water quality for irrigation in Bachok district complies with irrigation standard Class IV NWQS except for DO, TSS and ammonia. Classification using the water quality index found that anthropogenic and intensive aquaculture in sampling points 3 and 7 have caused the irrigation canal to become slightly polluted. The irrigation index also found that water in sampling point 3 is classified as a sodium hazard due to high MAR and SSP and needed treatment before water is used for irrigation. Half of the total water sample in Bachok is slightly polluted and

polluted, while 5% is unsuitable and 3% unsafe for irrigation. Strategies must be developed to reduce pollution and improve water suitability for irrigation. Paddy needed good and suitable water for irrigation to produce good yield and therefore household income can be upgraded and sustainable development can be achieved.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

*The authors confirm contribution to the paper as follows: **study conception and design:** Norlida M.H, Mohamad Shahid S; **data collection:** Norlida M.H, Mohamad Shahid S, Jamaliah J; **analysis and interpretation of results:** Norlida M.H, Mohamad Shahid S, Jamaliah J, Azhar A.H. Liew Juneng; **draft manuscript preparation:** Norlida M.H., Azhar A.H. All authors reviewed the results and approved the final version of the manuscript.*

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