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INVESTIGATION OF THE PHYSICO-CHEMICAL CHARACTERISTICS OF IRRIGATION WATER QUALITY AT AN AGRICULTURAL SITE IN PASIR PUTEH, KELANTAN, MALAYSIA

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ABSTRACT

This study was conducted to assess the physico-chemical characteristics of irrigation water quality, focusing on both chemical and physical elements at an agriculture site in Pasir Puteh, Kelantan, Malaysia. Eight sampling points were selected near four different crops namely corn, cucumber, longbean and luffa, with two sampling points located 10 meters apart for each crop. Water samples were analyzed *in-situ* and *ex-situ* in evaluating their physico-chemical characteristics including temperature, pH, salinity, conductivity, total dissolved solids (TDS), turbidity, chemical oxygen demand (COD), dissolved oxygen (DO) and biochemical oxygen demand (BOD). The findings revealed that the values of the observed water quality parameters did not exceed the specified standards aligning with the National Water Quality Standards (NWQS) water quality index Class IV – Irrigation. TDS levels at all sampling points were below the NWQS standard for Class I water (<500 mg/L). Although there is no specific turbidity standard for Class IV water, the highest turbidity value was recorded at sampling point 2 (246.50 ± 0.71 NTU). The average COD concentration across all sampling points was 43.63 ± 9.72 mg/L, with a DO value of 3.45 ± 0.55 mg/L, and a mean BOD of 5.80 ± 6.43 mg/L, all falling within Class III NWQS. In conclusion, all measured water quality parameters met the NWQS Class IV irrigation standards, indicating that the water is suitable for irrigation purposes.

Keywords: Irrigation; Water Quality Parameter; Agricultural.

1.0 INTRODUCTION

Water is essential to life and is widely used in industries including aquaculture, livestock farming, irrigation, and drinking. Water contamination is a major threat to species existence due to physical, chemical, and biological pollutants that need to be eradicated [1]. Agriculture has adverse effects on water quality, particularly in rural areas of both developing and developed countries [2]. One of the causes of river contamination is poor farming practices. For farmers, the application of technology to sustainable farming methods was a dynamic and difficult challenges [3]. A study by Tabikam et al. [4] revealed that all vegetable growers incorporate some form of agrochemicals as part of their integrated pest management (IPM) approach. Their findings reported 49.7% of pesticides and 50.3% being fertilizers out of the 155 agrochemicals identified. The primary cause of water contamination is runoff from agricultural sites and urban areas, where herbicides and pesticides enter the water by direct wastewater discharge or seeping into the soil [5]. As a result, groundwater poses greater health concerns than surface water.

Water contamination and poor sanitation can lead to the spread of diseases like dysentery, typhoid, diarrhea, cholera, polio and hepatitis A. Improper management of wastewater from agricultural sources, industries and urbanization also lead to the unsafe consumption of hundreds of millions of people's drinking water due to contamination or chemical pollution [6]. Water must be tested for its physical and chemical parameters before usage for drinking, industrial, or agricultural purposes. Determination of which parameters needed for water testing depends on the purpose of water usage and the degree to which its purity and quality are required [7]. Numerous types of suspended, dissolving, floating, microbiological, and bacteriological contaminants can be found in water. While chemical tests should be carried out to evaluate the substance's biochemical oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen, alkalinity, hardness, and other properties, some physical tests should be carried out to evaluate the substance's physical appearance, such as temperature, color, odor, pH, turbidity, and total dissolved solids (TDS) [8]. The Water Quality Index (WQI) evaluates water quality in a river basin, taking into account local pollution levels. Department of Environment (DoE), Malaysia assesses river quality using the WQI and National Water Quality Standards (NWQS). WQI classifies water into five categories based on its use, including water supplies, aquatic organisms, and irrigation purposes as shown in Figure 1 [9].

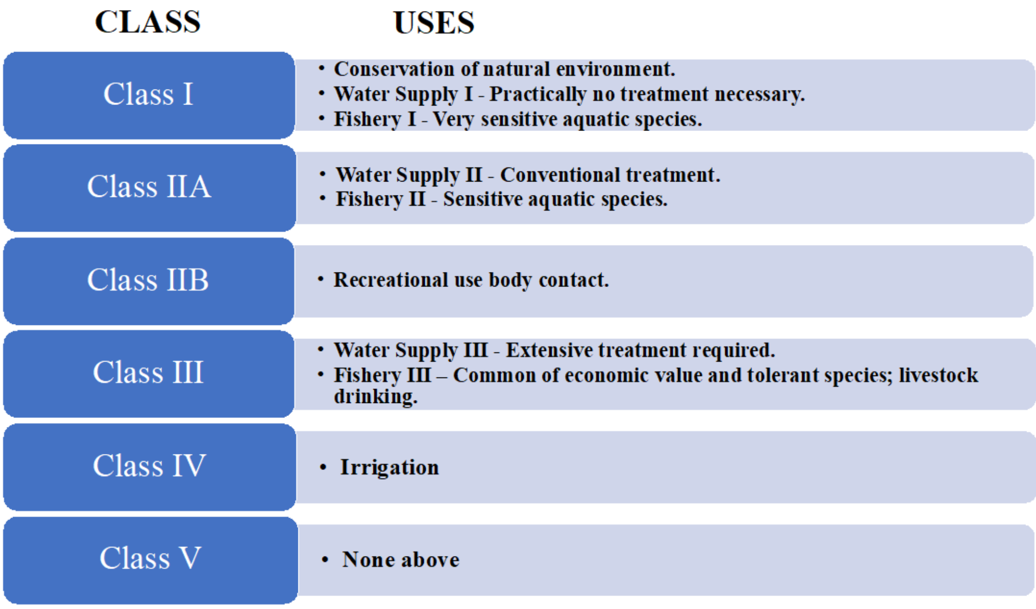

Figure 1. Water Classes and Use

` Source: Department of Environment [9]

Out of 672 rivers surveyed by the DoE, 161 rivers (24%) are reported as moderate (Class III) and the remaining 25 rivers (4%) are polluted (Class IV) in Malaysia [10]. The majority of Malaysia's household water consumption comes from surface water supplies, with the remaining portion coming from groundwater. Thirty percent of Malaysia's internal water resources are used for municipal uses [11]. Surface and groundwater are the main sources of processing and distribution for tap, bottled and mineral water, which are the main sources of drinking water in Malaysia [10]. Approximately, 50% or 600,000 of 1.2 million people in Kelantan now depend on wells or tube wells to get water supply after the problem was not solved more than 25 years ago. Among the badly affected areas without a treated and clean water supply are Pasir Mas, Tumpat, Pasir Puteh, Tanah Merah, Kota Bharu, Machang and parts of Kuala Krai and Machang [12]. In addition to giving households in rural areas access to food and income, agricultural activity is especially important because it accounts for 7.3% of Malaysia's gross domestioc products (GDP). Morever, one of the Malaysia's economic growth is driven by agriculture [13]. Therefore, this study aimed to evaluate the physico-chemical characteristics of water quality, encompassing chemical and physical elements in an agriculture site at Pasir Puteh, Kelantan, Malaysia. The objective is to create a baseline understanding of water quality by comparing these characteristics to the NWQS (Table 1) [14]. Bivariate statistical methods were also applied to anticipate possible sources of pollution and analyze the similarities and differences between the sampling areas.

Table 1. National Water Quality Standards for Malaysia

PARAMETER	UNIT	CLASS					
		I	IIA	IIB	III	IV	V
Ammoniacal Nitrogen	mg/L	0.1	0.3	0.3	0.9	2.7	> 2.7
Biochemical Oxygen Demand	mg/L	1	3	3	6	12	> 12
Chemical Oxygen Demand	mg/L	10	25	25	50	100	> 100
Dissolved Oxygen	mg/L	7	5 – 7	5 - 7	3 - 5	< 3	< 1
pH	-	6.5 - 8.5	6 – 9	6 - 9	5 - 9	5 - 9	-
Colour	TCU	15	150	150	-	-	-
Electrical Conductivity*	µS/cm	1000	1000	-	-	6000	-
Floatables	-	N	N	N	-	-	-
Odour	-	N	N	N	-	-	-
Salinity	%	0.5	1	-	-	2	-
Taste	-	N	N	N	-	-	-
Total Dissolved Solid	mg/L	500	1000	-	-	4000	-
Total Suspended Solid	mg/L	25	50	50	150	300	300
Temperature	°C	-	Normal + 2 °C	-	Normal + 2 °C	-	-
Turbidity	NTU	5	50	50	-	-	-
Faecal Coliform**	count/100 mL	10	100	400	5000 (20000)[a]	5000 (20000)[a]	-
Total Coliform	count/100 mL	100	5000	5000	50000	50000	> 50000

Notes:
N : No visible floatable materials or debris, no objectional odour or no objectional taste
* : Related parameters, only one recommended for use
** : Geometric mean
a : Maximum not to be exceeded

Source: Department of Environment [14]

2.0 METHODOLOGY

2.1 Study Location and Water Sampling Points

The location of this study was at a rural agricultural area in Pasir Puteh, Kelantan (5.7575367, 102.4403124). The 28 acres of agricultural land were used by the locals as their primary source of food, with chilly being the typical crop. Because the farmers practiced crop rotation, throughout the transitional period they also grew cucumbers, corn, ladies' fingers, and luffa. The irrigation canals next to every crop that was available for sampling during the sampling period (corn, cucumber, longbean, and luffa) were chosen as the locations for the water samples based on judgmental sampling. Two sampling sites were chosen at each of the identified crops, separated by 10 meters. As a result, a total of eight sampling points existed. Together with information on different yield kinds and farmer usage of pesticides and fertilizers, approval was obtained from management to collect water samples.

Two types of sampling bottles were used; (i) sampling bottles with a capacity of 500 mL (ii) glass bottles with a capacity of 300 mL, at each sampling site. The 500 mL bottle was immersed about 20 cm below the water surface, was filled to the brim and was tightly sealed. Whereas, similarly for the 300 mL glass bottles however after the water sample was filled in and tightly sealed, the glass bottles were wrapped with aluminum foil to protect the water sample from exposure to light. The collected sample bottles were well labelled and placed in icebox to maintain pH and temperature, and to minimize activities and metabolism of bacteria. Any accidental contamination has been avoided during water sample collection and transportation to the laboratory.

2.2 *In Situ* Water Quality Analysis

2.2.1 Physical Parameter (YSI 556 MPS Multi-probe Meter)

The instrument YSI 556 Multi Parameter (brand: YSI, United States of America (USA)) was employed to measure the temperature, pH, conductivity, salinity, TDS and DO water quality parameters *in situ* at each sampling site. After the probe module (protected with probe sensor guard) was connected to the instrument, it was first rinsed with distilled water. Then, the instrument was placed and immersed under the water surface (1.5 cm below the surface) at each sampling point. The module probe was continuously stirred and slightly moved until the readings on the instrument's screen stabilized. After getting the first reading (and recorded), the probe module is lifted and immersed again 1.5 cm below the water surface and these procedures were repeated 2 times to get an average. The sampling sites were observed, and the external factors were noted such as weather, condition of sampling site or main drain/discharge.

2.2.2 Turbidity (HACH 2100P Turbidity Meter)

Turbidity was also determined *in situ*, using the instrument HACH 2100P Turbidity Meter (brand: HACH, USA). Water samples were collected at each sampling site using a pail. Then, 15 mL water sample was poured into the sample cell up to the brim. Once inside the instrument cell compartment, the sample cell was carefully placed so that its mark lined up with the elevated orientation mark in front of the cell compartment. The cover was shut, readings were taken in triplicates and well recorded.

2.3 *Ex Situ* Water Quality Analaysis

After being collected, the water samples were brought to the lab for additional tests (COD and BOD). Following the manufacturer's instructions, the COD was analyzed using the Reaction Digestion Method 8000 (USEPA approved) and the colorimetric method using the DR890 colorimeter (brand: HACH, USA). In contrast, Method 8043 which was modified from Standard Procedures for the Examination of Water and Wastewater was used to analyze the BOD [15].

2.3.1 Chemical Oxygen Demand (COD)

Sample Digestion: After the water sample collected in the 500 mL sampling bottle was brought to the laboratory, it was first homogenized using a blender for 2 min and poured into a 500 mL beaker. Then, a COD Digestion Reagent Vial of the low range type (0 to150 mg/L) was held at an angle of 45-degree, into which 2 mL of homogenized water sample was pipetted. The COD vial's outside was cleaned with a gentle paper towel and washed with deionized water before being securely sealed. To mix the contents, the vial was held by the cap and repeatedly inverted. The vial was placed in a 150 °C preheated DRB 200 Reactor (HACH, USA) for 2 hours. A blank was prepared by substituting the sample with 2 mL deionized water. The vial was allowed to cool to 120˚C or below once the reactor was turned off (approximately 20 minutes). When the vial was still warm, it was inverted multiple times and set within a rack before being allowed to cool to room temperature.

The water sample that had undergone the digestion process, was analyzed using the DR 890 colorimeter (HACH, USA). Firstly, the device was zero calibrated using the prepared blank vial. To ensure correct alignment, the blank vial's outside was wiped with a towel before being pushed straight down until it sat firmly in the adaptor. The vial was then tightly covered with the instrument cap to prevent any external light interference. The procedures were repeated for water samples and the displayed COD readings were recorded.

2.3.2 Biological Oxygen Demand (BOD)

A series of detailed steps were followed based on the manufactucter's instruction to ensure accuracy and consistency in the results in measuring the BOD of water samples, following the 5-days incubation/test.

Dilution Water Preparation: Firstly, 1.5 L distilled water was prepared and stored in incubator at 20 °C. A suitable BOD nutrient buffer pillow was selected (cas: 1486166, HACH, USA) which are designed to treat a total volume of 300 mL water, hence a total of five buffer were required for 1.5 L distilled water. Each buffer pillow was tapped on a hard surface and shaken to mix the contents. Next, the contents of the buffer pillow were added to distilled water in a jug with plenty of headspace above the water (until about 3/4 full). To dissolve the nutrients and fill the water with air, the jug was tightly shaken for a minute while it was capped (to allow dissolution of oxygen).

Determination of sample volume: The sample volume was determined based on the estimated BOD. With an estimated BOD of 6 mg/L, 100 mL sample was required (Table 2).

Table 2. Minimum sample volume

Sample Type	Estimated BOD (mg/L)	Minimum Sample Volume (mL)
Polluted river water	6	100
	4	200
	2	300

BOD analysis: A total of 100 mL water sample (collected using the 300 mL glass bottle that was wrapped with aluminium foil) from each sampling point was carefully poured into BOD bottle (300 mL volume) and labelled accordingly. Each BOD bottle containing the water sample was then filled with dilution water just below the lip. To keep trapped air bubbles at bay, the diluting water was let to run down the bottle's sides. These steps were repeated for the remaining water samples into the second BOD bottle, from each sampling point. To act as a dilution water blank, an additional 300 mL of dilution water was added to a BOD bottle. This blank bottle was also labeled, and the dilution water was added carefully to avoid trapping air. The bottles were stoppered tightly to prevent any air bubbles and inverted several times to mix well. The stoppers were then lifted carefully to avoid introducing air bubbles.

A probe from a YSI 5000 dissolved oxygen instrument (YSI, USA) was used to measure the initial DO content for each bottle. Additionally, the dilution water blank's starting DO was measured. The dilution water was then poured into each bottle to just below the neck, again letting the water run down the sides to avoid air bubbles. Carefully stopping the bottles, more dilution water was poured to the lip of each BOD bottle to form a water seal. Each bottle's lip was covered with parafilm tape to keep the seal in place. For five days, the bottles were kept in an incubator with the temperature set to 20 °C. Each bottle's residual DO content was tested following the incubation time. The following formula was used to determine the BOD value:
When the water for dilution is not seeded:

$$BOD_5, \text{mg/L} = (D_1 - D_2)/P \quad (1)$$

Where:
BOD_5 = BOD value from the 5-day test
D_1 = DO of diluted sample immediately after preparation, in mg/L
D_2 = DO of diluted sample after 5-day incubation at 20˚C, in mg/L
P = Decimal volumetric fraction sample used (as the water sample to dilution water ratio is 1:3, hence 1/3)

2.4 Data Analysis

The mean and standard deviation of the results were displayed after a descriptive analysis. ANOVA was used to compare the water quality indicators between the various sampling locations. Data analysis was conducted using version 27 of the Statistical Package for the Social Sciences (SPSS) at a significance level of $p<0.05$.

3.0 RESULTS AND DISCUSSION

Land use changes driven by urbanization, industrialisation, and agricultural activities are expected to adversely affect water quality [16]. Table 3 presents an overview of the physico-chemical parameters of temperature, pH, salinity, conductivity, TDS, turbidity, COD, DO and BOD measured at eight different sampling points. Of these nine parameters, all readings fall within the standard for irrigation (Class IV) or better quality, except for specific parameters such as pH, DO, and BOD which exceeded the standard for certain points.

Temperature reflects the degree or intensity of heat within the irrigation water. Across all sampling sites, temperatures ranged from 23.20 °C to 30.60 °C, with an average of 26.83°C. Elevated temperatures were notably observed at sampling points with direct exposure to sunlight.

Table 3. Mean physico-chemical parameter water quality at different sampling points

Parameters	Unit	Mean ± SD									p value
		All points	Corn		Cucumber		Long bean		Luffa		
			Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Point 7	Point 8	
Temperature	(ºC)	28.18 ± 0.39	28.32 ± 0.02	28.45 ± 0.07	27.89 ± 0.02	28.47 ± 0.01	28.53 ± 0.01	28.60 ± 0.01	27.69 ± 0.02	27.54 ± 0.01	0.001*
pH		3.84 ± 1.34	3.51 ± 0.02	2.82 ± 0.07	5.81 ± 0.55	6.04 ± 0.01	3.23 ± 0.01	2.16 ± 0.01	3.90 ± 0.01	3.31 ± 0.09	0.001*
Salinity	Sal	0.02 ± 0.01	0.02 ± 0.01	0.01 ± 0.01	0.03 ± 0.01	0.02 ± 0.01	0.02 ± 0.01	0.02 ± 0.01	0.02 ± 0.01	0.02 ± 0.01	-
Conductivity	ms/cm	0.04 ± 0.01	0.04 ± 0.01	0.03 ± 0.01	0.07 ± 0.01	0.04 ± 0.01	0.04 ± 0.01	0.04 ± 0.01	0.04 ± 0.01	0.04 ± 0.01	-
Total dissolved solid (TDS)	mg/L	28.19 ± 7.38	26.00 ± 0.01	19.00 ± 2.82	42.50 ± 2.12	36.00 ± 1.41	27.50 ± 0.71	27.50 ± 0.71	24.00 ± 0.01	23.00 ± 0.01	0.001*
Turbidity	NTU	131.88 ± 79.54	228.50 ± 2.12	246.50 ± 0.71	125.70 ± 0.94	201.50 ± 0.82	66.50 ± 0.71	75.50 ± 0.71	34.00 ± 0.01	76.50 ± 0.71	0.001*
Chemical Oxygen Demand (COD)	mg/L	43.63 ± 9.72	36.00 ± 5.66	47.00 ± 4.24	38.00 ± 2.82	46.00 ± 2.82	32.00 ± 2.82	43.00 ± 1.41	43.00 ± 4.24	64.00 ± 2.82	0.001*
Dissolve oxygen (DO)	mg/L	3.45 ± 0.55	3.72 ± 0.04	4.33 ± 0.03	4.01 ± 0.05	3.26 ± 0.08	3.21 ± 0.01	3.45 ± 0.01	2.50 ± 0.10	3.15 ± 0.18	0.001*
Biological Oxygen Demand (BOD)	mg/L	5.80 ± 6.43	15.69 ± 0.01	16.26 ± 0.01	1.27 ± 0.01	0.92 ± 0.01	2.19 ± 0.01	2.40 ± 0.01	7.50 ± 0.01	0.24 ± 0.01	-

*p<0.05, statistical test – ANOVA

The pH scale has a neutral value of 7 and ranges from 1 to 6, representing acidity, and an alkaline range of 8 to 14. According to the National Water Quality Standards (NWQS), water utilized for irrigation is classified as Class IV (refer Figure 1), with a pH range of 5 to 9 [9]. However, the results obtained indicated strong acidity at all sampling points, with pH values below 4, except for Point 3 and Point 4 (near cucumber crop), which had pH values of 5.81 ± 0.55 and 6.04 ± 0.01, respectively. The lowest pH values during observation period was recorded at sampling point 6 at pH level 2.16 ± 0.01. The acidity may result from fertilizer and pesticide leaching, which contain chemicals that release acidic elements. Fertilizers containing ammonium, such as ammonium-based fertilizers, can lead to soil acidification. This occurs during the nitrification process, where ammonium is converted into nitrate, releasing hydrogen ions into the soil and increasing its acidity. It can also be attributed to the nitrification process of excess nitrogen fertilizer [17]. Additionally, different crops, such as corn, cucumber, long bean, and luffa, were grown in the area during the sampling period, and different crops have varying effects on soil and water pH. The stage of crop growth can also impact nutrient uptake and, consequently, the pH of the water. The results contradicted with the previous findings at paddy cultivation in Bachok, Kelantan reported pH 6.6 [2]. Further analysis using ANOVA revealed significant differences in pH values between different sampling points.

According to Millar et al. [18] TDS refers to total dissolved salts or mobile charged ions in water. This comprises both volatile and non-volatile solids, soluble hydrogen carbonate ions, chloride salts, sulfates, calcium, magnesium, sodium, and potassium. TDS is frequently linked to conductivity, salinity, alkalinity, and hardness measurements [19]. On the other hand, suspended solids indicate the existence of contaminants, which include both organic and inorganic materials such as sewage, dead plants, and industrial waste. The turbidity (cloudiness) of water is often correlated with the values of total suspended solids (TSS). High TSS levels and murky water prevent sunlight from penetrating the water, which stunts the growth of algae and plants. In actuality, the TDS findings at every test location fell short of the NWQS water quality standard for

Class I (<500 mg/L). While sampling point 2 had the highest turbidity value (246.50 ± 0.71 NTU), there is no set standard value for turbidity in Class IV water.

COD measures the amount of oxygen required to oxidize organic matter using a strong oxidizing agent. It is commonly used as an indirect indicator of the concentration of organic compounds in aquatic systems [20, 21]. Higher COD levels indicate a greater level of pollution in the water. The average COD was highest at sampling point 8, with values ranging from 32.00 to 64.00 mg/L across all sampling locations. The mean COD concentration was 43.63 ± 9.72 mg/L, which falls within Class III NWQS, and is considered acceptable for irrigation. Although this value is better than the standard for irrigation use, the study's findings indicate that the water is more polluted compared to other studies in Malaysia [2, 22].

DO refers to the amount of oxygen present in aquatic environments [23]. Low levels of dissolved oxygen indicate contamination. In this study, the average DO value across all sampling point was 3.45 ± 0.55 mg/L, which falls within Class III NWQS and is consistent with previous study [2]. The highest mean concentration of DO was found at sampling point 2 and the lowest mean concentration was found at sampling point 7. The highest mean DO concentration was observed at sampling point 2, while the lowest was at sampling point 7. Human activity and temperature have an impact on DO levels. As temperature rises, oxygen solubility in water drops [23, 24]. Additionally, agricultural activities can introduce organic waste into the water, further reducing DO levels. When DO levels are low, anaerobic microorganisms break down organic matter, releasing substances such as ammonia, nitrite, ferrous iron, hydrogen sulphide, and dissolved organic compounds into the water.

BOD measures the amount of dissolved oxygen required by aerobic organisms to break down organic material in a water sample at a specific temperature over a defined period [25, 26]. BOD is influenced by factors such as temperature, pH, the presence of certain microorganisms, and the amount of organic or inorganic substances in the water. It is commonly used to measure the amount of dissolved oxygen consumed by microorganisms during the decomposition of organic matter. This measurement helps determine the overall water quality and the extent of pollution caused by biodegradable organic material [20]. The mean BOD value across all sampling points was 5.80 ± 6.43 mg/L, placing it within Class III of the NWQS, however, the water is more polluted than other irrigation sources [2].

Table 4 shows that, except for COD, there were significant differences in mean values of physicochemical parameter of water quality when analyzed using ANOVA by types of crops (corn, cucumber, long bean and luffa), with $p < 0.05$. The highest mean DO and BOD was observed in irrigation near corn crop. One possible explanation for this is the use of pesticides and fertilizers to repel insects that damage corn and to maintain soil fertility leading to leaching into the water [27]. During a brief interview with a farmer, it was noted that most of the fertilizers and pesticides used are organic, which could account for the higher BOD levels found in various runoff samples. When selecting pesticides, it is crucial to consider their leaching potential, especially when the site has shallow groundwater and permeable soil. Farmers should consistently monitor their cornfields by checking the BOD, COD, pH, and turbidity of nearby water sources to ensure that the substances applied to crops remain within the permissible limits for water quality.

Table 4. Mean difference of physicochemical parameter water quality by types of crops

Parameters	Unit	Mean ± SD				p value
		Corn	Cucumber	Long bean	Luffa	
Temperature	(ºC)	28.38 ± 0.08	28.12 ± 0.34	28.55 ± 0.06	27.61 ± 0.09	0.001*
pH		3.16 ± 0.41	5.93 ± 0.35	2.70 ± 0.62	3.61 ± 0.35	0.001*
Salinity	Sal	0.02 ± 0.01	0.03 ± 0.01	0.02 ± 0.01	0.02 ± 0.01	0.035*
Conductivity	ms/cm	0.035 ± 0.01	0.065 ± 0.01	0.040 ± 0.01	0.037 ± 0.01	0.001*
Total dissolved solid (TDS)	mg/L	22.5 ± 4.36	39.3 ± 4.03	27.5 ± 0.58	23.5 ± 0.58	0.001*
Turbidity	NTU	237.5 ± 10.47	163.75 ± 43.6	71.0 ± 5.22	55.25 ± 24.54	0.001*
Chemical Oxygen Demand (COD)	mg/L	41.50 ± 7.55	42.0 ± 5.16	37.5 ± 6.60	53.5 ± 12.47	0.094
Dissolve oxygen (DO)	mg/L	4.02 ± 0.36	3.63 ± 0.43	3.33 ± 0.14	2.83 ± 0.39	0.001*
Biological Oxygen Demand (BOD)	mg/L	15.98 ± 0.33	1.09 ± 0.20	2.29 ± 0.12	3.87 ± 4.19	0.001*

*p<0.05, statistical test – ANOVA

4.0 CONCLUSION

Identifying and managing irrigation water quality is crucial for preserving freshwater resources and ensuring sustainable agriculture. The irrigation water in this study is rated as good and suitable for irrigation, with the exception of a few spots that exceeded the requirement. This is because all water quality metrics in the study met the Class IV irrigation limit of the NWQS. Ammoniacal Nitrogen and total suspended solids were not measured, making it impossible to calculate and determine the water quality index (WQI). Strategies to control pollution from agricultural runoff and leaching of pesticides and fertilizers into the river should be considered. Decision-makers must take preventive action in order to protect water supplies. In drainage canals used for supplemental irrigation, where deterioration in water quality can have an immediate effect on agricultural operations, further research is required to examine the quality of the water.

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