

WATER AND SOIL PHYSICOCHEMICAL CHARACTERISTICS OF DIFFERENT RICE CULTIVATION AREAS

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Abstract. In this study, the physicochemical characteristics of water and soil in conventional and organic rice cultivations are determined. Physicochemical parameters for water and soil samples are assessed by laboratory analysis. Chemical and physical parameters for water quality include temperature, pH, dissolved oxygen (DO), chemical oxygen demand (COD), biochemical oxygen demand (BOD₅), total suspended solids, and heavy metals. Parameters for the physicochemical analysis of soil include pH, particle size distribution, organic carbon, electrical conductivity (EC), cation exchange capacity, and heavy metals. Based on the water quality index, water qualities of conventional and organic rice fields are categorized into Class III. Based on the independent sample t-test, significant differences are observed between conventional rice and organic rice for pH, DO, BOD₅, COD, ammoniacal nitrogen (NH₃-N), arsenic (As), chromium (Cr), iron (Fe), and nickel (Ni) ($p < 0.05$). For soil samples, significant differences are observed between conventional rice and organic rice for pH, organic matter (OM), EC, As, Cr, Fe, and Ni ($p > 0.05$). The results of this study can serve as a guideline and basis for future studies on irrigation water and soil quality in sustainable agricultural management in Malaysia.

Keywords: *Malaysia, physicochemical parameters, rice production, crop management, sustainable agriculture*

Introduction

Malaysia has 688,770 hectares of land for rice cultivation, which produced 2,739,606 metric tons of rice in 2016 (DOSM, 2018). Recently, the tremendous growth in the population has led to an increase in the rice productivity. The need for high rice production has led to the expansion of irrigated areas. As a result, the rice cultivation area has increased, while rice production has decreased from 2014 to 2017. Although the use of hybrid rice varieties introduced by the Malaysian Agricultural Research and Development Institute (MARDI) has overcome some of the issues, the yield is still a factor that limits the increased production level due to bad weather as well as pests and diseases (USDA, 2018). To drive the modernization of Malaysia's agro-food sector, the

rice sector was included in one of the seven specialized industries listed by the National Agro-Food Policy (DAN) 2011–2020. DAN 2011–2020 targets to increase productivity and yields to ensure a sufficient food supply, high-value and sustainable agricultural development. By 2020, the Malaysian government also aims to achieve 80% self-sufficiency in rice (MOA, 2016). Hence, the government has provided several incentives such as subsidized seeds and fertilizers to encourage rice production.

The expansion of irrigated areas has become one of the major challenges in ensuring food security due to the high input used in rice cultivation such as water, fertilizers, and pesticides (Bouman, 2007; Hanafiah et al., 2019). With respect to these issues in rice cultivation, several methods have been explored for the application of less input in rice production, such as aerobic rice cultivation, system of rice intensification, ground-cover rice production system, raising beds, and alternate wetting and drying (Farooq et al., 2009). Moreover, organic cultivation practices have become an alternative to sustainable rice production as these practices avoid the use of synthetic fertilizers and chemical pesticides and exhibit benefits in terms of food security (Champagne et al., 2007; Keawpeng and Meenune, 2012).

Previous studies have independently reported that non-sustainable agriculture techniques can cause water quality problems (Reche et al., 2016; Banch et al., 2020; Bong et al., 2020). Water contamination in rice fields is caused by the chemical substances used for soil fertilization and pest control (Rhee et al., 2011). Iqbal (2011) has reported that pesticides do not exhibit adverse effects due to their low application amount; however, the continuous use of pesticides can slowly disturb the ecosystem and living organisms. Rice cultivation under flooded conditions causes a change in microbial activities from the aerobic to anaerobic fermentation of organic matter in rice fields. Hence, anaerobic respiration can produce substances that can cause the chemical reduction of soil components (Ethan, 2015). However, Haeefele et al. (2014) have reported that some negative soil characteristics, including low nutrient reserves and an extremely low cation exchange capacity (CEC), are not considerably affected by flooding.

Water quality index (WQI) is a scale related to a group of parameters that are combined into a single number to determine the overall water quality status at a certain time and location (Yisa and Jimoh, 2010; Leščešen et al., 2015; Ashraf and Hanafiah, 2017; Hanafiah et al., 2018a, 2019). However, the water quality parameters used were varied. Meher et al. (2015) have reportedly utilized 14 parameters for determining the WQI of the Ganges River, including pH, total dissolved solids (TDS), alkalinity, dissolved oxygen (DO), conductivity, and turbidity. On the other hand, Al-Shujairi (2013) has developed WQI to evaluate the water quality of two rivers in Iraq by utilizing seven water quality parameters of pH, DO, TDS, total hardness, biochemical oxygen demand (BOD₅), nitrate (NO₃), and phosphate, respectively.

The physicochemical analysis of soil is another important factor in the agriculture sector for plant growth, crop nutrient management, and soil management. This assessment can aid farmers in managing the nutrient input for crops during cultivation. Several

parameters can be employed for the monitoring of agricultural soil, including electrical conductivity (EC), soil organic matter (SOM), and heavy metal analysis. Aimrun et al. (2011) have reported that EC can provide information regarding soil texture, thereby permitting the estimation of the water content. In addition, EC can serve as a proxy for the physicochemical properties of soil, such as SOM, cation content, and CEC (Liu et al., 2011; Li et al., 2013; Wang et al., 2016, 2018). Several studies of soil in paddy fields have been conducted in Malaysia. Aimrun et al. (2011) have conducted a study regarding paddy soil properties and yield characteristics based on EC, while Khairiah et al. (2009) have conducted a study focusing on the heavy-metal content in paddy soil in Kedah. Physicochemical analysis of soil properties in rice fields can serve as a basis and reference to improve the rice cultivation process and reduce the environmental pollution in rice fields.

In recent years, as a result of increasing concerns of environmental pollution due to the application of chemical fertilizers, several efforts have been made to replace chemical fertilizers by organic fertilizers (Zhao et al., 2015; Lenka et al., 2016). Previously, Jat et al. (2015), Singh et al. (2017), and Thakur et al. (2016) have independently reported that organic rice cultivation increases rice production. However, the environmental impact also should be emphasized while simultaneously aiming for high rice productivity to ensure environmental sustainability. Currently, only a few studies on the impact of conventional and organic rice cultivations on the environment in Malaysia have been conducted. Accordingly, it is imperative to conduct a performance evaluation study on the physicochemical characteristics of water and soil for the purpose of increasing the rice yield and sustaining its production to meet the requirements in Malaysia. Hence, this paper aims to determine the physicochemical properties of water and soil for conventional and organic rice cultivations.

Materials and Methods

Samples collection and preservation

The water and soil samples were collected at Sabak Bernam, Selangor, Malaysia, from conventional and organic rice fields (3.684153°N, 101.022841°E) (*Figure 1*). Soil and water samples were collected from six sampling stations consists of conventional and organic rice fields. In total, 18 sampling points were included in the analysis. Water and soil samples were placed in polyethylene bottles and plastic bags, respectively. Water samples were preserved at 4–5°C to minimize biological activity and chemical changes. Soil samples were dried at room temperature in the laboratory before analysis was conducted. For BOD₅ tests, samples were collected using glass bottles wrapped with an aluminum foil to avoid the penetration of sunlight into the bottles. Samples for heavy metal tests were placed in different 50-mL polyethylene bottles. Samples were acidified to a pH less than 2 by the addition of HNO₃ to the samples. All samples that could not be analyzed immediately in the field were preserved following the method recommended by

GEMS (1978) and were transported to the laboratory within 24 h of sampling. *Table 1* summarizes the description of each sampling station.

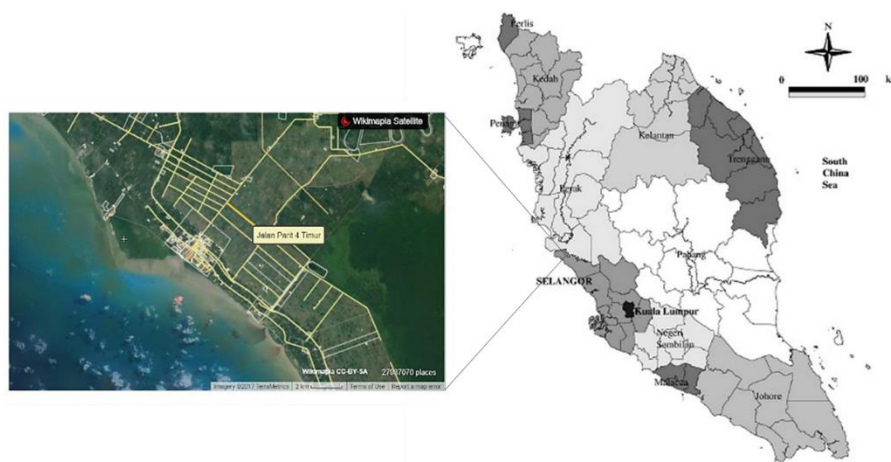


Figure 1. Location of conventional and organic rice fields for water and soil sampling

Table 1. Description of each sample based on the sampling station

Sampling station	Description
S1; P3	Located at the inlet of conventional rice field.
S2; P2	Located at the conventional rice field. There are paddy planting activities occurred such as fertilizing and pesticide application.
S3; P3	Sampling was done at the outlet of conventional rice field.
T1; Q1	Located at the inlet of organic rice field.
T2; Q2	Located at the middle of organic rice field. There are organic paddy planting activities occurred such as application of effective microbes.
T3; Q3	Located at the outlet of organic rice field.

S = represent water samples in the conventional rice field, T = represent water samples in the organic rice field, P = represent soil samples in the conventional rice field, Q = represent soil samples in the organic rice field

Water quality was analyzed according to temperature, pH, DO, BOD₅, COD, ammoniacal nitrogen, total suspended solid (TSS), and heavy metals. DO values, water temperature, and pH values were measured in situ using a YSI Model 556 Multi Probe system. COD, TSS, BOD₅, and ammoniacal nitrogen were analyzed in the laboratory following American Public Health Associations Standard (APHA, 1998) standard procedures. *Table 2* summarizes the parameters, methodology, and instruments used in this study.

Table 2. Parameters, applied methodologies, and instruments used in this study for the physicochemical analysis of water and soil

Parameters	Methodology	Instrument
Water analysis		
Temperature	-	YSI Pro2030 DO Meter
pH	-	pH meter HI8424
Dissolved oxygen (DO)	-	YSI Pro2030 DO Meter
Bio-chemical oxygen demand (BOD ₅)	BOD ₅	YSI 5000 Dissolved Oxygen meter
Chemical oxygen demand (COD)	Closed reflux	
Ammoniacal nitrogen	Direct Nesslerization	Hach DR 6000 spectrophotometer
Total suspended solid (TSS)	Photometric	
Heavy metals	EPA Method 200.8	Inductively Coupled Plasma Mass Spectrometry (ICP-MS)
Soil analysis		
pH	Was determined in distilled water with ratio 1:2.5 of soil: distilled water	pH meter (DELTA 320 model)
Organic matter	Gravimetric method based on loss on ignition	Oven, furnace, weighting scale
Electrical conductivity	Was determined in saturated extract of gypsum	EC meter Model H 18819 Hanna
Particle size distribution	Pipette method together with dry sieving	Sieve (ASTM)
Cation exchange capacity	EPA Method 9081: Sum of basic cations with acidic cations through summation method	Centrifuge tube and stopper, mechanical shaker, volumetric flask 100mL, Inductively coupled plasma atomic emission spectroscopy (ICP-AES)
Heavy metals	Acid digestion Method 3050B	Inductively Coupled Plasma Mass Spectrometry (ICP-MS)

Water quality analysis

The use of water is classified based on six classes (i.e., class I, IIA, IIB, III, IV, and V) by the Department of Environment (DOE, 2006). To determine the quality of water samples under the National Water Quality Standards for Malaysia (NWQS), WQI was calculated by the following equation *Eq. 1*:

$$\text{WQI} = (0.22 \times \text{SIDO}) + (0.19 \times \text{SIBOD}) + (0.16 \times \text{SICOD}) + (0.15 \times \text{SIAN}) + (0.16 \times \text{SISS}) + (0.12 \times \text{SIpH}) \quad (\text{Eq.1})$$

where,

SIDO = SubIndex DO (% saturation),

SIBOD = SubIndex BOD,

SICOD = SubIndex COD,

SIAN = SubIndex SS,

SIpH = SubIndex pH,

$0 \leq \text{WQI} \leq 100$.

Statistical analysis

Statistical analysis was done using the statistical package for social science software (SPSS). Data for physicochemical parameters of water and soil samples were represented as mean values. Independent sample t-tests were conducted to compare the results obtained for the water quality and physicochemical analysis of soil in different rice cultivation systems.

Results and discussion

Physicochemical properties of water in rice fields

Water quality is one of the key factors in the agriculture sector that ensures the healthy growth of crops (Harun and Hanafiah, 2018a, 2018b; Hanafiah et al., 2020; Nizam et al., 2020). The Department of Environment (DOE), Malaysia, has set six parameters to calculate the National Water Quality Index (Alssgeer et al., 2018; Hanafiah et al., 2018b; Ariffin et al., 2019): pH, DO, BOD₅, COD, ammoniacal nitrogen, and suspended solids. *Table 3* summarizes the physicochemical characteristics of water in conventional and organic rice fields.

pH is important for determining not only if a chemical or biological reaction can occur but also the degree of toxicity of some pollutants in water (Basheer et al., 2015). All samples were slightly acidic in the range from pH 5.41 ± 0.12 to 5.86 ± 0.18 for conventional rice fields and from pH 4.24 ± 0.13 to 4.50 ± 0.12 for organic rice fields (*Table 3*). Based on the NWQS for Malaysia, the average pH for conventional rice was categorized into class III, while the average pH for organic rice was categorized into class IV. Hence, the average pH values for conventional and organic rice are within the permissible range for irrigated agriculture. Results obtained from the independent sample t-test revealed a significant difference between conventional and organic rice ($p < 0.001$).

Table 3. Water analysis of conventional and organic rice fields

Parameter	Conventional rice				Organic rice			
	S1	S2	S3	Saverage	T1	T2	T3	Taverage
pH	5.86±0.18	5.41±0.12	5.58±0.10	5.62	4.24±0.13	4.50±0.12	4.39±0.25	4.38
DO (mg/L)	5.70±0.22	6.57±0.29	4.15±0.14	5.47	4.28±0.07	5.46±0.41	3.45±0.45	4.40
BOD ₅ (mg/L)	1.16±0.32	2.48±0.11	1.27±0.20	1.64	0.90±0.30	1.44±0.19	0.62±0.35	0.99
COD (mg/L)	11.45±3.48	29.88±0.32	27.68±1.45	23.00	27.16±2.02	47.83±2.84	38.09±1.62	37.69
NH ₃ -N (mg/L)	0.57±0.03	2.44±0.04	1.38±0.02	1.46	0.32±0.03	1.23±0.02	0.85±0.04	0.80
TSS (mg/L)	43.26±0.35	73.17±0.82	41.65±0.46	52.69	53.86±1.68	85.03±3.63	45.98±0.65	61.62
As (µg/L)	2.42±6.13E-05	3.38±3.30E-05	3.74±6.24E-05	3.18	2.57±2.55E-05	6.94±4.85E-05	6.54±3.69E-05	5.35
Cd (µg/L)	1.30±1.63E-05	8.81E-01±1.21E-05	1.50±6.11E-05	294.60	1.16±2.77E-05	7.70±1.84E-04	3.51E-01±1.73E-06	119.95
Cr (µg/L)	2.85±3.51E-05	2.84±2.95E-05	2.28±3.15E-05	2.66	5.93E-01±4.33E-05	1.24±1.67E-05	1.09±2.52E-05	198.44
Cu (µg/L)	11.70±6.11E-05	7.86±4.61E-05	11.80±1.30E-05	10.456	11.40±2.57E-05	15.70±1.10E-04	8.77±1.50E-05	11.96
Fe (µg/L)	7.23E02±4.60E-04	1.18E02±8.94E-04	1.40E02±4.24E-04	1101.00	7.46E02±9.45E-03	5.36E02±2.25E-03	5.14E02±7.07E-04	3748.67
Mn (µg/L)	31.30±4.11E-04	77.80±1.73E-02	87.90±5.13E-05	65.67	31.60±2.14E-05	65.90±1.11E-04	56.00±9.42E-05	51.17
Ni (µg/L)	3.46±1.06E-04	4.66±1.80E-05	4.10±2.95E-05	4.07	3.27±1.40E-05	3.59±2.65E-05	3.32±5.13E-06	3.39
Pb (µg/L)	9.57±3.04E-04	7.11±3.21E-05	12.30±1.91E-05	9.66	9.60±1.90E-05	9.94±3.95E-05	10.2±2.36E-05	9.91
Zn (µg/L)	4.10E02±1.02E-04	1.47E02±1.97E-04	2.19E02±1.57E-04	258.67	3.85E02±5.17E-03	1.53E02±2.49E-04	1.60E02±1.66E-04	232.67

*dissolved oxygen (DO), chemical oxygen demand (COD), biochemical oxygen demand (BOD₅), total suspended solids (TSS), ammoniacal nitrogen (NH₃-N), arsenic (As), cadmium (Cd), chromium (Cr), iron (Fe), manganese (Mn), lead (Pb), zinc (Zn) and nickel (Ni)

On average, the conventional rice value was 1.24 greater than the organic rice value. pH values for conventional rice fields were greater than those observed for the water samples in organic rice fields due to the application of urea in the conventional rice field. The application of urea in agriculture leads to increased pH (Whalen et al., 2000; Liu et al., 2010). Among conventional rice samples, sample S2 exhibited the lowest pH as the sampling point was located in the rice field, which was related to the decay by stagnant water in the rice field (Lee et al., 2015). pH values reported herein were comparable with those (pH 5.51–5.99) reported previously by Lee et al., (2015). The pH values recorded for water were within the permissible range for irrigation purposes as specified by the DOE.

Average ranges of DO recorded for conventional and organic rice were 4.15 ± 0.14 mg/L to 6.57 ± 0.29 mg/L and 3.45 ± 0.45 mg/L to 5.46 ± 0.41 mg/L, respectively (Table 3). Based on the NWQS for Malaysia, the average DO for conventional rice was categorized into class II, while the average DO for organic rice was categorized into class III. Hence, the recorded DO values of water are within the permissible range for irrigation and fishery purposes as specified by the DOE, Malaysia. Results obtained from the independent sample t-test revealed that significant differences are observed between conventional and organic rice ($p < 0.05$). On average, the conventional rice value was 1.08 greater than the organic rice value. Among conventional rice samples, sample S2 exhibited the highest mean DO value, while among organic rice samples, sample T2 exhibited the highest mean DO value due to the location of both samples S2 and T2 in the rice field. Adequate DO is a major indicator for good water quality as DO is crucial for the survival of aquatic organisms. Ariffin et al. (2019) have reported that aquatic life experiences stress if the water oxygen levels drop to less than 5.00 mg/L, and some fish species (e.g., catfish and tilapia) require a minimum DO of 3.00 mg/L for survival. The DO value for conventional rice was greater than that for organic rice due to the depletion of oxygen water by organic materials used in rice farming (Xu et al., 2017). Al-Shami et al. (2010) have reported that DO values for rice fields are greater due to the photosynthesis by algal populations. Moreover, the strong wind and shallow water of rice fields lead to high water turbulence, leading to rich DO (Frei and Becker, 2005; Nugraheni, 2017; Sule et al., 2018).

Table 3 shows the average ranges of BOD₅ recorded for conventional and organic rice were 1.16 ± 0.32 mg/L to 2.48 ± 0.11 mg/L and 0.62 ± 0.35 mg/L to 1.44 ± 0.19 mg/L, respectively. Based on the NWQS, the average BOD₅ for conventional rice was categorized into class II, while the average BOD₅ for organic rice was categorized into class I. Hence, the recorded BOD₅ values of water are within the permissible range for irrigation and fishery purposes as specified by the DOE, Malaysia. Results obtained from the independent sample t-test revealed a significant difference between conventional and organic rice ($p < 0.05$). On average, the conventional rice value was 0.65 greater than the organic rice value. The BOD₅ values for conventional rice were greater than those for organic rice due to the fertilization activity. The highest BOD₅ values were observed for

sample S2 (conventional rice) and sample T2 (organic rice) due to their sampling location in the rice field. During the cultivation phase, the BOD₅ value increased due to the decay process as well as other contributors such as the fertilizer application, which increased the organic content of water bodies (Hanafiah et al., 2018c). Ariffin et al. (2019) have reported that the nutrient content of chemical fertilizers can lead to the increase in the microorganisms in water, thereby contributing to the high BOD₅ values.

Average ranges of COD recorded for conventional and organic rice were 11.45 ± 3.48 mg/L to 29.88 ± 0.32 mg/L and 27.16 ± 2.02 mg/L to 47.83 ± 2.84 mg/L, respectively (Table 3). Based on the NWQS, the average COD for conventional rice was categorized into class II, while the average COD for organic rice was categorized into class III. Hence, the recorded COD values of water are within the permissible range for irrigation and fishery purposes as specified by the DOE, Malaysia. Results obtained from the independent sample t-test revealed a significant difference between conventional and organic rice ($p < 0.01$). On average, the organic rice value was 14.69 greater than the conventional rice value. The COD values for organic rice were greater than those for conventional rice due to the level of organic matter resulting from the organic fertilization of the organic rice field (Ahmad et al., 2014).

Average ranges of NH₃-N recorded for conventional and organic rice were 0.57 ± 0.03 mg/L to 2.44 ± 0.04 mg/L and 0.32 ± 0.03 mg/L to 1.23 ± 0.02 mg/L, respectively (Table 3). Based on the NWQS, the average NH₃-N for conventional rice was categorized into class IV, while the average NH₃-N for organic rice was categorized into class I. Hence, the recorded NH₃-N values of water are within the permissible range for irrigation and fishery purposes as specified by the DOE, Malaysia. Results obtained from the independent sample t-test revealed a significant difference between conventional and organic rice ($p < 0.05$). On average, the conventional rice value was greater than the organic rice value by 0.66. NH₃-N values for conventional rice were greater than those for organic rice due to the high application of urea in the conventional rice field. The decay of discharged organic waste in water can lead to the increase in the ammonia concentration (Li et al., 2008; Asman et al., 2017). Yang et al. (2017) have reported that a high pH value for the conventional rice field leads to a high ammoniacal nitrogen value as pH can increase the rate of dissolved ammonia available for volatilization.

Average ranges of TSS recorded for conventional and organic rice were 41.65 ± 0.46 mg/L to 73.17 ± 0.82 mg/L and 45.98 ± 0.65 mg/L to 85.03 ± 3.63 mg/L, respectively as shown in Table 3. Based on the NWQS, the average TSS results for conventional rice and organic rice were categorized into class III. Hence, the recorded TSS values of water are within the permissible range for irrigation and fishery purposes as specified by the DOE, Malaysia. Results obtained from the independent sample t-test revealed no significant differences between conventional and organic rice ($p > 0.05$). On average, the organic rice value was 8.93 greater than the conventional rice value. The nature of the muddy condition of rice fields as well as cultivation activities such as ploughing have contributed to high TSS (Al-Shami et al., 2010). Moreover, the

application of organic fertilizers in the organic rice field has increased the density of phytoplankton, thereby contributing to the increase in the TSS (Ahmed et al., 2013).

Results obtained from the independent sample t-test revealed a significant difference between conventional and organic rice for As, Fe, and Ni ($p < 0.01$) and Cr was $p < 0.001$. On average, the organic rice values for As and Fe were greater than the conventional rice values by 0.02 and 2.65, respectively. On the other hand, the average conventional rice values for Ni and Fe were greater than the organic rice values by 0.01 and 0.02, respectively. Harun and Hanafiah (2018a) have reported that the application of chemical fertilizers in the rice field leads to the increase in the heavy metal concentration. Notably, the organic rice field in this study was previously implementing conventional rice cultivation practices. Hence, similar results for heavy metals are observed for conventional and organic rice fields. The highest concentration of Fe was observed in the conventional and organic rice fields. Iron toxicity in lowland rice fields was related to the flooded condition and pesticide application during cultivation (Fageria, 2007).

Nutrients lost from the rice cultivation phase contaminate water bodies. Hence, concerns over the water quality of rice fields have increased in recent decades. The obtained results revealed that the WQI for conventional and organic rice is categorized into class III based on the WQI classification by the DOE, Malaysia. Hence, the WQI is suitable for irrigation and fishery activities. However, for water supply purposes, extensive water treatment needs to be conducted (Halim et al., 2017; Manikam et al., 2019). The results obtained herein were similar to those previously obtained by Ahmad et al. (2014) and Haque et al. (2010). In conclusion, the conventional rice cultivation in the examined rice field follows the permissible rate of fertilizer and pesticide applications. The results obtained herein can serve as a guideline for the future water quality management in rice field studies.

Physicochemical analysis of soil

Physicochemical analysis of soil for conventional and organic rice fields was performed according to parameters such as pH, SOM, EC, particle size distribution, and heavy metal analysis. *Table 4* summarizes the results obtained.

Average ranges of pH recorded for conventional and organic rice were 5.13 ± 0.02 to 5.30 ± 0.01 and 4.20 ± 0.10 to 4.43 ± 0.06 , respectively (*Table 4*). Results obtained from the independent sample t-test revealed a significant difference between conventional and organic rice ($p < 0.001$). On average, the conventional rice value was 0.86 greater than the organic rice value. The results obtained herein were comparable with those obtained by Aishah et al. (2010) and Khairiah et al. (2009), with the soil pH ranges within 4.63–5.14 and 4.5–5.0, respectively. In addition, the soil pH values for rice cultivation recommended by MARDI were within the pH range of 5.5–6.5 (Aishah et al., 2010).

Table 4. Physicochemical analysis of soil

Parameter	Conventional rice				Organic rice			
	P1	P2	P3	Paverage	Q1	Q2	Q3	Qaverage
pH	5.14±0.05	5.30±0.01	5.13±0.02	5.19	4.43±0.06	4.20±0.10	4.37±0.06	4.33
SOM (%)	1.90±0.02	3.33±0.15	2.66±0.12	2.63	2.77±0.15	3.68±0.16	3.15±0.05	3.20
EC (µS/m)	0.25±0.02	0.35±0.03	0.32±0.01	0.31	0.22±0.01	0.26±0.01	0.22±0.01	0.23
Silt (%)	65.00±2.00	62.33±0.58	56.00±3.61	61.11	59.67±2.72	68.67±3.51	63.00±4.00	63.78
Clay (%)	29.00±1.30	32.00±4.04	36.67±5.69	32.56	28.81±1.92	23.00±4.36	29.00±6.08	26.94
Sand (%)	6.00±0.44	5.67±2.00	7.33±2.65	6.33	11.52±0.52	8.33±3.21	8.00±2.18	9.28
As (µg/L)	31.0±4.48E-05	13.95±0.01	16.63±1.30E-05	20.5	27.49±1.93E-05	40.09±2.24E-05	75.09±1.08E-05	47.57
Cd (µg/L)	0.94±6.25E-05	1.45±5.19E-05	0.59±5.13E-06	20.57	0.81±1.31E-05	1.39±0.00	0.21±8.54E-06	0.81
Cr (µg/L)	1.7E02±7.69E-05	12.53E01±4.20E-05	1.41E02±2.02E-04	145.65	1.40E02±0.01	1.30E02±0.00	1.39E02±5.27E-04	136.72
Cu (µg/L)	5.4E01±6.54E-05	47.12±5.43E-05	46.427±6.52E-05	49.18	50.99±0.01	46.56±0.01	37.08±2.48E-05	44.88
Fe (µg/L)	11.7E04±0.01	71.75E03±0.01	84.99E03±3.31E-04	91.33E03	68.67E03±51.39	15.27E04±0.01	25.66E04±0.01	15.33E04
Mn (µg/L)	5.55E02±0.002	5.47E02±8.31E-05	3.47E02±4.67E-05	483.00	4.90E02±5.75E-05	2.78E02±9.29E-06	2.55E02±5.77E-05	341.20
Ni (µg/L)	36.99±6.29E-05	29.09±4.47E-05	28.39±9.51E-05	31.49	30.08±5.44E-05	22.86±4.74E-05	24.64±1.25E-05	25.86
Pb (µg/L)	2.24E02±5.9E-05	1.92E02±0.01	2.07E02±3.68E-05	207.67	1.99E02±8.18E-05	1.99E02±2.44E-05	2.05E02±2.13E-05	201.33
Zn (µg/L)	1.57E02±4.66E-05	1.05E02±0.01	1.50E02±5.38E-05	137.00	1.33E02±2.55E-05	1.33E02±6.87E-05	1.13E02±5.88E-05	126.51

* soil organic matter (SOM), electrical conductivity (EC), arsenic (As), cadmium (Cd), chromium (Cr), iron (Fe), manganese (Mn), lead (Pb), zinc (Zn) and nickel (Ni)

In addition, the use of chemical fertilizers has led to the increase in the soil humus, thereby affecting the pH values (Ahmad et al., 2014). Previously, Angelova et al. (2013), Sarwar et al. (2008) and Smiciklas et al. (2008) have reported that the application of organic fertilizers in rice fields leads to the decrease in the pH values as the application of organic fertilizers in organic rice field contributes to the production of organic acids such as amino acids and humic acid during the mineralization of organic materials by heterotrophs and nitrification by autotrophs; hence, a low pH is obtained (Sarwar et al., 2008).

Table 4 shows the average ranges of SOM recorded for conventional and organic rice were $1.90 \pm 0.02\%$ to $3.33 \pm 0.15\%$ and $2.77 \pm 0.15\%$ to $2.77 \pm 0.15\%$, respectively. Results obtained from the independent sample t-test revealed a significant difference between conventional and organic rice ($p < 0.05$). On average, the SOM of organic rice was 0.57 greater than that of conventional rice. The application of an organic fertilizer leads to a high content of organic matter in the soil (Kushwaha et al., 2001; Selvakumari et al., 2001; Smiciklas et al., 2008). Organic matter plays a key role in binding soil particles; hence, soil strength is enhanced. In addition, high organic matter can contribute to the high productivity (Hasan et al., 2020).

Soil EC is the ability of the soil to transmit an electrical charge (Chan et al., 2008). Average ranges of EC recorded for conventional and organic rice were 0.25 ± 0.02 mS/m to 0.35 ± 0.03 mS/m and 0.22 ± 0.01 mS/m to 0.26 ± 0.01 mS/m, respectively (*Table 4*). In this study, EC values were within the range of the suggested EC value (< 2.70 mS/m) for rice cultivation in tropical Asia (MAFF, 1970). Results obtained from the independent sample t-test revealed a significant difference between conventional and organic rice ($p < 0.01$). On average, the conventional rice value was 0.073 greater than the organic rice value. In this study, urea was applied in the conventional rice field. The combination of urea and NPK fertilizers can afford a high EC value (Han et al., 2016). Selvakumari et al. (2001), and Smiciklas et al. (2008) have reported that the reading of EC can increase under acidic and alkaline conditions by the application of organic materials to the soil.

Table 4 shows the particle size distribution percentage. Based on the obtained results, the soil samples contain a high percentage of the silt and clay fraction (grain size $< 63 \mu\text{m}$) for conventional and organic rice fields. Based on the United States Department of Agriculture (USDA), the type of soil for conventional rice and organic rice herein was classified as silty clay loam and silty clay, respectively. Results obtained from the independent sample t-test revealed no significant difference between silt, clay, and soil for conventional and organic rice ($p > 0.05$). Dou et al. (2016) have reported that soil texture as well as the interaction between the water regime and cultivar affect the rice yield. In addition, the high clay soil can contribute to the high yield due to the finer particles of clay soil, which can retain water and nutrients better than sandy soil (Tsubo et al., 2007; Dou et al., 2016; Aboudi Mana et al., 2017).

Results obtained from the independent sample t-test revealed a significant difference ($p < 0.01$) between conventional and organic rice for As, Fe, Ni, and Cr ($p < 0.0001$).

Previously, the organic field in this study was practicing conventional rice farming; hence, the difference between the metal results is nearly the same. The use of chemical pesticides can lead to the increase in the heavy metal content of the rice field (Aimrun et al., 2011; Jamil et al., 2011). Results revealed that among the metals tested, the total Fe content was the highest. However, the value was considered to be less than that reported previously by Khairiah et al. (2009), where Fe values ranged from 254 to 379 mg/kg. Jamil et al. (2011) have reported that flooded conditions in rice fields lead to the precipitation of dissolved Fe. Hence, the oxidized condition of Fe can occur as finely grained hydrous oxides ($\text{Fe}(\text{OH})_3$) with a disordered structure; hence, mixing with clays is possible (Khairiah et al., 2009).

Conclusions

In this study, the water quality and soil physicochemical characteristics were assessed by laboratory analysis. We found that water quality measured from the organic and conventional rice fields was classified as Class III. Although similar water and soil quality obtained for all sampling stations from both organic and conventional rice fields, organic farming is a better alternative to overcome the environmental contamination that is caused from the constant utilization of chemical fertilizers. However, future study can be done by considering a longer temporal duration of the water and soil quality measurements for a better understanding of the physicochemical characteristics of water and soil in conventional and organic rice fields in Malaysia.

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