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Assessment the Correlation between seasonal climate variables and water quality in coastal area: Bangkok, Thailand

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Abstract

Water is valuable natural resources that provide to maintain the survival of human beings, aquatic plants and animals. Determination of suitable water quality is essential for survival aquatic plants and animals and sustainable of various water uses that are depended on the physical, chemical and biological characteristics. Water quality variation was caused by anthropogenic activities and natural process (seasonal and annual variations). Therefore, this research examined the correlation between seasonal climate variability (rainfall, mean air temperature) and water quality parameters (temperature, pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), ammonia (NH_3-N), nitrate (NO_3^--N), total coliform bacteria (TCB), and fecal coliform bacteria (FCB)) by using Pearson's correlation. In addition, seasonal pollution loads are also investigated by using average sampling methods. The correlation analysis results showed that air temperature has significant positive correlation with DO in summer, whereas it has significant negative correlation with BOD. Although air temperature was positive correlated with water temperature and DO during rainy season, it was negative correlated with BOD and TCB. However, DO showed significant negative correlation with rainfall in rainy season. In winter, air temperature has significant positive correlation with pH, DO, and water temperature, and negative correlation with BOD. The results show that pollutant loads are highest in the rainy season followed by winter and summer, respectively. Therefore, this study suggests that famers need to consider water quality variations under seasonal climate change for culturing. Moreover, results can be used for sustainable water quality management in coastal aquaculture farming.

Keywords: Climate variable, Water quality, Aquaculture, Correlation

ထိုင်းနိုင်ငံ၊ ဘန်ကောက်မြို့၊ ကမ်းရိုးတမ်းဒေသရှိ ရာသီအလိုက်ပြောင်းလဲနေသည့် မိုးလေဝသ အခြေအနေများနှင့် ရေအရည်အသွေးအကြား ဆက်စပ်မှုများကို လေ့လာဆန်းစစ်ခြင်း

ဆုလှဲ့မြင့်၊ ဦးစီးအရာရှိ
ပတ်ဝန်းကျင်ထိန်းသိမ်းရေးဦးစီးဌာန

စာတမ်းအကျဉ်း

ရေသည် လူသားများ၊ ရေနေသတ္တဝါနှင့်အပင်များ အသက်ရှင်ရပ်တည်နိုင်ရန်အတွက် လွန်စွာအရေးပါသည့် သဘာဝသယံဇာတဖြစ်ပါသည်။ ရေနေသတ္တဝါနှင့်အပင်များ အသက်ရှင် ရပ်တည်ရေးအတွက် သင့်လျော်ကောင်းမွန်သည့် ရေအရည်အသွေးဖြစ်ရန် လွန်စွာအရေးကြီးပြီး အဆိုပါ ရေအရည်အသွေးသည် ရေ၏ ဓါတု၊ ရူပနှင့် ဇီဝဗေဒဆိုင်ရာ လက္ခဏာများပေါ် မူတည် ပါသည်။ ယခုအခါ လူသားတို့၏လုပ်ဆောင်မှုများနှင့် သဘာဝဖြစ်စဉ်များ (ရာသီအလိုက်၊ နှစ်အလိုက် ပြောင်းလဲနေသည့် ရာသီဥတုဆိုင်ရာ အခြေအနေ)ကြောင့် ရေအရည်အသွေး ပြောင်းလဲ လာခဲ့ပါသည်။ ထို့ကြောင့် ယခုသုတေသနသည် ရာသီအလိုက် ပြောင်းလဲနေသည့် ရာသီဥတု ဆိုင်ရာအခြေအနေများဖြစ်သည့် (မိုးရေချိန်၊ ပျမ်းမျှအပူချိန်)တို့နှင့် ရေအရည်အသွေး ဆိုင်ရာ parameters ဖြစ်သည့် temperature, pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), ammonia (NH_3–N), nitrate (NO_3^-–N), total coliform bacteria (TCB), and fecal coliform bacteria (FCB) တို့အကြား ဆက်စပ်မှု ရှိ/ မရှိကို Pearson's correlation ကို အသုံးပြု၍ လေ့လာခဲ့ပါသည်။ ထို့အပြင် ရာသီအလိုက်ပြောင်းလဲနေသည့် pollution loads သိရှိနိုင်ရန်အလို့ငှာ Average Sampling Methods အသုံးပြု၍ လေ့လာ ခဲ့ပါ သည်။ လေ့လာ ခဲ့မှုအရနွေရာသီ၌ လေထုအပူချိန် မြင့်နေချိန်တွင် ရေထုထဲတွင် Dissolved oxygen များပြီး Biological Oxygen Demand နည်းနေမှုကို တွေ့ရှိခဲ့ရပါသည်။ မိုးရာသီတွင်လည်း လေထု အပူချိန်မြင့်ပါက ရေထဲရှိ Dissolved oxygen နှင့် ရေအပူချိန် Water temperature မြင့်တက် နေပြီး Biological Oxygen Demand နှင့် TCB မှာ နည်းနေသည်ကို လေ့လာ သိရှိခဲ့ရပါ သည်။ သို့ရာတွင် မိုးရာသီ၌ မိုးရွာသွန်းမှုများပြီး မိုးရေချိန်များပါက ရေထဲရှိ Dissolved oxygen နည်းသွား သည်ကိုလေ့လာတွေ့ရှိခဲ့ရပါသည်။ ဆောင်းရာသီတွင်လည်း လေထုအပူချိန် မြင့်ပါက ရေထဲရှိ Dissolved oxygen ၊ ရေအပူချိန် Water temperatureနှင့် pH မြင့်တက်နေသည် ကို တွေ့ရှိခဲ့ပြီး Biological Oxygen Demand နည်းနေသည်ကို လေ့လာခဲ့ ရပါသည်။ ထို့အပြင် ရာသီ အလိုက် ရေထုထဲရှိ pollutant loads တွက်ချက်ခဲ့ရာ ရလဒ်များအရ မိုးရာသီ၌ ရေထုထဲရှိ pollutant loads အများဆုံးဖြစ်နေသည်ကို လေ့လာတွေ့ရှိခဲ့ရပါသည်။ ထို့ကြောင့် ယခုလေ့လာ ချက်အရ ကမ်းရိုး တန်း ဒေသတွင် ပုဇွန်မွေးမြူသူများ အနေဖြင့် ပုဇွန် မွေးမြူရေး လုပ်ငန်းများအတွက်ရာသီ

အလိုက်ပြောင်းလဲနေသည့် ရေအရည်အသွေးကို ထည့်သွင်းစဉ်းစားရန် လိုအပ်ပါ ကြောင်း အကြံပြုလိုပါသည်။ ထို့အပြင် ယခုသုတေသန ရလဒ်များကို ကမ်းရိုးတန်း မွေးမြူရေး လုပ်ငန်းများ အတွက် စဉ်ဆက်မပြတ်ရေအရည်အသွေး စီမံခန့်ခွဲမှုဆိုင်ရာ အစီအစဉ်များ ရေးဆွဲ ဆောင်ရွက်ရာ တွင် အသုံးပြုနိုင်ပါသည်။

Assessment the Correlation between seasonal climate variables and water quality in coastal area: Bangkok, Thailand

1. Introduction

Water is precious natural resource for human being survival, living organisms, aquatic ecosystem, fisheries, agricultural irrigation, and recreational activities (Sarker et al., 2015). It is the habitats of aquatic organisms' lives (Bandyopadhyay, 2008). Good water quality is essential for aquatic ecosystem. Determination the suitable water quality for survival of aquatic fauna and flora depend on physical, chemical, and biological characteristics (Ataguba et al., 2013).

Nowadays, anthropogenic activities (urbanization, industrialization, population growth, land use change, climate change, etc.) and natural process (temperature, precipitation rate, weathering processes, and hydrological conditions) are causes of water quality degradation or deterioration (Barakat et al., 2016; Qian et al., 2007). Municipal and domestic wastewater discharges from households, industries, and storm water runoff from agriculture and aquaculture farming are major pollutants entering water bodies (Quyang et al., 2006).

In addition, increasing greenhouse gas concentration can lead to different climate variables which can cause climate change. As climate change contributes extreme seasonal variations like increasing ambient air temperature, atmospheric deposition, extreme hydrological events (intense rainfall and drought), and raising solar radiation. These all are affected by surface water quality and lead to water quality degradation (Delpla et al., 2009; Duran-Encalada et al., 2017). Raising solar radiation causes increasing air and water temperature which can affect water quality. Increasing air temperature causes decreases in surface water quantity - in terms of increasing evapotranspiration rate. Besides, raising water temperature causes changing chemical and physical properties of water bodies and accelerates the eutrophication rate (Ataguba et al., 2013). Intense rainwater causes water resources contamination in terms of runoff. The large amounts of precipitation cause increasing the level of fecal contamination in surface water, and it can negatively affect on aquatic organisms (Laurent and Mazumder, 2014). Droughts increases dehydration and evaporation rate of surface water (Ahmed and Diana, 2015). Therefore, extreme seasonal variations caused by climate change lead to water quality degradation.

Mostly, in coastal areas, climate change causes flooding, and tidal fluctuations that can affect the water quality of these regions. Moreover, coastal water is recognized as a limitless absorber of waste from land and sea-based human activities, and contaminated by sewage and wastewater discharge from different point and non- point sources (Bandyopadhyay, 2008; Eng et al., 1989). Thus, coastal areas are more vulnerable than inland areas.

In coastal area, coastal land and water are common factors for onshore and offshore fish capture and aquaculture farming, especially for brackish shrimp and fish. Aquaculture farming is water intensive enterprise and needs daily water exchanges, therefore, aquaculture development depends on availability of water. In order to maintain the healthy ecosystem and nutritionally balanced, the available water quality must be suitable for aquaculture business especially in coastal area (Ataguba et al., 2013).

Coastal line of any country support many activities such as human settlements, industries, ports and harbors, agriculture and forestry, fishing and aquaculture, and tourism. In developing countries, most of the aquaculture farming occurs along coastal line (Bandyopadhyay, 2008). Thailand also possesses long coastal line bordering the Gulf of Thailand, and so on mostly aquaculture farming especially extensive and semi- intensive shrimp farming can be found around the coastal line (Anantanasuwong, 2001). Most of the farming directly take and use from adjacent canal water. Thus, canal water can affect on pond water quality. In addition, these farms culture fish and shrimp throughout of the year due to low production. Moreover, previously researches focuses on relationships between freshwater water quality and seasonal variables. There are few datapoints investigating the water quality in ponds and associated canals for aquaculture production (shrimp) in coastal areas and less information about the relationship between seasonal climate variables and water quality. Therefore, this research tries to assess the relation of seasonal climate variability and water quality near aquaculture in coastal areas.

2. Objective

1. To assess the correlation between seasonal climate variables and water quality in coastal area
2. To investigate seasonal pollution load of surface water near coastal aquaculture farms in coastal area

3. Methodology

3.1 study area

This study was conducted at Hua Krabue canal which is situated at the Bangkhuntien District of Bangkok province and Phra Samut Chedi District of Samut Prakan province in the central region of Thailand. Residential areas, factories and agricultural areas were located in the upstream of canal, whereas the Gulf of Thailand was situated in downstream of canal. This canal is important water resource for agriculture, aquaculture and transportation of the study area which is far around 10km from the Gulf of Thailand. Most of the coastal aquaculture farming especially extensive and semi-intensive shrimp and fishpond can be found along this canal. This study area has tropical monsoon climate. Thus, it occupied 3 seasons: rainy (middle of May to middle of October), winter (middle of October to middle of February) and summer (middle of February to middle of May) (www.tmd.go.th).

3.2 data collection and analysis

The climate data used for the study area were mean air temperature and precipitation that were collected from Meteorological Department of Thailand. Water quality parameters were water temperature, pH, DO, NH_3-N, TCB, FCB, biochemical oxygen demand (BOD), and NO_3^--N which were collected from three sampling points in Hua Krabue canal – C_0 (canal near water gate), C_1 (canal beside extensive farm), and C_2 (canal beside semi-intensive farm), and two sampling points in pond - P_1 at extensive pond and P_2 semi-intensive pond.

Each water sample was collected one day per each season during rainy (July), winter (December), and summer (March) season. For one season, samples were collected in every two hours from 7:00 am to 5:00 pm along the canal and ponds by grab sampling. Sample bottles and sampling devices rinsed three times with sample water before taking the sample. Then, sample water was collected in 1L polyethylene- plastic bottle for physiochemical parameters analysis and 500 ml steriled bottle for analysis of biological parameters. Collected water samples kept in coolers with ice pad and transported to laboratory on the same day and stored at 4 ^{o}C until analysis. However, sample water for biological parameters analysis separately kept in another icebox. Water depth and flow also measured at each sampling points during sample collection.

The analysis of physical and chemical parameters - water temperature, pH, DO, NH_3-N, biochemical oxygen demand (BOD), and NO_3^--N followed standard method for the Examination of Water and Wastewater (APHA, AWWA and WEF, 2012). To be accurate pH, dissolved oxygen (DO), water temperature and ammonia (NH_3-N) were examined on site measurement. Biological parameters of water quality: total coliform bacteria (TCB) and fecal coliform bacteria (FCB) were examined by membrane filtration with aseptic technique analysis within 24 hours.

3.3 statistical analysis

The correlation between two variables (climate parameters and water quality parameters) was analyzed using Pearson's correlation analysis to investigate the effects of seasonal climate variability on water quality. In this study, level of r-value was classified as follow: r = weak correlation (r= 0.10 - 0.25), r= fair correlation (r= 0.26 - 0.50), r= moderately strong correlation (0.51- 0.75) and r= strongly correlation (>0.75). Pearson's correlation coefficient (r) can be calculated following equation (1) (Prathumratana et al., 2008; Hong et al., 2010):

$$r = \frac{\sum(X-\bar{X})(Y-\bar{Y})}{\sqrt{\sum(X-\bar{X})^2\sum(Y-\bar{Y})^2}} \qquad \text{eq. (1)}$$

where, r is simple correlation of x and y variables, X is climatic parameters of the season, Y is water quality parameters of the season, X is mean climatic parameters for the season, and Y is mean water quality parameters for season.

3.4 pollution loads analysis

Pollution loads of NH_3-N, SS, BOD, NO_3^--N, TP, TCB, and FCB were investigated by using the average sample method (equation 2) as follows (Li et al., 2003; Son, 2013):

$$L_i=\left(\frac{1}{n}\sum_{i=1}^{n} C_i Q_i\right) \qquad \text{eq. (2)}$$

where: n is the number of samples within L_i segments; C_i and Q_i are the instantaneous values of concentration and water flow, respectively, at the time of each sampling.

4 Result and Discussion

4.1 seasonally water quality evaluation

Mean value and standard deviation of rainy, winter, and summer seasons samples collected for physical, chemical, microbiological water quality parameters were presented in **Fig 3.1 (a-i).** Water quality parameters of canal and pond were compared with referenced coastal water quality standard for aquaculture farm (class 3), 2006 and effluent standard of coastal aquaculture pond.

As detailed in **Fig. 3.1a,** water temperature was high in summer, low in winter and lowest in rainy at all sampling points in pond and canal. The range varied 29.05-29.25 ^{o}C in rainy season, 29.0 - 30.47 ^{o}C in winter, 30.77- 31.48 ^{o}C in summer at all sampling points. This range was within the coastal water quality standard (28-32 ^{o}C). Water temperature was higher during pre-monsoon periods because of heat raising the temperature of surface water. Intensity of solar radiation, evaporation, fresh water influxes and cooling influences surface water temperature (Gadhia et al., 2012). Similar results were found in the study of Barakat et al. (2015).

As shown in **Fig. 3.1b,** higher pH value of canal and pond was found in summer season in terms of higher photosynthesis rate in water, and lower rates in rainy season due to higher turbidity which blocks sunlight for photosynthesis. Similar results were found by the study of Barakat et al. (2016), Hanh et al. (2010), Ojok et al. (2017), Islam et al. (2015) and Sthiannopkao et al. (2014). However, the result of canal and pond water quality were suitable for coastal shrimp farming due to coastal water quality standard (7.0- 8.5) and effluent standard of coastal aquaculture pond (6.5-8.5).

According to **Fig. 3.1c**, highest DO content was found in summer season and lowest was found in rainy season at canal and pond. It might be due to a higher photosynthesis rate of algae under high temperature in summer. Xu et al. (2008) mentioned that algal photosynthesis can caused pH and DO value changes. Islam et al. (2014) also presented that high concentration of DO and pH value were found in dry season, and low content of DO and pH value was occurred in wet season. Ojok et al. (2017) mentioned that high temperature increased photosynthesis activities of aquatic organisms (plants and animal); consequently to high DO concentration in water bodies. In addition, similar findings were reported by Islam et al. (2015) and Uddinl et al. (2014). In this study DO content of canal water was met the coastal water quality standard (≥4 mg/l) in summer season. However, DO content of pond was met the coastal water quality standard in in all seasons. In addition, DO content of pond water was higher than canal water because pond water has more activities than canal water.

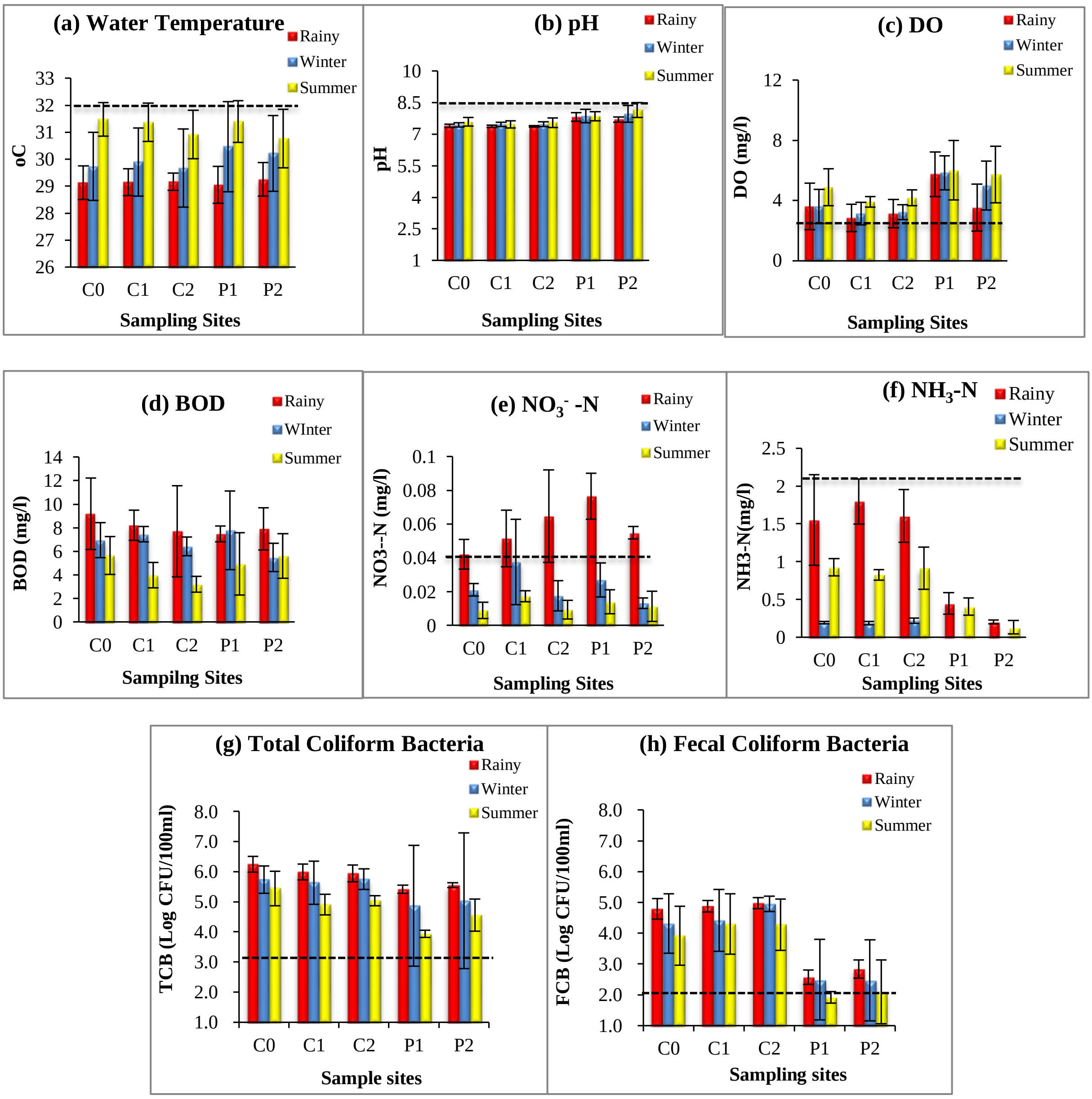

Figure. 3.1 a-i Chemical, physical, and microbiological properties of canal (C_0, C_1 and C_2) and pond (P_1 and P_2) water quality in rainy, winter and summer season.

As detailed in **Fig. 3.1d**, highest BOD value was found in rainy season and lowest was occurred in summer season at canal. It can also be due to high effluents discharge from industrial and urban area, and decomposition of organic matter in canal that combined with seawater during rainy season. This result was in accordance with Gadhia et al. (2012) who found that the level of BOD was high in monsoon, low in post monsoon and lowest in pre-monsoon. Besides, the result is similar to the finding of Ojok et al. (2017). However, the sampling point in pond P_1 showed highest amount of BOD in winter and lowest amount in summer. Canal water entered into this pond (P_1) because high water levels in the canals occurred in the winter. Thus, the BOD value of P_1 was highest in the winter season. At P_2, the value of BOD was higher in the rainy season compared with the winter and summer seasons. However, BOD of pond water (P_1 and P_2) met the effluent standard of coastal aquaculture pond (< 20 mg/l).

Due to **Fig. 3.1e**, maximum value of NO_3^--N was recorded in rainy season (0.04- 0.08 mg/l) and minimum value was recorded in summer season at all sampling points. Therefore, seasonal variation of NO_3^--N in pond and associated canal water has relationship in all seasons. If NO_3^--N concentration increased in canal during rainy, the concentration NO_3^--N in pond also increased. Similar result was found in the study of Mrozik et al. (2019). The reasons for this increasing NO_3^--N concentration in the rainy season is due to fresh water inflow and terrestrial runoff by intense rainfall, and oxidation of ammonia to nitrite formation (Gadhia et al., 2012; Hanh et al., 2010). Barakat et al. (2015) and Gadhia et al. (2012) presented that the concentration of NO_3^--N was high in monsoon and post monsoon compared to pre-monsoon. However, this canal water was still suitable for shrimp farming in all seasons except at C_2 where NO_3^--N concentration exceeded the coastal water quality standard of NO_3^--N (≤60 μg–N/l) for aquaculture farming during rainy season.

As shown in **Fig. 3.1f**, the value of NH_3-N was high in rainy season (0.20-1.8 mg/l), low in summer (0.20-0.92 mg/l) and lowest in winter season (0.02- 0.22 mg/l) at all sampling points. However, higher NH_3-N concentration was found in canal water compared with pond because canal water is receiver of waste from residential and agricultural area and pond water has self-purification. Therefore, the value of NH_3-N in canal exceeds the permissible limit for coastal water quality (< 7 μg N/l). Pond water quality was also still within the effluent standard of coastal aquaculture pond (<1.1 mg N/l).

At all sampling points, higher microbiological water parameters (TCB and FCB) amount observed during rainy season compared to winter and summer season, it might be due to large amount of rainfall, and higher surface runoff from surrounding land (**Fig. 3.1 g and h**). Barakat et al. (2016) presented that the amount of FCB was high in wet season. It comes from animal husbandry, grazing area, untreated wastewater, and application of manure. Hong et al. (2010) mentioned that level of coliform bacteria were high in wet season compared with dry season. Nguyen et al. (2016) mentioned that the amount of TCB was high in wet season and low in dry season. In addition, seasonal variation of TCB and FCB of canal has relationship with each associated pond. Therefore, the impact of TCB and FCB in canal can affect pond water quality; it might be due to directly use the canal water for aquaculture farming. Both TCB and FCB in ponds were less than in canal because of the stagnation of water in pond and sunlight could reduce the microorganisms. Mrozik et al. (2019) also mentioned that each canal is source of fecal bacteria which transported into pond water during water exchange. Thus, higher amount of bacteria could be occurred in pond if higher amount of bacteria found in canal.

4.2 analysis of seasonally correlation of water quality and climatic parameters

Table 3.1 shows the correlation of water quality parameter and climate data in rainy, winter and summer seasons. As detail in **Table 3.1**, air temperature and water temperature showed strong positive correlation in rainy (0.91 to 0.79) and in winter season (0.92 to 0.87), and fair positive correlation at canal (r= 0.37) and weak correlation at pond (r= 0.16) in summer season (r= 0.37). The same correlation results also found in all season at P1 and P2. Thus, it can be assumed that water temperature was consistent with air temperature in all seasons. Rahaman et al. 2015; Anisha and Yunus, 2016; Hammond and Pryce, 2007; Fonseca et al. 2014; Astrom et al. 2007 also mentioned that air and water temperature has direct relationship. However, water temperature has fair negative correlation with rainfall (-0.54 to -0.43) during rainy season,

As detailed in **Table 3.1**, pH has moderately strong positive (r= 0.68) and strong positive correlation (0.83 to 0.91) with air temperature in canal and pond, while it had a fairly negative correlation (r= 0.31) and moderately strong negative correlation (0.62 to 0.67) with rainfall in rainy season in canal and pond. Prathumratana et al. (2008), Delpha et al. (2009) and Anisha and Yunus, 2016 also presented that pH was negatively correlated with precipitation. Because of the chemical compositions of rainfall depends on air quality through its fall. Thus, low pH value was found during and after raining because rainwater washout acid ions in atmosphere. And then, pH presented a strong to fair positive correlation with air temperature in the winter (0.90 to 0.82) and summer (0.32 to 0.50) because higher temperatures accelerate the growth of algae and consequently increased hydrogen ions in water.

According to the **Table 3.1**, dissolved oxygen was strong positive correlated with air temperature in rainy (0.86 to 0.78), winter (0.78 to 0.90) and summer (0.96 to 0.75). During rainy season, DO and rainfall has strong negative correlation (r= -0.84) at canal and moderately strong negative correlation (-0.56 to -0.61) at pond because rainfall cause turbidity, which can block the sunlight and interfere photosynthesis in water bodies consequently to decrease dissolved oxygen. These results are in accordance with Prathumratana et al. (2008) who found that DO was negative correlated with precipitation and positive correlated with air temperature.

The data of **Table 3.1** presented that strong negative correlation was occurred between BOD and air temperature in rainy (r= -0.95), winter (r= -0.89) and summer season (r= -0.94). Besides, moderately strong positive correlation (r= 0.71) also found between rainfall and BOD in rainy season. Because increasing rainfall reduce dissolved oxygen through increasing turbidity in water. In wet season, discharge from different land use cause increasing BOD concentration in water (Bordalo et al., 2001).

Table 3.1 Seasonally correlation of water quality and climatic parameters of canal and pond water

Parameters	Rainy						Winter			Summer		
	Air Temperature			Rainfall			Air Temperature			Air Temperature		
	canal	P1	P2	canal	P1	P2	canal	P1	P2	canal	P1	P2
Water Temp	0.91***	0.88**	0.79*	-0.45	-0.54	-0.43	0.92***	0.87**	0.91***	0.37	0.16	0.94***
pH	0.68	0.91***	0.83**	-0.31	-0.62	-0.67	0.82**	0.90***	0.84**	0.32	0.50	0.90**
DO	0.86**	0.91***	0.78*	-0.84**	-0.56	-0.61	0.82**	0.78*	0.90***	0.75*	$\boxed{0.94^{***}}$	0.96***
BOD	-0.95***	-0.40	-0.67	0.71	-	0.59	-0.89***	-0.96***	-0.98***	-0.94***	-0.61	-
NH_3-N	-0.18	-0.43	-0.43	0.47	0.63	0.69	-0.59	-	-	0.44	-0.72	-0.51
NO_3^--N	-0.60	-0.70	-0.31	0.71	0.68	0.22	-0.03	-0.79*	-0.47	-0.59	-0.83**	-0.41

TCB	-0.79*	-0.33	-	0.17	-	0.32	-0.72	0.13	-	-0.43	-	-0.39
FCB	-0.36	-0.14	-0.60	0.52	0.47	0.10	-0.64	-	0.13	-0.38	-0.29	-0.47

Note- *Correlation is significant at the ≤ 0.1 (99%), ** Correlation is significant at the ≤ 0.05. (95%), ***Correlation is significant at the ≤ 0.01(90%), P_1- extensive pond, P_2- semi-intensive pond

NH_3-N has weak and moderately strong negative correlation with air temperature in rainy (r= -0.18), winter (r= -0.59), whereas it has fair positive correlation (r= 0.44) with air temperature in summer due to low dilution and high temperature (**Table 3.1**). Wyk and Scarpa, (1999) reported that the linear relation was found between unionized ammonia and temperature. Thuong and Thach, (2017) and Bandyopadhyay, (2008) mentioned that higher temperature causes raising microbial decomposition rate as a result, it could increase NH_3-N concentration that has negatively affected shrimp growth. During rainy season, NH_3-N has also fair positive correlation (r= 0.47) with rainfall due to increase discharge from residential area and agriculture land.

In case of nutrient parameters, NO_3^--N showed moderately strong negative correlation with air temperature in rainy (r= -0.60) and in summer season (r= -0.59) (**Table 3.1**). The study of Barakat et al. (2016) showed similar relationship between nitrate and air temperature. Increasing air temperature causes decreasing nitrate concentration (Delpla et al., 2009). Moreover, NO_3^--N has moderately strong positive correlation (r= 0.71) with rainfall during rainy season. As a result, higher runoff carried pesticides and fertilizers from agriculture lands, which can affect water quality by increasing pollutant concentrations (MRC, 2005; Qian et al., 2007). Similar result was found in the studied of Prathumratana et al. (2008).

In correlation matrix (**Table 3.1**), TCB was strong to fair negative correlation with air temperature in rainy, winter, and summer, (r= -0.79), (r= -0.70), (r= -0.43), respectively. In case of FCB showed fair negative correlation with air temperature in rainy (r= -0.36) and summer (r= -0.38) and moderately strong negative correlation in winter (r= -0.60). In addition, TCB and FCB have weak and fair positive correlation with rainfall in rainy season. The study of Leight et al. (2016); Astrom et al. (2007) and Laurent and Mazumder, (2014) showed that fecal and total coliform bacteria densities were positively correlated with precipitation and negatively correlated with air temperature. Nguyen at el. (2016) mentioned that TCB amounts were higher in wet season and lower in dry season. Hong et al. (2010) also presented that TCB and FCB increased by seasonal precipitation.

4.3 analysis of seasonal pollution loads

Table 3.2 presents seasonally pollutants load which was varied between different seasons in the study area. The highest loads of BOD (1,595.01 kg/ day), NO_3^-N (8.56 kg/ day), TCB (1.77277 E^+15 cfu/ day) and FCB (1.63721E^+14 cfu/ day) occurred in rainy season compared to winter and summer season. From present study, the high canal flow occurred in rainy season due to heavy and large amount of rainfall. Thus, pollutants load were high in rainy season due to increase discharge from different land use. In addition, land use and land cover changes of each study area are caused increases in water pollution during rainy season. Sthiannopkao, et al. (2014) mentioned that urban area pollution loads were depending on the precipitation. Qian et al. (2007), Arreghini et al. (2005) and Laznik et al. (1999) reported that pollutants load was higher in wet season than dry season (summer and winter) due to greatest total runoff from point source. Laznik et al. (1999) also mentioned that seasonal nutrient loads were direct correlated with seasonal variation in runoff. However, higher load of NH_3-N was observed during rainy and summer season than winter season. Because NH_3-N comes from the decomposition of organic matter that is, depend on temperature. Thus, the high NH_3-N was found in summer and rainy season because higher air and water temperature was found in summer and rainy season compared to winter season.

Table 4.6 Seasonal variation of pollutants load in canal

Pollution Load	Rainy	Winter	Summer
NH_3-N (kg/day)	297.79	22.06	95.39
BOD (kg/day)	1,595.01	767.71	435.59
NO_3^-N (kg/day)	8.65	2.91	1.21
TCB (cfu/day)	1.77×10^{15}	8.41×10^{14}	2.30×10^{14}
FCB (cfu/day)	1.63×10^{14}	8.39×10^{13}	3.92×10^{13}

5 Conclusion

This study revealed the correlation analysis results that DO has significantly positive correlation with air temperature in summer, while BOD has negative correlation with air temperature. In rainy season, significantly negative correlation was occurred between rainfall and DO, and between air temperature and two water quality parameters: BOD and TCB. However, significant positive correlation was observed between air temperature and two water quality parameters: DO and water temperature during rainy season. In winter, air temperature was significantly positive correlated with water temperature, pH and DO, whereas it was negative correlated with BOD. Regarding the pollution load analysis, high pollutants loads occurred in rainy season due to increase runoff and high water flow. In summer, NH_3-N concentration was also high in summer compared to winter season because of high temperature. Thus, it could be said that the winter season has less impact on water quality compared with other seasons. However, water quality variables under seasonal variations need to consider for sustainable water quality management of aquaculture farming which is located in coastal area.

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