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Research Article

Evaluate coastal seawater quality and propose sampling frequency for monitoring in the Northeast of Quang Ninh Province, Vietnam

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Abstract: Sampling frequency plays important role in water quality monitoring activity. A suitable sampling frequency could save time and cost of monitoring work. In this study, coastal seawater quality of the Northeast of Quang Ninh Province, Vietnam was evaluated by single indicator and statistical analysis of the monitored data from 2016–2019. Then the monitoring frequency was adjusted to match the current pollution status of the study area. The results showed that seawater of the area has good quality. Monitored parameters: pH, DO, TSS, Oil, and grease, Coliform were under the QCVN 10–MT:2015/BTNMT. The manager should pay more attention to NH_4^+ concentration in seawater by controlling the pollution source of $NH4^+$. Seawater sampling frequency should be rearranged. More samples should be taken at potential pollution points, while reduced in low potential pollution points.

Keywords: Coastal seawater; seawater quality; sampling frequency; Quang Ninh.

1. Introduction

Monitoring seawater quality plays important role in managing and controlling pollution in a coastal zone. The monitored data helps managers make right decisions to adjust polluted activities or to expand social economic development. A suitable seawater monitoring stations and frequency will inform right status of seawater quality, track the change, and identify pollution sources. To evaluate seawater quality, many methods could be used such as WQI [1–2], satellite imagery [3–4], grey systems theory [5], modelling [6]. Particularly, statistical method could be used to analyze water quality parameters and identify pollution factors or pollution sources [7–8]. In Vietnam, there are some researches were performed to assess seawater quality by monitoring station data in the South region of Vietnam [9], in Quang Ninh–Hai Phong coastal area [10], in Quang Binh province [11]. These researches mainly focused on assessing the status of water quality. To get more values, it is necessary to further analyze and use monitoring data. Determination of a suitable sampling frequency is important to water quality monitoring. A good sampling frequency could save time and cost. In addition, the number of samples could have influence on the evaluation of water quality status [12] or the usage of data, the prediction reliability of modelling [13]. Some common methods could be used to calculate water sampling frequency: statistical method [14], systems analysis [15], non–parametric tests [16] or cost–effective selection [17]. In which, historical monitoring data was an important parameter to calculate or adjust sampling frequency by statistical analysis [14, 18].

The Northeast region of Quang Ninh plays important role in development of social economic of the province. With the increasing of rapid investment and development in the region, seawater quality may be affected by those activities. Current seawater monitoring points in the region had equal sampling frequency as 4 samples/point/year. This frequency does not consider the current pollution status of the region and may not timely adjust to meet the rapid changing of environmental quality under the impact of increasing development activities. Therefore, it is necessary to analyze the seawater quality of the region, then propose a suitable sampling frequency to match the new management requirement.

In this research, a combination of water quality assessment by statistical analysis with historical monitoring data to analyze and propose a sampling frequency. The objectives of this study included: (1) Assessment of seawater quality of coastal zone in the Northeast region of Quang Ninh province from 2016–2019; (2) Calculate and adjust sampling frequency for monitoring points.

2. Methods

2.1. Study area

This study was conducted in coastal zone in the Northeast of Quang Ninh Province. The data was collected from 2016–2019 in 10 monitoring points (coded as P01–P10) (Table 1 and Figure 1). These points monitored the seawater quality through 6 parameters: pH, Dissolved Oxygen (DO), Total Suspended Solid (TSS), Oil and grease, Ammonium (NH_4^+), and Coliform [19]. These parameters play important role in evaluating coastal seawater for beaches and aquaculture.

Table 1. Coordinates of sampling points.

No.	Sampling points	Code	Coordinates	
			Latitude	Longitude
1.	Mong Duong river mouth	P01	21.07112	107.366827
2.	Cam Hai, Cam Pha City	P02	21.09351	107.371072
3.	Mui Chua Port	P03	21.28557	107.458244
4.	Dam Ha–Dam Ha District	P04	21.31621	107.629111
5.	Quang Phong, Quang Dien–Hai Ha District	P05	21.37457	107.751824
6.	Quang Nghia–Mong Cai City	P06	21.49848	107.817986
7.	To Chim–Hai Hoa–Mong Cai City	P07	21.5111	108.038567
8.	Tra Co Beach–Mong Cai city	P08	21.47793	108.029884
9.	Co To Port	P09	20.96942	107.761974
10.	Vung Cat 2. 3 Group 4, Co To Town	P10	20.95323	107.740462

2.2. Methods

2.2.1. Statistical analysis

The collected data were analyzed using R software – a statistical programming language. The ggplot2 package was used to draw graphs. The monitored data was compared with the national technical regulation on marine water quality QCVN 10–MT:2015/BTNMT.

2.2.2. Frequency calculation

To calculate water sampling frequency for multiple variables and multiple stations, [14] introduced an equation based on comparing the weighting factors of whole monitoring network [14, 18].

$$N_k = W_k \times P \quad (1)$$

where P is the total number of samples obtained through the monitoring network in a year; W_k weighting values of station s.

$$W_k = \frac{\sum_{j=1}^{n} W_i}{n}; \quad W_i = \left(\frac{M_i}{\sum_{i=1}^{s} M_i}\right) \quad (2)$$

where W_i is the weighting value of variable i at station s; N_k is the number of samplings at station i; M_i is the historical mean value of variables at station i; s is the number of stations; n is the number of variables.

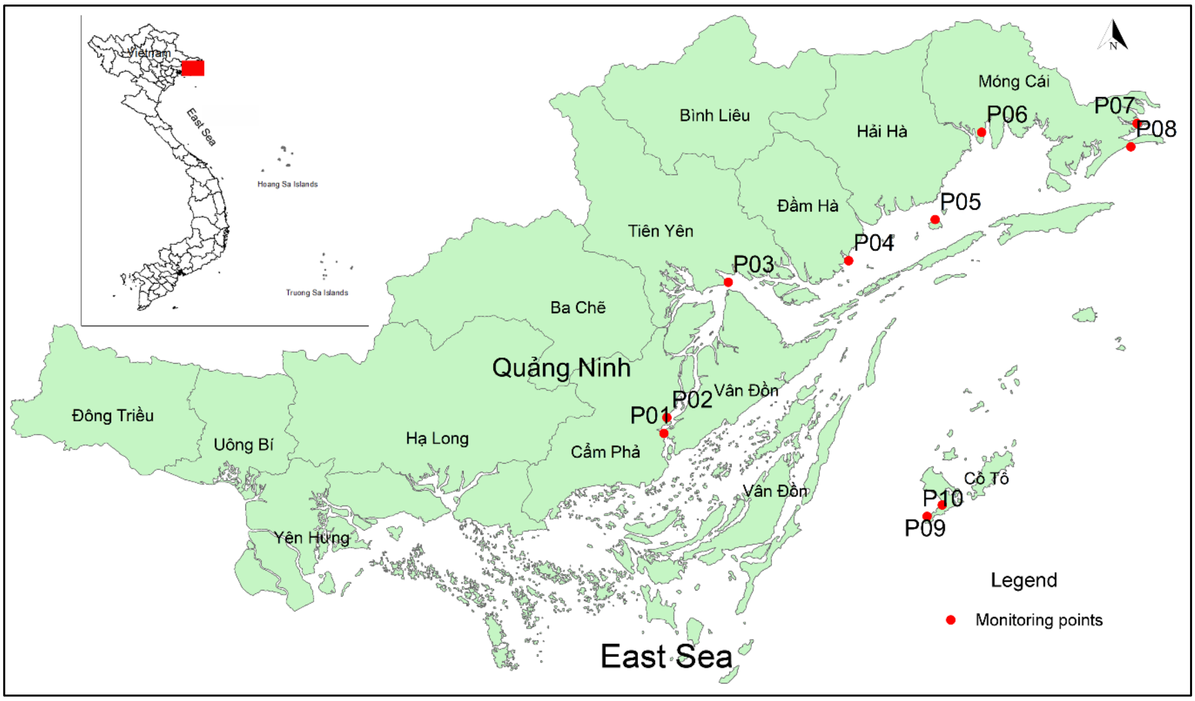

Figure 1. Coastal seawater monitoring points.

3. Results and Discussion

3.1. Coastal seawater quality

a) pH

The pH values of seawater in the region ranged from 7.4 to 8.4. Average and median were 8.0 and 7.99 respectively. All pH values of 10 points were in compliance with the national technical regulation on marine water quality QCVN 10–MT:2015/BTNMT (range, 6.5 to 8.5). Figure 2 showed that the pH values of points P01, P09 and P10 were stable, while points P06, P07 and P08 were more fluctuated in 4 years.

b) DO

The mean value of DO concentration was 6.95 mg/l (range, 5.9 mg/l to 8.3 mg/l (Figure 3). DO concentration of all points were higher than the QCVN 10–MT:2015/BTNMT (DO ≥ 5 mg/l for beach and water sports, DO ≥ 0.4 mg/l for Aquaculture). Most of DO values concentrated at 6.5 mg/l to 7.5 mg/l. The concentration indicated that DO in seawater is suitable to any seawater using purposes.

c) TSS

Figure 4 showed the distribution of TSS concentrations. TSS values ranged from 2.5 mg/l to 57.2 mg/l. The mean value of TSS was determined to be 13.6 mg/l. About 98.7%

TSS concentration were under the QCVN 10–MT:2015/BTNMT (TSS ≤ 50 mg/l). TSS concentration at P03 and P08 were more fluctuated than the others.

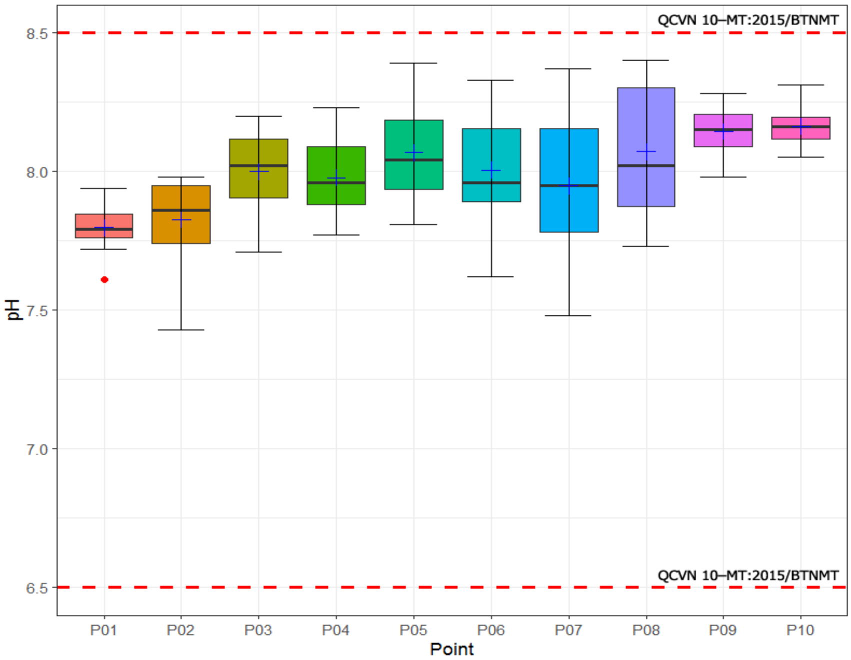

Figure 2. pH values (2016–2019).

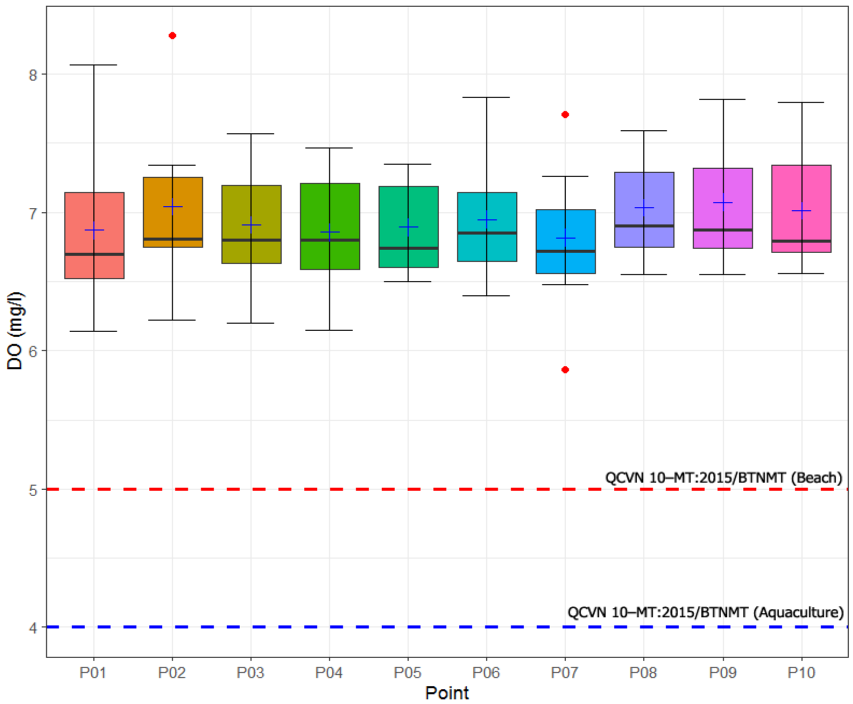

Figure 3. DO concentration (2016–2019).

d) NH_4^+

NH_4^+ concentration was found to be the most polluted parameter in the region. The mean and median values (0.38 mg/l and 0.286 mg/l respectively) were all higher than QCVN 10–MT:2015/BTNMT for marine species protection and aquaculture ($NH_4^+ \leq 0.1$ mg/l) but lower than QCVN 10–MT:2015/BTNMT for beach and watersport ($NH_4^+ \leq 0.5$ mg/l). The TSS concentration were also highly fluctuate from 0.036 mg/l to 0.952 mg/l (Figure 5). About 24.67 % NH_4^+ concentration was lower than the QCVN 10–MT:2015/BTNMT (≤ 0.1 mg/l) and 62.67% concentration lower than the QCVN 10–MT:2015/BTNMT (≤ 0.5 mg/l), concentrated in 2017 with the mean value of 0.343 mg/l. However, in 4 years, i.e., 2016–2019, the mean value of NH_4^+ concentration was still lower than the standard.

Domestic wastewater released from channel and river flowing through community was identified as pollution sources of NH_4^+. To control NH_4^+ concentration, it is necessary to collect and treat domestic wastewater before discharging to coastal zone.

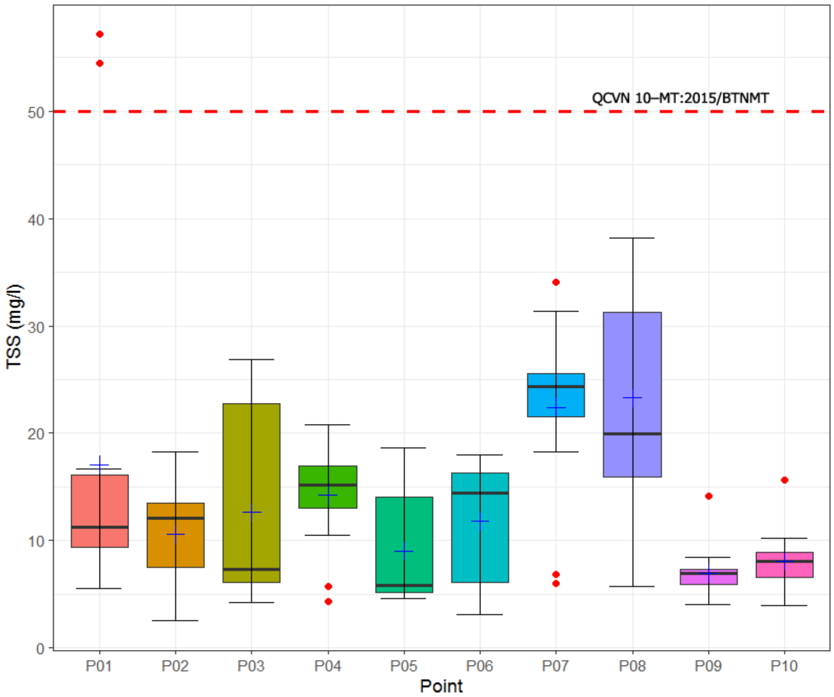

Figure 4. TSS concentration (2016–2019).

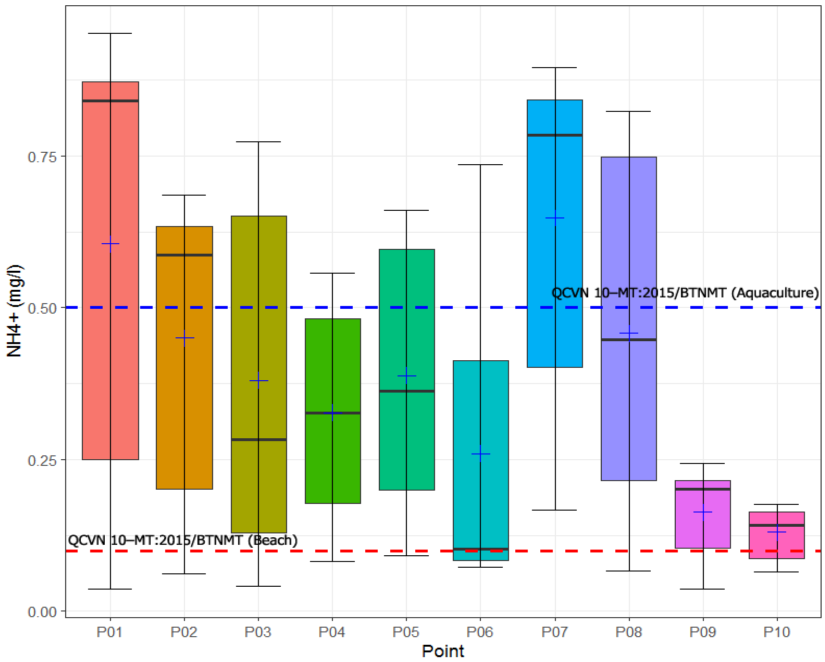

Figure 5. NH_4^+ concentration (2016–2019).

e) Coliform

In 4 years, 2016–2019, 99.32% Coliform samples were lower than the QCVN 10–MT:2015/BTNMT (1000 NPM/100ml). The Coliform concentration were very highly fluctuated from 3 NPM/100ml to 1500 NPM/100ml (Figure 5). Points with high Coliform concentration appeared near river mouth (P02 and P07), while monitoring points located in island had lower Coliform concentration (P05, P09 and P10). Average Coliform concentration in 4 years meet water quality requirement for all using purposes.

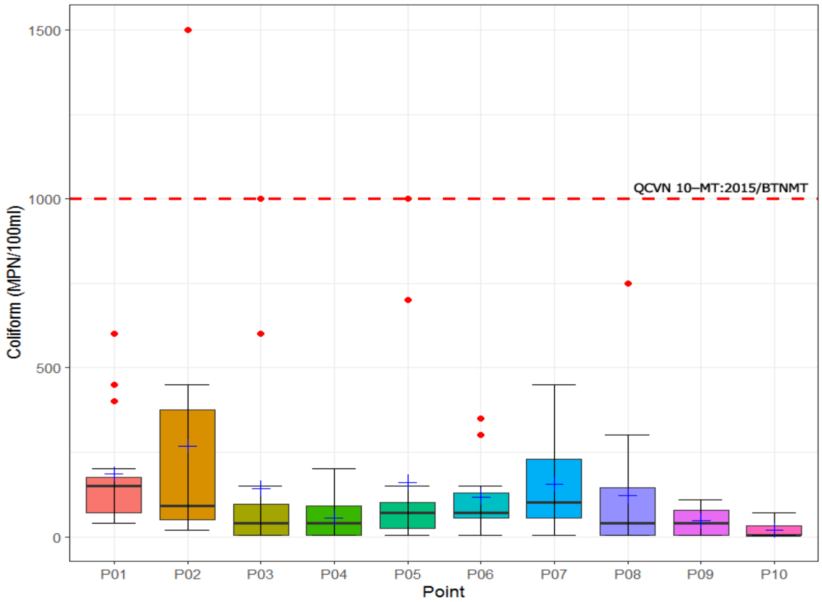

Figure 6. Coliform concentration (2016–2019).

f) Oil and grease

All the monitoring points had lower oil concentration than the QCVN 10–MT:2015/BTNMT (0.5 mg/l). This result indicated that, inspire of high ship activities in the region, the oil and grease concentration still very low (Figure 7). This well supports for the development of the ecosystem in the coastal zone of the region.

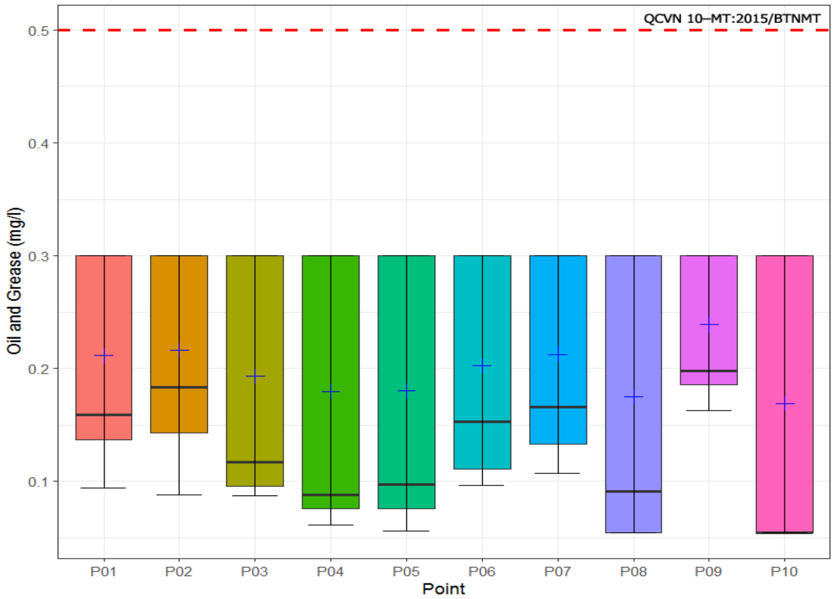

Figure 7. Oil and grease concentration (2016–2019).

3.2. Sampling frequency

a) Weighting values of variables

Comparing weighting values of pH, DO, TSS, $NH4^+$, Oil and Coliform among 10 monitoring points indicated that points P09 had the highest weighting value of pH, DO and Oil, while TSS, NH4+, and Coliform were P08, P07, and P01, respectively (Table 2 and Figure 8). The high weighting value of variables in 10 points (W_k) were P07, P01, P02, and P08. It indicated that sampling frequency of these points should be increased while the P09 and P10 should be decreased.

Table 2. Weighting values of variables.

Point	W_{pH}	W_{DO}	W_{TSS}	W_{NH4^+}	W_{Oil}	$W_{Coliform}$	W_k
P01	0.098	0.099	0.126	0.160	0.107	**0.146**	**0.122**
P02	0.098	0.101	0.077	0.118	0.112	0.210	**0.119**
P03	0.100	0.099	0.093	0.099	0.096	0.113	0.100
P04	0.100	0.099	0.105	0.086	0.091	0.044	0.088
P05	0.101	0.099	0.066	0.102	0.091	0.127	0.098
P06	0.100	0.100	0.087	0.068	0.102	0.092	0.091
P07	0.099	0.098	0.165	**0.170**	0.107	0.122	**0.127**
P08	0.101	0.101	**0.171**	0.120	0.086	0.095	**0.112**
P09	**0.102**	**0.102**	0.051	0.042	**0.122**	0.036	0.076
P10	0.102	0.101	0.059	0.034	0.086	0.015	0.066

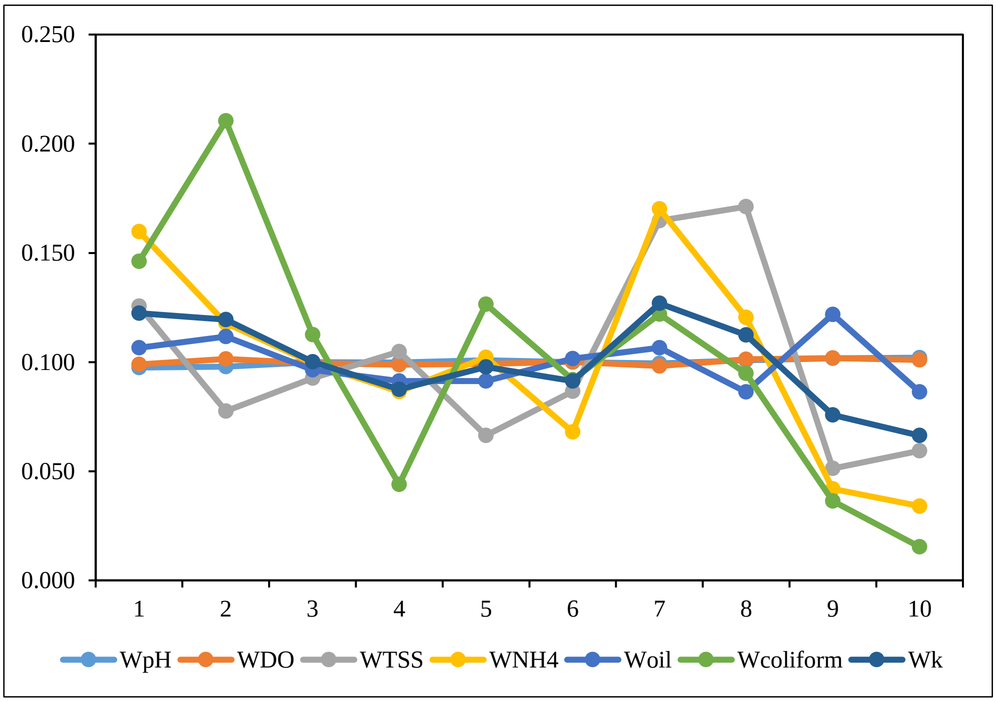

Figure 8. Weighting values of pH, DO, TSS, NH_4, Oil and grease, Coliform and Wk.

b) Sampling frequency

The W_k indicated that point P01, P02, P07, and P08 were more polluted than the others, while point P09 and P10 had better seawater quality. Figure 9 showed the sampling frequency of 10 points in a year, in which the frequency should be increased at point P01, P02, and P07, while decreased at point P09 and P10.

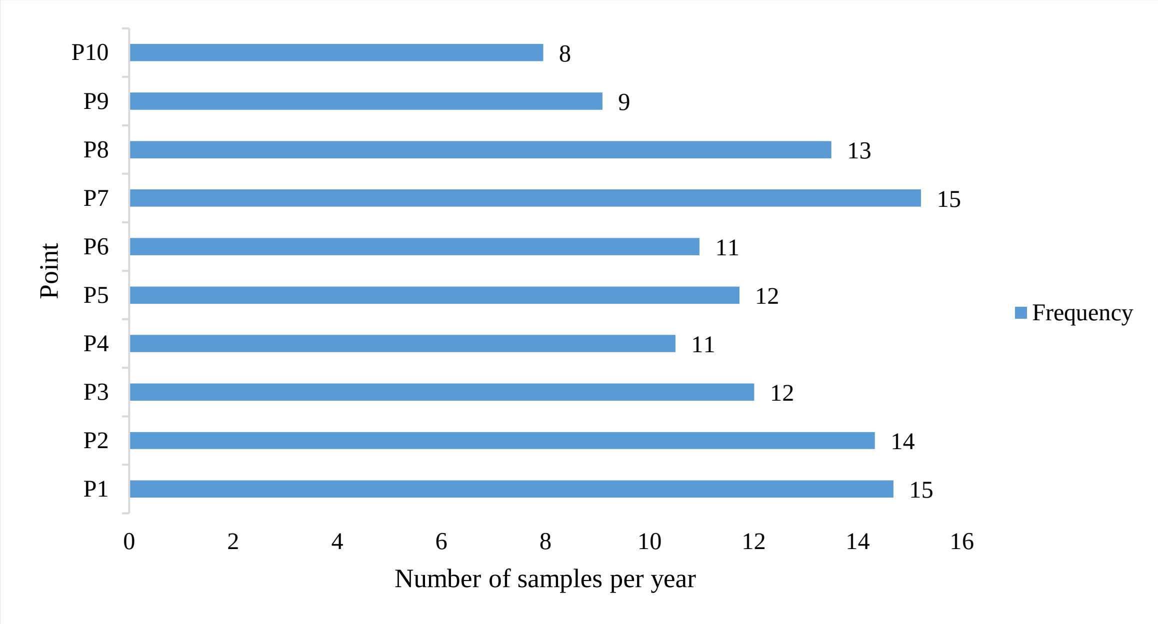

Figure 9. Proposed sampling frequency.

In environmental monitoring and management, the places with more polluted than the others, more actions should be considered to control pollution sources [14, 18]. In which, monitoring activities should be increased to monitor and track the sources as well as the changes of pollution. The calculated sampling frequency indicated that the monitoring activities should be focused on P01, P02 and P07, while reduced in P9 and P10.

4. Conclusion

Seawater in the study area has good quality. In 6 monitored parameters in 4 years, 2016–2019, (pH, DO, TSS, Oil and grease, NH_4^+, Coliform), 5 parameters were under the QCVN 10–MT:2015/BTNMT. However, it had a signal of NH_4^+ pollution. Manager should pay more attention to NH_4^+ concentration in seawater of the region by controlling pollution source of NH_4^+. Sampling frequency should be rearranged. More samples should be taken at potential pollution points P01, P02 and P07, while reduced in P09 and P10. Industrial and domestic wastewater near P01, P02, P08 and P09 must be treated before releasing. Data series of this research were short so the research results were limited.

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Conflicts of Interest: The authors declare no conflict of interest.

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