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Assessment of physical, chemical and dissolved trace metals parameters of marine water quality in East Malaysia's port

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Abstract

A port is an important national asset that needs to be carefully protected. Ports should be maintained to preserve both public health and the natural environment. This study focused on determining the status of a port in Peninsular Malaysia based on water quality analysis. Marine water samples in the port were collected from eight sampling locations. Fifteen physical and chemical parameters and trace metal concentrations were measured in-situ and in a laboratory using standard methods. The ranges of the results were as follows; 26.6–32.2 °C for temperature, 7.2–9.5 for pH, 7.18–8.55 mg/L for DO, 6.27–423.33 NTU for turbidity, 41–751 mg/L for TSS, 1.1–10.5 mg/L for BOD_5, 57–2791 mg/L for COD, 6.00–679.50 mg/L for O&G, and 0.17–7.28 mg/L for NH_3–N. The trace metal concentrations were as follows; 0.000–0.080 mg/L for Al, 0.000–0.048 mg/L for Cr, 0.001–0.197 mg/L for Cu, 0.002–0.821 mg/L for Fe, 0–0.038 mg/L for Ni, and 0.001–0.068 mg/L for Zn. The parameters of total suspended solid, chemical oxygen demand, oil and grease, ammonia-nitrogen and Cu were mostly unacceptable in terms of water quality and sources of pollution. It stemmed from the phenomenon of the tides, port activities and the diversity of shipload, effects of antifouling ship, sewage and stormwater runoff are the main contributors of marine pollution. Therefore, water quality monitoring and control of the release of untreated organic and dissolved metal wastes into marine waters are greatly needed.

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1.0 Introduction

Maritime transport is considered the most cost-effective way for moving goods and materials, with data showing that more than 90% of the world's trade is carried by sea (IMO, 2018). Marine transportation has become very important in the import and export trade, which is a major focus of economic activity. However, shipping and port operations contribute approximately twelve percent to total marine pollution (AAPMA 2001). Marine pollution sources from port operations include shipping wastes (ballast water, oily bilge water, ship paint and sewage and onboard wastewater), stormwater runoff, oil spills, dredging activities, port development, and other activities (O'Brien, 2011; Diane et al., 2004). Major oil spills sources include marine terminals, pipe leaks in harbours, offshore drilling leaks, destruction of oil tankers and barges, and the washout of oil into storm drains (Ford et al., 2008; SoE, 1996).

Substances observed in marine waters include persistent toxins (heavy metals, Polychlorinated biphenyl (PCBs) etc.), suspended solids, harmful pathogens, oils, wastewater compounds, and visible pollutants such as plastics and other rubbish. Marine pollution directly affects aquatic organisms and indirectly affects human health and resources (Zhao et al., 2018). This pollution can affect humans in both the short and long term if no action is taken. Moreover, pollution could either cause the death of aquatic organisms or lead to their mutation, resulting in potential sterility or other adverse ecosystem effects. Heavy metal pollutants are not fixed in sediments, which may act as a secondary pollution source, with pollutants being released back into water columns under certain conditions resulting from natural or anthropogenic causes (mainly including geological disturbances, earthquakes, and changes in pH, dissolved oxygen, and redox potential) (Kang et al., 2017). The International Maritime Organization has stated that approximately 3,000 non-native species are estimated to be transported in ballast water each day, although only 3% of these species settle in the new habitat. However, this transport has led to a 39% loss of biodiversity, which will likely cause many future problems (Vitousek et al., 1996).

A previous study of the Klang River found that some pollution sources originated from urban runoff, construction sites, faulty septic systems, and certain industrial activities (Sharifah et al., 2015). East Malaysia's port must assess the water quality in their port area by identifying the types of contamination in the marine water and the level of pollution contaminating the marine water. It is essential to increase customer trust, extend invitations to potential customers, and improve operational efficiency and performance by providing the following competitive advantages: a commitment to health and safety, increased worker productivity, and controlled and maintained water quality at a level that suits the activities of all concerned.

This study discovers the analysis of physical and chemical properties (temperature, pH, turbidity, dissolved oxygen (DO), total suspended solids TSS), biochemical oxygen demands (BOD_5), chemical oxygen demands), dissolved trace metals (Al, Cr, Cu, Fe, Ni and Zn), and oil and grease (O&G) in the East Malaysia's port that can be beneficial for Department of Environment of Malaysia (DOE) and port's community to resolving the impacts of different port activities on the water environment. This study will help the researcher uncover the critical areas of marine pollution caused by port and shipping activities that many researchers could not explore (as outside personnel is not permitted to enter the port area without permission).

2.0 Methodology

2.1 Selection of sampling stations, frequency and duration

The subject of this study is one of the largest multi-purpose ports in South Asia and handles up to 60% of the nation's trade. It is located in Peninsular Malaysia, and it operates marine services, conventional cargo services, on-dock logistics services, and container services. The port offers its services to customers in Malaysia, China, Europe, the United States, and many other countries worldwide and operates up to 600 vessels monthly.

To fulfill this study, water samples were collected from different sampling locations with both low and high tidal influences representing the context of the marine ecosystem in the port (Fig. 1). The locations and site descriptions are provided in Table 1. The sampling stations consist of areas with different environmental contexts and port activities.

2.2 In-situ parameter measurement of seawater

The physical and chemical characteristics of the water samples were determined using both in-situ and laboratory analysis. For the in-situ parameter measurements, the pH, temperature, dissolved oxygen,

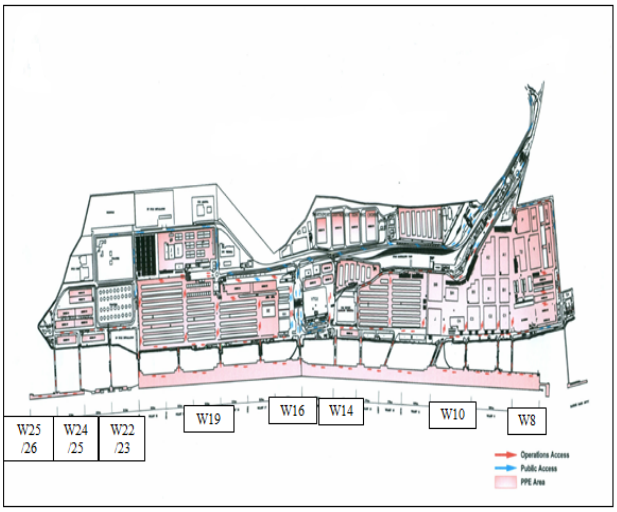

Fig 1: Layout showing the water sample collection stations in the port

Table 1: Sampling information with descriptions of the sampling stations

No.	Station (Wharf)	Location mark (m)	Water depth (m)	Cargo description
1	W8	120	11.0	Container from Asia and Europe
2	W10	755	13.2	Container from Asia and Europe
3	W14	1560	15.0	Container from Asia and Europe
4	W16	1840	12.7	Container handling kernel oil
5	W19	2585	13.0	Container from coasta area
6	W22/23	3345	11.7	Container handling untreated LPG
7	W24/25	3800	11.7	Container handling fir particles
8	W25/26	3985	12.0	Container handling fir particles

and turbidity measurements were taken using Multiparameter System Water Quality Meter (YSI 556) in triplicate to determine the average and the accuracy (Marine and Water Quality Monitoring, 2010). The reading was acquired from many different points to represent the location where the water samples were collected.

2.3 Laboratory analysis of seawater

Analysis of dissolved trace metal concentrations (Al, Cr, Cu, Fe, Ni and Zn), ammonia nitrogen, COD, BOD_5, TSS and O&G were evaluated in the laboratory; the samples were stored at 4 °C before analysis to maintain quality. The trace metal concentrations were determined using inductively coupled plasma mass spectrometry (ICPMS) (Agilent 7500a) (Yap et al., 2011). The standard methods used in the chemical analysis are described in Table 2. Besides, the acceptable standard for each parameter tested was evaluated based on Malaysian Marine Water Quality Standards (MMWQS) for Class 3 (ports, oil and gas fields), as shown in Table 3.

Table 2: Standard methods used in the chemical analysis of the liquid samples

Parameter	Method
Total suspended solids (TSS)	APHA 2540D: TSS dried at 103–105 °C
Biochemical oxygen demand (BOD_5)	APHA 5210B: 5-day BOD test
Chemical oxygen demand (COD)	APHA 5220B: open reflux method
Oil and grease (O&G)	APHA 5520G: gravimetric method
Ammonia Nitrogen (HH_3–N)	HACH 2005: method 8038: USEPA Nessler method
Heavy metals	APHA 3125: Inductively coupled plasma mass spectrometry (ICPMS) method

Table 3: Malaysian Marine Water Quality Standards (MMWQS) for Class 3 (ports, oil and gas fields) (Marine and Water Quality Monitoring, 2010)

PARAMETER (µg/l) unless otherwise stated	CLASSIFICATION					
	CLASS 1	CLASS 2	CLASS 3	INTERIM CLASS E1	INTERIM CLASS E2	INTERIM CLASS E3
	Sensitive Marine Habitats	Fisheries (including Mariculture)	Industry, Commercial Activities & Coastal Settlements	Estuaries		
				Coastal Plain	Lagoon	Complex Distributary Network
Dissolved Oxygen (mg/l)	>6.0	>5.0	>3.0	>5.0	>5.0	>5.0
Total Suspended Solids (mg/l)	25.0	50.0	100.0	30.0	30.0	30.0
Phosphate	5.0	75.0	670.0	100.0	180.0	180.0
Nitrate	10.0	60.0	700.0	200.0	570.0	430.0
Ammonia	35.0	50.0	320.0	5.0	10.0	10.0
Mercury	0.04	0.04	0.04	0.04	0.04	0.04
Cadmium	0.50	2.00	3.00	1.00	1.00	1.00
Chromium (VI)	0.14	10.00	20.00	10.00	10.00	10.00
Copper	1.30	2.90	8.00	1.00	1.00	1.00
Cyanide	2.00	7.00	14.00	5.00	5.00	5.00
Lead	2.20	8.50	12.00	1.30	2.00	2.00
Zinc	7.00	50.00	100.00	16.00	5.00	5.00
Arsenic (III)	1.00	3.00	3.00	3.00	1.00	1.00
Aluminium	27.00	27.00	55.00	27.00	27.00	27.00
TBT	0.001	0.010	0.050	0.002	0.002	0.002
PAH	100.0	200.0	1000.0	5.0	5.0	5.0
Total Phenol	1.0	10.0	100.0	10.0	10.0	10.0
Oil & Grease mg/l	0.01	0.14	5.00	1.00	1.00	1.00
Faecal Coliform (Cfu/100ml)	70	70	70	70	70	70
Temperature (°C)	≤ 2°C increase over maximum ambient					
pH	6.5 - 9.0					
Marine litter	Free from marine litter					

3.0 Results and discussion

The physical and chemical characterisation, organic contaminants, and NH_3–N concentration at the eight sampling stations for both tidal influences are summarised in Table 4. Meanwhile, the dissolved trace metal concentrations in the port water samples are presented in Table 5. The concentrations of Al, Cr, Cu, Fe, Ni, and Zn were studied in water samples from the study port. Trace concentrations were observed at all sampling stations, where they show signs of metal contamination.

3.1 Physical and chemical parameters

Water temperature represents the heat present in marine waters and regulates aquatic communities. Changes in water temperature affect the proportion of metabolic activities and life cycles (Singh et al., 2005; Basualto et al., 2006; Dallas, 2008). The observed water temperature ranged from 26.6 to 30.5 °C at high tide and 26.9 to 32.2 °C at low tide. All the water temperatures in high tide are below the threshold limit established by the DOE, which is below 31.0 °C. This water temperature is comparable to Bugtong et al. (2018) that ranged from 24.0 to 29.1 °C, and within the acceptable standard required by DENR (DENR, 1990). However, the results obtained are much better than that of Screenivasulu et al. (2015). The water temperature ranged between 33.9 to 34.9 °C (Screenivasulu et al., 2015) which is believed due to the environmental location factors between India and Malaysia. Variation in water temperature is generally affected by the ambient temperature, groundwater inflows, stormwater runoff, turbidity, and sunlight contact.

The allowable standard for pH stated by MMWQS is between 5 to 9 (Marine and Water Quality Monitoring, 2010). The pH values of the sampled water ranged from 7.2 to 9.2 at high tide and from 7.2 to 9.5 at low tide. The pH pattern of this study is in line with the study conducted by Jahan & Strezov (2017) and Screenivasulu et al. (2015); with a value between 7.6 until 8.3, and from 7.1 to 7.4 (almost neutral pH is observed at all locations), respectively. However, Bugtong et al. (2018) reported slightly higher pH levels of 10.3 to 11.2, exceeding the standard range required. Because pH is an indicator of biological life by indicating the suitable pH range, pH values greater than 9.0 are unsuitable for aquatic organisms.

The most critical environmental quality requirement for aquatic life is the DO level, which refers to the amount of oxygen dissolved in the water (Weiss, 1970; Dave et al., 2011). Oxygen enters the marine water from the surrounding air through the photosynthesis process from aquatic plants. High levels of DO (greater than 7 mg/L) are considered a healthy ecosystem, supporting a better diversity of marine organisms. The DO level is important for marine organisms to mitigate against adverse effects (Best et al., 2007). The allowable standard for DO stated by MMWQS is 3.0 mg/L (Marine and Water Quality Monitoring, 2010). DO level ranges from 7.53

Table 4: Overall values of the marine water samples' physical and chemical parameters collected in the port

Station	Tidal	Temp (°C)	pH	DO (mg/L)	Turbidity (NTU)	TSS (mg/L)	BOD_5 (mg/L)	COD (mg/L)	O&G (mg/L)	NH_3-N (mg/L)
W8	HT	28.6 ± 2.0	8.1 ± 0.6	7.91 ± 0.4	25.47 ± 24.53	112 ± 43	5.2 ± 2.9	876 ± 737	40.20 ± 12.30	1.49 ± 0.05
	LT	30.3 ± 2.6	8.2 ± 1.0	7.63 ± 0.41	66.20 ± 110.4	170 ± 218	6.6 ± 1.1	757 ± 404	25.30 ± 12.70	2.40 ± 0.05
W10	HT	28.2 ± 1.7	8.3 ± 1.1	7.87 ± 0.52	19.40 ± 30.60	105 ± 52	3.6 ± 2.3	1565 ± 732	72.40 ± 151.60	3.71 ± 0.01
	LT	29.7 ± 2.4	8.2 ± 0.9	7.71 ± 0.67	122.80 ± 187.20	189 ± 194	6.1 ± 4.4	892 ± 1149	51.50 ± 91.00	1.57 ± 0.03
W14	HT	28.6 ± 0.9	8.2 ± 1.0	7.89 ± 0.39	16.00 ± 6.00	96 ± 46	3.9 ± 4.7	1012 ± 511	123.90 ± 370.10	2.37 ± 0.01
	LT	29.5 ± 2.6	8.2 ± 0.9	7.65 ± 0.62	146.60 ± 276.73	178 ± 205	4.2 ± 6.3	1060 ± 1113	18.10 ± 5.10	2.12 ± 0.03
W16	HT	28.5 ± 1.0	8.4 ± 0.9	7.80 ± 0.37	18.93 ± 4.07	97 ± 52	3.8 ± 1.5	797 ± 501	153.50 ± 88.00	3.72 ± 0.03
	LT	29.5 ± 2.6	8.2 ± 1.0	7.70 ± 0.85	135.67 ± 227.66	186 ± 192	3.0 ± 2.9	918 ± 555	13.30 ± 7.00	2.70 ± 0.04
W19	HT	28.5 ± 0.8	8.3 ± 1.1	7.84 ± 0.37	23.87 ± 21.13	100 ± 93	3.2 ± 1.8	685 ± 351	153.30 ± 307.70	1.79 ± 0.01
	LT	29.4 ± 2.5	8.3 ± 1.2	7.69 ± 0.71	137.53 ± 189.14	205 ± 308	6.0 ± 4.2	964 ± 344	195.90 ± 483.60	4.10 ± 0.02
W22/23	HT	28.5 ± 1.0	8.3 ± 0.8	7.86 ± 0.42	23.27 ± 15.73	93 ± 64	3.5 ± 2.1	695 ± 445	136.00 ± 372.50	2.48 ± 0.01
	LT	29.3 ± 2.9	8.1 ± 0.7	7.69±0.53	112.40 ± 190.93	213 ± 537	3.2 ± 2.4	1054 ± 1078	140.60 ± 396.40	2.10 ± 0.02
W24/25	HT	28.7 ±0.2	8.2±1.0	7.80±0.37	22.73 ± 12.06	111 ± 60	3.7 ± 1.3	455 ± 334	161.50 ± 474.00	0.46 ± 0.03
	LT	29.4 ± 2.7	7.9±0.6	7.73±0.49	72.37 ± 206.72	145 ± 324	4.0 ± 1.0	455 ± 817	27.400 ± 49.60	1.89 ± 0.05
W25/26	HT	28.6 ± 0.5	8.2 ± 1.0	7.82 ± 0.26	24.80 ± 20.20	99 ± 116	4.3 ± 3.1	538 ± 175	99.10 ±164.40	1.65 ± 0.03
	LT	29.4 ± 2.8	7.9 ± 0.6	7.74 ± 0.65	39.05 ± 80.95	127 ± 249	3.6 ± 2.3	1624 ± 1166	44.10 ± 98.90	1.65 ± 0.04

*Note: (HT: high tide, LT: low tide)

Table 5: Overall values of dissolved trace metal concentrations in the port

Station	Tidal	Al (mg/L)	Cr (mg/L)	Cu (mg/L)	Fe (mg/L)	Ni (mg/L)	Zn (mg/L)
W8	HT	0.008 ± 0.022	0.004 ± 0.005	0.075 ± 0.051	0.331 ± 0.309	0.028 ± 0.009	0.018 ± 0.029
	LT	0.002 ± 0.002	0.004 ± 0.004	0.050 ± 0.049	0.066 ± 0.063	0.016 ± 0.014	0.016 ± 0.015
W10	HT	0.007 ± 0.016	0.003 ± 0.006	0.086 ± 0.062	0.277 ± 0.263	0.022 ± 0.004	0.017 ± 0.039
	LT	0.002 ± 0.000	0.004 ± 0.010	0.081 ± 0.080	0.065 ± 0.062	0.017 ± 0.015	0.018 ± 0.021
W14	HT	0.005 ± 0.008	0.004 ± 0.004	0.085 ± 0.071	0.255 ± 0.235	0.025 ± 0.005	0.018 ± 0.025
	LT	0.002 ± 0.003	0.004 ± 0.006	0.059 ± 0.058	0.147 ± 0.343	0.016 ± 0.014	0.013 ± 0.020
W16	HT	0.017 ± 0.049	0.007 ± 0.000	0.080 ± 0.069	0.403 ± 0.427	0.026 ± 0.004	0.017 ± 0.043
	LT	0.002 ± 0.003	0.004 ± 0.012	0.057 ± 0.037	0.069 ± 0.067	0.021 ± 0.020	0.018 ± 0.030
W19	HT	0.012 ± 0.028	0.007 ± 0.023	0.084 ± 0.074	0.270 ± 0.220	0.029 ± 0.005	0.017 ± 0.038
	LT	0.002 ± 0.005	0.003 ± 0.006	0.062 ± 0.043	0.079 ± 0.077	0.017 ± 0.017	0.016 ± 0.031
W22/23	HT	0.007 ± 0.009	0.011 ± 0.037	0.085 ± 0.076	0.268 ± 0.212	0.029 ± 0.005	0.029 ± 0.034
	LT	0.002 ± 0.005	0.002 ± 0.005	0.062 ± 0.061	0.085 ± 0.083	0.017 ± 0.016	0.014 ± 0.030
W24/25	HT	0.014 ± 0.040	0.009 ± 0.031	0.087 ± 0.079	0.263 ± 0.197	0.033 ± 0.004	0.030 ± 0.038
	LT	0.004 ± 0.008	0.003 ± 0.006	0.066 ± 0.065	0.082 ± 0.080	0.017 ± 0.017	0.015 ± 0.026
W25/26	HT	0.020 ± 0.019	0.011 ± 0.029	0.090 ± 0.036	0.227 ± 0.163	0.026 ± 0.012	0.002 ± 0.005
	LT	0.004 ± 0.004	0.002 ± 0.003	0.069 ± 0.068	0.088 ± 0.086	0.017 ± 0.017	0.016 ± 0.029

*Note: (HT: high tide, LT: low tide)

to 8.39 mg/L at high tide and from 7.18 to 8.55 mg/L at low tide. All sampling stations have a DO level greater than the threshold level of 3.0 mg/L, which is considered acceptable for marine water quality. Furthermore, the DO level of this study is the highest compared to the study conducted by Jahan & Strezov (2017), Screenivasulu et al. (2015) and Bugtong et al. (2018), with the DO ranged from 3.2 to 4.7, 3.2 to 4.7, and 5.67 to 6.86 mg/L, respectively. During the low tide, the DO was low due to hydrocarbon contamination from imported petroleum products inside the main port (Best et al., 2007). Besides, low ranges of DO indicate the presence of high nutrient levels, the release of domestic and industrial effluents (Pollard & Rankin, 2003; Wang et al., 2007).

A sampling station with high turbidity has a substantial amount of settleable suspended solids and pollutants at the bottom of the marine water, which affects the submerged plants. The photosynthesis process becomes unstable due to insufficient light sources and increased water temperature (Yap et al., 2011). Generally, marine water in a shipping area with port activities has turbidity values in the range of 15-30 NTU (fair). However, the allowable standard for turbidity stated by MMWQS is 100 NTU or less (Marine and Water Quality Monitoring, 2010). Turbidity values at high tide ranged from 10.67 to 50.00 NTU, while these values ranged from 6.27 to 423.33 NTU at low tide. Based on the measured values, only the samples collected at high tide meet the MMWQS standard (below 100 NTU), and most of the values at low tide exceeded the allowable limit. This result is due to the water level increase during high tide, which leads to a decreased concentration of particulate matter in the water.

Then, the allowable standard for TSS stated by MMWQS is 100 mg/L (Marine and Water Quality Monitoring, 2010). The measured TSS values ranged from 42 to 216 mg/L at high tide and from 41 to 751 mg/L at low tide. The handling of kernel oil particles at W16, port development at W8, W10, and W14, handling fine particles at W24/25 and W25/26, and the dredging activities at the other stations increased the TSS values. Although all 3 stations (W8, W10 and W14) are for the container from Asia and Europe, normally, W8 does not operate. Loading-unloading activities happened at W10 and W14, while there were construction activities occuring beside W8.

TSS and turbidity changed due to the watershed hydrologic process, soil sediment characteristics and land use pattern (Lawler, 2004). Finally, it markedly depends on the tidal pattern. The turbidity can be increased in the coastal region due to the river's rise closely related to precipitation (Fukuda et al., 1954). Thus, turbidity and TSS were higher during the rainy season, and low levels were determined during the dry weather condition.

3.2 Organic contaminants

Organic contaminants in the marine water were assessed by the BOD_5, oil and grease and COD values. In addition to DO, BOD_5 is another laboratory technique to determine the relative oxygen requirements of polluted water. The high BOD_5 value is an indication of poor water quality. The BOD_5 standard required by the DOE Malaysia is 6 mg/L (Marine and Water Quality Monitoring, 2010). The sampling results determined that only the stations at W16, W22/23, W24/25, and W25/26 met the BOD_5 for both tidal influences. BOD_5 values at high tide were much lower than those at low tide due to the relatively increased volume and speed of the water, which reduces the concentration of organic contaminants. The high BOD_5 values at W8, W10, and W14 came from the organic waste caused by construction activities to improve and develop the port system. During construction, many workers rapidly increased, which resulted in higher rates of untreated sewage discharge. Without proper toilet facilities, untreated sewage is discharged into the marine bodies without treatment. Any discharge of organic matter from ships also contributes to this problem and affects water quality.

Oil and grease analysis was performed to verify the uncertainty caused by indiscriminate dumping of waste oil and poor oil management within the stations. All of the sampling stations in East Malaysia's port exceeded the MMWQS allowable limit (below 5.00 mg/L), and the values were higher at high tide than at low tide for all of the dates. The main cause of high O&G in East Malaysia's port is runoff water across the land to marine bodies. Daily washing activities in wharf driveway areas contributed to oily runoff to the marine water. Besides, the combination of a minor oil spill and grease from vessels into the water bodies during loading and unloading containers had increased the O&G value. All sampling stations in East Malaysia's port exceeded COD's allowable limits (50 mg/L) (Marine and Water Quality Monitoring, 2010) except for W10. The COD ranged from 308 to 1778 mg/L at high tide and from 57 to 2791 mg/L at low tide. The high COD concentrations could be due to higher solids, oil and grease, and organic antifouling coatings of marine vessels.

3.3 Ammonia-nitrogen concentration

An excess level of ammonia may harm aquatic life because it accumulates inside organisms' bodies and causes metabolism changes as pH increases. The allowable standard for NH_3–N stated by MMWQS is below 2.70 mg/L (Marine and Water Quality Monitoring, 2010). The NH_3–N results range from 0.49 to 3.75 mg/L at high tide and from 1.54 to 4.12 mg/L at low tide. Only W14, W22/23, W24/25 and W25/26 at both tides had NH_3-N values below the DOE standard at all sampling stations. Poor NH_3–N levels were reported for W8 due to construction activities besides the wharf area. A low tide tends to have higher NH_3–N values than a high tide (W10 and W19) due to increased water level during high tide, leading to increased volume and speed of the water and cause a decreased concentration of particulate organic matter untreated sewage in the water. Without proper toilet facilities at wharf areas and ships, untreated sewage and domestic waste are discharged into the marine bodies without treatment.

3.4 Dissolved trace metal concentrations

The wide ranges of trace metal concentrations observed at all sampling stations indicated signs of trace metal pollution. The study conducted by Jahan & Strezov (2017) revealed a high level of Cu, Fe, Cd, and Zn responsible for the poor water quality at the port areas. The allowable standard for Cu stated by MMWQS is below than 0.010 mg/L (Marine and Water Quality Monitoring, 2010). Cu level ranged from 0.008 to 0.126 mg/L at high tide, and from 0.001 to 0.197 mg/L at low tide. All the sampling stations exceeded the standard required by DOE (0.010 mg/L of Cu) except for W19, W22/23, W24/25 and W25/26 at high tide. Also, the highest concentration of Cu was observed to increase between W8 and W24/25. The high level of Cu detected originates from painted vessels that introduce toxic substances and Cu residues into the marine environment and containers with large amounts of electronic components (Singh et al., 2005). A more extended period was required to unload containers handling untreated LPG and fine particles, which might cause antifouling additives containing tributyltin (TBT), which is a toxic chemical, to leach into the water (Screenivasulu et al., 2015). Painted vessels can introduce toxic substances and metal residues such as Cu, Cr, and Zn, present in pigments, driers, and corrosion-inhibitors into the marine environment. Once these additives are exposed to water, TBT is absorbed by marine life, where it can build up in their bodies as well as in the bodies of predators. TBT causes serious health issues in shipyard workers, including skin irritation, stomach aches, influenza, colds, and neurological symptoms, such as headaches, fatigue, and dizziness (Weiss, 1970).

The allowable standard for Fe stated by MMWQS is below 0.500 mg/L (Marine and Water Quality

Monitoring, 2010). Dissolved Fe concentrations ranged from 0.105 to 0.821 mg/L at high tide, and from 0.002 to 0.490 mg/L at low tide. All the sampling stations in east Malaysia's port had values less than the standard of 0.500 mg/L at low tide. W8 and W16 exceeded the allowable limit at high tide, with values up to 0.800 mg/L, caused by rusting steel equipment in constant contact with water used during kernel oil and construction activities port system and development. The high concentration of Zn at W22/23, W24/25, and W25/26 on certain samplings was due to the longer periods needed to unload untreated LPG containers and fine particles. The antifouling additives containing Zn could have leached into the water. A slight increase in the levels of this metal may interfere with physiological processes. The presence of an excessive amount of Cu, Fe and Zn confirm the impacts of the port activities associated with the trade of crude oil, fossil fuel, chemicals, and bio-fuels. Moreover, the trade of coal, steel products, fertilizers, mineral sands and preservative chemicals from woodchips signify the excess amounts of Cu, Fe, and Zn in the port water. Finally, effluent from shipping activities, storage of hazardous products in the port vicinity is often overlooked while they may also be the sources of metals in the studied port areas (Jahan & Strezov, 2017; Goonetilleke et al., 2009).

Various factors potentially contribute to marine pollution either directly or indirectly. Natural factors such as tidal conditions that occur daily significantly impact water quality parameters, such as turbidity. Water quality is significantly improved during high tide and is much better than during low tide. This is due to the water-level increase from the mixing of port water and seawater, resulting in dilution during high tide, leading to decreased particulate matter in the water. During low tide, water quality is much worse due to pollutants settling into the lower part of the water column. Port activities and the diversity of cargo, the effects of ship antifouling, sewage, and surface water runoff also result in marine severe water pollution. The analysis found that TSS, COD, O&G, NH_3–N and Cu concentrations exceeded the MMWQS for both tidal conditions.

4.0 Conclusion

The study of physical, chemical and dissolved trace metals parameters of marine water quality in the port has achieved its purpose. The main types of pollutants found in ports are TSS, O&G, COD, NH_3–N, and Cu trace metal concentration. However, natural factors such as tidal conditions have a high impact on water quality parameters, including turbidity, TSS and COD, as the water pollution increases at low tide. Although this study achieved its objective, there are constraints in the research process. In accordance with the port studies' law, outsiders are only permitted to enter the port's area less than 5 times. If more time and samples can be taken, the results may be more precise. Additionally, studies in the port's area can be extended by studying the pollution associated with air, noise and water, and their combination. Therefore, strict control over marine pollution causes should be closely monitored to maintain the water quality at an appropriate level for all port activities.

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