Water Quality and Heavy Metal Pollution Status in the Rupat Strait, Indonesia

Sri Fitria Retnawaty[1,4*], *Aweng* A/L Eh Rak[1], *Ahmad Abas* Kutty[2], *Wahyu* Meka[3], and *Yeeri* Badrun[4]

[1]University Malaysia Kelantan, Jeli Campus, 17600 Jeli, Kelantan, Malaysia
[2]University Kebangsaan Malaysia 43600 UKM Bangi, Selangor, Malaysia
[3]Institut Teknologi Sepuluh Nopember, Kampus ITS Keputih Sukolilo, Surabaya 60111, Indonesia
[4]Universitas Muhammadiyah Riau, Kota Pekanbaru, Riau, 28156, Indonesia

Abstract. Rupat strait is located in the north of Dumai, Riau, Indonesia. Rupat strait is the center of shipping, industry, farming, and urban activities. The vast activities are expected to give pressures to Rupat strait ecosystem and its water quality. This study aims to identify the status of Rupat strait water contamination via determination of the degree of heavy metal pollution in Rupat strait water. Samples was taken from 10 location across Rupat strait while the remaining 1 location is the reference location. Sampling was conducted according to SNI 6964.8:2015 in both dry and wet seasons in 2022. The respective physical and chemical parameters were also measured during sampling. Based on the measurement, significant distinction of physical and chemical parameters other than water salinity, TSS, and turbidity ($p>0.05$) were observed in between wet season and dry season. Rupat strait water was moderately polluted in dry season with Pij 4-8 and mildly polluted in wet season with Pj 3-5. For heavy metal contamination, Rupat strait water was mildly polluted for the whole year with PLI 0.3-0.6. This finding is expected to contribute as references for the surrounding community to maximize the socioeconomic productivity in Rupat strait.

1 Introduction

Rupat strait is a small strait with length of ± 72,4 km and width of 3.8-8 km and has accommodated vast number of anthropogenic activities [1]. Rupat strait lies in the north of Dumai as one of major cities in Riau, Indonesia [2]. Industrial activities in Dumai grows rapidly since Dumai executive government has decided to conduct regional development towards coastal areas [3]. With the presence of Rupat strait, Dumai is directly connected with Malacca strait as one of the busiest international shipping routes. This circumstance sets Rupat strait as a primary international shipping hub connecting cities in Riau with other cities in Indonesia and worldwide [4].

Shipping activities in Rupat strait primarily consist of transportation, storage, and oil distribution [5]. Other than shipping activities, industrial, agricultural, and urban activities

* Corresponding author: fitriretno@umri.ac.id

are also common on the land across Rupat strait due to rapid growing socioeconomic activities promoted via growing number of populations [6]. Shipping, industrial, and urban activities within the coastal areas of Dumai could potentially give negative impacts to Rupat strait waters. These negative impacts are sourced from waste, namely: industrial waste, municipal solid waste, transportation waste, and shipping waste. The waste produced is primarily solid waste, liquid waste, and heavy metals [3]. Heavy metal pollution in Rupat strait has occurred for the past few years. In 2022, lead and cadmium content surpassed the allowable limit. Later in the same year, copper and zinc was also found to exceed their allowable limit in Rupat strait water [7].

On the other hand, CNBC Indonesia [8] reported that, on March 2nd 2021, at around 8.4 barrel of oil contaminated Rupat strait water due to leakage. This oil contamination occurred quite often as similar cases were reported in earlier years. Toxic heavy metal contamination in Rupat, which originates from industrial waste, is registered as serious problems in the last few years [9]. Heavy metals have bioaccumulation capability and environmental persistence which give heavy metals abilities at certain degrees to penetrate and accumulate in organic ecosystem. Heavy metals are naturally sourced from rock erosion and abrasion and volcanic eruption. Furthermore, atmospheric heavy metal concentrations could increase dramatically due to anthropogenic activities such as industrial operation, residential activities, and shipping [10]. Heavy metals are poisonous to water organisms when their concentrations are above allowable limits [11]. Suspended and settling heavy metals in waters are eventually absorbed by sediments [12]. Absorption rates of sediments depend on sediment particle sizes. Fine sediment particle sizes promote rapid absorption rates [4]. Heavy metal contamination on water and sediments leads to negative consequences on the ecosystem since heavy metals further contaminates food chains [12]. Food chain contamination with heavy metals eventually endangers human health as the end species in the food chains [11].

Hence, sediment quality was used as a contamination indicator [13]. Research on Rupat strait for the last decade has been done on its physical, chemical, biological analysis [14], organic content analysis [4, 15], diatomic characteristics [15], bacterial characteristics [6], sediment characteristics and qualities [1, 4], and metal content analysis [4]. This research aimed to determine contamination status of Rupat strait [3, 2, 16]. However, to the best of author's knowledge, research on how these parameters is dependent one another has never been done. Hence, this research aims to investigate the relationship among physical and chemical parameters in Rupat strait in each season to determine water quality status in Rupat strait.

2 Material and Methods

2.1 Study site

Research location was across Rupat strait chosen based on industrial, shipping, and residential activities. Purposive sampling was conducted to distribute nine stations of research into three regions, namely: two stations in northern Dumai, five stations across central Dumai, and two stations in eastern Dumai. A control station was located in the north of Rupat Island since it was considered free from anthropogenic activities and currently was used for tourism.

2.2 Measured Parameters

Measured parameters consisted of physical and chemical parameters. Physical parameters were DO, TDS, TSS, salinity, turbidity, depth, and current velocity. Chemical parameters were pH and concentrations of heavy metals such as Pb, Cd, Cu, Fe, and Zn.

2.3 Sampling and Data Acquisition

Sampling was conducted twice in 2022 in March (wet season) and in September (dry season). Sampling of water and sediment was conducted at each sampling stations, namely 9 primary sampling locations and 1 control sampling location. Water sampling was conducted via purposive sampling according to SNI 6964.8:2015. Sample measurement was conducted with 2 methods, namely: in-situ measurement and laboratory analysis. In-situ measurement was repeated 3 times at each sample from each station, the results of which was averaged. Measured parameters in in-situ measurement were current velocity, depth, TDS, pH, and salinity. Equipment used in in-situ measurement was current meter, echosounder, TDS meter, pH meter, and refractometer. Parameters measured via laboratory equipment were turbidity, DO, TSS, and heavy metal content. Data analysis in the laboratory was in accordance with SNI 8910:2021. The equipment used was atomic absorbance spectrophotometry and gravimetry for TSS.

2.4 Data Analysis Method

Regulations of Indonesian Ministry of Environment and Forestry Number 27 Year 2021 for Harbour Waters Quality Status Determination was used as the standard to determine Rupat strait water quality. Analysis on metal contamination was conducted to compare metal content in Rupat strait water with metal content regulated in the quality standards. Metal contamination status was determined by calculating geo accumulation indices and contamination a factor. Pearson correlation analysis was conducted on water parameter to comprehend the relation among parameters while t-test was conducted on both physical and chemical parameters to compare influences of both wet and dry seasons.

3 Results

3.1 Physical and Chemical Parameter Measurement

Maximum pH in dry and wet seasons were ranged from 6.74 to 8.34 and from 4.51 to 7.15, respectively. Mean pH was higher in dry season than in wet season at all stations. Salinity in dry and wet seasons was ranged from 10.17 to 10.24 ppt and from 10.09 to 10.2 ppt, respectively. Mean salinity was higher in dry season than in wet season. TDS in dry and wet seasons was ranged from 5285.67-9857.33 ppm and from 1442.33-1964.00 ppm, respectively. Mean TDS was significantly higher in dry season than in wet season. TSS in dry and wet seasons was ranged from 77.33-137.67 mg/L and from 84.67-153.33 mg/L, respectively. Mean TSS was significantly higher in wet season than in dry season.

Turbidity in dry and wet seasons was ranged from 5.93-29.13 NTU and from 8.54-30.23 NTU, respectively. Mean turbidity was significantly higher in wet season than in dry season. DO in dry and wet seasons was ranged from 2.65-3.67 mg/L and from 3.68-4.51 mg/L, respectively. Mean DO was significantly higher in wet season than in dry season. TDS in dry and wet seasons were dramatically different. TDS in dry season was more than three times of wet season TDS, which also exceeded maximum allowable TDS. In dry season, station 7

near a harbour had the highest TDS while, in wet season, all stations had almost identical TDSs which are still well below the maximum allowable value. This indicated that Rupat strait water was contaminated with waste from activities on land, primarily harbours, across Rupat strait in dry season.

In wet season, rain enhanced both organic and inorganic matter solubility so that water colour, taste, and odour are weaker than those in dry season. Station 9 located in eastern area closer to farming and industries had the highest TSS and turbidity in dry season. In wet season, the highest TSS was found at station 1 located in northern area closer to industrial complex. Measurement results emphasized that TSS correlates with turbidity, which showed that high turbidity was due to high concentration suspended particles. DO in dry season was below its maximum allowable value but it increased to slightly above its maximum allowable value for primary stations and significantly higher than its maximum allowable value for control station in wet season.

3.2 Heavy Metal Content

Heavy metal content was higher in wet season than in dry season. Pb concentration in dry season was undetermined due to concentrations below measurement equipment bottom limit. In wet season, Pb concentration was ranged from 0.2 to 0.45 ppm. Cd concentrations in dry season was undetermined due to concentrations below measurement equipment bottom limit. In wet season, Cd concentration was 0.005 ppm at all stations.

Cu concentrations in dry season was undetermined due to concentrations below measurement equipment bottom limit. In wet season, Cu concentration was ranged from 0.015 to 0.078 ppm. Fe concentrations in dry and wet seasons were ranged from 0.12 to 0.34 ppm and from 0.054 to 0.352 ppm, respectively.

Zn concentrations in dry and wet seasons were ranged from 0.012 to 0.091 ppm and from 0.0033 to 0.015 ppm, respectively. Heavy metal contents were likely lower in dry season than in wet season at all stations, except for Fe and Zn. High heavy metal concentrations in wet season were possibly due to heavy metals flowing from lands to the Rupat strait via watershed.

3.3 Statistical Analysis

Table 1 shows the statistical analysis on physical and chemical parameters in wet and dry season .The pH, salinity, TDS, DO, Pb concentrations, Cu concentrations, Fe concentrations, and Zn concentrations in dry season were significantly different in those in wet season with p-value less than 0.05.

On the other hand, statistical analysis did not express extreme difference between TSS and turbidity in dry season and those in wet season with p-value 0.22 for TSS and 0.39 for turbidity. Cu concentrations did not vary in both seasons at all stations.

Table 1. Variation of physical and chemical parameters in dry and wet seasons

Parameter	Standard Deviation		p-value	annotation
	Dry season	Wet season		
pH	0.542403	0.870944	0.00	different
Salinity	0.03604	0.041952	0.00	different
TDS	1340.29012	214.517374	0.00	different
TSS	18.884542	25.101793	0.22	similar
Turbidity	8.804146	9.10098	0.39	similar
DO	0.377177	0.547199	0.00	different
Pb	0.003162	0.069634	0.00	different

Cd*	-	-	-	-
Cu	0.018232	0.00	0.01	different
Fe	0.08765	0.104371	0.04	different
Zn	0.004933	0.024946	0.02	different

* Immeasurable

3.4 Water Quality Status Determination Calculation

Water quality status determination was conducted via contamination index calculation for each station in both seasons. The calculation method was based on Indonesian Ministry of Environment and Forestry Regulation Number 27 Year 2021. The physical and chemical parameters were used for calculation inputs. Calculation results were compared with water quality criterion score listed in Appendix VI of Indonesian Government Regulation Number 22 Year 2021. The comparison was used to determine the quality status at each location. All results are shown in Table 2. Based on Table 2, Rupat strait waters was mildly and moderately contaminated in dry season and mildly contaminated in wet season at all stations. This suggests that rain reduced contaminant concentrations possibly via dilution.

Table 2. Pij value and dry and rainy season water quality status

Station	Dry Season		Wet Season	
	PIJ	Pollution status	PIJ	Pollution status
1	5.23221685	Moderate	4.82263859	Light
2	4.079893901	Light	3.760588415	Light
3	4.261140856	Light	3.731484722	Light
4	5.74907883	Moderate	4.365914558	Light
5	5.060100235	Moderate	3.856602247	Light
6	7.70435514	Moderate	4.119137702	Light
7	7.317057927	Moderate	4.01122672	Light
8	5.598562812	Moderate	3.977261044	Light
9	5.504697495	Moderate	3.968546381	Light
10	4.499787705	Light	3.701855878	Light

3.5 Heavy Metal Contents on Sediment

Pb concentrations in dry and wet season was ranged from 23 to 33.5 ppm and 8 to 16.01 ppm, respectively. Pb concentrations at all stations in dry season were higher than those in wet season. Cd concentrations in dry and wet season was ranged from 0.98 to 1.25 ppm and 0.54 to 0.98 ppm, respectively. Cu concentrations in dry and wet season was ranged from 1.19 to 3.75 ppm and 3.57 to 6.07 ppm, respectively. Fe concentrations in dry and wet season was ranged from 11394 to 18476 ppm and 6903 to 10693 ppm, respectively. Zn concentrations in dry and wet season was ranged from 40.7 to 72.5 ppm and 31.24 to 43.66 ppm, respectively. Heavy metal concentrations in the sediment at control station were very low compared to those at the other stations in both seasons. This suggests that control station was relatively unaffected by anthropogenic activities. Table 3 shows the statistical analysis on heavy metal concentrations in the sediment in dry and wet seasons. The concentrations of Pb, Cd, Cu, Fe, and Zn in dry season were significantly different from those in wet season with p-value less than 0.05.

Table 3. Variations in the results of dry and wet season sediment samples

Parameter	Standard Deviation		p-value	annotation
	Dry season	Dry season		
Pb	0.00446	8.17292	0.000003	different
Cd	0.00033	0.22507	0.00	different
Cu	0.00164	0.93524	0.000258	different
Fe	2.94342	5089.73426	0.000015	different
Zn	0.01231	19.03941	0.00	different

3.6 Heavy Metal Contamination Status Determination

Heavy metal contamination status determination in dry and wet season was conducted via calculations of heavy metal contamination factors and heavy metal contamination burden indices. The calculation method was based on Indonesian Ministry of Environment and Forestry Regulation Number 27 Year 2021.

Heavy metal contents were used for calculation inputs. Calculation results were compared with water quality criterion score listed in Appendix VI of Indonesian Government Regulation Number 22 Year 2021. The comparison was used to determine the quality status at each location. Rupat strait waters was mildly contaminated in dry season and mildly contaminated in wet season at all stations (Table 4).

Table 4. Contamination factors and status of metal pollution in the dry and rainy seasons

Station	**Dry Season**		**Wet Season**	
	PLI	**Pollution Index**	**PLI**	**Pollution Index**
1	0.5541	Not Polluted - Lightly Polluted	0.5920	Not Polluted - Lightly Polluted
2	0.3775	Not Polluted - Lightly Polluted	0.4853	Not Polluted - Lightly Polluted
3	0.4010	Not Polluted - Lightly Polluted	0.7152	Not Polluted - Lightly Polluted
4	0.6211	Not Polluted - Lightly Polluted	0.7028	Not Polluted - Lightly Polluted
5	0.5035	Not Polluted - Lightly Polluted	0.6879	Not Polluted - Lightly Polluted
6	0.5485	Not Polluted - Lightly Polluted	0.5787	Not Polluted - Lightly Polluted
7	0.4125	Not Polluted - Lightly Polluted	0.7586	Not Polluted - Lightly Polluted
8	0.4971	Not Polluted - Lightly Polluted	0.5613	Not Polluted - Lightly Polluted
9	0.6136	Not Polluted - Lightly Polluted	0.5853	Not Polluted - Lightly Polluted
10	0.0000	Not Polluted	0.0688	Not Polluted - Lightly Polluted

4 Discussion

Measured pHs in dry season was generally within the allowable range for harbour water and higher than those in wet season. This finding is in accordance with previous research on

Rupat strait quality assessment [18, 19, 20]. It was also discovered that pH at station 4 and 6 was relatively high in dry season. Station 4 and 6 was located in Dumai's industrial area, harbour, logistics, economic and trading activities, and residences. Anthropogenic activities in the area promoted high pH in the waters. In addition, the absence of rain reduced the amount of water flowing into the area also increased water pHs. In overall, all stations had pH within the allowable range for harbour. This concludes that Rupat strait had good water quality. Significant difference between pHs in dry season and pHs in wet season indicates strong influence of rain water to pH dynamics in Rupat strait. Salinity measurement suggested that the salinity in dry season was higher than salinity in wet season. Nevertheless, the salinity generally was less than Indonesia's average waters salinity which roughly was 32-34% . Low salinity in Rupat strait was due to tide movement and supply of freshwater from nearby river. Increasing salinity in station 3, 4, 5, and 5 was probably due to domestic activities, such as cloth washing and bathing. Low salinity was in accordance with previous research [18, 19, 20]. Significant difference between salinity in dry season and salinity in wet season indicates strong effect of rain water on nearby river flow.

Measured total dissolved solid (TDS) and total suspended solid (TSS) varies in both seasons and at all stations. TDS in dry season far exceeded the maximum allowable limit while TDS in wet season was slightly more than the maximum allowable limit at all stations. High TDS in dry season could be due to high TSS and turbidity. TSS consisted of mud, fine sand, and microorganisms originating from eroded soil flowing to the waters. TSS affects sun light penetration. High TDS, TSS, and turbidity was due to low DO in dry season. High concentrations of suspended solid promoted sun light intensity reduction which inhibited photosynthetic process and consequently reduced oxygen concentrations in the waters. Significant reduction of TDS in wet season was due to physicochemical reactions such as sedimentation, coagulation, and rain water runoff.

In contrary, the increase of rain intensity did not significantly affect the reduction of TSS and turbidity. Measured DO concentrations suggested that DO concentrations were well below the maximum allowable limit in dry season but higher than the maximum allowable limit in wet season [19]. Low DO concentrations negatively impact aquatic life and even cause deaths of macroorganisms. DO has strong affiliations with anthropogenic and domestic activities in the waters. DO concentrations decrease as the amount of waste, water temperatures, and water velocity increased. In this research, the decrease of DO concentrations was associated with high TDS, TSS, and turbidity. Metal contamination in the waters is considered a serious matter. Released metals to the waters tended to accumulate in the sediment and later be consumed by aquatic organisms. Heavy metal concentration analysis on the water and sediment samples suggested that Pb and Cd concentrations in the sediment obtained in wet season exceeded average concentrations of those in natural waters. In contrary, Cu, Zn, and Fe had lower concentrations than their average concentrations in natural waters. In dry season, Cd concentrations were higher than those of natural Cd concentrations in waters. Metal concentrations in waters tend to be higher in wet season than in dry season. Generally, the increase of rain intensity enhance water runoff and erosion which consequently accumulate metal in sediment.

Nevertheless, Pearson correlation in wet season did not show correlation between metal concentrations in water and sediment while in dry season significant correlation was present with negative correlation. Metal concentrations in the waters along with physical and chemical parameters were used as indicators to determine environmental contamination status. Based on the physical and chemical parameter and metal concentration measurement, contamination status of Rupat strait generally was moderately contaminated in dry season and heavily contaminated in wet season. The increase of rain intensity reduced contamination intensity via water velocity enhancement and fine particle removal. Two stations, namely: station 2 and 3, were mildly contaminated while the rest, not including control station, were

moderately contaminated. The presence of river near station 2 increase the amount of water. Fresh water flow from the river flowing to Rupat strait also reduced physical and chemical parameter. Metal contamination status in Rupat strait was uncontaminated to mildly contaminate. This trend shows that Rupat strait water quality was not affected with contaminant coming from the surrounding anthropogenic activities.

5 Conclusion

This research concluded that physical and chemical paramater and heavy metal concentrations in water and sediment were significantly distinctive in both seasons except for TSS and turbidity. However, water contamination status in Rupat strait was the same in both seasons, which was mildly contaminated to moderately contaminated in dry season and wet season with heavy metal contamination status of uncontaminated to mildly contaminate. Rupat strait water quality was in good conditions and uncontaminated with wastefrom the surrounding environment.

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