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Seasonal Variation on Dissolved Oxygen, Biochemical Oxygen Demand and Chemical Oxygen Demand in Terengganu River Basin, Malaysia

ABSTRACT

The rise in human population densities and the pace of development had intensified the depletion of the water quality. This study aimed to analyze the concentration of dissolved oxygen (DO), biochemical oxygen demand (BOD) and chemical oxygen demand (COD) during wet season and dry season at Terengganu River in 2016. A total of 29 monitoring stations in the study area were selected and three water quality parameters were analyzed using descriptive statistics and the correlation matrix methods. The DO ranged from 2.11 to 8.07 mg L^{-1}, COD from 2.24 to 39 mg L^{-1} and BOD from 0.67 to 6.52 mg L^{-1} for the wet season while in dry season, DO ranged from 2.30 to 6.05 mg L^{-1}, COD from 1.9 to 20.48 mg L^{-1} and BOD from 0.04 to 13.99 mg L^{-1}. Spearman's correlation test shows there was a weak correlation between DO and COD during wet season, while in the dry season, there was a weak correlation between DO-COD and DO-BOD. This study also found out that urbanization and anthropogenic activities in the area can gave the more impact towards seasons and water quality deterioration in Terengganu River, Malaysia.

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INTRODUCTION

Rivers are one of the major water supplies and offer many benefits, such as drinking water supply, irrigation, industry, agriculture and recreation. According to Department of Environment (DOE), Malaysia, there are several factors influencing river quality degradation including such land use growth, urbanisation and geomorphology factors (*Pantelic et al. 2016; Kamarudin et al. 2015*). While figures vary, the World Health Organization (WHO) estimates that about 36% of urban and 65% of rural Indians do not have access to clean drinking water (*Manda and Das 2011*). Water has its own criteria for composition and purity for various uses, and each body of water must be tested on a daily basis to ensure its suitability. Water is the most significant way of maintaining life and energy in all economic activities related to agriculture and industry (*Baltazar et al. 2016*). Water quality index (WQI) is useful in assessing the suitability of river waters for a variety purposes such as agriculture, aquaculture, and domestic use (*Kamarudin et al. 2020*).

In the seasonal cyclic phenomenon of the tropical climate, rainfall plays an important role and induces major shifts in water quality changes in the environment. River water quality has been studied to vary with seasons particularly with changes in temperature and rainfall (*Wahab et al. 2019; Suratman et al. 2016*). During the wet season where heavy rainfall period takes place (October to December), lower mean temperature values (28 to 29ºC) were recorded. On the other hand, higher mean values (29 to 33°C) were reported during the dry season (January to September). This happened because during the wet season, the weather is typically cloudy and rainy (*Suratman et al. 2006*). This results in cooler temperatures due to the lack of direct sunlight. The same trend occurs in the Terengganu River Basin (*Wahab et al. 2019*), where this study was conducted. In a tropical country like Malaysia, the intensity of rainfall during dry and wet seasons changes the water quality significantly. Owing to increased surface runoff from anthropogenic activities, the high rainfall during the wet season may either minimize the pollution load by dilution or worsen the water quality (*Ling et al. 2017*).

The water quality parameters considered in this study were dissolved oxygen (DO), chemical oxygen demand (COD) and biochemical oxygen demand (BOD). Disolved Oxygen refers to the stable non-compound oxygen volume content in water or other liquids. Due to its effect on the living organisms in bodies of water, it is an important criterion for assessing the quality of water. Disolved Oxygen enters water through the air or as a plant by-product. Meanwhile, BOD reflects the quantity of oxygen absorbed by microorganisms when decaying organic matter under aerobic conditions (oxygen is present) at a given temperature. chemical oxygen demand is a measurement of the oxygen required to oxidize soluble and particulate organic matter in water (*Malenab et al. 2016; Shuhaimi et al. 2007*).

This study aimed to analyze the water quality during the dry and wet seasons by referring to the concentrations of dissolved oxygen (DO), biochemical oxygen demand (BOD), and chemical oxygen demand (COD) in the Terengganu River Basin. The evaluation of water quality was based on National Water Quality Standards (NWQS). The NWQS for Malaysia varies depending on the parameters involved in the calculation of water quality index (WQI) and classification according to uses (**Table 1**). The WQI is commonly used by researchers to evaluate the water quality of river system and classify them based on quality (*Suratman et al. 2009; Simoes et al. 2008*). The DOE-WQI scale classifies the water quality into 3 categories, which are 'clean' (81 to 100%), 'slightly polluted' (60 to 80%) and 'polluted' (0 to 59%) (*Suratman et al. 2015*).

MATERIALS AND METHODS

Research area

The Terengganu River basin (4°41-5°20'N) is located in Terengganu State, in the east coast of

Table 1. National Water Quality Standards (NWQS) for Malaysia.

Parameter	Unit	Class				
		I	II	III	IV	V
PH	-	> 7	6 – 7	5 - 6	<5	>5
DO	mgL^{-1}	>7	5 -7	3 - 5	1 - 3	<1
BOD	mgL^{-1}	<1	1 – 3	3 - 6	6 - 12	>12
COD	mgL^{-1}	<10	10 – 25	25 - 50	50 - 100	>100
TSS	mgL^{-1}	<25	25 – 30	50 - 150	150 - 300	>300
AN	mgL^{-1}	<0.1	0.1 – 0.3	0.3 – 0.9	0.9 – 2.7	>2.7
Water Quality Index (WQI		<92.7	76.5 – 92.7	51.9 – 76.5	31.0 – 51.9	>31.0
Class I	Conservation of natural environment Water supply I – Practically no treatment necessary Fishery I – Very sensitive aquatic species					
Class IIA	Water supply II – Conventional treatment required Fishery II – Sensitive aquatic species					
Class IIB	Recreational use with body contact					
Class III	Water supply III – Extensive treatment required Fishery III – Common of economic value and tolerant species; livestock drinking					
Class IV	Irrigation					
Class V	None of the above					

Source: *DOE 2006*

Peninsular Malaysia. It has a length of 100 km and an aggregate catchment area of roughly 500 km². Terengganu River is the main river in Terengganu, which starts from Kenyir Dam, Hulu Terengganu and ends in Kuala Terengganu discharge through the South China Sea (**Figure 1**). The Terengganu River includes Nerus River, Telemong River, Berang River, and Pueh River. These rivers flow through different socio-economical activities area such as agricultural plantations, farming, aquacultures, commercial industries, urban and rural settlements, reserves and forests. Both Kuala Terengganu and Kuala Berang are densely populated cities. It has a tropical wet climate with no dry or cold season, thus it is constantly moist (*Serengil et al. 2007*).

The annual mean air temperature varies between 26 and 28°C and the annual rainfall is about 3300 mm. The northeast monsoon season (November to March) brings heavy rains to this basin.

Sample Collection

The sampling collections were conducted in January 2016 (wet season) and July 2016 (dry season). The locations of the sampling stations were chosen based on the land-use pattern of the area, which included sand mining, farming and agricultural, industries and residential (**Figure 1 and Table 2**). The latitude and longitude of the sampling stations were measured using GPS.

The water samples were collected from 29 different predetermined sampling stations from downstream to upstream area along Terengganu River Basin. Three replicate samples were taken randomly at each station using polyethylene bottles and were labelled with station number. The samples were collected by directly filling the container from the surface body and by decanting the water from a collection device (*Kamarudin et al. 2015*).

Preservations were made on site immediately at the time of the processing of the sample. Collected samples were stored in the icebox at a temperature of about 4°C to suppress or slow down the metabolism of the organism in the sample. All the samples were stored in the refrigerator at the temperature less than 6°C with covered layer to maintain dark condition. Open reflux method was used to determine the value of COD, in which the samples were refluxed for 2h in an acidic medium, using potassium dichromate as an oxidizing agent. Both BOD and DO were determined by using the water-quality Multiprobe Model DO Meter YSI 58 and BOD Check Portable (*Wahab et al. 2019*). This multiprobe meter was calibrated before field sampling. Laboratory analysis was performed based on the standard method of analysis (*APHA 1998*) procedure.

Statistical analysis

The statistical analysis used in the study was descriptive statistical analysis and correlation test. The

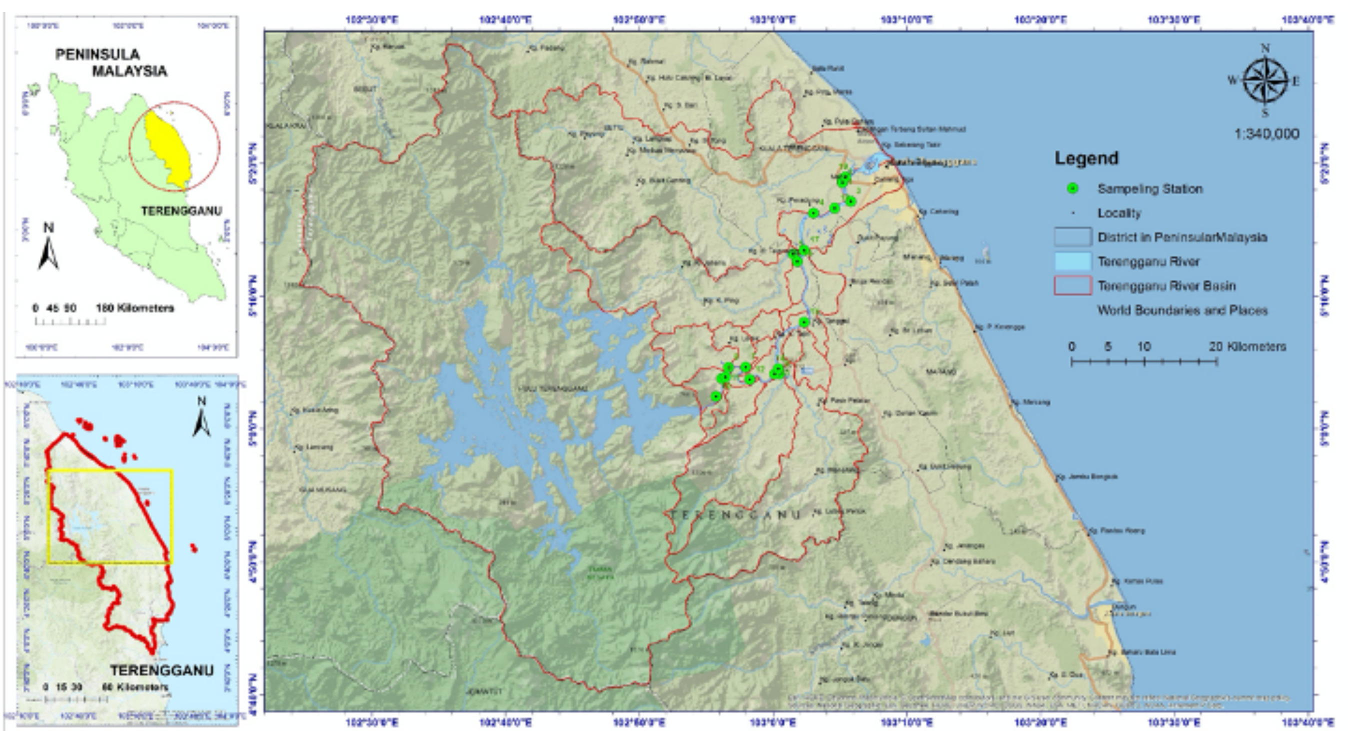

Figure 1. Location of the 29 sampling stations along Terengganu River, Terengganu, Malaysia.

Table 2. Location of the 29 sampling stations along Terengganu River, Malaysia (January 2016 and July 2016).

Sampling Stations	Latitude	Longitude
WQ1	5°20'23.93"N	103° 8'21.92"E
WQ2	5°19'26.55"N	103° 6'20.14"E
WQ3	5°19'40.59"N	103° 5'56.80"E
WQ4	5°18'48.53"N	103° 5'12.22"E
WQ5	5°18'32.74"N	103° 5'12.42"E
WQ6	5°17'7.75"N	103° 5'50.67"E
WQ7	5°16'14.99"N	103° 3'3.64"E
WQ8	5°13'9.00"N	103° 1'32.70"E
WQ9	5°12'42.04"N	103° 1'40.09"E
WQ10	5° 7'37.61"N	103° 2'9.46"E
WQ11	5° 4'8.14"N	103° 0'31.30"E
WQ12	5° 3'22.80"N	102°58'43.16"E
WQ13	5° 4'39.67"N	102°57'58.26"E
WQ14	5° 4'37.96"N	102°56'41.24"E
WQ15	5° 3'48.46"N	102°56'10.96"E
WQ16	5° 2'26.86"N	102°55'46.47"E
WQ17	5° 1'55.10"N	102°55'37.24"E
WQ18	5° 3'54.70"N	102°56'28.08"E
WQ19	5° 4'37.88"N	102°57'4.74"E
WQ20	5° 3'43.35"N	102°58'16.48"E
WQ21	5° 4'8.88"N	103° 0'8.50"E
WQ22	5° 4'31.96"N	103° 0'25.47"E
WQ23	5° 8'2.35"N	103° 2'21.33"E
WQ24	5°11'2.74"N	103° 2'35.85"E
WQ25	5°12'36.82"N	103° 1'50.56"E
WQ26	5°13'26.72"N	103° 2'21.83"E
WQ27	5°16'37.05"N	103° 4'38.05"E
WQ28	5°17'37.90"N	103° 5'29.09"E
WQ29	5°18'57.56"N	103° 5'27.17"E

descriptive statistical analysis was applied to describe DO, BOD and COD data after laboratory analysis. For this study, the Correlation test was adapted to determine the variables with strong relationship for further analysis as the test is suitable to measure two variables.

In this study, the relationship between significant selected parameters in water quality data (DO, BOD and COD) was calculated and the strength of parameters' relationship was determined this analysis. Spearman's rank coefficients is one of the most common forms of correlation, the former involving ordinal data since the equation would be based on data ranking. It also calculates the degree of intensity for the coefficient between the variables considered in the analysis.

RESULTS AND DISCUSSION

DO, BOD and COD concentration

The lowest value of DO concentration was at station 17, which is 2.3 mgL^{-1} and the highest value is 6.05 mgL^{-1} at station 19 during dry season. The mean value for DO was 3.45 mgL^{-1} (**Table 3**). During wet season, the lowest value for DO was at station 3, which is 2.11 mgL^{-1} and the highest value was 8.07 mgL^{-1} at station 11. The mean value for DO was 4.49 mgL^{-1} (**Figure 2**). Due to the pollution caused either by geomorphology and anthropogenic factor, the concentration of DO can drop below essential level. Plant and aquatic organisms are highly dependent on the DO concentration. The velocity of the water and the intensity of rainfall are factors that influenced the concentration of DO in river water. (*Ata et al. 2018*). When the higher discharge value and water velocity, the higher amount of concentration DO (*Jindal and Sharma 2011; Sinsock et al. 2003*).

For dry season, the lowest value of BOD was 0.04 mgL^{-1} at station 26 and the highest value was 13.99 mgL^{-1} at station 25. While for the COD, the lowest value was 1.9 mgL^{-1} in station 3 and 5, while the highest value was 20.48 mgL^{-1} in station 4. The mean for BOD and COD were 4.75 mgL^{-1} and 3.88 mgL^{-1}, respectively. During the wet season, the lowest value of BOD was 0.67 mgL^{-1} at station 6, while highest value was 6.52 mgL^{-1} at station 7. The mean for BOD was 1.15 mgL^{-1} , while for the COD, the lowest value was 2.24 mgL^{-1} in station 5 and the highest value was 39 mgL^{-1} in station 2. The mean value for COD was 4.94 mgL^{-1} (**Figure 3 and Figure 4**). The BOD concentration can increase with the presence of high amounts of pollutants such as pesticide, fertilizers and others nutrients. Oxygen used in the decomposition process robs the other oxygen that used by aquatic organisms to live (*Wahab et al. 2019*). Chemical oxygen demand is used as an indicator of oxygen equal to the organic matter composition of a sample prone to oxidation by a heavy chemical oxidant. Chemical oxygen demand is used to measure the pollutant load in the water body and can be related to BOD, organic matter and organic carbon. The BOD and COD concentrations ranged from 0.67 to 6.52 mgL^{-1} during wet season and 1.52 to 21.00 mgL^{-1} during dry season, and 2.24 to 39.00 mgL^{-1} on wet season and 1.90 to 20.48 mgL^{-1} on dry season, respectively. Generally, the BOD concentration is directly associated with DO concentrations. As BOD value increases, the DO value will decline. The increasing of COD values caused by the improper sanitation in local villages near stations 1 to 3 might bring extra biological loading into the river since the stations are located in Kuala Terengganu where there is high population. In addition, there was a general decreasing trend in the BOD and COD concentrations from downstream to upstream stations.

Table 3. Descriptive statistical for dissolved oxygen (DO), chemical oxygen demand (COD) and biochemical oxygen demand (BOD) concentration data at Terengganu River, Malaysia.

	Wet Season			Dry Season		
	DO	COD	BOD	DO	COD	BOD
Number of observations	29.00	29.00	29.00	29.00	29.00	29.00
Minimum	2.11	2.24	0.67	2.30	1.90	0.04
Maximum	8.07	39.00	6.52	6.05	20.48	13.99
Median	4.25	3.10	0.94	3.29	2.93	3.30
Sum	130.30	143.21	33.27	99.93	112.50	137.63
Mean	4.49	4.94	1.15	3.45	3.88	4.75
Variance (n)	2.37	49.14	1.06	0.52	11.87	14.18
Standard deviation (n)	1.54	7.01	1.03	0.72	3.45	3.77
Standard error of the mean	0.29	1.32	0.19	0.14	0.65	0.71

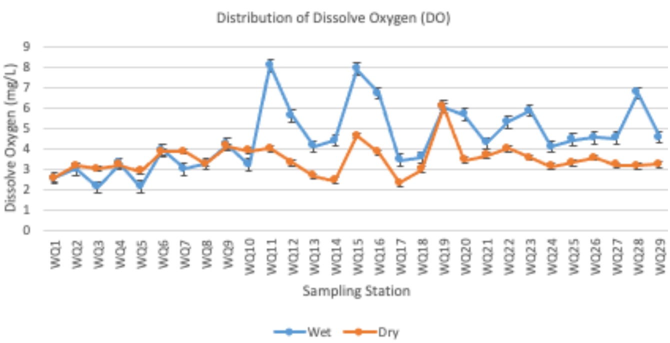

Figure 2. The distribution of Dissolved Oxygen (DO) during wet season and dry season at Terengganu River, Malaysia.

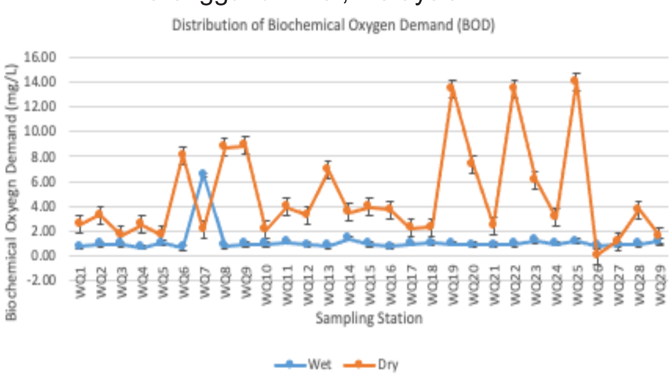

Figure 3. The distribution of Biochemical Oxygen Demand (BOD) during wet season and dry season at Terengganu River, Malaysia.

Higher amounts of DO during the rainy season than dry season can be attributed to seasonal stratification due to the temperature-dependent density of the water. It shows that dissolved oxygen in water is more likely to be held by water at lower temperatures. The DO concentration can change significantly throughout the day. This is a daily cycle due to the photosynthetic activities by aquatic plants and algae during daylight that produce excess oxygen. The BOD study provides the closest measurement of oxygen demand processes currently happening in the natural water environment, many unknown factors such

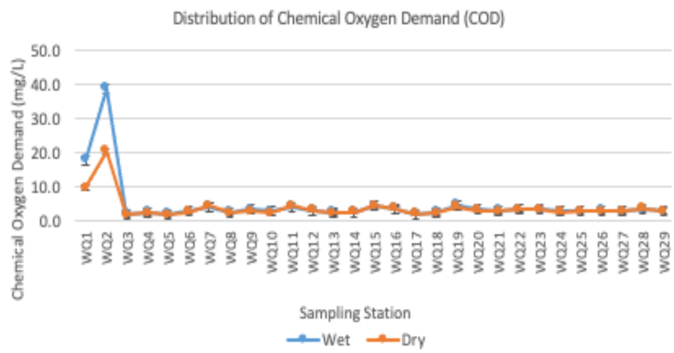

Figure 4. The distribution of Chemical Oxygen Demand (COD) during wet season and dry season at Terengganu River, Malaysia.

as contaminants, sources, concentration, amount and viability of active microorganisms present to affect the oxidation of all pollutants have been a challenge to high variability of performance (*Wahab et al. 2019*). Higher values of COD indicate pollution due to oxidizable organic matter and surface water bringing chemicals directly from farmland into the river. Higher BOD and COD speak to lower DO concentrations during the dry season may be attributed to a rise in temperature, increased biological activity, respiration of organisms and an increase in the rate of decomposition of organic matter as found in this research.

Terengganu River Water Quality Index

The water of the Terengganu River Basin (upstream until downstream) was classified as Class III (polluted), but all stations showed WQI level not below than 60% which is suitable for body contact and recreational activities. However, there are an extensive treatment required to maintain the water quality status. The study found that the downstream and middle stream stations (WQ1 until WQ14) where industrial, farming, sand mining and residential area were present recorded low water quality in the area. In order to solve this problem, the management and control approach must be conducted (*Fulazzaky et al. 2010; Kamarudin et al. 2020*). In contrast, high water quality was recorded at the upstream stations of the basin, which are neart Kenyir Dam (**Figure 5**).

Correlation Test Relationship Results

The correlation test was performed for this study in order to see the relationship between DO, COD and BOD. The r value for DO-COD is 0.453, which is the highest among the other parameters (**Table 4**). It shows that DO is positively correlated with COD with $p < 0.05$. However, correlation between DO-COD is still considered low according to the rule of thumb of correlation coefficient by *Guildford* (*1973*). This finding indicates that any changes in DO does not have major impact on COD value during that particular time. This value may change according to the condition of the study site.

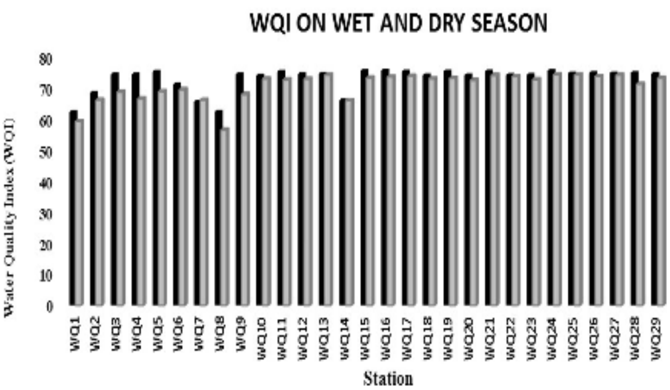

Figure 5. The Distribution of WQI at Terengganu River on January 2016 (Wet Season) July 2016 (Dry season).

Table 4. Spearman correlation matrix between dissolved oxygen (DO), chemical oxygen demand (COD) on wet season.

Variables	DO	COD	BOD
DO	1	0.453*	0.134
COD	0.453*	1	0.024
BOD	0.134	0.024	1

**Correlation is significant at the 0.05 level*

Table 5. Spearman correlation matrix between dissolved oxygen (DO), chemical oxygen demand (COD) on dry season.

Variables	DO	COD	BOD
DO	1	0.300	0.471*
COD	0.300	1	0.408*
BOD	0.471*	0.408*	1

**Correlation is significant at the 0.05 level*

The DO is positively correlated with COD and BOD and significant with $p < 0.05$. With r-value 0.471 and 0.408, it showed that DO has a weak relationship with COD and BOD. It was the same result recorded by *Hanafiah et al.* (*2018*) in Tekala River, Selangor, where there was a weak correlation between DO, BOD and COD (**Table 5**).

CONCLUSION AND RECOMMENDATION

The DO, BOD and COD were slightly higher during the wet season than in the dry season. Water quality analysis showed that BOD was high in the dry season but COD and DO were high in the wet season. High concentration of COD and BOD indicates the presence of pollutants in the water. From the Spearman's correlation, there is weak relationship between DO, COD and BOD. The data from this study were also compared to NWQS standard where WQI level not below than 60%, which is suitable for body contact and recreational activities. Nevertheless, river basin management, land use activities and anthropogenic activities must be monitored continuously to avoid water quality deterioration.

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