Water Quality of the Jerteh River Basin, Terengganu, Malaysia During the Northeast Monsoon

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Abstract. Human activities that cause land use changes are factors affecting the river’s water quality. This study was centred on assessing the quality of the water in the Jerteh River basin that was affected by the land use changes. The water samples were collected at five monitoring stations along the Jerteh River. The fieldwork was conducted between November 2017 and February 2018. The water samples were analysed in the laboratory for six water quality parameters: Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), Ammoniacal Nitrogen (NH₃-N), Alkalinity Index (pH) and Dissolved Oxygen (DO). The results showed that the water quality index for the Jerteh River was classified as moderately polluted (Class II). Three parameters, namely COD, TSS, and NH₃-N, were in Classes III and IV during the study period. This study concludes that land use changes due to human activities have impacted the water quality of the Jerteh River basin during the Northeast Monsoon season. Therefore, mitigation and drastic measures should significantly improve the Jerteh River basin’s water quality. All relevant parties should have worked collectively to improve the water quality of the Jerteh River rather than leaving it to the authorities.

1. Introduction

Studies on water quality, particularly in river basins, have always piqued the interest of hydrologists. The study on the water quality of river basins is critical because its resources provide the lion’s share of the water required for human survival. Apart from serving as a source of domestic water, it is essential for industrial operations and agricultural irrigation [1] [2] [3]. Thus, authorities should prioritise integrated drainage basin management to ensure that water resources are properly maintained and available for use continuously.

The process of development and land use change is one factor that contributes to the deterioration of water quality in a drainage basin [4] [5] [6] [7] [8]. As a result of increased human activity, the river has become a garbage dump, which could degrade the quality and quantity of the river. Recently, the number of river basins supplying water for domestic use has been discovered to be decreasing. Malaysia’s current situation indicates that some rivers are still moderately polluted or polluted, with 205 rivers (30%) being moderately polluted and 59 rivers (9%) being polluted [9]. As a result, it is not surprising that water resources have been elevated to a high priority in achieving the Sustainable Development Goals (SDGs), precisely goal number 6 on Clean Water and Sanitation.

The river is supplied with water by a drainage basin, an open system constantly threatened by ineffective management. The Jerteh River basin is no exception; as one of the significant sub-basins of the Besut River, it is constantly threatened by a variety of human activities that have a detrimental effect on the quantity and quality of the Jerteh River’s water. The Jerteh River is undeniably an essential source of domestic water for the residents of the Besut district. The purpose of this article
was to assess the Jerteh River’s water quality during the rainy season when the Northeast Monsoon winds blew.

2. Material and Method

2.1 Study area and sampling stations

This research was conducted in the Jerteh River basin, located in the district of Besut, Terengganu. It was chosen as the study area due to the pollution caused by rapid land development, particularly in the city of Jerteh. Municipal land use, housing, and agriculture are growing in this region. The Jerteh River is one of the Besut River’s sub-basins. According to the Terengganu State Survey and Mapping Department [10], the total length of this river is approximately 2.8 km, with a width of 30 m. The basin of the Jerteh River covers an area of 18 km².

Additionally, the Jerteh River is administered by the Besut District Council and the Besut District Irrigation and Drainage Department. Five sampling stations were located along the Jerteh River to determine its water quality (Table 1 & Figure 1). The first sampling station, designated point A, was located at the estuary. While the second and third stations, labelled as points B and C, were located in the midstream of the river. Finally, the fourth and fifth stations, labelled as points D and E, were located upstream of the Jerteh River.

| Station | Location  | Latitude       | Longitude       | Land Use                                      |
|---------|-----------|----------------|-----------------|----------------------------------------------|
| A       | Downstream| 5°44'17" U     | 102°29'51" T    | Recreational activities and housing           |
| B       | Midstream | 5°44'14" U     | 102°29'48" T    | Municipality, residential, and industrial activities |
| C       | Midstream | 5°44'6" U      | 102°29'51" T    | Municipality and housing                      |
| D       | Upstream  | 5°43'48" U     | 102°30'11" T    | Agriculture, housing, and forest reserves     |
| E       | Upstream  | 5°43'20" U     | 102°29'53" T    | Agriculture and housing                       |

Figure 1. Positions of water quality sampling stations in the Jerteh River.
2.2 Sampling activities and analyses

Between November 2017 and February 2018, water samples were collected four times at five designated stations along the Jerteh River. This observation could correspond to the current situation, i.e. the wet season. Essentially, rivers’ water sampling methods in this field were guided by the American Public Health Association’s (APHA) [11]. The following six water quality parameters were used: dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammoniacal nitrogen (NH₃-N), total suspended solids (TSS), and pH. Water samples were collected and analysed at the Physical Geography Laboratory, Department of Geography and Environment, Faculty of Human Sciences in the Sultan Idris Education University.

Six water quality parameters were used in the analysis, as the Malaysian Department of Environment (DOE) used only these parameters to determine the state of a river’s water quality, referred to as the DOE Water Quality Index Classification (DOE WQIC). The DOE WQCI categorises water quality into five categories and determines the water’s current state, as shown in Table 1. Table 1 indicates the range of subindex values (SI) for each water quality index (WQI) parameter. This WQI was calculated using the formula developed by Malaysia’s DOE:

\[
WQI = (0.22\times\text{SI}_{\text{DO}}) + (0.19\times\text{SI}_{\text{BOD}}) + (0.16\times\text{SI}_{\text{COD}}) + (0.15\times\text{SI}_{\text{NH₃-N}}) + (0.16\times\text{SI}_{\text{TSS}}) + (0.12\times\text{SI}_{\text{pH}})
\]

(Formula 1)

where:
- \( \text{SI}_{\text{DO}} \) = subindex DO (% saturation)
- \( \text{SI}_{\text{BOD}} \) = subindex BOD
- \( \text{SI}_{\text{COD}} \) = subindex COD
- \( \text{SI}_{\text{NH₃-N}} \) = subindex NH₃-N
- \( \text{SI}_{\text{TSS}} \) = subindex TSS
- \( \text{SI}_{\text{pH}} \) = subindex pH

0 ≤ WQI ≤ 100

To facilitate the calculation of WQI, the SI value from the River Water Quality Index Calculator was converted using a dedicated website. WQI classifications are as follows: Very Good (Class I), Good (Class II), Moderately Polluted (Class III), Polluted (Class IV), and Heavily Polluted (Class V). This water classification could be used to ascertain the purposes of water resources for various human activities, as shown in Table 2. Simultaneously, Malaysia’s DOE established the WQI for each body of water, specifically a river, and classified it as Clean (81-100%), Slightly Polluted (60-80%), and Polluted (0-59%). All data on water quality parameters were analysed using descriptive statistics to explain each parameter’s value, specifically the minimum, maximum, and average values. Each parameter data is then presented in tables and graphs to explain and show whether it exceeds or does not exceed the established standard.

| Parameter | Unit | I | II | III | IV | V |
|-----------|------|---|----|-----|----|---|
| NH₃-N | mg/l | <0.1 | 0.1-0.3 | 0.3-0.9 | 0.9-2.7 | >27 |
| BOD | mg/l | <1 | 1-3 | 3-6 | 6-12 | >12 |
| COD | mg/l | <20 | 10-25 | 25-50 | 50-100 | >100 |
| DO | mg/l | >7 | 5.7 | 3.5 | 1.5 | <1 |
| pH | | >7.0 | 6.0-7.0 | 5.0-6.0 | <5.0 | >5.0 |
| TSS | mg/l | <25 | 25-50 | 50-150 | 150-300 | >300 |
| WQI | | >92.7 | 76.5-92.7 | 51.9-76.5 | 31.0-51.9 | <31.0 |

Source: Department of Environment [9]
3. Results and Discussions

The study's findings and discussion in this section lead to an assessment of the Jerteh River’s water quality based on the six parameters established and the Water Quality Index’s status. Furthermore, the discussion on water quality parameters referred to Class III, which uses the river as a source of drinking water that requires the least amount of intensive treatment. The highest, lowest, and average values of each Jerteh River’s water quality parameter are shown for each of the five monitoring stations. Table 3 shows the concentrations of six water quality parameters observed in the study area during the wet season.

Table 3. Water classes and uses.

| Class | Uses |
|-------|------|
| I     | Natural environment conservation. Water supply I does not require any treatment in practice. Fishery is for extremely sensitive aquatic species. |
| IIA   | Water supply II necessitates conventional treatment. Fishery II is for vulnerable species. |
| IIB   | Appropriate for body-contact-based recreational activities. |
| III   | Water supply III requires intensive treatment. Fishery III is for livestock drinking. |
| IV    | Irrigation. |
| V     | Apart from the activities mentioned above. |

Source: Department of Environment [9]

3.1 Analyses of the Jerteh River’s water quality based on parameters

3.1.1 Dissolved Oxygen (DO)

The DO value is a critical parameter in determining a river’s water quality. An increased DO value in water indicates that the water is of good quality and suitable for aquatic life. DOE[9] established a water quality standard of 3.5 mg/l for the DO parameter in Class III. The highest DO reading was 7.78 mg/l (Class I) at Station A in November 2017, while the lowest DO value was 6.30 mg/l (Class II) at Station B in January 2018. The average DO value in November 2017 across all observation stations was 7.5 mg/l (Class I), the highest DO reading ever recorded. Meanwhile, the lowest average DO value recorded in January 2018 was 6.67 mg/l (Class II). Overall, changes in land use in the study area had a minor effect on DO readings. A total DO amount in water that meets DOE standards allows aquatic flora and fauna to survive in Class III. Thus, with proper treatment, this water source is suitable for drinking and recreational purposes[12].

3.1.2 Chemical Oxygen Demand (COD)

The COD value represents the amount of oxygen required to oxidise organic and inorganic chemicals found in bodies of water[13]. A higher COD value indicates that the water’s quality has deteriorated. In December 2017, the maximum value recorded at Station C was 58 mg/l (Class IV), while the minimum value recorded at Station E was 23 mg/l (Class II). Meanwhile, the average COD value by month showed a maximum of 49.8 mg/l (Class III) in December 2017 and a minimum of 28.2 mg/l (Class III) in January 2018. The average COD reading for the five stations during the study period was 35.3 mg/l, indicating that the water quality was Class III. This finding showed that the Jerteh River's water quality was moderately polluted. This finding also revealed that changes in land use in the Jerteh River basin increased pollutants and effluent emissions, resulting in higher COD readings. Industry, housing, construction, and agriculture were all identified as land use activities in the vicinity of the river basin, contributing to the increase in COD amounts at the five observation stations.
3.1.3 Biochemical Oxygen Demand (BOD)

The BOD parameter assesses the toxicity of industrial and household wastes by calculating the amount of oxygen required for the oxidation process.[13] A higher BOD reading indicates that the water’s quality has deteriorated. The minimum BOD value was 0.52 mg/l (Class I) at Station E in January 2018, while the maximum value was 2.32 mg/l (Class II) at Station A in December 2017. Meanwhile, the minimum average BOD value was 0.94 mg/l (Class I) in January 2018 and the maximum value was 1.8 mg/l (Class II) in December 2017. Overall, the Jerteh River’s BOD value during the study period was 1.3 mg/l (Class II). The water quality of the Jerteh River was classified as moderately polluted based on the average BOD reading. If the BOD level is high, so is the amount of pollution in the water, and vice versa. However, changes in land use in the vicinity of the Jerteh River did not significantly impact this BOD parameter.

3.1.4 pH

The pH of a body of water, such as a river, lake, or pond determines its acidity and alkalinity. The pH value of a river’s water indicates its quality and is related to aquatic life. DOE [9] specifies that the pH for river water in Class III must be between 5.0 and 6.0. The minimum pH value was 5.90 (Class III) at Station Bin November 2017, while the maximum value was 6.40 (Class II) at Station A in December 2017. The average minimum pH value was 6.07 (Class II) in November 2017, and the average maximum pH value was 6.28 (Class II) in January 2018. Overall, the pH value in the Jerteh River was 6.2 (Class II) throughout the study period, indicating that land use change activities in the river had impacted its pH value.

3.1.5 Ammoniacal Nitrogen (NH₃-N)

The NH₃-N parameter is used as a primary indicator of contamination caused by human, animal, and urban domestic waste, as well as industrial and agricultural fertiliser waste. A higher NH₃-N value indicates contamination in the presence of extremely high levels of organic matter. DOE[9] set a range of 0.3-0.9 mg/l for the NH₃-N value in Class III. A reading of more than 0.9 mg/l indicates that the river has been polluted. The maximum value was 0.56 mg/l (Class III) at Station A in February 2018, while the minimum value was 0.04 mg/l (Class I) at Station E. The average NH₃-N value with the lowest value of 0.12 mg/l (Class II) was recorded in January 2018, while the highest value was 0.35 mg/l (Class III) in February 2018. Overall, the NH₃-N value was 0.25 mg/l (Class II) in the Jerteh River basin. This finding revealed an increase in the NH₃-N value in the river basin in February 2018. The changes in land use in the study area, such as residential development, resulted in sewage waste being discharged directly into the river. Moreover, active agricultural activities, specifically paddy cultivation, were carried out in February 2018. Paddy ploughing activity has been held responsible for the rise in NH₃-N readings. Furthermore, observations in the study area revealed that many farmers used pesticides and chemical fertilisers on their rice crops. This activity occurred near the Jerteh River basin's upstream area. Thus, this flowing water carried these materials into the Jerteh River, indirectly increasing its NH₃-N level.

3.1.6 Total Suspended Solids (TSS)

TSS in water bodies is typically caused by sewage sludge, soil erosion, sand dredging, and natural waste [13]. The higher the TSS value, the poorer the water quality. The maximum TSS value was 170.3 mg/l (Class IV) at Station A in December 2017, while the minimum value was 131 mg/l (Class II) at Station E (November 2017). The highest average TSS was 161.02 mg/l (Class IV) in December 2017, while the lowest was 144.72 mg/l (Class III) in November 2017. Overall, the TSS reading in the Jerteh River was 150 mg/l (Class IV), indicating that it was polluted. The finding showed that TSS readings at the five stations increased from November 2017 to January 2018, then slightly decreased in February 2018. It occurred due to increased land use, particularly in the river’s upstream and middle reaches. Land use changes in the area have included building construction, housing, and
agriculture. Another factor, such as riverbank erosion, influenced the amount of TSS in the Jerteh River. Based on observations made in the study area, the river’s current was discovered to be high or fast. It resulted in erosion and transport of particles, silt, and pollutants along the river’s course.

| Month       | Station | DO  (mg/l) | BOD (mg/l) | COD (mg/l) | NH$_3$-N (mg/l) | pH | TSS (mg/l) |
|-------------|---------|------------|------------|------------|----------------|----|------------|
| November 2017 A | 7.78    | 1.84       | 37         | 0.41       | 6.19           | 152 | 50.3       |
|              B | 7.67    | 1.72       | 40         | 0.36       | 5.90           | 152.3 |           |
|              C | 7.44    | 1.38       | 33         | 0.32       | 6.13           | 145.8 |           |
|              D | 7.35    | 0.84       | 34         | 0.24       | 6.07           | 142.5 |           |
|              E | 7.28    | 0.67       | 24         | 0.19       | 6.08           | 131  |           |
| December 2017 A | 7.29    | 2.32       | 48         | 0.34       | 6.40           | 170.3 |           |
|              B | 7.34    | 2.13       | 51         | 0.31       | 6.25           | 166  |           |
|              C | 7.61    | 1.83       | 58         | 0.24       | 6.33           | 161.3 |           |
|              D | 7.72    | 1.61       | 45         | 0.20       | 6.15           | 154.5 |           |
|              E | 7.51    | 1.12       | 47         | 0.19       | 6.12           | 153  |           |
| January 2018 A | 6.90    | 1.51       | 38         | 0.22       | 6.36           | 153.2 |           |
|              B | 6.30    | 0.95       | 27         | 0.14       | 6.32           | 154.3 |           |
|              C | 6.63    | 0.86       | 29         | 0.09       | 6.34           | 149  |           |
|              D | 6.81    | 0.84       | 24         | 0.06       | 6.18           | 131.5 |           |
|              E | 6.71    | 0.52       | 23         | 0.04       | 6.20           | 136  |           |
| February 2018 A | 6.84    | 1.62       | 29         | 0.56       | 6.28           | 155.8 |           |
|              B | 6.90    | 1.43       | 30         | 0.49       | 6.19           | 153.5 |           |
|              C | 6.78    | 1.21       | 32         | 0.35       | 6.15           | 150.4 |           |
|              D | 6.61    | 0.96       | 29         | 0.24       | 6.11           | 145  |           |
|              E | 6.92    | 0.59       | 28         | 0.11       | 6.10           | 143.3 |           |
| Min         | 6.30    | 0.52       | 23         | 0.04       | 5.90           | 131  |           |
| Max         | 7.78    | 2.32       | 58         | 0.56       | 6.40           | 170.2 |           |
| Mean        | 7.12    | 1.3        | 35.3       | 0.25       | 6.20           | 150  |           |
| Class       | I       | II         | III        | II         | IV             |      |            |

### 3.2 Status and Water Quality Index of the Jerteh River

The Jerteh River’s water quality status was determined using six major water quality parameters previously discussed. Formula 1 was used to evaluate the river’s water quality status. Also, the WQI at each station was determined based on DOE[9] as the range index for the following statuses: Clean(81-100), Slightly Polluted (60-80), and Polluted (0-59).

Water quality analysis conducted throughout the study revealed that the Jerteh River was moderately polluted and classified as a Class II(Table 3). During the study period, the highest WQI recorded was 85, which was classified as Class II with a Clean status at Stations D and E in January 2018. While the lowest WQI readings were recorded in December 2017 at Stations A, B, and C, classified as Class II and Slightly Polluted. Overall, December 2017 had the lowest average WQI value of 77.8 (Class II) with a Slightly Polluted status, and January 2018 had the highest average WQI value of 82.6 (Class II) with a Slightly Polluted status. With an WQI value of 80.1 (Class II), it can be concluded that the Jerteh River's water quality was Slightly Polluted during the study period. However, the Class II designation indicates that the water in the Jerteh River can still be used as a source of drinking water and requires conventional treatment. It is also suitable for sensitive species fishing and recreational activities involving body contact.

There is no doubt that land use development in the Besut district in general, specifically in the Jerteh River basin, has impacted the Jerteh River's water quality. The deterioration of its water quality has been linked to urbanisation activities, particularly in terms of TSS, COD, andNH$_3$-N parameters.
Furthermore, studies conducted during the wet season contributed to the accumulation of pollutants in the river, as heavy rainfall transports all silt and sediment directly from the earth's surface into the river[14][15][16].

| Month       | Station | WQI | Class       | Status            |
|-------------|---------|-----|-------------|-------------------|
| November 2017 | A       | 78  | II          | Slightly Polluted |
|             | B       | 78  | II          | Slightly Polluted |
|             | C       | 80  | II          | Slightly Polluted |
|             | D       | 81  | II          | Clean             |
|             | E       | 84  | II          | Clean             |
| December 2017 | A       | 77  | II          | Slightly Polluted |
|             | B       | 77  | II          | Slightly Polluted |
|             | C       | 77  | II          | Slightly Polluted |
|             | D       | 79  | II          | Slightly Polluted |
|             | E       | 79  | II          | Slightly Polluted |
| January 2018  | A       | 79  | II          | Slightly Polluted |
|             | B       | 81  | II          | Clean             |
|             | C       | 83  | II          | Clean             |
|             | D       | 85  | II          | Clean             |
|             | E       | 85  | II          | Clean             |
| February 2018 | A       | 78  | II          | Slightly Polluted |
|             | C       | 79  | II          | Slightly Polluted |
|             | D       | 80  | II          | Slightly Polluted |
|             | E       | 83  | II          | Clean             |
| Mean        |         | 80  | II          | Slightly Polluted |

4. Conclusions

Changes in land use and development in a drainage basin endanger both the quantity and quality of water, particularly river water. This situation will indirectly impact human well-being in the drainage basin that relies on water for various purposes. In this regard, land use development in the Besut district is proliferating, posing a threat to the Jerteh River's water quality. The Jerteh River's water quality was moderately polluted, with a WQI value of 80, corresponding to a Class II classification. Despite increasing land use changes in this drainage basin, this status and WQI value indicate that the Jerteh River is still in good condition and is not heavily polluted. The wet season factor associated with Northeast Monsoon winds also influenced changes in the Jerteh River's water quality, particularly for the TSS, COD, and NH₃-N parameters. Simultaneously, this study should be expanded in the future to assess the state of water quality during the Southwest Monsoon’s dry season, which runs from May to September, in order to compare the Jerteh River’s water quality status during the wet and dry seasons.

5. References

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