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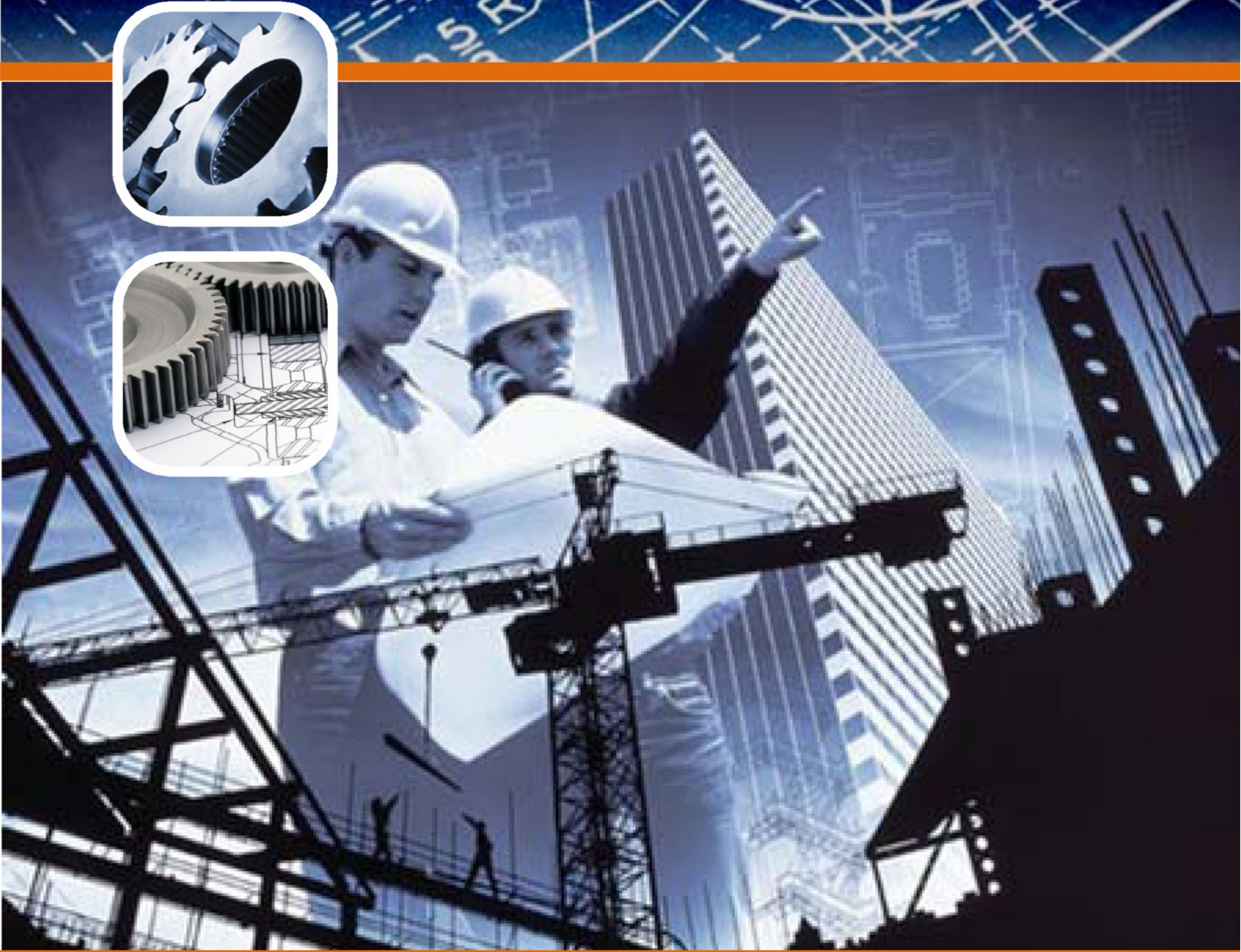

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WATER QUALITY OF RIVERS THAT FLOW INTO BAKUN HYDROELECTRIC DAM RESERVOIR, SARAWAK, MALAYSIA

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ABSTRACT

After Bakun Dam was filled to its full supply level 2 years ago, little is known about the water quality of the rivers that flow into the reservoir. After the impoundment, sections of rivers of Batang Balui were submerged. Those rivers are still important for aquatic organisms and they will affect the reservoir water quality. A previous study showed that one of the rivers to the south of the dam has high dissolved oxygen and high turbidity which affected the turbidity in the reservoir. Therefore, the objective of this study was to determine the water quality of some of the other rivers. Results show that all the five rivers are well-aerated with dissolved oxygen of above 7 mg/L. However, the Belepeh River had very high total suspended solids and turbidity when it was raining and it falls in Class III of INWQS. In contrast, turbidity values of the other four rivers complied with Class II standard. In terms of BOD_5, when it rained, all the rivers fall in Class III except for the Bulo River which complied with Class II. There is a need to reduce the inflow of sediments into the Belepeh River to provide suitable environment for sensitive aquatic species.

Keywords: Balui River; Belepeh River; Wat River; Na River; Bulo River.

1. INTRODUCTION

Balui River was impounded and the Bakun Dam was filled to its full supply level on the 9th of March 2012. In the process, part of Balui River and the lower courses of many rivers and confluences were submerged. The remaining river sections are very important riverine habitat and nursery areas for aquatic organisms such as fish. It has been reported that the population density of trout fry increased in most afferent streams at Cow Green Reservoir in England (Crisp, Mann & Cubby, 1984). Previous studies have also shown that the density of fish in the rivers upstream of reservoirs has been found to increase after impoundment compared to that prior to the impoundment in England, Canada and Brazil (Penczak, Mahon, & Balon, 1984; Crisp et al., 1984; da Silva, Reynalte-Tataje, & Zaniboni-Filho, 2012).

Besides, the rivers continue to flow into the dam reservoir and thus its water quality may affect the reservoir water quality. A previous study of water quality at the Bakun Reservoir two months prior to it reaching the full supply level showed that one of the rivers to the south of the dam, namely the Kebhor River, has high turbidity attributed to suspended solids from

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exposed soil due to logging activities, which affected the turbidity in the reservoir (Nyanti, Ling, & Grinang, 2012). Other than suspended solids, other anthropogenic pollutants such as organic matter and nutrients also affect the river water quality. Studies conducted in Ai River and Engkari River upstream of the Batang Ai Hydroelectric Dam Reservoir showed that high total phosphorus and significantly higher biochemical oxygen demand were observed in the river near to villages in Engkari River (Ling, Lee, & Nyanti, 2013a; Ling, Nyanti, Leong & Wong, 2013b). In addition, studies on Serin River also showed the impacts of land use on organic matter, nutrients and trace metals in the river (Ling, Srikaran, Kho & Nyanti, 2010). Therefore, the water quality of rivers that flows into Bakun Dam need to be investigated.

2. METHODOLOGY

Five rivers flowing into the Bakun Hydroelectric Dam located in Belaga were selected for this study. Samplings were conducted in November 2013 and February 2014. Descriptions of the five stations are as shown in Figure 1 and Table 1.

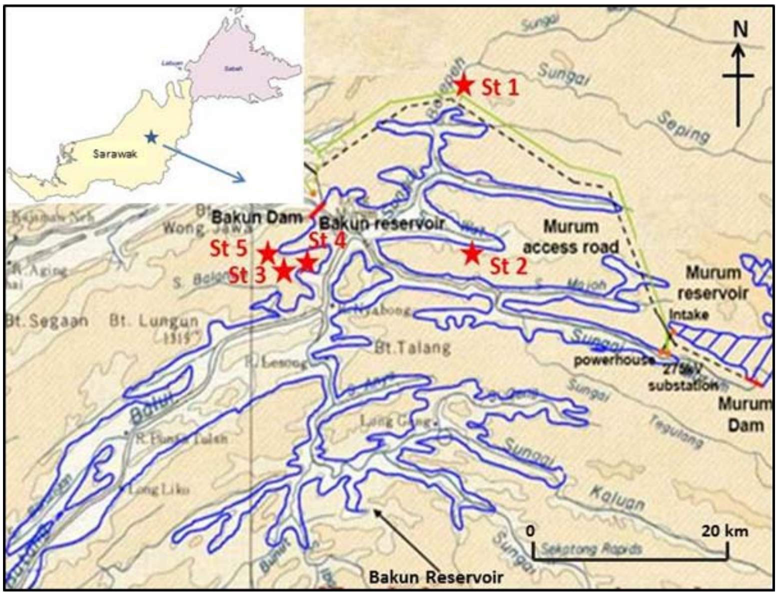

Figure 1: Map of the sampling stations in relation to Bakun Hydroelectric Reservoir.

Table 1: Sampling stations with GPS locations.

Station	River	Coordinates
1	Sungai Belepeh	N 02°49'24.1" E 114°07'46.9"
2	Tributary of Sungai Wat	N 02°44'27.1" E 114°09'23.1"
3	Tributary of Sungai Na	N 02°43'43.5" E 114°02'38.8"
4	Tributary of Batang Balui	N 02°43' 56.4 E 114°03'11.7"
5	Sungai Bulo	N 02°44'18.5 E 114°01'20.6"

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In-situ measurements taken were temperature, dissolved oxygen (DO), pH, and turbidity. Temperature, pH, and turbidity were measured using YSI 6820 whereas DO was measured using YSI Pro 20 DO meter. The water samples were collected from the subsurface of the water at the five chosen stations along the rivers flowing into the Bakun Dam for analysis. Three replicates were collected for the same purpose. Biochemical oxygen demand (BOD_5) test which was conducted according to the Standard Method of Examination of Water and Wastewater (APHA, 1998) began in the field. Water sample was transferred into a 300 ml BOD bottle and the initial DO was measured before incubation. After five days, the DO was measured again. The difference between the initial and final DO was taken as BOD_5 value.

Data obtained were analyzed for significance difference. One-way ANOVA was used to test for any significant difference among stations for each trip. Two-way ANOVA was used to compare the means between trips. Whenever there was a significant difference among stations, Tukey's test was used for pairwise comparisons. All statistical analyses were conducted using IBM SPSS Statistics 22.

3. RESULTS AND DISCUSSION

Figure 2 shows that, for the first trip, the highest temperature recorded was at Station 2 whereas the lowest temperature recorded was at Station 4 and the range was 24.2°C-25.2°C which did not show much difference among the stations. However, in the second trip, the range of temperature of the stations was higher at 24.5°C-30.2°C, where the highest temperature was observed at Station 1 and the lowest temperature recorded was at Station 2. The temperature recorded at most of the stations in the second trip was higher than the first trip due to the dry weather as it did not rain for 3 days prior to the sampling. In the second trip, water temperature was the highest at Station 1 and the second highest at Station 3 respectively because of different factors. At Station 1, during the second trip, the water temperature was higher than the first trip because in the second trip, it was stagnant and thus the water heated up by solar radiation stayed at the surface whereas in the first trip, due to the rain, the water was fast flowing. During second trip, Station 3 was less shaded and the water flow was slower than Station 2 and Station 4. That explained the higher temperature of Station 3 compared to Stations 2 and 4. The higher temperatures of 29.2°C and 30.2°C are similar to the subsurface temperature reported for the stations in Bakun Reservoir in January 2012 (Nyanti et al., 2012). However, all the temperatures recorded in the present study are higher than that recorded upstream of the Kebho River (22.9°C) to the south of the dam in their study. The lower values observed in this study fall in the range observed in the Serin River, 23.5°C-26.2°C (Ling et al., 2006) and they are typical of rivers in the tropics.

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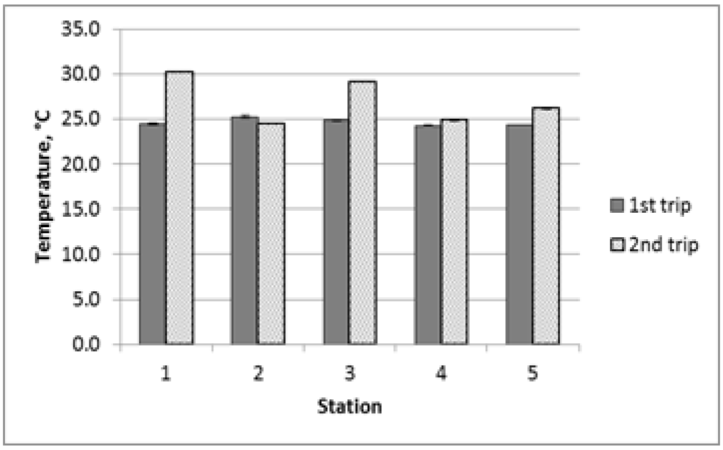

Figure 2: Temperature at the five stations for the two trips.

For the first trip, the highest pH value recorded was at Station 2 whereas the lowest was recorded at Station 5 (Figure 3). For the second trip, the highest pH value was recorded at Station 1 and the lowest pH value was recorded at Station 3. Generally, the trend shows an increase in pH value from the first trip to the second trip, except for Station 2 and 3. pH value is an indicator of the acidity of the water and the range in pH value observed in this study was 6.8-7.8 which indicates that the water was around neutral and it falls in Class I (6.5-8.5) of the Interim National Water Quality Standard of Malaysia (INWQS). This range of pH values is close to that of the Serin River, pH 6.5-7.1 (Ling, Harold, Then & Apun, 2006). Compared to the pH of the upstream water of Kebhor River (pH 6.41), the pH observed in this study were higher (Nyanti, Ling & Grinang, 2012).

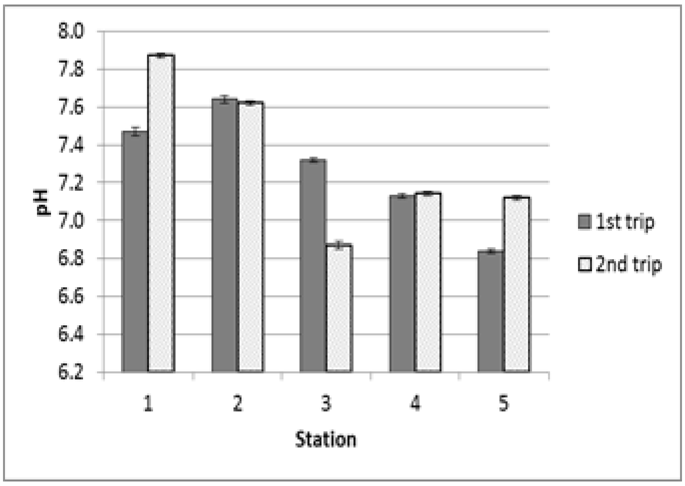

Figure 3: pH at the five stations for the two trips.

Turbidity measured during the trips indicated that the highest turbidity was at Station 1 during the first trip whereas the lowest turbidity recorded was at Station 2 during both trips (Figure 4). At Station 1, the turbidity during the first trip was 22 times that of the second trip. The high turbidity during the first trip at Station 1 was due to the soil eroded from exposed land due to logging activities upstream which was transported by runoffs when it rained. As the weather was dry a few days prior to the second sampling, the soil particles have settled at the bottom of the river and thus the turbidity was much lower. The turbidity ranged from 5.6 to

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126.8 NTU for the first trip and from 2.6 to 10.7 NTU for the second trip. In the first trip, turbidity at Stations 1, 2, 4 and 5 were significantly different from all the other stations (P<0.05). On the other hand, turbidity at Station 3 was not significantly different from 4 and 5 (P>0.05) but significantly different from the others (P<0.05). There was a significant difference among all stations in the second trip (P<0.05). The highest turbidity observed in this study was even higher than that observed at upstream section of Kebhor River in January 2012 as it was reported to be 93.7 NTU which was also attributed to logging activities in the watershed (Nyanti, Ling & Grinang, 2012). Station 1 of the first trip exceeded Class II limit (50 NTU) of INWQS whereas Station 2 of both trips and Station 3 of the second trip complied with Class I (5 NTU) and the others complied with Class II.

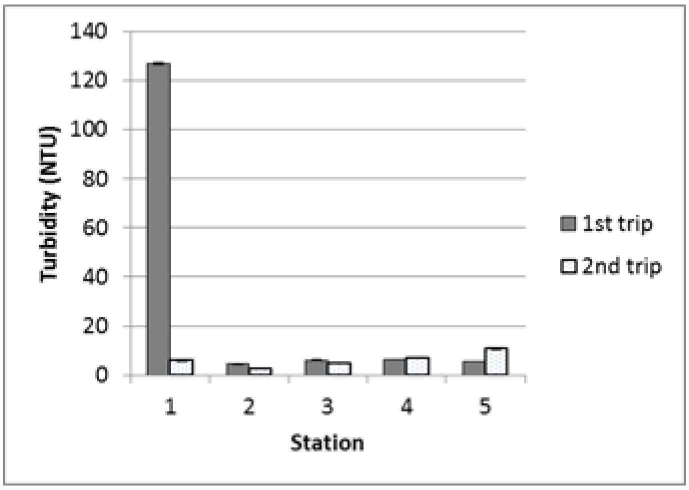

Figure 4: Turbidity at the five stations for the two trips.

The DO value at the subsurface water ranged from 7.3 to 8.9 mg/L and 7.2 to 9.1 mg/L for the first and second trips respectively with both trips showing the highest DO value at Station 1 whereas the lowest DO value was recorded at Station 4 (Figure 5). Those DO values were all above 5 mg/L which is the minimum required for healthy aquatic organisms (Chapman, 1996). In the first trip, DO at Stations 1-3 were significantly different from all the other stations (P<0.05) whereas DO at Stations 4 and 5 were not significantly different from each other (P>0.05). In the second trip, DO at Stations 1, 2 and 4 were significantly different from all the other stations (P<0.05) whereas Stations 3 and 5 were not significantly different from each other (P>0.05). The high DO values were due to sufficient aeration at subsurface and for the rivers of Stations 2-5, the water was fast flowing. Nyanti et al. (2012) also reported that the flowing of the Kebhor River to the south of the dam had high DO of 9.35 mg/L. All the DO values fall in Class I (> 7 mg/L) of the INWQS.

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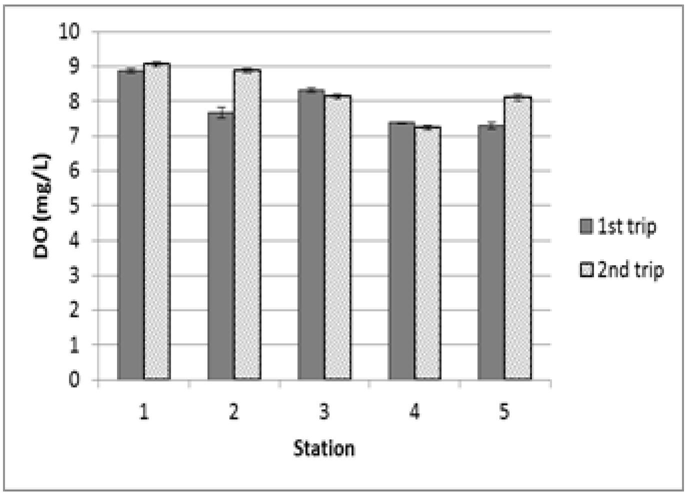

Figure 5: Dissolved oxygen (DO) at the five stations for the two trips.

For the first trip, the highest BOD_5 value recorded was at Station 1 whereas the lowest BOD_5 value recorded was at Station 5. The range in BOD_5 value is from 2.6-5.2 mg/L for the first trip. Station 2 was significantly different from Stations 1, 3, and 5 ($P<0.05$) but not significantly different from Station 4 ($P>0.05$). Meanwhile, for the second trip, the highest BOD_5 value recorded was also at Station 1 and the lowest BOD_5 recorded was at Station 4. The range in BOD_5 value was 0.9-4.0 mg/L for the second trip. There was a significant difference between the means of all the five stations ($P<0.05$). Station 1 has the highest BOD_5 in both trips because of the station being downstream of active logging areas and also downstream of the log pond used to store the logs. Organic matter derived from household and physiological waste of loggers staying in the area other than the plants debris led to the significantly higher BOD_5 observed there. Two-way ANOVA shows that the first trip showed significantly higher mean BOD_5 value (3.74 mg/L) than the second trip (2.42 mg/L) ($P<0.0005$). This shows that during raining, BOD_5 was higher than during dry time as organic matter derived from land brought by runoffs and also from the riverbed through turbulence resulted in more demand for oxygen. In the watershed of the rivers where Stations 2-5 were located, there were no active logging activities during the present study but the area has been logged previously and thus, not as high BOD_5 was observed in the dry day but higher during the rainy day. Compared to Serin River BOD_5 values (6-9 mg/L), these rivers have lower BOD_5 values, most likely because the Serin River watershed is populated and has agricultural activities, and animal and fish farming which contributed to more organic matter at the river. Station 1 of both trips and Stations 2, 3 and 4 of second trip fall in Class III (3-6 mg/L) of INWQS whereas Station 5 of both trips and Stations 2 and 3 of second trip fall in Class II (1-3 mg/L). The lowest BOD_5 value was at Station 4 during second trip and it falls in Class I of INWQS.

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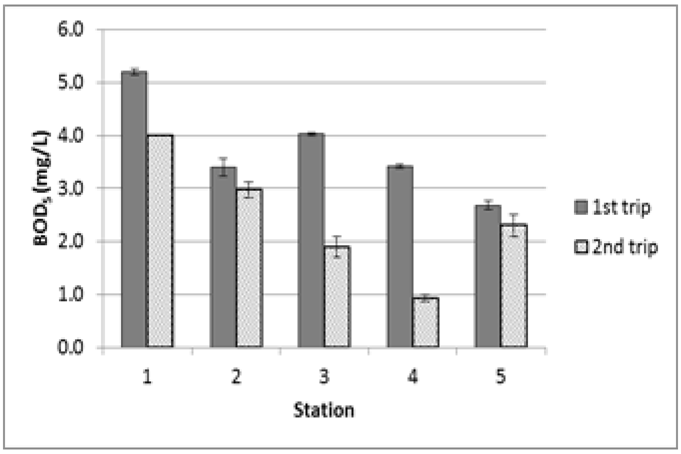

Figure 6: Five-day biochemical oxygen demand (BOD_5) at the five stations for the two trips.

4. CONCLUSION

This study shows that Belepeh River which has active logging activities in the watershed showed very high turbidity when it was raining. The other four rivers did not show high turbidity and they complied with Class II. However, during rainy day, BOD_5 of all stations were higher than dry days and at three of the five rivers, BOD_5 dropped from Class II to Class III eventhough no active logging activities were going on as compared to before. Thus, there is a need to reduce the turbidity of the Belepeh River for the health of aquatic organisms.

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