Improvement of Dissolved Oxygen in Perlis River based on Various Aeration Systems

M F H Rani1,2, N S Kamarrudin1,2, A B Shahriman1,2, Z M Razlan1,2, K Wan1,2, M S M Hashim1,2, I Ibrahim1,2, A Rahman1,2, Z Ibrahim3, M K Faizi1,2, M A S M Hassan1,2, A A Abd Manap4 and I F Zainuddin4

1Faculty of Mechanical Engineering Technology, Pauh Putra Campus, Universiti Malaysia Perlis (UniMAP), 02600 Arau, Perlis, Malaysia
2Centre of Excellence Automotive & Motorsports (MoTECH), Pauh Putra Campus, Universiti Malaysia Perlis (UniMAP), 02600 Arau, Perlis, Malaysia
3Department of Mechanical Engineering, Faculty of Engineering, Universiti Teknologi Brunei, Jalan Tungku Link, Mukim Gadong A, BE1410 Brunei Darussalam
4Department of Irrigation and Drainage Perlis, JPS Perlis Complex, Pengkalan Asam, 01000 Kangar, Perlis, Malaysia

Email: faizhilmi@studentmail.unimap.edu.my

Abstract. Water pollution is closely related to the Water Quality Index (WQI). One of the parameters in classifying WQI is dissolved oxygen (DO) that can be improved by introducing the surface and subsurface aerations. Herein, the Perlis River’s water quality was investigated by evaluating the DO’s improvement based on various aeration systems. The changes of DO (mg/L) and DO improvement (%) were evaluated during both low and high tide conditions. A total of 9 sets of data collection had been studied by comparing base DO (without running of aeration) and measured DO (with running of aeration) of river. The DO sensor was used to measure the changes of DO in the aeration measurement system. Results found that the DO improvement managed to achieve 74.89%, 10.18%, 35.58%, and 52.45% for water jet, air compressor, commercial venturi, and DIY venturi, respectively. Besides, different behaviour of DO’s improvement was observed during low and high tide conditions.

1. Introduction
Rivers are essential for fresh drinking water, for the livelihoods of people and aquatic life [1]. A good water quality is vital since 98% of the water consumption comes from rivers [2]. The race of modernization and urbanization has accelerated the water river pollution due to poor water management practices [3]. It is undeniable that this problem has an adverse impact on the global sustainability of water resources [4]. In Malaysia specifically, the major causes of river pollution are originated from anthropogenic activities such as industrial areas, agricultural activities, animal husbandry activities, sewages, workshops, residential areas, markets, and hawker stalls [5]. Such anthropogenic influences cause excessive runoff of heavy metals, mercury, coliforms, and nutrients into the rivers. Without a proper river treatment, algae blooms will stimulate aggressively. As algae die off, decomposition takes place that using up dissolved oxygen (DO) in the rivers. Consequently, the rivers suffer low concentration of DO and unable to support other aquatic life.
According to Water Quality Index (WQI) classified by Department of Environment (DOE) Malaysia [6], most of Malaysia’s rivers were in WQI Class II (required conventional water treatment) and Class III (required extensive water treatment). This statement can be supported based on the river water quality trend in Malaysia from 2008 to 2017 based on figure 1 [6]. The clean rivers were found to be in decreasing trend. In contrast, the slightly polluted rivers show an increasing trend. The polluted rivers were observed to be in sideway. It is anticipated that the uptrend of slightly polluted and polluted rivers will be more visible if there is no proper water treatment process.

Figure 1. River water quality trend in Malaysia, 2008–2017 [6].

The outbreak of novel coronavirus (Covid-19) pandemic seems a blessing in disguise to the polluted rivers in Malaysia. A sudden decline in human activities during the enforcement of Movement Control Order on March 18, 2020 has directly increased the rivers’ water quality [7]. However, such a total lockdown would paralyze the Malaysia’s economic growth although this move is very effective in curbing the spread of Covid-19 [8]. Hence, this research attempts to investigate an alternative solution to recover rivers’ water quality by improving the DO content in a river based on various aeration systems.

2. Methodology

2.1 Experimental setup

The improvement of DO in Perlis river was evaluated by using various aeration systems, which are specified to water jet (WJ), air compressor (AC), commercial venturi (VA), and DIY venturi (VB). Among those tested aerators, WJ is a surface-type aerator, while AC, VA, and VB are subsurface-type aerators. Figure 2 illustrates the aeration measurement system, which was developed to measure the changes of DO in a moving water systematically. The primary parts, as summarized in table 1 comprise of PVC pipes, i.e., horizontal main drainage pipe, 5 vertical measured DO holes, and 1 hole as the placement of aerator system. The secondary parts consist of DO sensor (YSI Professional Plus Multiparameter 6050000 with DO reading’s accuracy of ± 6%), truck tyre tube, air compressor pump, water pump, water flowmeter (FP111 Global Water Flow Probe with accuracy of ± 0.1 m/s) and anemometer (Benetech Digital Anemometer GM8902 with air velocity’s accuracy of ± 3%).
Figure 2. Illustration of aeration measurement system.

Table 1. Primary parts of aeration measurement system.

| Primary parts          | Dimensions                  | Functions                                      |
|-----------------------|-----------------------------|------------------------------------------------|
| Horizontal main drainage pipe | Number of holes: 1 Length: 288.5 cm Diameter: 15.2 cm | To evaluate the improvement of DO of water in volume (m³/s). |
| Vertical measured pipe | Number of holes: 5 Length: 45.7 cm Diameter: 7.6 cm | To place the DO sensor properly in the water during the DO measurement. |
| Aerator hole          | Number of holes: 1 Diameter: 7.6 cm | Placement of aerator system. |

2.2 Data collection and testing conditions

The data collection was performed at Perlis River, 01000 Kangar, Perlis, (specifically, at the Pengkalan Asam Trails Recreational Park) https://goo.gl/maps/A237jasBdfIDprwa6. The Perlis River is not equipped with a water gate at the estuary, therefore, the river is highly affected by tides of the sea. To date, 9 days of data collection had been undertaken during 2 tide conditions i.e., high and low tide at the Perlis River as shown in table 2. The changes of DO was investigated by setting up systematic experimental rigs as shown in figure 3. Next, the experiment was started by measuring the base DO of water first (without a running of aerator) at the Hole 1 and Hole 5. Then, with a running of an aerator, the DO of water was measured at Hole 1, 2, 3, 4, and 5. For each data collection, the DO data was recorded after the reading is stable. At the same time, the water’s velocity (by water flowmeter) and the wind velocity (by anemometer) were recorded. Once all the DO measurement at all location (Hole 1–5) for one type of aerator are completed, the next type of aerator was set up and the measurement procedures were repeated starting from the measurement for the base DO as mentioned earlier. Table 3 summarizes the data collected based on hole’s number for base DO and measured DO for each type of aerator.
Figure 3. Experimental setup for data collection at Perlis river.

Based on Equation 1, the mass flow rate was calculated by multiplying the measured water’s velocity when allowing it to flow via the main drainage pipe with the surface area of the pipe. The average DO changes, $\Delta DO$ (mg/L) and the percentage of DO improvement, $\Delta DO\%$ (%) were calculated based on Equation 2 and Equation 3, respectively.

\[
\text{Mass flow rate of water, } \dot{V}_{\text{water}} \text{ (m}^3\text{/s)} = A_{\text{pipe}} \times V_{\text{water}} \tag{1}
\]

\[
\text{Average DO changes, } \Delta DO \text{ (mg/L)} = \frac{\text{DO}_{\text{measured}} - \text{DO}_{\text{base}}}{\text{DO}_{\text{base}}} \tag{2}
\]

\[
\text{Percentage of DO improvement, } \Delta DO\% \text{ (%) = } \frac{\text{DO}_{\text{measured}} - \text{DO}_{\text{base}}}{\text{DO}_{\text{base}}} \tag{3}
\]

Where,
- $A_{\text{pipe}}$ = Surface area of pipe (m$^2$)
- $V_{\text{water}}$ = Water velocity (m/s)
- $\text{DO}_{\text{measured}}$ = Average measured DO (mg/L)
- $\text{DO}_{\text{base}}$ = Average base DO (mg/L)
Table 2. Tide table based on the day of data collection.

| Data collection | Date       | Time            | Tide condition               |
|-----------------|------------|-----------------|------------------------------|
| 1               | 30/09/2020 | 7.36 AM–1.37 PM | LOW (0.55 m) to HIGH (2.13 m) |
| 2               | 19/10/2020 | 9.51 AM–3.52 PM | LOW (0.00 m) to HIGH (2.26 m) |
| 3               | 20/10/2020 | 10.30 AM–4.31 PM| LOW (0.11 m) to HIGH (2.07 m) |
| 4               | 04/11/2020 | 10.04 AM–4.03 PM| LOW (0.23 m) to HIGH (1.97 m) |
| 5               | 11/11/2020 | 4.51 AM–10.47 AM| LOW (0.87 m) to HIGH (1.88 m) |
| 6               | 12/11/2020 | 5.59 AM–11.52 AM| LOW (0.63 m) to HIGH (2.02 m) |
| 7               | 19/11/2020 | 4.22 AM–10.58 AM| HIGH (2.41 m) to LOW (0.23 m) |
| 8               | 23/11/2020 | 7.32 AM–3.02 PM | HIGH (1.63 m) to LOW (0.77 m) |
| 9               | 24/11/2020 | 9.21 AM–4.24 PM | HIGH (1.54 m) to LOW (0.73 m) |

Table 3. Summary of data collected for base DO and measured DO.

| Hole number | Base DO (Without aerator) | Measured DO (With aerator) |
|-------------|---------------------------|----------------------------|
| 1           | ✓                         | ✓                          |
| 2           | X                         | ✓                          |
| 3           | X                         | ✓                          |
| 4           | X                         | ✓                          |
| 5           | ✓                         | ✓                          |

3. Results and discussion

Table 4 demonstrates the sample of data analysis based on WJ aerator on day 1. Figure 4 (a) and figure 4 (b) review the findings further at various types of aerators – water jet (WJ), air compressor (AC), commercial venturi (VA), and DIY venturi (VB). No data collection for AC, VA, and VB on 3rd, 1st, and 1st day, respectively due to problems that cannot be avoided.

The highest DO by WJ was found on 6th day (2.13 mg/L at mass flowrate of $0.55 \times 10^{-3}$ m$^3$/s), but its highest DO% was found on 3rd day (147.43% at mass flow rate of $0.55 \times 10^{-3}$ m$^3$/s). The highest DO and DO% by AC were found on 1st day, which are 0.65 mg/L and 66.46%, respectively at mass flow rate of $1.10 \times 10^{-3}$ m$^3$/s. The highest DO and DO% by VA were found on 6th day, which are 1.41 mg/L and 108.30%, respectively at mass flow rate of $0.55 \times 10^{-3}$ m$^3$/s. While, the highest DO and DO% by VB were found on 2nd day, which are 2.96 mg/L and 212.24%, respectively at mass flow rate of $1.10 \times 10^{-3}$ m$^3$/s.

In overall, the WJ aerator showed the highest DO% for all day except on 2nd day of data collection. Both VA and VB aerators showed almost the same behaviour on 4th, 5th, 7th, 8th, and 9th days of data collection. In the meantime, the AC exhibited the lowest DO% for all day of data collection. Besides, the tides of the sea that are connected to the Perlis river show a significant effect to the improvement of DO at various aeration systems. A higher DO% was observed during low to high tide condition (1st–6th days of data collection). This can be attributed due to the increasing of the water’s salinity (salt concentration) that leads to a decrease in oxygen solubility in a river [9].
Table 4. Sample of data analysis on day 1 of data collection by water jet (WJ) aerator.

| Hole | Base DO (mg/L) | Measured DO (mg/L) | Changes of DO, ΔDO (mg/L) | DO improvement, ΔDO% (%) |
|------|----------------|--------------------|---------------------------|--------------------------|
| 1    | 1.010          | 2.020              | 1.025                     | 103.015                  |
| 2    | -              | 2.310              | 1.315                     | 132.161                  |
| 3    | -              | 2.370              | 1.375                     | 138.191                  |
| 4    | -              | 2.300              | 1.305                     | 131.156                  |
| 5    | 0.980          | 2.170              | 1.175                     | 118.091                  |
| Average | 0.995      | 2.234              | 1.239                     | 124.523                  |

Figure 4(a). Summary of DO improvement based on various aeration systems, Average changes of DO, ΔDO (mg/L).
4. Conclusion
The improvement of DO in Perlis river based on various aeration systems had been investigated. The experiment focused on water jet, air compressor, commercial venturi, and DIY venturi aerators. Results found that the improvement of DO by water jet aerator greatly outweigh the other aerators. More data collection is necessary to have a better understanding of DO improvement in a moving water and its behaviour during low/high tide conditions. Future works will also consider the weather condition and wind effect during the data collection as experimental conditions to support the overall findings.

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