WATER TEMPERATURE SIMULATION OF RIVERS IN INDONESIA

INTAN SUPRABA
Universitas Gadjah Mada, Yogyakarta, Indonesia, intan.supraba@ugm.ac.id

ISTIARTO
Universitas Gadjah Mada, Yogyakarta, Indonesia, istiarto@ugm.ac.id

RADIANTA TRIATMADJA
Universitas Gadjah Mada, Yogyakarta, Indonesia, radianta@ugm.ac.id

DJOKO LEGONO
Universitas Gadjah Mada, Yogyakarta, Indonesia, djokolegono@ugm.ac.id

ABSTRACT

Water temperature has a major influence on biological activity and growth which are measured by the amount of chlorophyll and bacteria present. It also affects water chemistry and water quantity measurements, and governs the kinds of organisms living in water bodies such as rivers and lakes. Higher temperature will increase the rate of chemical reactions. The concentration of dissolved oxygen in warm water is lesser compared to cold water thus affecting the survival of different species of aquatic life. Global News reported that hundreds of thousands of fish have died in Darling River, Australia. On 29 January 2019 New South Wales Department of Primary Industries mentioned that the death is caused by the decrease of dissolved oxygen concentration due to air temperature increase. The aim of this study is to find the water temperature of many rivers in Indonesia, to find the normal temperature for fish life, and to analyze the impact of climate change to the water temperature. Results showed that measured water temperature in 13 rivers varies from 23-32.4°C (upstream) and 25.5-34°C (downstream) that is caused by variation of air temperature, humidity, solar radiation, and wind speed. The normal water temperature for fish species in the downstream region at Opak River such as *Barbonymus sp.*, *Puntius binotatus*, and *Rasbora argyrotaenia* varies from 28.6°C to 29.6°C, while water temperature in this study shows increment in the range of 28.92°C to 30°C in the future. However, the location of this study is around 65 km of the upstream side of the location of the previous study. Hence, further study is required to understand the acceptable increment of water temperature for the sustainability of fish life by making direct comparison of the object study.

Keywords: Air temperature rise, water temperature, fish life

1. INTRODUCTION

Many rivers in Indonesia are facing water related hazards such as floods, droughts, and pollution. On 17th January 2017 flash flood occurred at Sojomerto village and 31 housing were submerged due to overflow from Blukar River with water depth up to 70 cm (SindoNews.com, 2017). On 3rd December 2018, it was reported that many housing around Belik River were submerged with water depth up to 1 m (Kumparan.com, 2018). And recently Jakarta as the capital city of Indonesia experienced flood due to continuous rainfall occurred from 31 December 2019 till 1st January 2020 with water depth varied from 30 cm to 200 cm. **Figure 1** shows map of area in Jakarta affected by flood.

Figure 1. Map of flood area in Jakarta (BNPB, 2020)

To make it worst, many rivers in Indonesia have been contaminated with majority having status heavily polluted. In 2018, 74 rivers were monitored by Ministry of Environmental and Forestry, and results showed that 58.82% of those rivers having status heavily polluted, and 35.6% rivers having status moderately polluted. Rivers in Indonesia are classified into 4 classes according to Government Regulation No.82/2001 on Water Quality Management and Water Pollution Control. Those rivers being used for fisheries is classified into 3rd class. One of important parameters is water temperature, and the required water temperature is ± 3°C from its natural condition. The water temperature is affected by air temperature, humidity, solar radiation, and wind speed. River issues like floods and pollution affect the water temperature. Water temperature has a major influence on biological activity and growth which are measured by the amount of chlorophyll and bacteria present. It also has an effect on water chemistry, can determine water quantity measurements, and governs the kinds of organisms that can live in water bodies such as rivers and lakes. Higher temperature will increase the rate of chemical reactions. The concentration of dissolved oxygen in warm water is lesser compared to cold water, hence it may affect the survival of different species of aquatic life. Some compounds are also more toxic to aquatic life at higher temperatures. Ecological hypoxia (oxygen depletion) is one of the most common natural causes of fish deaths. The hypoxic event may be brought on by factors such as algae blooms, droughts, high temperatures and thermal pollution.

Some national newspapers in Indonesia recently published articles that thousands of fish found dead in Ambon Sea. It was reported that the death can be caused by the upwelling in the sea which lower down the sea surface temperature up to 3-4°C. Hence, it was out of the preferred temperature for the fish to stay alive. On 25th October 2019, it was reported that Arapaima Gigas fish experienced sudden death due to increment of air temperature up to 42°C (Kompas.com, 2019). On 17th November 2019, it was reported that massive fish death occurred at the upstream of Batang Maek River, Kecamatan Pangkalan Koto Baru, Kabupaten Limapuluh (Republika.co.id, 2019). Wahana Lingkungan Hidup Indonesia Sumatera Barat suspected that the death was caused by the damage of waste storage when flood occurred. Global News reported that hundreds of thousands of fish have died in Darling River, Australia. On 29 January 2019 New South Wales Department of Primary Industries mentioned that the death is caused by the decrease of dissolved oxygen concentration due to increase of air temperature. Stephanie Quinn-Davidson, a biologist specializing in salmon and the director of the Yukon Inter-Tribal Fish Commission said that climate change and warming rivers have caused the mass death of salmon in parts of Alaska. Scientists believe that the cause of large numbers of salmon died prematurely in some Alaskan rivers in July could be the unprecedented heatwave that gripped the state last month. According to Sue Mauger as Cook Inletkeeper's Science Director, in the Deshka River, an important salmon stream in southern Alaska, stream temperatures reached 27.6°C on 7th July 2019. That was abnormal because based on stream temperatures measurement in non-glacial systems across the Cook Inlet watershed since 2002, usually the stream temperatures never show above 24.4°C. As streams warm, fish become stressed, and more vulnerable to pollution, predation, and disease (Independent, 2019). Thus, the aim of this study is to find the water temperature of many rivers in Indonesia, to find the normal temperature for native species of aquatic life in each of the rivers, and to analyze the impact of climate change to the water temperature.

2. METHODOLOGY

Water temperature data of many rivers are secondary data which obtained from various sources. The data are supposed to be utilized as the boundary and initial conditions to simulate the water quality analysis by using Hydrologic Engineering Center River Analysis System (HEC RAS) 4.1.0. However, due to limitation of the data as those data are measured in the past years, then the water temperature is calculated based on the relationship between water temperature and air temperature. Morrill et al. (2001) studied data from over 50 streams in 13 countries. Results showed that the majority of streams show an increase in water temperature of about 0.6 to 0.8 degrees for every 1-degree increase in air temperature. Global average surface air temperature is expected to increase by 3-5°C by the middle of this century. Trend of increment of air temperature due to climate change is obtained from Indonesia Meteorological Agency namely Badan Meteorologi, Klimatologi, dan Geofisika (BMKG) website i.e. bmkg.go.id. BMKG website informed that based on observation data from year 1981 to 2018, air temperature in Indonesia tends to increase 0.03°C/year, so within 30 years the air temperature will be increased by 0.9°C. However, in this study, it is assumed that the increment of air temperature is 5°C. Results of water quality analysis before and after increment of air temperature for the next 30 years are being compared. Then the results are analyzed against the required water temperature for the native fish species in specific rivers analyzed in this study.

3. DATA

3.1 Water Temperature Data

Table 1 shows measured water temperature of many rivers in Indonesia. Although the values in different rivers are obtained in the different time due to difficulty to obtain data at the same time, but it is for showing that the water temperature varies in each rivers.

Table 1. Measured water temperature of many rivers in Indonesia

No	RIVER NAME	LOCATION	MEASURED WATER TEMPERATURE	DATA SOURCE
1	Blukar	Kendal Regency	31-34°C	Agustiningsih, 2012
2	Gadjah Wong	Bantul Regency	28.5-29.3°C	Sagala, 2019
3	Belik	Yogyakarta City	27-28°C	Zannah and Sulaiman, 2018
4	Serang	Kulon Progo Regency	29-32°C	Aida and Utomo, 2012
5	Code	Sleman Regency, Bantul Regency, Yogyakarta City	25-29°C	Imroatushoolikhah et al., 2011
6	Opak	Daerah Istimewa Yogyakarta	23-30°C	Sugiharyanto et al., 2011
7	Metro	Malang Regency	26-27°C	Mahyudin et al., 2015
8	Porong	Sidoarjo Regency	32.4-33.2°C	Sari et al, 2013
9	Donan	Cilacap Regency	28.6-32.56°C	Permadi et al., 2016
10	Jeneberang	Gowa Regency	27-31.5°C	Thamrin et al., 2018
11	Winongo	Sleman Regency, Bantul Regency, Yogyakarta City	23.5-25.5	Marlina et al., 2016
12	Gelis	Kudus Regency	24-28°C	Hanisa et al., 2017
13	Citarum	Jawa Barat Province	24.2-26.8°C	Utami, A.W., 2015

Figure 2 shows the example of boundary condition of water temperature at Opak River.

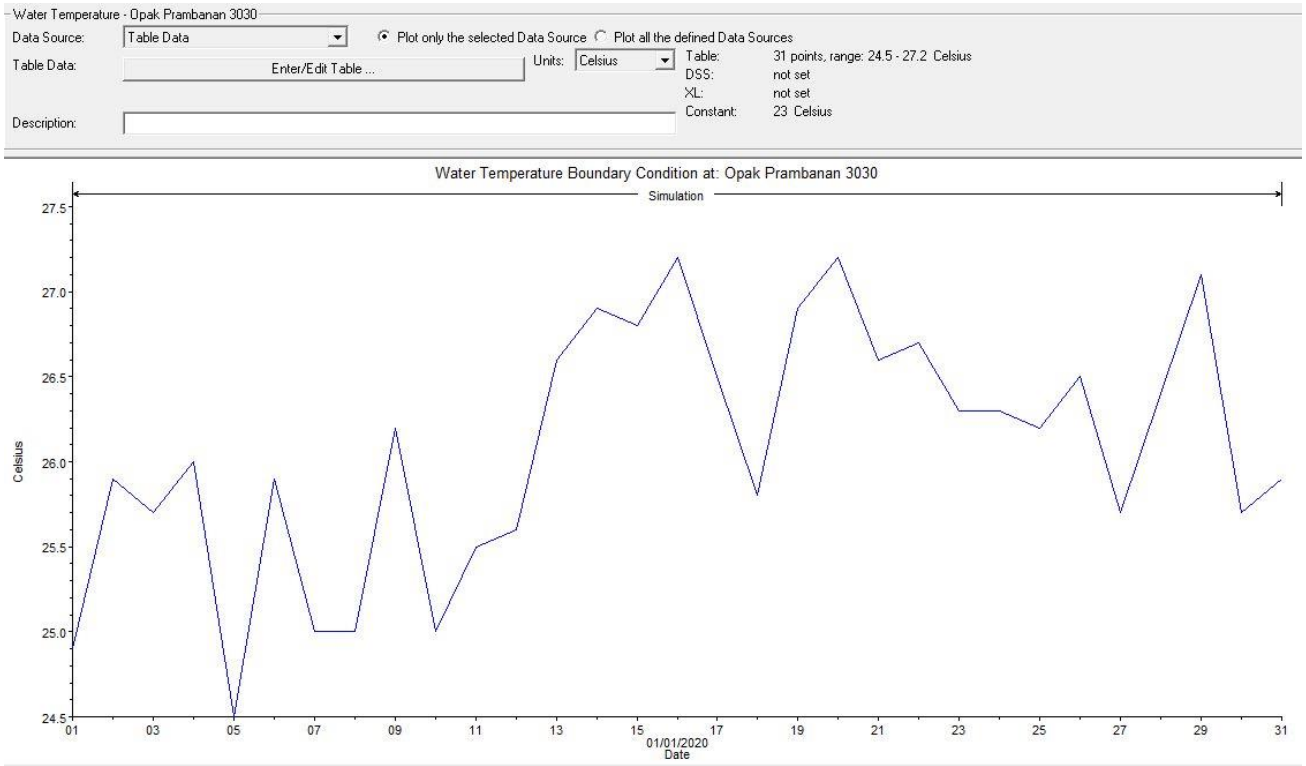
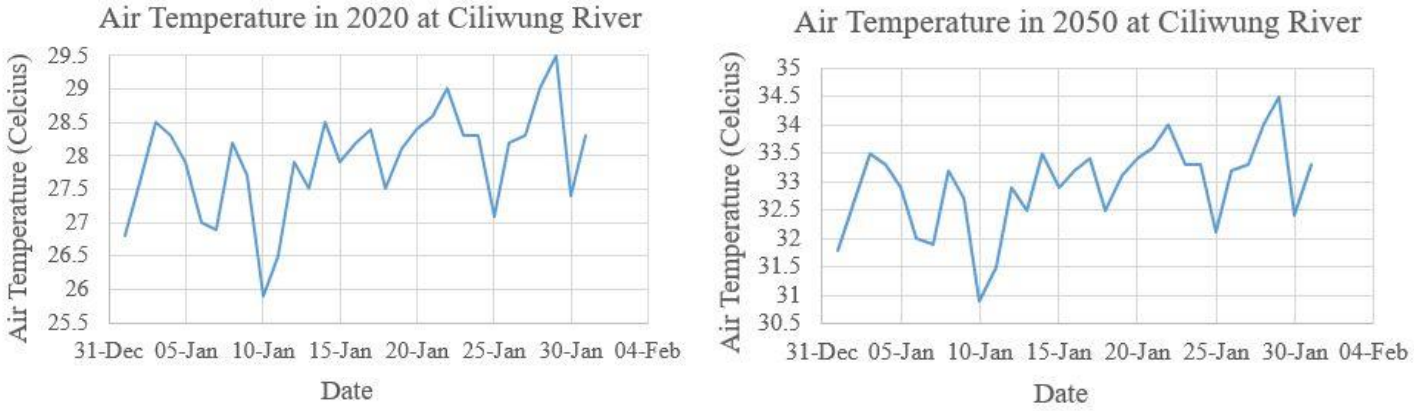


Figure 2. Initial condition of water temperature at Opak River

3.2 Case Study

This study analyzes 4 rivers i.e. Opak River, Oyo River, Serang River, and Ciliwung River. For each river, there are 2 scenarios i.e. present scenario and future scenario. For the future scenario, the values of air temperature are added by 5°C. **Figure 3** shows the example of different air temperatures of present scenario and future scenario for Ciliwung River.



a) **b)**

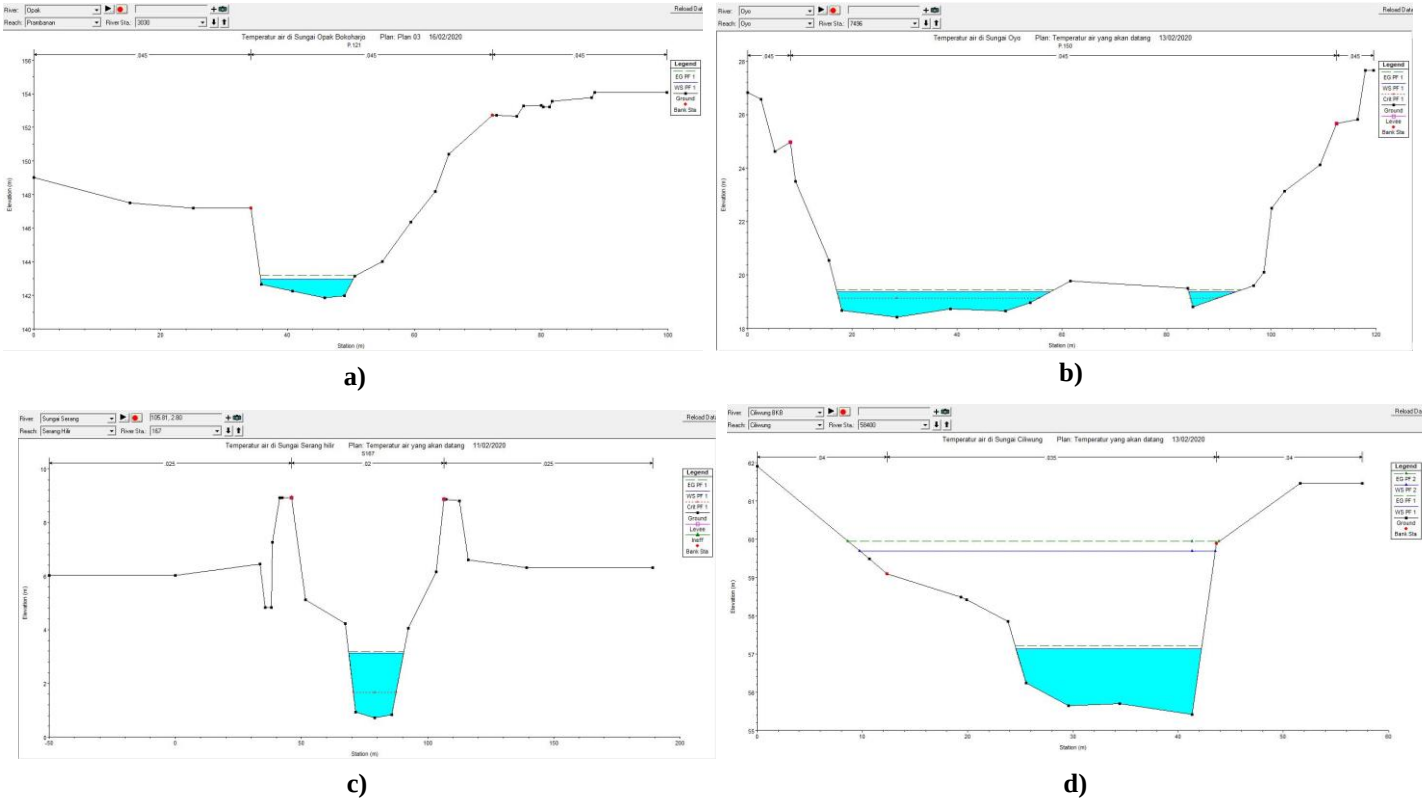
Figure 3. Air temperature at Ciliwung River for a) present scenario (2020), b) future scenario (2050)

The air temperature values in the year 2020 (**Figure 3a**) was recorded at Kemayoran Meteorological Station obtained from BMKG website, while the values of air temperature in the year 2050 (**Figure 3b**) was obtained by adding 5°C into the values shown in **Figure 3a**.

4. RESULTS & DISCUSSIONS

4.1 Cross Section

Cross section of four rivers (Opak River, Oyo River, Serang River, Ciliwung River) are shown in **Figure 4**.



a) **b)**

c) **d)**

Figure 4. Cross section of a) Opak River, b) Oyo River, c) Serang River, d) Ciliwung River

4.2 Water Quality Analysis

Water quality analysis result shows the water temperature at the downstream of Opak River (RS 95-0) as can be seen at **Figure 5**.

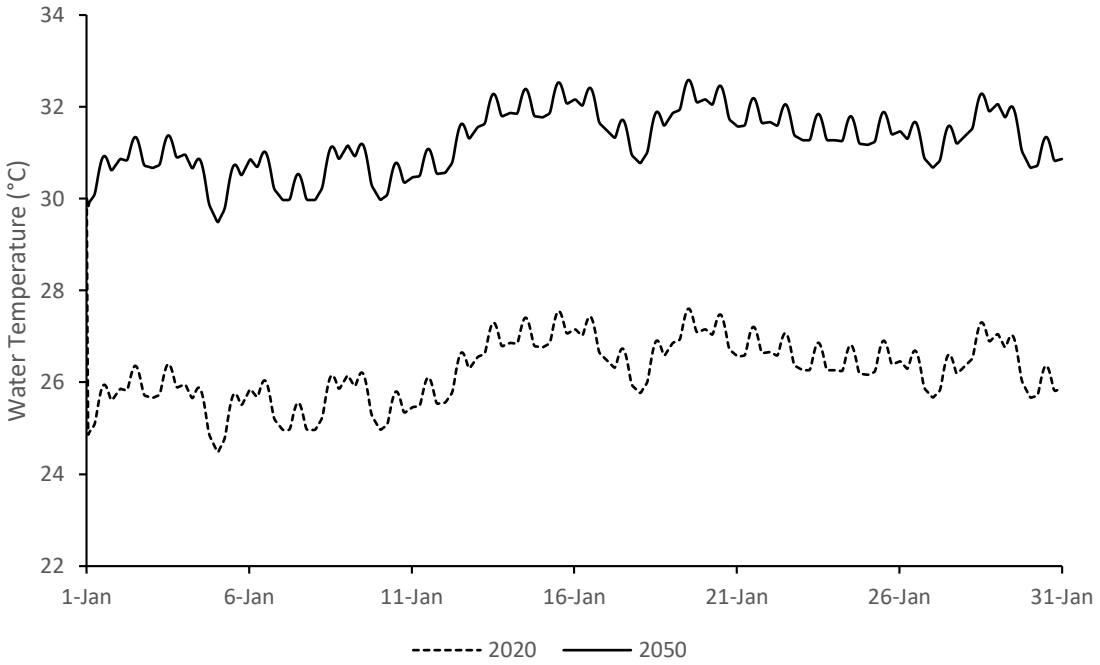


Figure 5. Water temperature simulation at Opak River for present scenario (2020) and future scenario (2050)

And the increment of water temperature at the downstream of Opak River (RS 95-0) is presented at **Figure 6**.

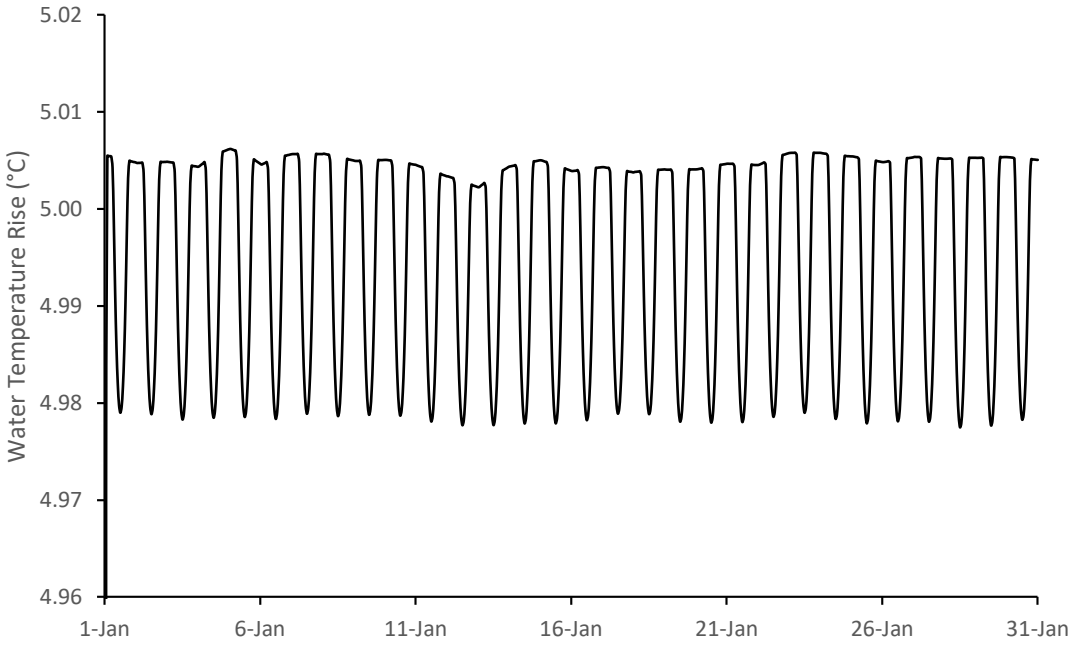


Figure 6. The increment of water temperature at Opak River in 30 years (2020-2050)

Table 2 presents the average daily water temperature values within 1 month (1st to 31st January) of present scenario and future scenario in the downstream region of each river, while **Table 3** shows the deviation of the average daily water temperature between present and future scenarios.

Table 2. The average daily water temperature

RIVER NAME	WATER TEMPERATURE FOR PRESENT SCENARIO (2020) (°C)	WATER TEMPERATURE FOR FUTURE SCENARIO (2050) (°C)
OPAK	26.25	31.25
OYO	26.51	31.48
SERANG	26.58	31.55
CILIWUNG	30.08	34.70

Table 3. Water temperature deviation

RIVER NAME	WATER TEMPERATURE DEVIATION BETWEEN FUTURE AND PRESENT SCENARIO (°C)
	DOWNSTREAM
OPAK	5
OYO	4.97
SERANG	4.97
CILIWUNG	4.62

Table 3 shows that the rising of water temperature among 4 rivers varies from 4.62°C to 5°C in the downstream region of each river. This shows that the increment of water temperature tends to be linear to the increment of air temperature. By adding 5°C to the future air temperature, the average water temperature increment is around 4.89°C.

4.3 Normal Temperature for Fish at Opak River

Djumanto et al (2013) studied the species, abundance, and distribution of fishes in the downstream region of Opak River in Yogyakarta. Results showed that there were 2295 individuals of fishes comprising of 7 orders, 23 families, 30 genera, and 35 species. The most abundant family was Cyprinidae, and the highest individual abundance was *Barbonymus sp.*, followed by *Puntius binotatus*, and *Rasbora argyrotaenia*. The temperature at 5 sampling stations in downstream region of Opak River showed that the temperature varies from 28.6°C to 29.6°C.

The water quality plot on 1st January 2050 for Opak River is presented in **Figure 7**.

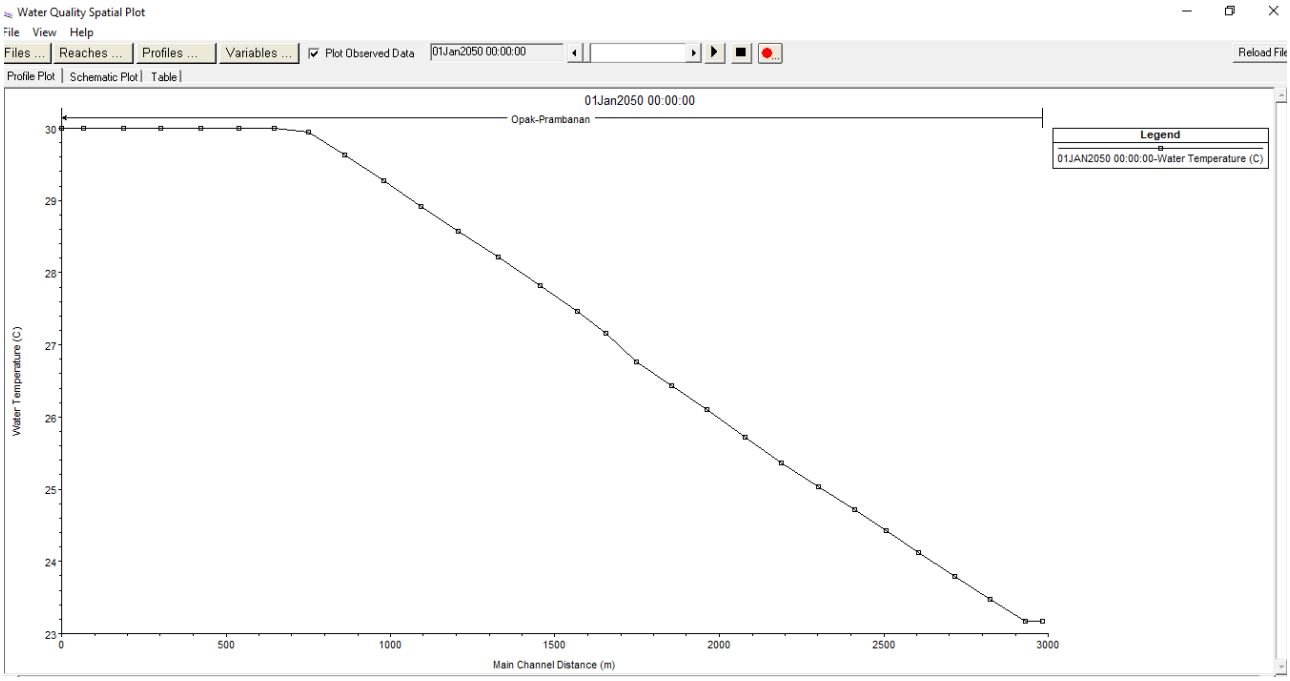


Figure 7. Water temperature simulation at Opak River on 1st January 2050

Figure 7 shows that the water temperature within 1 km from the downstream region varies from 28.92°C to 30°C. By comparing those values with the values in 5 sampling stations in the previous study, there is a rise in the temperature at Opak River in a range of 0.32°C to 0.4°C. However, the location of this study and the previous study is different. The location of this study is around 65 km of the upstream side of the location of the previous study done by Djumanto et al. Hence it may explain why the temperature at the downstream region in the year 2020 is 26.25°C whereas that of in the year 2013 was 28.6°C which is warmer because the location is already next to the river mouth. It needs further study to understand the value of temperature increase that will give significant impact to the sustainability of fish life at Opak River.

5. CONCLUSIONS & SUGGESTIONS

This study is a preliminary study to understand the important of water temperature for the sustainability of fish life. Some conclusions are as follows:

- Water temperature in a river differs from that of in other rivers which is highly affected by air temperature, humidity, solar radiation, and wind speed including pollution in the area where that river is located.
- By assuming that the air temperature will be increased by 5°C in the future, it is found that the rising of water temperature among 4 rivers analyzed in this study will also be increase by 4.89°C in the downstream region.
- The normal water temperature for fish species in the downstream region at Opak River such as *Barbonymus sp.*, *Puntius binotatus*, and *Rasbora argyrotaenia* varies from 28.6°C to 29.6°C. Simulation result in this study shows that the water temperature at Opak River will increase to 28.92°C to 30°C. However, it is not a direct comparison because the location of this study is located around 65 km of the upstream side of the location of the previous study done by Djumanto et al. Although it is not a direct comparison, it is interesting to know whether increment of water temperature in a range of 0.32°C to 0.4°C will affect the sustainability of fish life or not.

The authors realized that there are limitations in this preliminary study such as:

- The difficulty to predict all of future meteorological data required to conduct water quality analysis. Like in this study, only air temperature rise is considered in the simulation, while other variables such as atmospheric pressure, humidity, short wave radiation, cloudiness, and wind speed are assumed remain constant.
- The difficulty to obtain all of required data for running flow and water quality analysis of many rivers in Indonesia.
- Limitation of study regarding required water temperature for native fish species in a river.

Hence, some of suggestions to improve this study are:

- To continue finding secondary data of many rivers in Indonesia. Indeed, if it is possible, to conduct independent study to get primary data.
- To conduct research collaboration with researchers from fishery department in order to understand the maximum increment water temperature that will not disturb fish life.

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