

Analysis of the influence of reservoirs utilization to water quality profiles in Indonesia (Saguling – Jatiluhur) and Malaysia (Temengor – Chenderoh) with special references to cascade reservoirs

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Abstract. Tropical reservoir is the one ecosystem which is functioning in both ecological and economical services. As the settling of water volume, it harbors many species of fish. The objective of this study is to analyze the utilization and management of reservoirs related to their water quality conditions, represent by tropical reservoirs from Indonesia and Malaysia. Survey at Jatiluhur and Saguling (Indonesia) was conducted in March 2014 and September 2015, respectively while in Temengor and Chenderoh (Malaysia), the survey was done in January 2014 and April 2017, respectively. Based on elevation, Saguling and Temengor are upstream reservoirs. On the contrary, Jatiluhur and Chenderoh are downstream reservoirs. The results of the surveys in Jatiluhur and Saguling reservoirs showed that the average depths are 32.9m and 17.9m, respectively. On the other hand, Temengor and Chenderoh reservoirs are 100m and 16.2m, respectively. All of them play multi-functional roles including as a source of power plant, fisheries and tourism, as well as water sources for irrigation. In addition, Saguling and Temengor reservoirs are relatively dendritic in shape. In Indonesia, there are three consecutive reservoirs along Citarum River, whereas in Malaysia there are four consecutive reservoirs along Perak River. The results showed the potential impact of fish cages as pollutant, especially at Indonesian reservoirs. In addition, these tropical reservoirs have become famous tourism getaway. The capabilities of economic values of these reservoirs and ecosystem should be balanced. Basic ecological information is necessary for the next study.

1. Introduction

Water is our most valuable natural resource. The availability and quality of inland waters do not only impact human health and well-beings, but also the functioning of essential ecosystems, including rivers, wetlands, lakes and coastal ecosystems. Without sound water resources management, human activities can upset the delicate balance between water resources and environmental sustainability. The purposes of the construction of reservoirs in Indonesia varied in different functions such as irrigation, water supply and hydropower plant [1]. Being located in a tropical region, Indonesia and Malaysia are exposed to the sun throughout two seasons; dry season and rainy season. In big cities and areas with few forests, rainy season often results in floods. The long dry season is often detrimental to the population, especially for the farmers whose crops get lack of water

Indonesia is one of the countries with the highest precipitation in the world. It implies that the actual availability of water is plentiful but water availability is not balanced in terms of place



(location) and season (time). It was found that the condition where excessiveness exists is in the western part of Indonesia and lacking in eastern part of Indonesia.

The strategic functions of Citarum River basin and Jatiluhur, Cirata and Saguling reservoirs at the national scale and its socio-environmental problems are two important reasons why these locations were selected. Citarum River basin is one of main river basins in Indonesia which experiences flood problem. Furthermore, the topographic condition and geographical location also contribute to the occurrence of flood disaster in Citarum River basin. The upper Citarum River basin is also recognized as an area with some of the most persistently active landslides in Indonesia. The floods that trigger the landslides occur almost every year and cause extensive damage. The Citarum River is of vital importance for West Java Province and Jakarta City, Indonesia, in terms of economic development and the prosperity of the people.

On the other hand, Saguling reservoir is used for power generation that has an installed capacity of 700 MW [2,3]. In addition, the condition of the upper river basin is an important factor in controlling its hydrological response, including floods, soil erosion, landslide, and sediment input to the Saguling Reservoir. Temengor reservoir is situated in the North of Perak in the hilly Titiwangsa Mountains extending from southern Thailand at the height of 263 m above sea level. Malaysia's second largest dam after Kenering is one of four dams built on the river Perak [4]. The dam began to generate hydroelectric power in 1978 and then supplied water for domestic use in 1999. This feature is usually indicated by a dam built on the river that is located in the highlands covering the lower order streams [5]. Water damming has changed the hill tops into islands in different shapes and size, and the shape of the hill gaps formed a bay area. Subsidence clear water provides a high index of coastal development of Dam Temengor.

The main water source of three rivers in the catchment area of Forest Belum (134,167 ha), Forest Grik (37,220 ha) and Forest Temengor (148,870 ha), receives an average annual rainfall of over 2,000 mm [6]. The main rivers flowing throughout the year are: Kejar River, Tiang River, Singor River and Sara River on the North part of the dam and Temengor River, Kertei and Kenering on the South part of the dam. The catchment is a partial primary forest that has been designed for conservation. There are no activities around the catchment area except for a few permanent settlements and native nomad and farmer logging.

Apart from the main function stated, the dam also provides a clear space for traditional fisheries or aquaculture activities undertaken by the locals. There are about 13 species of fish in the dam and the commercial values are tengalan, kelah and catfish [7]. Aquaculture fish are from species of red tilapia, catfish and carp. On July 31, 2003, the north dam catchment areas have been declared as "The Royal Belum" by the Sultan of Perak HRH Sultan Azlan Shah. This situation directly provides opportunities for tourism and attracts tourists not only from Malaysia but also from around the world. Fishing, tourism and water logging in the aforementioned, are getting the attention. The effects of these activities on the ecosystem of the dam, however, are still less studied. In addition, Chenderoh reservoir is the downstream dam which was built on the river Perak among four dam reservoirs (Temengor – Bersia – Kenering – Chenderoh).

An increasing trend of high water supply fluctuations from the basin between wet and dry seasons restricts continuous hydropower generation. Water deficiency during the dry season disrupts hydropower generation; resulting in the application of costly rain-harvesting techniques. Reservoir degradation is rooted in socio-economic problems. The objective of this study is to analyze the utilization and management reservoirs related to their water quality conditions, represented by tropical cascade reservoirs from Indonesia and Malaysia.

2. Methods

Surveys in Jatiluhur and Saguling (Indonesia) were conducted in March 2014 and September 2015, respectively. Meanwhile, in Temengor and Chenderoh (Malaysia), the surveys were done in January 2014 and April 2017, respectively (Figure. 1 & 2) not only performing surveys in field, but also collecting the secondary data to supporting the analyses.

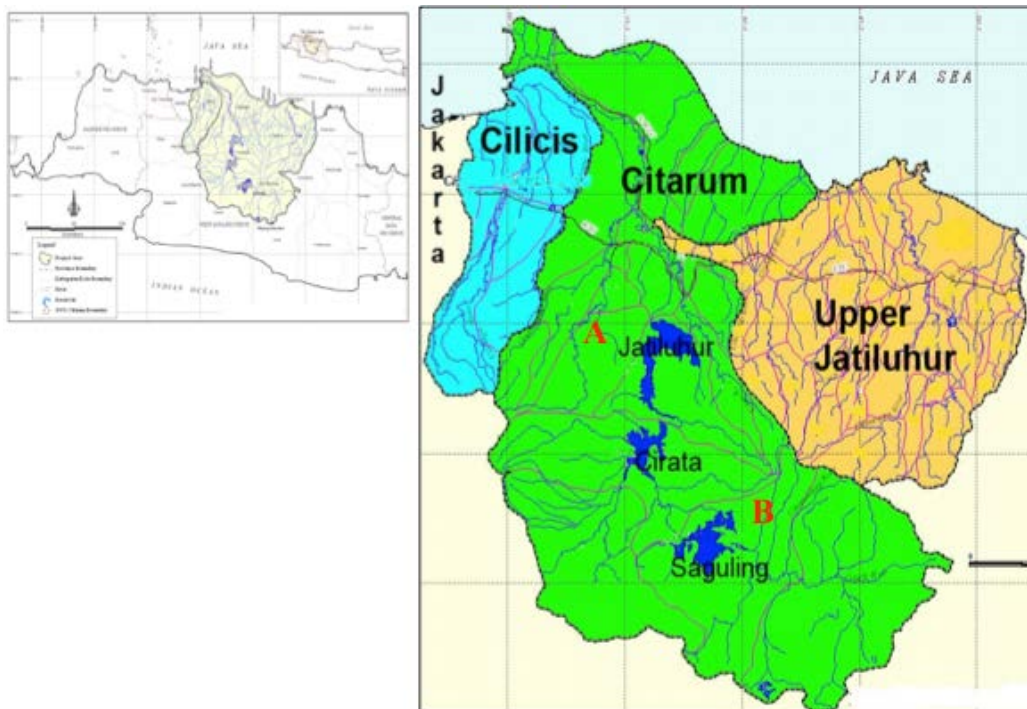


Figure. 1 Locations of study area in Indonesia, (A) Saguling reservoir (B) Jatiluhur reservoir (source: PJT II Jatiluhur – PU).

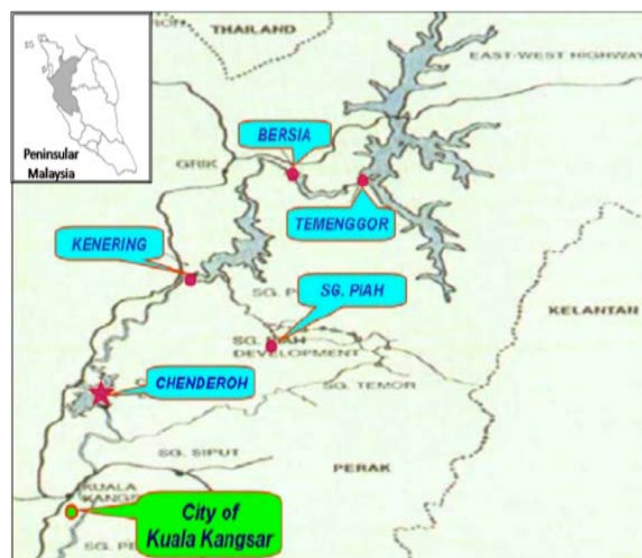


Fig. 2 Locations of study area in Malaysia, Temengor and Chenderoh reservoirs.

Jatiluhur reservoir is located at an altitude of 111m above sea level with a surface area of 7,780ha and an average depth of 32.9m. The source of water comes from Citarum river with basin area of 660,000ha with length of 270km which is flowing to Saguling, Cirata and Jatiluhur reservoirs. The magnitudes of volume and outflow discharge are similar at both sites.

On the other hand, at Temengor reservoir, the results of measurements on a 5-point sampling station showed an average depth of 44.3m. Dam structure has a height of 127m above sea level and capable of accommodating about 6,050 million cubic meters of water [6]. Based on these data, the

average depth of the dam is estimated at approximately 40m whereas at Temengor reservoir, hydroelectric for power generation, water released at the dam gates are located at an average depth of 8 m from the minimum level of water reservoir (23 m above sea level). Dam water level generally ranges between a minimum average of 238 m and a maximum of 247 m above sea level.

Water samples at Jatiluhur and Saguling reservoirs were taken in March 2014 and September 2015, respectively by ringko profiler, supported by University of Tsukuba, Japan. The logger version CTD profiler with optical fast DO sensor RINKO-Profiler was used for survey. Depth (semiconductor pressure sensor with ranged 0 to 600 m and resolution 0.01m), temperature (thermistor with a range between -3 to 45°C and resolution of 0.001°C) and dissolved oxygen/DO (phosphorescence with ranged 0 to 20 mg/L and resolution 0.001mg/L) were obtained at each reservoir. Measurements were carried out until the depth of 47.8m and 72.7m with an interval of 10m for Saguling and Jatiluhur, respectively. Meanwhile, multi-probe sensor YSI 6600 was used with the support of a Biology team from Universiti Sains Malaysia for water samples at Temengor reservoir in March 2012. Measurements were carried out until to the depth of 30m with an interval of 1m. Water temperature and dissolved oxygen (DO) profiles were obtained (temperature with ranged -5 to 50°C and resolution 0.01°C and dissolved oxygen (DO) with ranged 0 to 50 mg/L and resolution 0.01 mg/L. In addition, similar to Saguling and Jatiluhur, water samples at Chenderoh reservoir was taken in April 2017 by ringko profiler, supported by Research Centre for Limnology – LIPI for depth, temperature and dissolved oxygen/DO parameters. Measurement was carried out until the depth of 12.7m with an interval of 10m.

To support the analysis, water level at Saguling and Temengor reservoirs, based on secondary data, was obtained to analyze the fluctuation patterns. Finally, fish aquaculture cages established at all reservoirs were also observed and accounted.

3. Result and Discussion

The results on the survey in Jatiluhur and Saguling reservoirs showed that the average depths are 32.9m and 17.9m, respectively. On the other hand, Temengor and Chenderoh reservoirs are 100m and 16.2m, respectively.

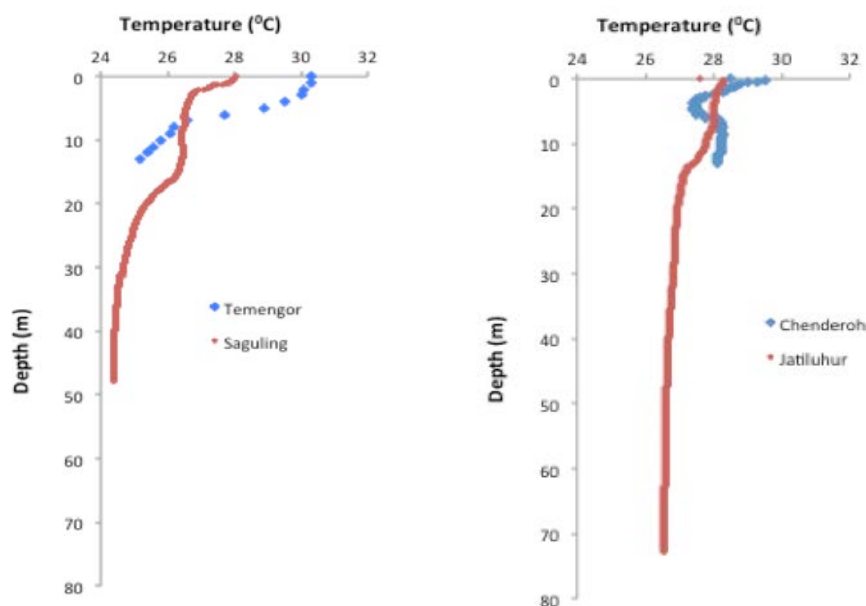


Figure 3. Average temperature profiles at Saguling – Jatiluhur and Temengor – Chenderoh reservoirs.

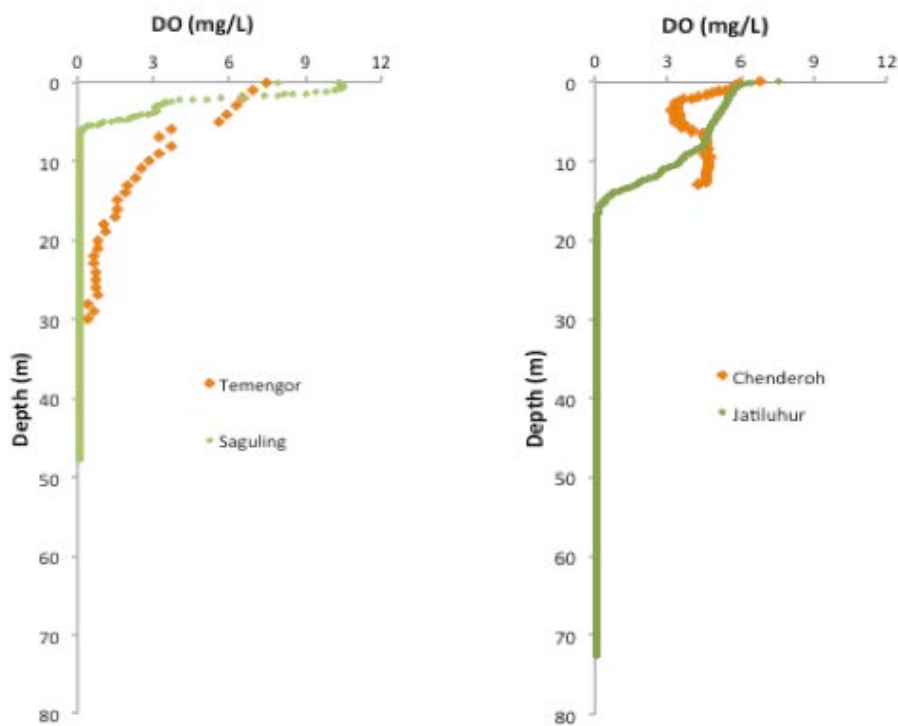


Figure 4. Average DO profiles at Saguling – Jatiluhur and Temengor – Chenderoh reservoirs.

The degradation of environment, including in water quality of reservoir occurred in the area. The anthropogenic activities contributed to the decrease of water quality. The growth of population influenced the activities of people in the surroundings of the reservoir. The location of Saguling reservoir is located in West Bandung Regency. It covers the regions of Padalarang, Cililin, Sindangkerta and Batujajar.

Figure 3 & 4 refers to the water column at Saguling reservoir and it was divided into two primary layers which are epilimnion which is characterized as a column of hot water and less dense layer at the surface to a depth of 10m and hipolimnion, a cooler, denser, and deeper layer, which depth ranges the average of 20m to 47.8m. Between the two layers, there is a layer that resembles metalimnion layer which is indicated by a sudden drop in temperature between the average 27°C to 26°C from an average depth of 10m to 20m. The top of this layer bordering the epilimnion constantly changing depth, while the bottom layer adjacent to hipolimnion remained stable at an average depth of 47.8 m. It suggested that the density at Saguling reservoir was stratified in September 2015. In addition, the characteristics of conductivity were related to temperature profile [8, 9 & 10].

Based on Figure 4, the values of dissolved oxygen (DO) at Saguling and Jatiluhur reservoirs were relatively smaller than those at Temengor and Chenderoh reservoirs. It suggested that the water quality conditions at Temengor and Chenderoh reservoirs were better.

Figure 3 & 4 refers to the water column at Temengor reservoir that was divided into two primary layers which are epilimnion (characterized as a column of hot water and less dense at the surface to a depth of 6m) and hipolimnion (cooler, denser, and deeper; divided between the average depths of 25m to 30m). Between the two layers, there is a layer that resembles metalimnion layer that is indicated by a sudden drop in temperature between the average 27°C to 23°C from an average depth of 6 m to 30 m. Top of this layer bordering the epilimnion constantly changing depth, while the bottom layer adjacent to hipolimnion remained stable at an average depth of 30m.

On the contrary, there was not a so large change of temperature in Saguling and Jatiluhur reservoirs. It could be explained the mixing of water column was easier at both reservoirs than those at Temengor and Chenderoh reservoirs.

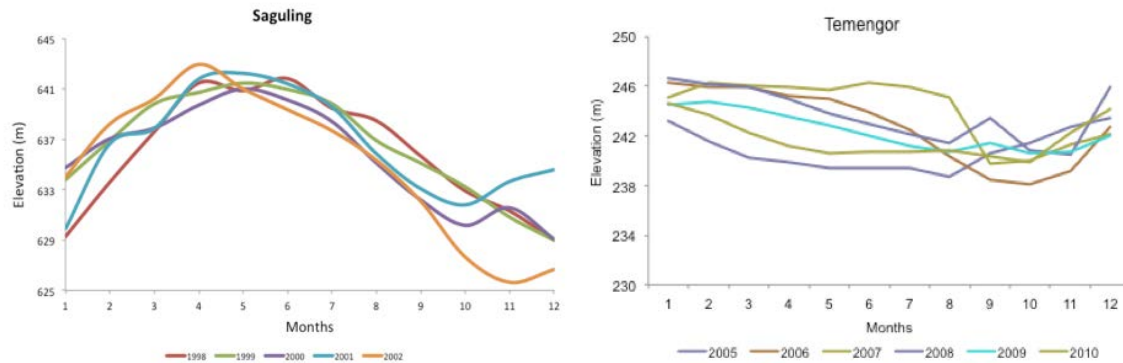


Figure 5.Water level at Saguling and Temengor reservoirs.

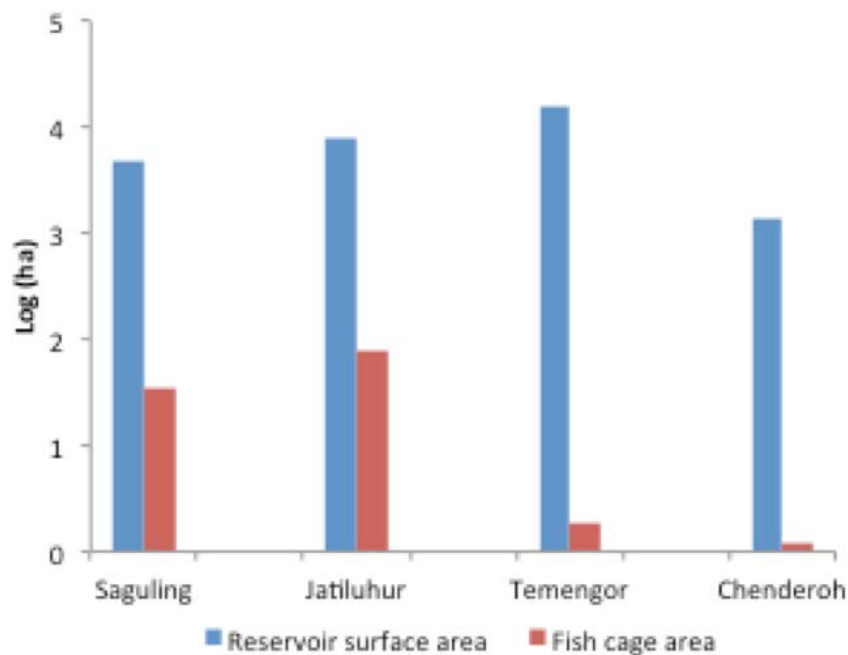


Figure 6.Comparison between surface and fish cage areas at all reservoirs.

The water level (Figure. 5) at Saguling reservoir is almost constant throughout the year whereas in Temengor reservoir, the water level is fluctuating. This phenomenon suggested that the hydrodynamics and mixing of water at Temengor reservoir was higher than those at Saguling reservoir. It could be explained that the changes of water column are different at both lakes. In addition, it seems that Temengor reservoir has been free from the trapped pollutants for many years.

Based on our survey and secondary data, Figure 6 showed the ratio between surface area and area fish cage (unit (ha) in logarithm). The percentage value of fish cages at Saguling and Jatiluhur reservoirs were larger (0.70% and 1.00%, respectively) than those at Temengor and Chenderoh reservoirs (0.01% and 0.09%, respectively). It indicates that the potential impacts from fish cages as pollutant at Saguling and Jatiluhur reservoirs are larger than those at Temengor and Chenderoh reservoirs.

Figure 7 & 8 show the condition of fish cage at all sites. It shows that the number fish cages at Saguling and Jatiluhur reservoirs are larger than those at Temengor and Chenderoh reservoirs.



Figure 7. Fish cage conditions at Saguling and Temengor reservoirs (upstream).



Figure 8. Fish cage conditions at Jatiluhur and Chenderoh reservoirs (upstream).

4. Conclusions

Based on elevation, Saguling and Temengor are upstream reservoirs. On the other hand, Jatiluhur and Chenderoh are downstream reservoirs. The results show the potential impact of fish cages as pollutant, especially at Indonesian reservoirs. In addition, these tropical reservoirs have become famous tourism getaway. The integrated reservoir management at both countries with different conditions (fish cages, land use change, tourism activities and electric supply) is needed to be maintained for utilization of the reservoirs. The capabilities of economic values of these reservoirs and ecosystem should be balanced. Basic ecological information is necessary for the next study.

Acknowledgments

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