Water Supply Treatment Sustainability of Semambu Water Supply Treatment Process - Water Footprint Approach

Edriyana A Aziz\textsuperscript{1,2}, Marlinda Abdul Malek\textsuperscript{3}, Syazwan N. Moni\textsuperscript{1}, Iqmal H. Hadi\textsuperscript{1}, and Nabil F. Zulkifli\textsuperscript{1}
\textsuperscript{1} Faculty of Civil Engineering & Earth Resources, Universiti Malaysia Pahang, Lebuhraya Tun Razak, 26300, Kuantan, Pahang, Malaysia.
\textsuperscript{2} Center for Earth Resources Research & Management (CERRM), Universiti Malaysia Pahang, Lebuhraya Tun Razak, 26300, Kuantan, Pahang, Malaysia.
\textsuperscript{3} The Institute of Energy, Policy and Research (IEPRe), Universiti Tenaga Nasional, Malaysia.

Email: edriyana@ump.edu.my

Abstract. In this study, the assessment by using Water Footprint (WF) approach was conducted to assess water consumption within the water supply treatment process (WSTP) services of Semambu Water Treatment Plant (WTP). Identification of the type of WF at each stage of WSTP was carried out and later the WF accounting for the period 2010 – 2016 was calculated. Several factors that might influence the accounting such as population, and land use. The increasing value of total WF per year was due to the increasing water demand from population and land use activities. However, the pattern of rainfall intensity from the monsoonal changes was not majorly affected the total amount of WF per year. As a conclusion, if the value of WF per year keeps increasing due to unregulated development in addition to the occurrences of climate changing, the intake river water will be insufficient and may lead to water scarcity. The findings in this study suggest actions to reduce the WF will likely have a great impact on freshwater resources availability and sustainability.

1. Introduction
In this study, water consumption of WSTP needs to be determined. WSTP is a process of water treatment through few steps begins with the water intake, aeration, mixing, flocculation, sedimentation, filtration and backwash. WF approach was used as a tool to assess the amount of overall water consumption for the WTP.

For years, Life Cycle Assessment (LCA) has been used to evaluate a wastewater treatment plant and all the impacts are evaluated from the construction process to operation and until the dismantling process [1]. In this assessment, the most importance phase that also an adapted method from LCA of all 4 phases [2] is the impact assessment phase. However, LCA is a broad impact assessment tool and all environmental impacts connected with a product or service have to be assessed [3] from the early stage which is before the construction begin until the demolishing and transportation of waste materials stage [4]. Basically, LCA is used to estimate the broad environmental impact such as global warming, eutrophication, acidification, human toxicity, pollution and many more impacts based on standard methodology named ISO 14040 [2]. However, the importance of water uses and impacts are
being assessed in LCA but LCA does not quantify and map indirect water use that involved along the supply chain in water resources management [5]. In term of sustainability of water resources, it is not fare if not assessing on overall water resources.

Hence, the aim of this study is to introduce a WF approach in order to determine the sustainability of the services category through the WF accounting for WSTP. Therefore, the sustainability of WSTP will be able to be identified.

2. Methodology
In this study, Semambu WTP is located at Kuantan (3° 52’ N) has been chosen. The site selection was based on its capacity to supply treated water to sub-district of Sg Karang and Beserah with the average population of 84930 people. Meanwhile, the area for both sub-districts are 30 300.00 Hectare (Ha).

2.1. Data Collection
In this study, data such as rainfall intensity, river flowrate, temperature and water intake volume were collected from Department of Drainage and Irrigation (DID), Malaysia Meteorological Department and Pengurusan Air Pahang Berhad (PAIP) respectively. Meanwhile the land use development of Kuantan district was collected from the Majlis Perbandaran Kuantan (MPK).

2.2. Water Footprint Accounting
WF accounting can be divided into three types of water; blue water, green water and grey water. The unit of the green water footprint process is water volume per unit of time. Time refers either to the day, week or year. Meanwhile, backwash water from the filtration process was considered as WFgrey in this study.

2.3. River Water Availability
The WF of water supply treatment process (WSTP) is defined as the summation of all the water consumed in whole stages of process and can be expressed as the following equation [6]:

\[ WF_{\text{blue}} = BWE + BWI + LRF \] (1)

\[ BWE = \text{Blue water evaporation} \]
\[ BWI = \text{Blue water Incorporation} \]
\[ LRF = \text{Lost Return flow} \]

The unit of the blue process water footprint is water volume per unit of time. In this study, the LRF was not considered in the calculation.

The WFgreen in other hand refers to the precipitation that does not runoff or recharge the groundwater but is stored in the soil or temporarily stays on top of the soil. However in this study, the WF green is considered as a water that being incorporated in the open tank area of the WTP. The WFgreen can be represented with the following equation:

\[ WF_{\text{green}} = GWE + GWI \] (2)

\[ GWE = \text{Green water evaporation} \]
\[ GWI = \text{Green water Incorporation} \]

Water intake resource globally is mostly from the river. Semambu WTP water intake is from Sg. Kuantan. The river water availability is important to ensure the continuity of water supply to consumer. Water availability is referring to the existing volume of the river. Climate change is a factor that contributes to the changes of river water volume. In this study, the volume of river was obtained from the volumetric flowrate (Q) provided by DID.
2.4. Effect of Land Use
Over the past five years, the population of Kuantan has increased rapidly. Semambu WTP distributes to 2 sub-districts which Sungai Karang and Berserah. Table 1 and 2 show the land use of Sungai Karang and Berserah.

Table 1. Land use of Sungai Karang sub-district

|                      | Existing Landuse (2004) | Proposal Area | Landuse (2015) |
|----------------------|-------------------------|---------------|----------------|
|                      | Area (ha) | % | Area (ha) | Area (ha) | % |
| Residential          | 1272      | 25 | 644  | 1,916  | 38 |
| Commercial           | 103       | 2  | 90   | 193    | 3  |
| Industrial           | 63        | 1  | 561  | 624    | 12 |
| Institutional        | 118       | 2  | 13   | 131    | 2  |
| Open Space           | 95        | 1  | 80   | 175    | 3  |
| Infrastructure       | 158       | 3  | 43   | 201    | 4  |
| Transport            | 419       | 8  | 81   | 500    | 10 |
| Agricultural         | 1209      | 24 | -603 | 605    | 12 |
| Forestry             | 599       | 12 | -72  | 527    | 10 |
| Water Body           | 57        | 1  | -    | 57     | -  |
| Beach Area           | 43        | 1  | -    | -      | -  |
| Empty Land           | 794       | 16 | -    | -      | -  |
|                      | 4935      | 99 | -    | 4,935  | 98 |

Table 2. Land use of Beserah sub-district District

|                      | Existing Landuse(2004) | Proposal area (ha) | Landuse (2015) |
|----------------------|------------------------|---------------------|----------------|
|                      | Area (ha) | % | Area (ha) | Area (ha) | % |
| Residential          | 1,412      | 5 | 1,169  | 2,582  | 10 |
| Commercial           | 362        | 1 | 554    | 916    | 3  |
| Industrial           | 1,984      | 7 | 1,929  | 3,914  | 15 |
| Institutional        | 370        | 1.46 | 30  | 400    | 1  |
| Open space           | 204        | 0.8 | 29   | 233    | 1  |
| Infrastructure       | 289        | 1  | 120   | 409    | 1  |
| Transport            | 623        | 2.45 | 2,477 | 3,110  | 1  |
| Agricultural         | 3,216      | 12 | -1,028 | 2,188  | 9  |
| Forestry             | 13,434     | 53 | -2,401 | 11,032 | 43 |
| Water Body           | 577        | 2.28 | - | 577    | 2  |
| Beach Area           | 158        | 0.62 | -158 | -      | -  |
| Empty Land           | 2,731      | 10 | -2,731 | 25,365 | 99 |

|                      | 25,365     | 100 | -2,731 | 25,365 | 99 |
3. Result and Discussion

![WATER FOOTPRINT AMOUNT](image)

**Figure 1**: Water Footprint per Year Amount

Figure 1 shows the WF amount from year 2010 – 2016 at Semambu WTP. In 2014, the WF amount shows the highest with the value of 668 249.9 m\(^3\)/year due to high precipitation occurrences as shown in Fig. 3. During 2014, Kuantan district received a major flood event.

![Rainfall Intensity per Year](image)

**Figure 2**: Rainfall Intensity per Year

| Years | Rainfall Intensity (mm) |
|-------|-------------------------|
| 2010  | 4895.962                |
| 2011  | 4744.416                |
| 2012  | 3331.5                  |
| 2013  | 4868.2                  |
| 2014  | 5224                    |
| 2015  | 4246                    |
| 2016  | 3771.41                 |

| Year | Total water availability per year (m\(^3\)) |
|------|---------------------------------------------|
| 2010 | 68,387,169.54                               |
| 2011 | 141,745,382.8                               |
| 2012 | 94,936,559.23                               |
| 2013 | 101,101,078.9                               |
| 2014 | 233,734,173.7                               |
| 2015 | 156,029,090.4                               |
| 2016 | 154,894,943.4                               |
In 2014 it is clearly shows that the water availability of Sungai Kuantan is the highest as during that year Kuantan received a massive flood due to the high rainfall intensity.

This graph shows the water availability in 2011 is increasing but decrease back when it reaches 2012 and 2013. 2013 is the year where there is dry season (El Nino) happen and 2016 where wet season happen.

3.2. Land Use Development

From Table 1 and 2, it is clearly shows that there was a multiplication of growth in residential and industrial activities. It is believed that the increased of land used activities affected the water demand for the Panching WTP. Figure 5 shows the total water demand in year 2015 and 2016.

### Table 5. Percentage water footprint on water demand

| Year | Water Demand x10^6 (m^3/yr) | Water Footprint x10^6 (m^3/yr) | Total Water Intake x10^6 (m^3/yr) | Percentage Water Footprint Based on Water Demand (%) |
|------|-----------------------------|---------------------------------|-----------------------------------|-----------------------------------------------|
| 2010 | 9.0                         | 491.57                          | 108.1                             | 98.17                                         |
| 2011 | 9.3                         | 600.24                          | 118.1                             | 98.5                                          |
| 2012 | 9.6                         | 563.21                          | 124.8                             | 98.30                                         |
| 2013 | 10.0                        | 545.84                          | 114.9                             | 98.17                                         |
| 2014 | 10.4                        | 668.91                          | 103.0                             | 98.45                                         |
| 2015 | 10.7                        | 579.43                          | 98.1                              | 98.15                                         |
| 2016 | 10.9                        | 579.85                          | 105.0                             | 98.12                                         |

In this study, the water footprint of Semambu WTP was highly dependent to water intake. Meanwhile, every year, water demand keep increasing due to increasing population and land use development. The WF amount increased from 2010 to 2012. However, the percentage decreased from 2012 to 2015. This result shows that the overall water consumption during the water supply treatment process was beginning to reduce although the water intake and water demand were increasing. Therefore, the results show that reducing amount of WF based on water demand is good but WF was still greater than water intake value. This shows that WSTP in Semambu WTP is not sustainable since the percentage of water intake to water demand is very high.

The following Table 5 shows water availability amount to WF at Sg. Kuantan intake. In 2010 - 2016, percentage of WF to water availability was 86.09%, 76.39%, 83.13%, 81.48%, 65.06%, 73.08% and 73.29% respectively. Those values were all greater than the Sg. Kuantan water availability. This shows unsustainable WSTP occurrences at Semambu WTP.
4. Conclusion
As a conclusion, objectives are all achieved. One conclusion can be made from the study. From the trend of water footprint and water demand as keep increasing year by year thus action must be taken. We can conclude from objective 2 that water availability is not available at the river and new intake location should be considered. There are also new WTP constructed at new river intake at Kuantan district since the development of Kuantan is rapidly growth yearly. WF approach can be used to assess water consumption of WSTP as this approach indicates the overall amount of water according to WFblue, WFgreen and WFgrey. All types of water are important and need to be considered in order to ensure the sustainability of water supply management of Semambu WTP.

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| Year | Water Availability x10^6 (m^3/yr) | Water Footprint x10^6 (m^3/yr) | Percentage Water Footprint Based on Water Availability (%) |
|------|----------------------------------|-------------------------------|----------------------------------------------------------|
| 2010 | 68.4                             | 491.57                        | 86.09                                                   |
| 2011 | 141.7                            | 600.24                        | 76.39                                                   |
| 2012 | 95.0                             | 563.21                        | 83.13                                                   |
| 2013 | 101.1                            | 545.84                        | 81.48                                                   |
| 2014 | 233.7                            | 668.91                        | 65.06                                                   |
| 2015 | 156.0                            | 579.43                        | 73.08                                                   |
| 2016 | 154.9                            | 579.85                        | 73.29                                                   |