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

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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]:

$$WF_{blue} = BWE + BWI + LRF \tag{1}$$

BWE= Blue water evaporation
BWI = Blue water Incorporation
LRF = 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 to 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. TheWFgreen can be represented with the following equation:

$$WF_{green} = GWE + GWI \tag{2}$$

GWE= Green water evaporation
GWI = 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 Area (ha)	Landuse (2015)	
	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	100	-2,731	25,365	99

3. Result and Discussion

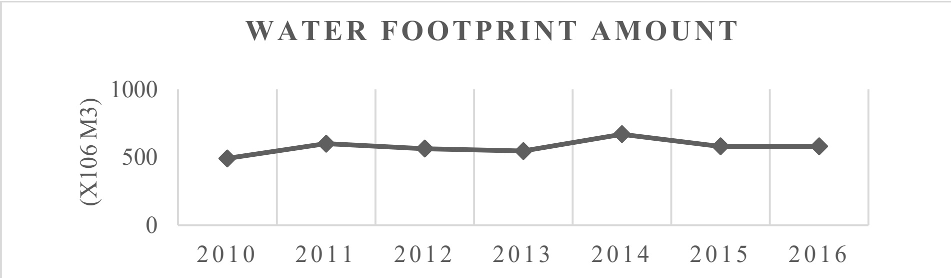

Figure 1 : Water Footprint per Year Amount

Figure 2 shows the WF amount from year 2010 – 2016 at Semambu WTP. In 2014, the WF amount shows the highest with the value of 668 913 249.9 m^3/year due to high precipitation occurrences as shown in Fig. 3. During 2014, Kuantan district received a major flood event.

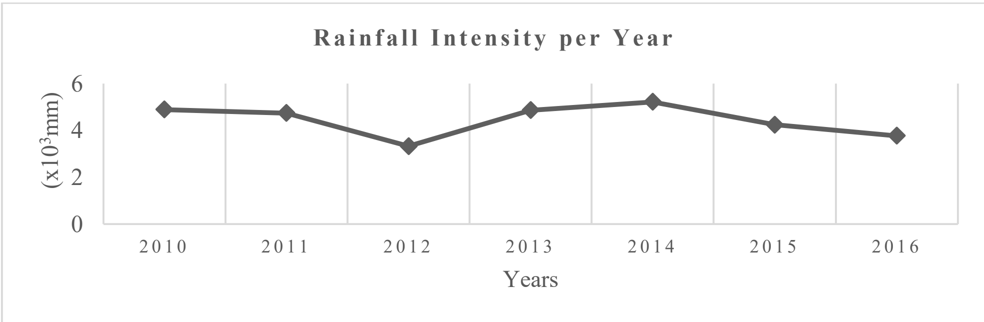

Figure 2 : Rainfall Intensity per Year

Table 3. Rainfall Intensity

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

3.1. Water Availability

Table 4. Total Water Availability

Year	Total water availability per year (m^3)
2010	68 387 169.54
2011	141 745 382.8
2012	94 936559.23
2013	101 101 078.9
2014	233 734 173.7
2015	156 029 090.4
2016	154 894 943.4

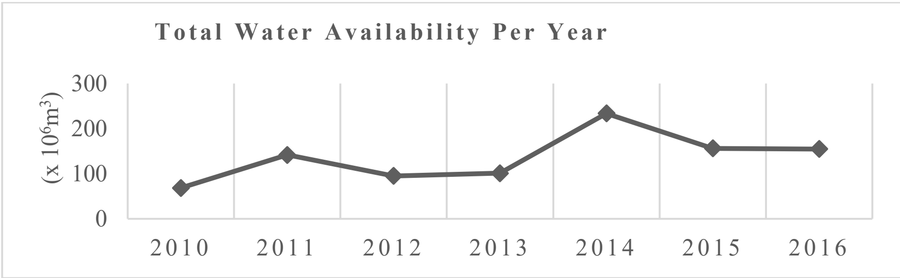

Figure 3 : Total Water Availability per Year

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. Table 3 shows that when the water intake increased the water footprint was also increased. 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.

Table 6. Water Availability and WF

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

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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