WATER FOOTPRINT OF WATER SUPPLY FOR INDUSTRIAL SECTOR WITHIN KUANTAN RIVER BASIN

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ABSTRAK

Di Malaysia, perindustrian merupakan salah satu aktiviti ekonomi yang menjana pendapatan negara dan kini menunjukkan pertumbuhan yang pesat. Oleh itu, dijangkakan penggunaan air daripada aktiviti perindustrian semakin tinggi. Sejak 2016, Bandaraya Kuantan menghadapi isu kekurangan air berikutan beberapa keadaan termasuk berpunca daripada aktiviti ekonomi. Objektif kajian ini adalah untuk menentukan dan meramalkan jejak air bagi bekalan air dalam sektor perindustrian di Lembangan Sungai Kuantan. Pengiraan jejak air ini dilakukan dengan merujuk kepada Manual Jejak Air bagi dua kawasan perindustrian yang terletak di dalam Lembangan Sungai Kuantan. Kajian ini juga menggunakan sistem model iaitu, *Artificial Neural Network* (ANN). Ia digunakan bagi tujuan meramal jejak air. Faktor yang mempengaruhi pengiraan jumlah WF_i boleh ditakrifkan berdasarkan factor persekitaran, sosial dan ekonomi. Dari tahun 2015 hingga 2019, kategori industri berat menyumbang nilai tertinggi jejak air biru (WF_{bi}) diikuti oleh kategori industri sederhana dan ringan. Nilai tertinggi WF_{bi} untuk industri berat adalah pada 2016 dengan 20.21 juta m^3, namun menurun ke arah 2019 sebanyak 17%. Kajian ini juga menunjukkan bahawa aktiviti pembuatan adalah yang tertinggi menggunakan bekalan air di Lembangan Sungai Kuantan iaitu hampir 60% dalam sektor perindustrian. Dari segi pengiraan jejak air kelabu dalam industri (WF_{gi}), ia menunjukkan kategori industri ringan memberikan nilai tertinggi diikuti oleh industri sederhana dan berat. Nilai WF_{gi} bagi kategori industri ringan menunjukkan peningkatan dari 2015 dan mencapai kemuncak pada 2017 iaitu 1.26 juta m^3. Walaubagaimanapun, menjelang 2019, ia menurun sebanyak 54% - 62%. Sementara itu, jumlah jejak air industri (WF_i) adalah yang tertinggi pada tahun 2016 dengan 27.14 juta m^3 dan kemungkinan disebabkan oleh jumlah penggunaan air dan bilangan industri terbesar pada tahun tersebut. Ini berkemungkinan kerana nilai WF_{bi} direkodkan sebagai tertinggi berbanding WF_{gi} bagi kedua-dua kawasan perindustrian. Jumlah jejak air industry (WF_i) menunjukkan peningkatan bermula dari 2015 hingga 2016, namun menurun pada tahun 2019 sebanyak 14%. Selain itu, nilai tertinggi bagi jumlah WF_i disumbangkan oleh kategori industri berat diikuti oleh industri sederhana dan ringan. Dalam percubaan untuk meramalkan jumlah aliran WF_i dengan menggunakan ANN, kawasan perindustrian di Semambu dan Panching menunjukkan peningkatan masing-masing sebanyak 33% dan 100%. Nilai ramalan untuk WF_{bi} jatuh secara purata sebanyak 30% di Semambu dan meningkat kepada 85% di Panching. Sementara itu, nilai ramalan WF_{gi} meningkat secara purata sebanyak 90% bagi kedua-dua kawasan. Oleh itu, dapat disimpulkan bahawa aktiviti industri berat yang semakin meningkat dan menyumbang kepada peningkatan pengiraan jumlah WF_i semasa serta arah aliran ramalan. Akhir sekali, faktor persekitaran boleh ditakrifkan sebagai factor penting yang mempengaruhi jumlah WF_i berbanding faktor sosial dan ekonomi. Kesimpulannya, kajian ini menekankan kepentingan keazaman Jejak Air dalam membantu Kerajaan Negeri menguruskan peruntukan bekalan air dalam lembangan sungai sebagai salah satu cara untuk memastikan kelestarian sumber air kita.

ABSTRACT

In Malaysia, industrialization is an economic activity generating national income and currently showing rapid growth. Hence, it can be anticipated that the water demand from industrial activities is increasingly intensified. Since 2016, Kuantan City has been facing water shortage problems due to several circumstances such as economic activities. Thus, it is important for water regulators to manage the water supply efficiently. This study aims to determine and predict the water footprint (WF) of water supply for industrial sectors within the Kuantan River Basin (KRB). All calculations followed the WF Manual and estimated two industrial areas within KRB. Meanwhile, the deep machine learning tool Artificial Neural Network (ANN) was utilized for prediction purposes. The factor influencing the calculation of total WF_i can be categorized into environmental, social, and economic factors. The results indicated that from 2015 to 2019, the heavy industry category contributed the highest value of blue water footprint (WF_{bi}), followed by the medium and light industry categories. The highest value of WF_{bi} for the heavy industry was in 2016, with 20.21 million m^3, which decreases in 2019 by 17%. This study also shows that the manufacturing activity of all industry categories consumes the most of KRB's water supply which is responsible for almost 60% of the water consumption in the industrial sector. Regarding the calculated industrial grey water footprint (WF_{gi}), the light industry category depicted the highest value, followed by medium and heavy industries. The trend of WF_{gi} for the light industry category showed an increment from 2015 and reached a peak in 2017 with 1.26 million m^3. However, in 2019, the trend decreased by 54% - 62%. Meanwhile, the total industrial water footprint (WF_i) was the highest in 2016 at 27.14 million m^3. It might be due to the largest volume of water consumption and the greatest number of industries during that particular year. The results also indicated that the heavy industry category contributed the highest value of total WF_i, followed by the medium and light industries. In attempting to predict the total WF_i trend using ANN, Semambu and Panching industrial areas showed an increment of 33% and 100%, respectively. The predicted value for WF_{bi} falls on average by 30% in Semambu industrial area. It rises to 85% in the Panching industrial area. Meanwhile, the predicted value of WF_{gi} increased on average by 90% for both areas. Thus, it can be concluded that an increasing heavy industry activity contributed to the increasing calculation of current total WF_i and the prediction trend. Finally, the environment factor could be defined as the significant factor that influences the total of WF_i compared to social and economy factors. In conclusion, this study highlights the significance of WF determination in assisting the state government in managing the water supply appropriation within the river basin as one way to ensure the sustainability of our water resources.

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LIST OF SYMBOLS

V_n	Value of normalization
V	Current value
min_a	Minimum value
max_a	Maximum value
L	Load of Pollutant
C_{max}	Maximum Acceptable Concentration
C_{nat}	Natural Concentration
WD_n	Water Demand at the end of the year
P_i	Projected Industry at the end of the year
C	Per Capita Factor at the end of year
F_i	Service Factor
D_n	Additional Demand at the end of the year
R^2	Square value of Correlation Coefficient

LIST OF ABBREVIATIONS

ANN	Artificial Neural Network
AI	Artificial Intelligence
BOD	Biochemical oxygen demand
CCE	Coca-Cola Enterprise
CDC	Crepe de Chine
COD	Chemical oxygen demand
DID	Department of Irrigation and Drainage Malaysia
DOE	Department of Environmental Malaysia
DOSP	Department of Statistic Pahang
ECER	East Coast Economic Region
ESCAP	Economic and Social Commission for Asia and the Pacific
FAO	Food and Agriculture Organization
GA	Genetic Algorithm
GAM	Generalized additive model
GDP	Gross Domestic Product
IPS	Institutional of Postgraduate Studies
IRBM	Inland Revenue Board of Malaysia
ISO	International Standards Organisation
JKNP	Pahang State Health Department
KRB	Kuantan River Basin
LCA	Life Cycle Assessment
LPT	Lebuhraya Pantai Timur
LRM	Linear regression model
MAE	Mean average error
MBK	Kuantan City Council
MSE	Mean squared error
NH_3N	Ammoniacal Nitrogen
NWQS	National Water Quality Standards
PAIP	Pahang Water Management Limited
PET	Polyethylene terephthalate
PSO	Particle swarm optimization

RAE	Relative absolute error
RMSE	Root mean squared error
RRSE	Root relative squared error
RSE	Root squared error
SMI	Small and medium industry
SVM	Support Vector Machine
TSAM	Time Series Additive Model
TSS	Total Suspended Solid
VOC	Volatile organic compounds
WD	Water demand
WF	Water Footprint
WFA	Water Footprint Assessment
WPL	Water Pollution Level
WQI	Water Quality Index
WTP	Water Treatment Plants
WWTP	Wastewater Treatment Plants

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