長崎大学大学院工学研究科研究報告第４１巻第７７号平成２３年７月

A Research on the Trend Pattern Analysis of Industrial Water Consumption

by

Seong Hoon KIM*, Wataru NISHIDA**, Dong Mun KIM***
Yong Min LIM**** and Byungdug JUN*****

The purpose of this study is to propose the average trend pattern of the industrial water consumption. A real-time sensing technique was adopted for the consumption data acquisition. Data were transformed from the field equipments to the management server in every 5 minutes. The data acquired were substituted to a polynomial formula selected. As a result, a series of models were developed for each day. Each of these models is finalized to represent the average water consumption for the day. In this way, an average consumption pattern is derived for each day of a week. As a result of the aforementioned research, the proposed trend pattern analysis technique is expected to offer some important role for the water supply forecasting administration and management.

Key words *: urban water, industrial water, water consumption, polynomial model, forecasting model, trend analysis, pattern analysis*

1. Preamble

Industrial water is the water used for the industrial production activities and is an essential input element creating economic value by its role of production. Accordingly investment to secure supplies for industrial activities should be implemented in an effective manner and the information on its economic value is indispensably required to make the related decision making (Euh Seung Sub, 2010).

Notwithstanding such importance of industrial water which is one of urban water realms, it has investigated that studies on the industrial water had been made with less attention. Future demands on the industrial water are generally forecasted by an indirect assumption method but it is not so well standardized as the one to estimate demands on the livelihood water. As the industrial water consumed by each type of industry and company should take lots of variables such as manufacturing process, extents of automation, use of recycled water, etc. into account, basic units of represent ability are difficult to be estimated. Hence, this study aims at developing and suggesting a series of forecasting models by analyzing the trends of industrial water consumption. To serve this purpose, real time data in five minutes interval making use of the latest technology are acquired and accumulated in a computer database.

2. Research Trends and Method

平成２３年　６月１４日受理

*　Associate Professor, Department of GIS Engineering, Namseoul University, Korea
**　Associate Professor, Graduate School of Engineering, Nagasaki University, Japan
***　Associate Professor, Department of GIS Engineering, Namseoul University, Korea
****　Graduate Student, Department of GIS Engineering, Namseoul University, Korea
*****　Professor, Faculty of Education, Nagasaki University, Japan

2.1 Research Trends

Substantial achievement has been made so far in the research area related to the demands analysis and estimation. And also researches on analyzing and estimating water consumption according to its characteristics have been made continuously.

Lim Sung Jin (2001) suggested how to improve the policy on the water resources focused on demand management while Yoo Myung Jin and others(2004) conducted water demand forecast by hours emphasizing operation and maintenance of the relevant facilities of the distribution reservoirs of Seoul using linear(Fourier Series, combined model of ARIMA) and non-linear (Kalman Filter) models. On the other hand, Min Dong Kee(2005) developed an industrial water demand forecasting model by selecting the elements influencing the demand. Euh Seung Sup and the other(2010) estimated the consumer' s surplus and economic value of the industrial water supply.

Researches abroad were made in this area as well. In particular, Minami Harudaka(2005) fulfilled case studies on developments and operations of lots of GIS-based water management systems. Most of the research cases are characterized by selecting their specialized models for each object to be analyzed. Such kinds of researches were of help for subsequent studies to some extent but they were understood to be insufficient for the improvement of utilization through convergence and combination of new technologies.

2.2 Research Method

Research on analyzing the trends of consuming industrial water in real time was conducted in phases following the procedure shown on Fig.1. First of all, previous studies applying demand and pattern analysis techniques in diverse areas of urban water were reviewed. Secondly, the two scopes which are contents and space are determined. Hereafter, real-time flux data are collected and properly tuned. Then, water consumption models are developed by performing a series of regression analyses. Finally, industrial water consumption trend patterns are derived from the developed models.

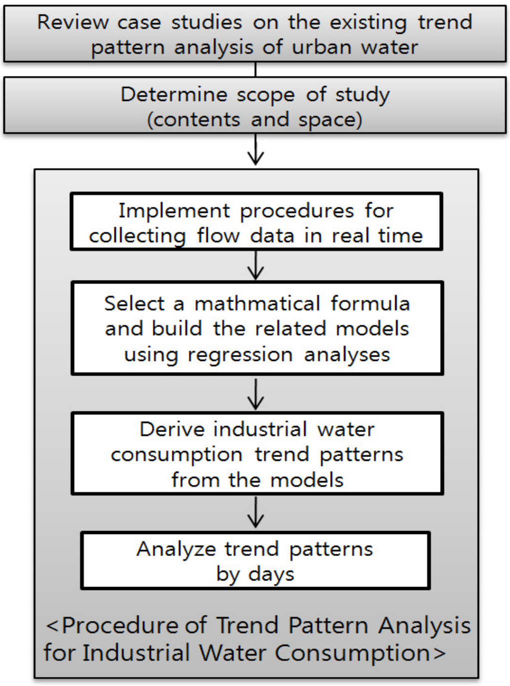

Fig. 1 Research Method.

3. Research Scope and Date Acquisition

3.1 Scope by Contents

Overall water circulation can be classified into natural and artificial systems as shown in Fig. 2. Artificial system/urban water/industrial water out of the hierarchical structure of water circulation were set to be included in this paper.

Industrial water means the water used for operating, washing and freezing the production facilities.

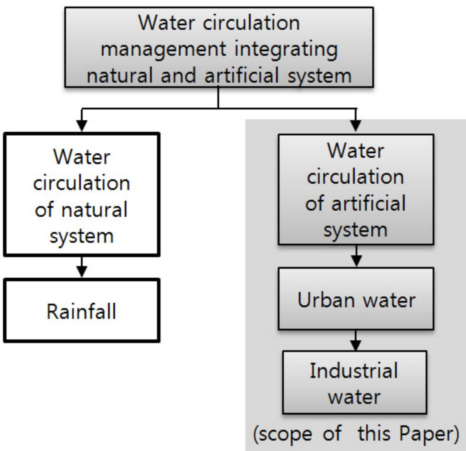

Fig. 2 Scope by Contents.

3.2 Scope by Space

As the target area of this study, an area containing Gwanpyeong Stream in Yuseong-gu, Daejeon-si, Korea was selected as shown in Fig. 3. This area is mixed up with urban and farming areas where a small stream called Kwangpyung, first branch of Kapchun River flows. The area of stream basin is 10.85km^2 and the extension of flow path is 5.45km. Its midstream consists of farm land while downstream consists of residential and industrial complexes. Water consumption of the areas shows diversified patterns, which is proper to this research target area.

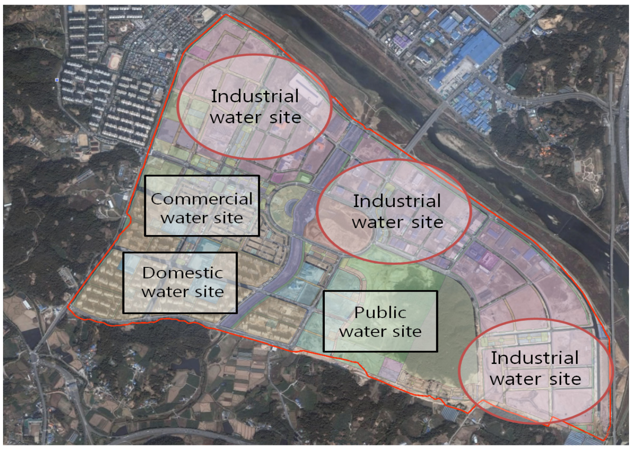

Fig. 3 Scope by Space.

3.3 Data Acquisition

Discharge of industrial water was measured by a large flow meter (100mm) as shown in Fig. 4 and the data is transmitted to the server on the site with installing a wireless transmitting device in CDMA. Data transmitted in real time into the site server from the flow meter are converted to be suitable for the codes of the related programs located in a management server and then transmitted to the management server. Data are collected by the management server and saved according to the designed format.

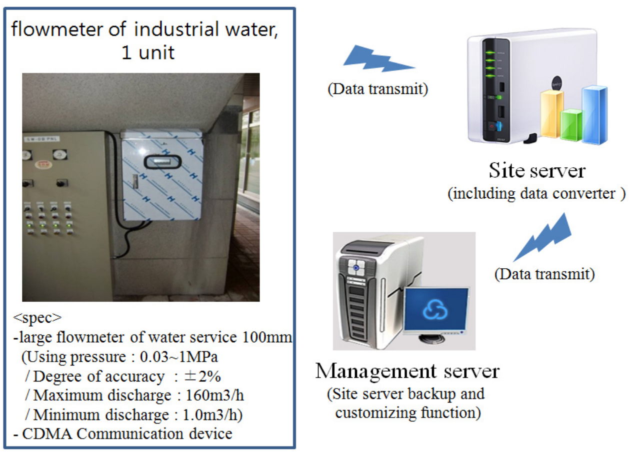

Fig. 4 Procedure of Data Acquisition.

4. Trend Pattern Analysis of Industrial Water Consumption using Polynomial Models

4.1 Used Polynomial

A series of simple-regression analyses were applied to the selected polynomial to find out the optimal models by substituting the real-time data in five minute interval(Ha Dong Myung 2004). Mathematically, the regression analysis is to forecast the values of dependent variables from the independent variables and aims at describing the relation between the independent variables and dependent variables in a form of detailed function. Equation (1) shows the basic shape of the models to be suggested as a general formality of a polynomial.

$$Q = a + bQ_t^1 + cQ_t^2 + dQ_t^3 ... + nQ_t^{n-1} \qquad (1)$$

Where, the parameter Q_t means time and Q means a trend curve.

4.2 Trend Pattern of Industrial Water consumption by each day of a week

The data collected from the flow sensor by five minutes interval(Q_t) for seven months from October 2009 to April were applied to the 4th order polynomial. As a result, a series of models were developed and then time-series trend pattern analyses were performed using the developed models. As a procedure to draw the trend pattern of the industrial water consumption by each day of a week, a two dimensional rectangular coordinate system was adopted, where the X coordinate represents the time(Q_t) and the Y coordinate represents the flux(Q).

Table 1 Data Conversion by Day of a Week.

Day	Number of Models Drawn (based on 7 months)	Time Range (Q_t)	Discharge Range (Q)	Average Consumption (Q_{ave})
	legend	*X* axle	*Y* axle	-
Monday	30	0～287	0～12100	about 180.9ℓ
Tuesday	30	0～287	0～12200	about172.7ℓ
Wednesday	30	0～287	0～13300	about190.0ℓ
Thursday	31	0～287	0～12600	about185.1ℓ
Friday	31	0～287	0～11000	about151.1ℓ
Saturday	30	0～287	0～3000	about36.5ℓ
Sunday	30	0～287	0～1600	about18.4ℓ

A day (24 hours) were set by five minute interval (from 12:00 to 23:55) and the figures were converted into the range of 0～287 to be expressed in the *X* coordinate. While the minimum and maximum value of discharge range (Q_t) were set on the *Y* coordinate. And the data conversion for each day of a week for the selected seven months was conducted as is described at **Table 1**.

For each day, 30 or 31 models were drawn by substituting the data collected for seven months. As is shown on **Fig. 5**, each model reveals the trend pattern in similar forms during the same time zone. To assure the standardization of such models, the models for each day were integrated in a single model which represents the consumption trend of the industrial water for each day. Data set used for **Fig. 5** was the Wednesday's one because the day had the highest average consumption values comparing to those of other days. Similarly, an average consumption model for each day of a week was developed and expressed (**Fig. 6**).

The average industrial water consumption pattern for each day shows slightly different tendency. The average water consumption on Wednesday is reduced from 12:00 to 04:10. After this time zone, it is increased from 07:00 reaching the maximum consumption of about 440ℓ by 18:00 and is reduced afterwards. Consumption patterns on Monday, Tuesday and Thursday are similar with the one of Wednesday except the maximum consumption of about 370ℓ. Friday shows

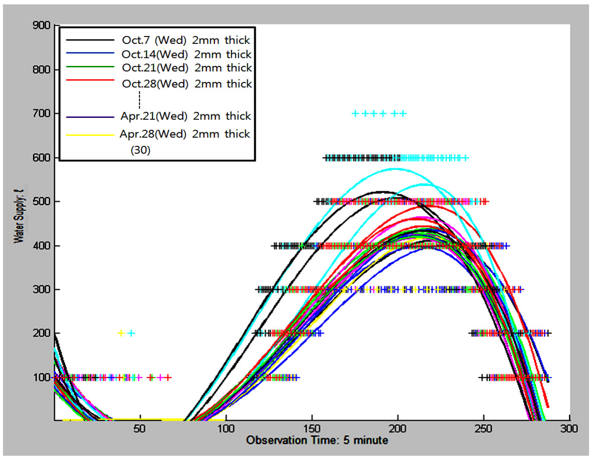

Fig. 5 Consumption Models of Wednesdays.

increasing pattern from 07:00 to reach the maximum of about 310ℓ by 18:00 and is reduced again after the peak. As described above, consumption patterns during week days show different maximum consumptions but they have similar consumption patterns in general. Unlike the above, consumption on Saturday is increased from 08:00 to reach the maximum of about 70ℓ by 20:00 and is reduced again after the peak. Consumption on Sunday is reduced having its maximum of around 50ℓ and average of about 18ℓ, which shows a substantial decrease comparing to those of week days. Above analysis reveals a distinctive difference of consumption patterns between week days and weekend.

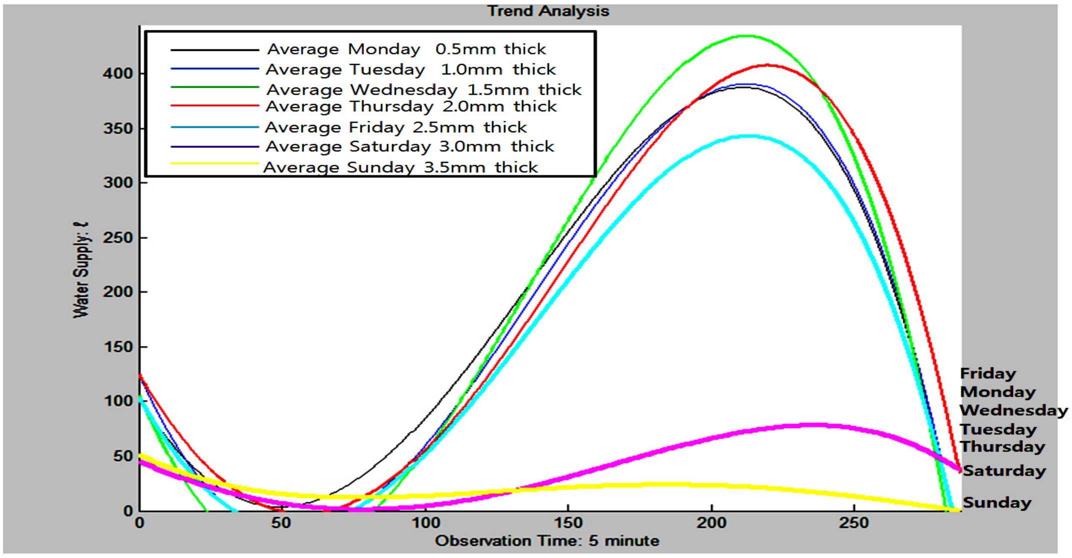

Fig. 6 Average Consumption Models of Each Day.

5. Conclusions

This study, based on the real-time monitoring data of urban water, set the research scope as the industrial water out of urban water. A series of polynomial models were developed and the consumption trend patterns were derived for each day. Such analysis confirmed that water consumptions on weekdays are distinctively different from those of weekends. And as a result of performing quantization process, the average consumption pattern as well as the related flux figures in a day range for each day could be obtained. These results is expected to be useful as the basic information for the administration to forecast the required industrial water amount and its overall management in accordance with the expected water shortage as time goes by and the increased necessity of managing water supply.

References

1) Dong-Ki Min : Estimating the demands for industrial water and the pricing policy, *J. of the Korean Resource Economics Association*, Vol.14-2, pp.475-491, 2005.

2) Myong-Jin Yu, Ja-Yong Koo, Yuon-Hee Ku, and Shin_Geol Kim : Forecasting hourly water demands using linear and non-linear models, *J. of the Korean Society of Environmental Engineering*, Vol.26-3, pp.277-283, 2004.

3) Seung-Seob Euh and Seung-Hoon Yoo : The consumer surplus and economic value of industrial water in Korea, *J. of the Korean Research Institute for Human Settlements*, Vol.65, pp.151-162, 2010.

4) Sung-Jin Leem : On the improvements in the water resource policy from a demand - side management standpoint, *J. of the Korean Political Science Association*, Vol.35-3, pp.237-259, 2001.

5) Dong_Myeong Ha : Measurement and prediction of autoignition temperature(AIT) of flammable substances - methanol and ethanol -, *J. of the Korean Society of Safety*, Vol.19-2, pp.54-60.

6) Minami Harudaka : The development and operation case studies of the GIS-based water information systems, *J. of the Japan Water Work Association*, Vol.74-11, 2005.