International Journal of u and e-Service, Science and Technology
Vol. 9, No. 3, (2016), pp. 351-360
http://dx.doi.org/10.14257/ijunesst.2016.9.3.33

Technical Analysis of Clearwell in Water works using CF

Jinhong Jung[1*] and Gyewoon Choi[2]

[1]Korea Institute of Civil Engineering and Building Technology, Environmental and Plant Engineering Research Institute, Republic of Korea
[2]Incheon National University Graduate School of Engineering, Republic of Korea
[1]jinhong98@kict.re.kr, [2]gyewoon@incheon.ac.kr

Abstract

The purpose of this study was to evaluate retention time distribution and flow line clearwell in water works using computational fluid dynamics. With the finite volume method using the computational fluid dynamics (CFD), a technical diagnosis of clearwell in the water purification process was performed using an unstructured hexahedral grid system. A vector simulation showed stagnation for over 400 seconds at the circulation areas. Where clearwell have an average flow rate, a vector analysis at a height of 1.0 m showed a normal flow downstream. However, some sections of the L-shaped rear section at the left bottom of Clearwell No. 1 partially had the vortex that could cause stagnation. An analysis of flow speed contour line showed that a row of dividers in clearwell partially served as partitions. The results of the analysis can be used as basic data for the creation of alternatives such as the installation of supplementary training walls within clearwell.

Keywords*: Technical Analysis, Clearwell, Water works, Retention Time, CFD*

1. Introduction

The Waterworks Law provides in its Article 4 (1) that "Minister of Construction and Transportation, Special Metropolitan City Mayor, Metropolitan City Mayors, Mayors of Municipalities and Heads of Gun should update their existing waterworks maintenance plan every 10 years for appropriate and rational installation and management of general waterworks and industrial waterworks." They also should perform a technical diagnosis every 5 years under Article 74 (1) of the Waterworks Law, and the enforcement regulations of the Waterworks Law, which were amended in September, 2007, specifies general technical diagnosis for a clearwell of five thousand tons or less capacity per day and professional technical diagnosis for a clearwell of more than five thousand tons capacity per day, depending on size.

The objectives of technical diagnosis of clearwell can be summed up in three main points: first, meet the requirements of the Waterworks Law for technical diagnosis, and promote economic viability to fulfill obligations for water service providers under the Waterworks Law and increase the efficiency of diagnosis cost; second, provide professional technologies and secure technical competitiveness for each water purification plant to secure technical competitiveness by improving and providing diagnostic technique, a collective integrated technique of waterworks design and operation; third, improve the quality of tap water and pursue rational management by presenting optimum conditions for purification facilities, contributing to securing the safety and quality of tap water, presenting optimum methods to improve and replace facilities, and presenting reasons to establish a basic plan for short- and long-term waterworks facilities. The ultimate goal of the technical diagnosis of water purification plants is to contribute to the health hygiene of citizens and increase public trust in drinking water by presenting the direction of construction of a supply system for sufficient

ISSN: 2005-4246 IJUNESST

supply of delicious and safe water, diagnosing functions for the problematic factors of deteriorated water purification plant facilities and presenting improvement methods [1-2].

Water purification plants in Korea use computational fluid dynamics (CFD) to provide agent addition and mixing in processing tanks for mixing basins, distribution channels, sedimentation basins, filter basins and clearwell, and an efficiency evaluation for flow distribution and flow pattern, including natural convection due to density difference and forced mixing [3-6].

This study discusses on evaluation methods for the functions of a clearwell using CFD, focusing on the case of technical diagnosis of water purification plant Y in city A, Gyeonggi-do [7].

2. Experimental Apparatus and Methods

2.1. Clearwell

The clearwell of the water works in city A, Gyeonggi-do consists of two chambers (Table 1, Figure 1). Effective depth of water at clearwell is 6.0 m, and their top freeboard 0.5 m

Table 1. Jar-test Results According to N.C. Dosage

Heading level	Exam	Criteria	Status
Frame	Chamber No.	more than 2 chambers	2 chambers
	Demission	-	26.5mW×40mL×6.0mH
	Depth	3-6 m	6.0 m
	Upper margin	More than 30 cm	30 cm
Spec.	Available capacity	more than 1 hr	11.12 hr

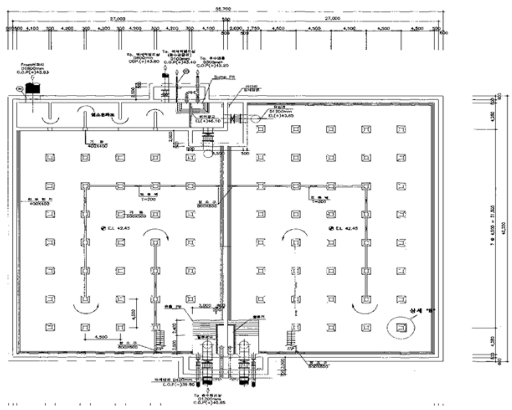

Figure 1. Plane Figure of Clearwell

2.2. Computational Fluid Dynamics (CFD)

This study used program ANSYS CFX 10.0 and FLUENT 6.2.16, and used an unstructured hexahedral grid system for the finite volume method. The condition of the residual of the discretization equation being below 10-6 was selected as convergent and discriminant validity to produce the approximate solution (Table 2). The clearwell had initial conditions entered to identity and interpret flow patterns and the presence of stagnation for maximum, minimum and average flow using three-year operation data for the target water purification plant (Table 3).

Table 2. Condition of CFD

No.	General condition of CFD
1	Setting result of steady flow as initial condition
2	Injection tracer by pulse input

Table 3. Initial Condition of Water Quantity in clearwell

	Flow(kg/s)	Ave. Velocity(m/s)	Retention time(sec)
Ave. Flow	1,504.89	0.02862	7,674.63
Max. Flow	1,863.54	0.03280	6,830.37
Min. Flow	897.69	0.02561	8,775.60

2.3 Tracer Experiment Method

To verify the reliability of computational fluid dynamics (CFD), a comparative analysis of tracer experiment values for the clearwell was made. Tracer materials were subject to a pulse input tracer test, in which fluorosilicic acid (H2SiF6, 25%) is instantaneously injected. After sample injection, samples were collected at the outlet every five minutes over a total of two hours, and fluorine ion was analyzed using a Dionex DX-500 Ion Chromatography(Table 4).

Table 4. Sampling Time Collected during the Experiment

	Starting Time	Sample No.	Interval between Sampling	Ending Time
Segment 1	0 T	10	0.025 T	0.25 T
Segment 2	0.25 T	30	0.042 T	1.5 T
Segment 3	1.25 T	10	0.050 T	2 T
Segment 4	2 T	10	0.100 T	3 T
Segment 5	3 T	5	0.200 T	4 T

3. Results and Discussion

3.1. CFD for Inlet of Clearwell

Modelling was performed the analysis of mixing after chlorine injection in the clearwell (Figure 2). After the filtration process, the flow comes through the inlet of the clearwell, and chlorine is injected through the chlorine inlet. Treated water comes from the outlets of Clearwell No. 1 and Clearwell No. 2. Flow analysis was limited to average flow. Liquid chlorine is usually injected after evaporation, but in this study, on the assumption that liquid chlorine is injected for the convenience of CFD modelling, an analysis was conducted.

The speed vector was marked to find flow patterns (Figure 3). The scale on the left had vector marked in color to indicate speed (m/s). The flow is not smooth on the whole, but arises only on one side, and a great circulation current occurs behind each partition wall. The main flow downstream is fast in speed because the surface is not entirely used, and the circulating current was found to be very slow in speed.

Residence time distribution, and the scale on the left was indicated in second. The analysis showed stagnation for more than 400 seconds in the area where circulation takes place as in the vector. Stagnation due to the circulating current causes the accumulation of pollutants or mixture in the flow. A simulation where chlorine is injected in a gaseous state shows that chlorine concentration for the central part of the stagnated flow is higher than where chlorine is injected in a liquid form (Figure 4).

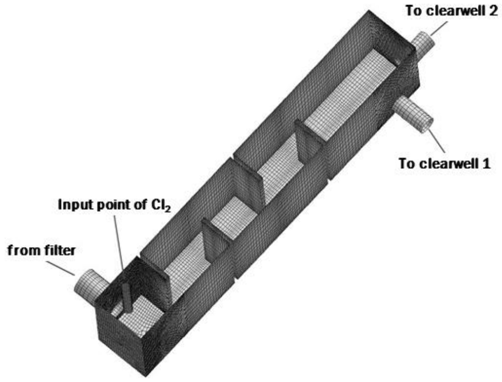

Figure 2. Model of Influx in Clearwell

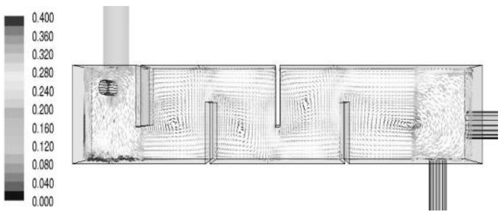

Figure 3. Plane Figure of Vector in Clearwell Influx

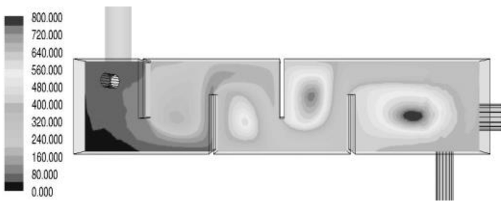

Figure 4. Plane Figure of Residence Time Distribution in Clearwell Influx

3.2. CFD for the Whole of Clearwell

Speaking in terms of average flow, the analysis of the flow pattern of the whole of clearwell showed flow speed contour line at a height of 1.0 m. The scale on the left had the speed expressed in m/s. The analysis showed that the flow was slow in speed overall compared with that of the mixture, and the flow behind columns was very slow, causing stagnation (Figure 5).

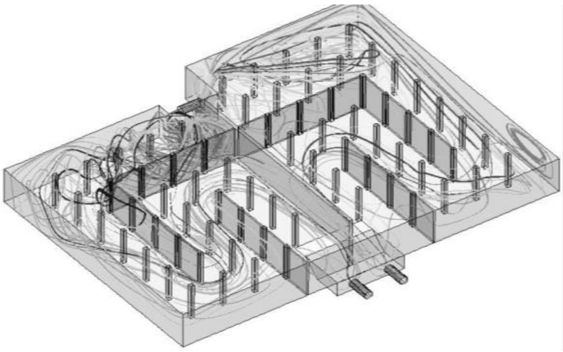

Figure 5. Solid Figure of Contour Line in Clearwell

Table 1. Jar-test Results According to N.C. Dosage

N.C. dosage (mg/L)	0	20	40	60	80	100
Light Intensity (lux)	3800	4600	5100	4900	4500	3700
Chl-a Conc. (μg/L)	54.1	16.2	11.1	8.9	7.4	7.1
Turbidity (NTU)	7.81	1.98	1.04	0.97	1.6	0.92
pH	6.97	6.83	6.87	6.83	6.86	6.92
Alkalinity (mg/L, $CaCO_3$)	94	84	84	80	78	72
Floating speed (min)	-	39	40	41	40	45
Number of particle ($\times 10^2$)	266	210	190	163	146	122

The vector diagram was calculated at a height of 1.0 m for average flow of clearwell. The scale on the left shows the speed expressed in m/s. In a simulation of the whole of clearwell, the flow turned out to be normal downstream. However, some sections of the L-shaped rear section at the left bottom of Clearwell No. 1 partially had the vortex that could cause stagnation. As the flow speed contour line, a row of dividers in clearwell partially serve as partitions. Thus, flow patterns are different between the right and left of clearwell dividers, and only one side of the row has flow, while the other side locally has a reverse flow (Figure 6).

A flow speed contour line was analyzed on the assumption of a minimum influx (Figure 7). A low influx led to reduced water level and reduced flow speed. However, a significant chance in flow patterns due to a low influx was not found. A simulation of the contour line was simulated for a maximum influx, in which the overall flow volume increased, leading to an increase in water level and an increase in flow velocity (Figure 8).

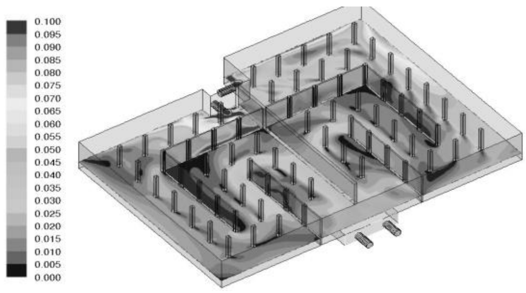

Figure 6. Solid Figure of Vector in Clearwell Reaching 1.0 m Under Average Influx

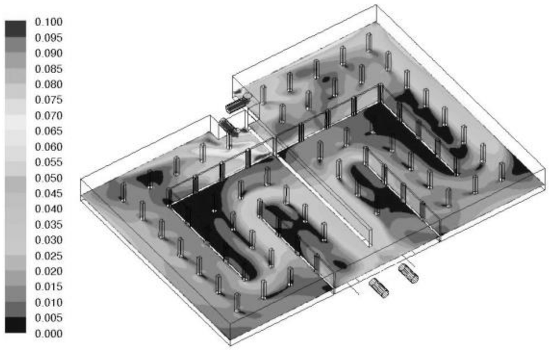

Figure 7. Solid Figure of Vector in Clearwell Reaching 1.0 m Under Minimum Influx

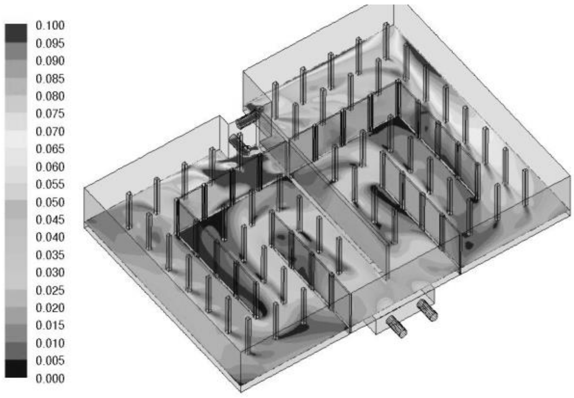

Figure 8. Solid Figure of Vector in Clearwell Reaching 1.0 m Under Maximum Influx

It was calculated the residence time distribution at a height of 1.0 m in a simulation of average flow for clearwell. The scale on the left was expressed in minutes. It shows that stagnation occurred in those sections of reverse flow and vortex. In particular, it turned out that the last section of clearwell outlets had stagnation for around 80 minutes (Figure 9).

It was simulated residence time distribution contour lines for the results of an analysis of the assumed maximum and minimum influx into clearwell, respectively. According to the results, the more reduction in flow, the greater stagnation, and a minimum flow had stagnation for more than 150 minutes (Figure 10, Figure 11).

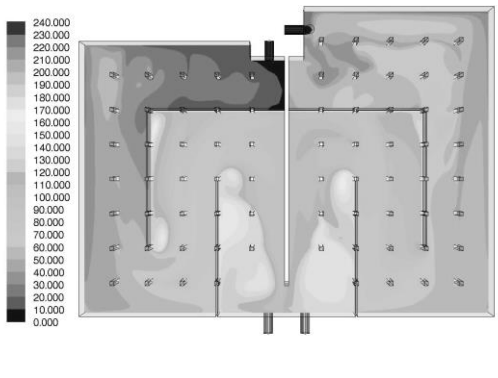

Figure 9. Solid Figure of Residence Time Distribution in Clearwell Reaching 1.0 m Under Average Influx

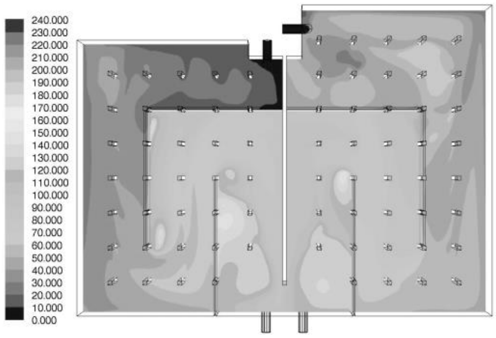

Figure 10. Solid Figure of Residence Time Distribution in Clearwell Reaching 1.0 m Under Maximum Influx

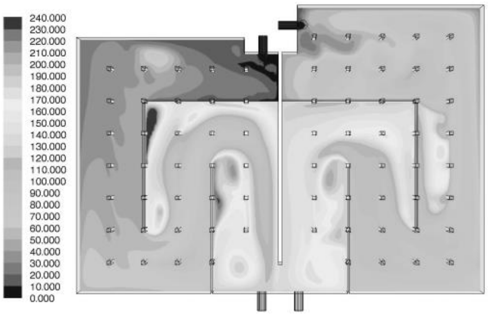

Figure 11. Solid Figure of Residence Time Distribution in Clearwell Reaching 1.0 m Under Minimum Influx

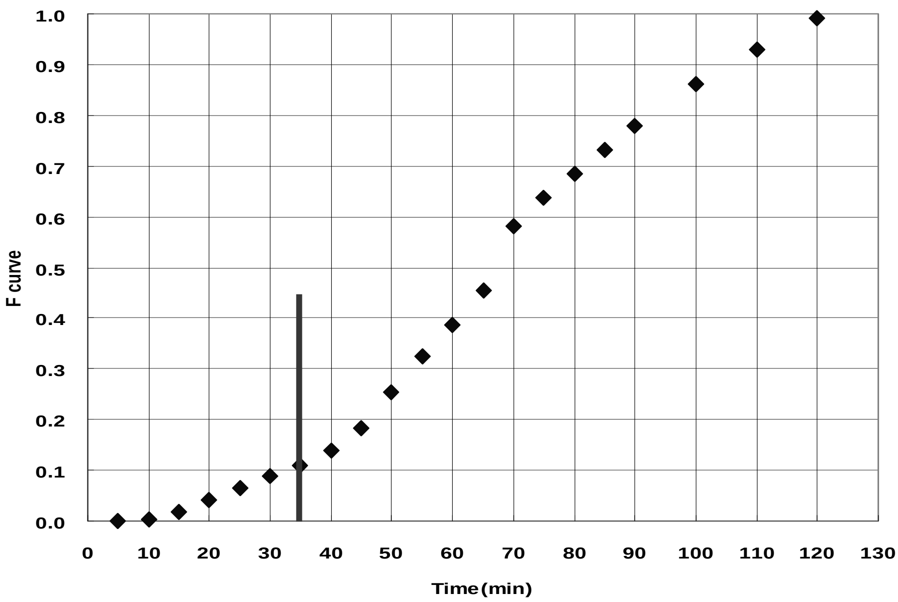

Figure 12. T_{10} of F Curve as Tracer Test

4. Conclusion

With the finite volume method using the computational fluid dynamics (CFD), a technical diagnosis of clearwell in the water purification process was performed using an unstructured hexahedral grid system.

To identify flow patterns and the presence of stagnated flow in clearwell, average, maximum and minimum influxes were simulated. Due to the characteristics of CFD, the simulation was performed on the assumption that chlorine is injected in a liquid form.

The simulation showed that the flow at the inlet of clearwell did not move smoothly on the whole, but moved along only one side of walls, a great circulation occurred behind each partition, and the main flow moved very quickly downstream because it did not use the whole surface, while the circulation moved very slowly. A vector simulation showed stagnation for over 400 seconds at the circulation areas.

Where clearwell have an average flow rate, a vector analysis at a height of 1.0 m showed a normal flow downstream. However, some sections of the L-shaped rear section at the left bottom of Clearwell No. 1 partially had the vortex that could cause stagnation. An analysis of flow speed contour line showed that a row of dividers in clearwell partially served as partitions.

An analysis of the flow speed contour line on the assumption of a minimum influx showed that a reduced influx led to a low water level and a low flow velocity. However, a significant chance in flow patterns due to a low influx was not found. A simulation of the contour line for a maximum influx showed that the flow increased overall, leading to increases in wat er level and flow speed.

A simulation of an average flow rate in clearwell showed that there occurred a stagnation in the sections of residence time distribution, reverse flow and vortex at a height of 1.0 m from the floor. In particular, it turned out that the last section of clearwell outlets had a stagnation for around 80 minutes.

As above, this study used the computational fluid dynamics (CFD) to diagnose residence time distribution and flow patterns for clearwell, the last part of the water purification process. The results of the analysis can be used as basic data for the creation of alternatives such as the installation of supplementary training walls within clearwell.

In the future, a series of process will be necessary to increase the accuracy of CFD with some calibration based on the results of tracer experiments.

Acknowledgements

This research was supported by the Technology Innovation Program (10052814, Technology development of ultra-pure water process for semiconductor level industrial water and localization for 4 kinds of consumable material) funded By the Ministry of Trade, industry & Energy(MI, Korea).

References

[1] Waterworks Law **(2014)**.
[2] Ministry of Environment, Criteria of Waterworks (**2007)**.
[3] Y. M. Cho, J. S. Roh, J. H. Bin, T. K. Kim and Y. I. Choi, "Evaluation of Economic L/W Ratio and the Best Shape of Baffle in Clearwell by Using CFD", Korean Society of Environmental Engineers, vol. 33, no.6, **(2011)**, pp. 432-438.
[4] Z. Liu and J. K. Yoon, "A Study on Heat Transfer and Pressure Drop Characteristics of Staggered Tube Banks using CFD Analysis ", Journal of the Korea Academia-Industrial cooperation Society, vol. 16, no.5, **(2015)**, pp. 2985-2992.
[5] S. H. Lim, C. S. Kim, L. S. Yoon, E.S. Park and Y. J. Lee, "L/W Ratio Evaluation of Expansion Reservoir through Tracer Test and CFD", 2012 Korean Water Congress. vol. 2012, **(2012)**, pp. 732-733.
[6] Y. H. Kim, J. J. Park and G. H. Rhee, "Numerical Analysis for Optimization with Variation of Guide Wall and Porosity in Clearwell", Journal of the Institute of Industrial Technology, vol. 12, **(2004)**, pp. 59-64.

[7] T. M. Hwang, H. J. Oh, J. H. Jung and J. W. Kim, "Technical Assessment of Prechlorination and Postchlorination basin using CFD (CFD:Computational Fluid Dynamics)", Korean Water Congress, vol. 2007, **(2007)**, pp. 283-284.
[8] J. H. Jung and G. W. Choi, "A Study on Analysis of Clearwell in Water works by Computational Fluid Dynamics", Science and Engineering Research Support soCiety (SERSC), vol. 120. **(2015)**, pp. 217-222.

Authors

Jinhong Jung, Oct. 2012: Incheon University, Doctor Completion
Jan. 1994 – current: senior researcher in KICT
Research Interests: Water treatment, Non-point contamination
E-Mail: jinhong98@kict.re.kr

Gyewoon Choi, Oct. 1994 – current: Professor Incheon Univ. in Korea Research Interests: Hydrology, Numerical Modeling, Scour, IWRM E-Mail: gyewoon@incheon.ac.kr