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Simulation of orientation of baffles in a longitudinal direction in chlorine contact tanks

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ABSTRACT: Disinfection is a process designed to disable pathogens, thereby preventing the transmission of waterborne diseases. An important aspect of chemical disinfection is the design of chlorine contact basins. Chlorine contact systems with sufficient time (contact time) disinfect the water for chemical reactions to inactivate pathogens. Design of chlorine contact basin or chlorine contact tanks is to maximize the phenomenon of residence time through the flow of spiral of baffles through the basin or contact tank. Historically, chlorine contact tanks have been investigated by empirical relationships, physical model studies, or tracer studies after the construction of a contact tank. Construction of laboratory samples and tracer studies are time consuming and costly. In recent years, computational fluid dynamics models have been used to investigate the flow and processes of solute transport in contact tanks, which is the best way to design contact tanks before construction. In this study, a 3D simulation of the CT-1 contact tank is performed using Multiphysics 5.3a software. Also, several 3D simulations in the CT-1 contact tank, in which the effect of the baffle orientation in a longitudinal direction with three different channel widths was performed, it was concluded that the narrow channel with a ratio of Winlet /Wch=0.68 (channel to inlet width ratio) and Lbo / Wch ratio (baffle opening length to Channel width ratio) equal to 1 has the highest baffle factor and the least amount of Morill index and therefore optimal hydraulic.

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1. INTRODUCTION

Chlorine contact tanks are commonly used to disinfect drinking water before distribution. These tanks are usually open compartments that are divided by a series of baffles. The separation of the compartments helps to control the flow of water through the tanks and improves the process of disinfection of the chlorine. The main purpose of chlorine contact tanks provide a suitable residence time for both micro-organisms and disinfectants to achieve the desired degree of inactive germs [1].

In this study, the simulation of the 3D model of the CT-1 contact memory model using the Comsol Multiphysics 5.3a software is presented. The experimental model of this tank located at the Hyder Lab of the Water and Environmental Research Center at Cardiff University of England (Fig 1) [1].

The orientations of the baffles along the longitudinal direction are simulated in three wide-channel, normal, and narrow channel widths, and three modes of L_{bo} to L_T ratio (rotational radius ratio around the baffles to the tank length) of 20%, 40%, and mode $L_{bo} = W_{ch}$ (W_{ch} the input channel width) were considered and performed. The Residual Distribution Curve (RTD) and Flow through Curves (FTC) were extracted for each mode in order to evaluate and compare their performance.

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2. METHODOLOGY

In this simulation, the geometry is plotted in the Comsol software environment. The tank with dimensions of $3 \times 2 \times 1.2$ meters has 7 baffles with dimensions of $1.2 \times 1.63 \times 0.012$ m and the walls are spaced at the same distance of 0.365 meters. Also, the channel entrance level is 0.365×0.3 m and the water depth is 1.02.

The produced mesh in this simulation has been Coarse. Simulation of the CT-1 tank model is performed over three stages. First, the steady-state simulation of turbulent velocity field is performed, simulation time for this stage 3 hours 25 minutes and 59 seconds. The second and third stages, the concentration field is simulated with respect to immediate release of tracer in unsteady state conditions for calculating the residence time in the form of pulses and steps release. Simulation time is 4 hours and 48 minutes and 34 seconds for a pulse release, and is 3 hours 45 minutes and 19 seconds for the system CPU 3 GHz and 8 GB of memory respectively.

The reaction speed equation is obtained by using equation 1:

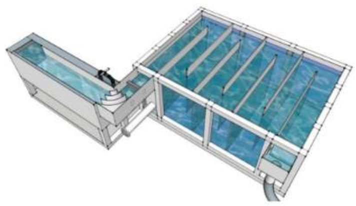

Fig 1. Geometric Contact Tank Model CT-1 [1].

Table 1. Results of hydraulic performance indicators for CT-1 contact tank

CT-1 Tank	t_{10}/T	t_{90}/T	MI
EXP	0.7	1.48	2.12
Comsol	0.71	1.3	1.71

Table 2. Calculation of hydraulic performance indices for longitudinal orientation of baffles.

L	L_b	MI (wide)	BF (Wide)	L_{bo}/W_{ch}	L_{bo}/L_T
L_1	2.6	3.05	0.68	0.8	0.2
L_2	2.2	2.78	0.64	1.6	0.4
L_3	2.5	2.52	0.68	1	0.25
L	L_b	MI (Normal)	BF (Normal)	L_{bo}/W_{ch}	L_{bo}/L_T
L_4	2.6	1.97	0.81	1.21	0.2
L_5	2.2	2.17	0.76	2.42	0.4
L_6	2.67	2.14	0.82	1	0.165
L	L_b	MI (Narrow)	BF (Narrow)	L_{bo}/W_{ch}	L_{bo}/L_T
L_7	2.6	1.57	0.80	1.6	0.2
L_8	2.2	1.59	0.82	3.2	0.4
L_9	2.75	1.55	0.86	1	0.125

$$\frac{\partial Cl}{\partial x} = -k\,.Cl \quad (1)$$

Where Cl is the concentration of chlorine, k is the decay rate of disinfectants that is generally dependent on the quality of water and also the conditions of disinfection .In this study, the concentration of chlorine at the inlet and equal to 1.2 mg / l and the amount of k used is equal to $^{4-}10*2.77\ S^{-1}$ [2].

The calculation of the concentration in the pulse is obtained by equation 2:

$$E(t) = \frac{C(t)}{\int_0^{\infty} C(t)dt} \quad (2)$$

Where C(t) the concentration of the tracer at the outlet of the tank and E(t) is a function, which represents different time of the presence of fluid in the tank [3].

The calculation of the concentration in the output from Equation 3:

$$F(t) = \frac{C(t)}{\sum_{i=1}^{n} C_0} \quad (3)$$

Where C_0 is the initial concentration of the tracer at the injection moment to the tank input, and F(t) indicates the cumulative distribution function [4].

Usually a dimensionless time (θ) is defined which is the ratio between time t and time T, theoretically restraint. Equation 4 is used to calculate hydraulic performance indicators and compare them [3].

$$\theta = \frac{t}{T} \quad (4)$$

3. RESULTS AND DISCUSSION

Table 1 shows the calculated hydraulic performance indicators for the CT-1 contact tank using distribution curves of the residence time and the flow curve in the output of the contact tank. These indices are t_{10}/T, t_{90}/T, MI, which are compared in two EXP (experimental study), Comsol (numerical simulation performed in this study by finite element method).

Subsequently, more simulations were carried out to determine the effect of the direction of the baffles in the longitudinal direction. Table 2 shows simulation results for baffle orientation for three wide, normal, and narrow channels.

Finally, from the sensitivity analysis results in the direction of the baffles in a longitudinal direction it concluded; from three channel widths (wide, normal, and narrow), the highest amount of baffle factor and the lowest value of the morill index (values close to 1) refers to a narrow channel with values of 0.86 and 1.55, respectively, for the Baffle Factor and the Morill Index. In fact, the geometry of the L_9 tank with dimensionless ratios of the baffle length mouth to the width of the channel equal to 1 and the ratio of the baffle mouth length to the length of the tank equal to 0.125 since the flow conditions is close to the ideal flow of plugs and more uniformity and reduction of rotating flow and dead regions thus it is the optimum hydraulic mode.

4. CONCLUSIONS

In this research, numerical simulation of chlorine disinfection contact tanks using Comsol software has been investigated. Using the hydraulic performance indicators, the performance of the tank is determined. The best performance is when the amount of Baffle Factor (t_{10}/T) is maximum and the Morill index (MI) is minimum. The initial simulation results showed that numerical results have good agreement with laboratory model results.

Further simulations were performed to investigate the effect of baffle orientation on the hydraulic performance of contact tanks. The results of the sensitivity analysis of the orientation patterns of the baffles in the longitudinal direction; in three cases of wide, normal, and narrow channels, showed that, in the first scenario, the wide channel with a ratio of W_{inlet}/W_{ch}=1.37 (L_3 tank), in the second scenario of the normal channel with a W_{inlet}/W_{ch}=0.9 ratio (L_4 tank), and in the third scenario of the narrow channel with a ratio of W_{inlet}/W_{ch}=0.68 (tank L_9) is the optimal hydraulic mode of each group. As well as comparing the optimal state of each group with each other, the L_9 tank with the highest baffle factor of 0.86 and the lowest of the Morill index of 1.55 are the optimal hydraulic state. In fact, from different widths, wide and narrow channels, a narrow channel with a ratio of W_{inlet}/W_{ch}=0.68 optimal hydraulic mode. It was also observed in the narrow and normal channels that, with decreasing L_{bo}/L_T ratios increased hydraulic performance.

5. REFERENCES

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