# MR JEPAS_The pattern of hydrodynamic in water treatment disinfection to estimate organism removal

*by* Euis Nurul Hidayah

MERIT RESEARCH JOURNALS
www.meritresearchjournals.org

Merit Research Journal of Engineering, Pure and Applied Sciences Vol. 1(1) pp. 005-009, November, 2013
Available online http://www.meritresearchjournals.org/epas/index.htm


*Full Length Research Paper*

# The pattern of hydrodynamic in water treatment disinfection to estimate organism removal

**Euis Nurul Hidayah* and Okik Hendriyanto C**

Department of Environmental Engineering, UPN "Veteran" Jatim Surabaya, Indonesia

***Corresponding Author's E-mail: euisnh@yahoo.com**

**Abstract**

**Direct evaluation of the performance and efficiency of disinfection tanks could more costly and time consuming. Mathematical model can be a good alternative to observe the hydrodynamic in a disinfection basin. Mathematical model was constructed from two hydrodynamic equations, namely the continuity equation and momentum equation. This research aims to study mathematical models of velocity, NRe, NFr, E.coli distribution and residual chlorine patterns in baffle channel disinfection tanks based on the hydrodynamic model (HPAd Model) mathematical formulation. Research includes the formulation of mathematical models whose results will be visualized with Mathlab, the acquisition of primary data using physical models, testing the model using Mathlab with the primary data input. The result of running the program input data showed variations in E.coli distribution patterns in the disinfection basin which explained that the channel from the inlet to the outlet there is an increase of flow velocity pattern (u), Reynolds numbers (NRe) and Froude numbers (NFr), but E.coli distribution and residual chlorine decrease. This research focus on pattern of hydrodynamic to disinfection process, thus simulation only showed E.coli can be removed around 30%-50% and residual chlorine 50-80% removal. Implementation of the HPAd model still in laboratory scale and effect of hydrodynamic conditions, then the research will continue to use optimum disinfectant dosage to remove organism in relation with hydrodynamic condition.**

**Keywords:** Hydrodynamic model, Disinfection tank, Residual chlorine

## INTRODUCTION

Generally, tanks are characterized by hydrodynamic phenomena, such as density water, Eddy's currents, sensitive to temperature changing and wind effects. As it was well known, disinfection tanks which used to remove pathogens also will be influenced by hydrodynamic condition during disinfection process. Many factors could be influenced the performance and efficiency of disinfection tank such as velocity flow and geometry basin (Razmi, et. al., 2009), concentration and suspended particles characteristic (Sammarrae, 2009), effect of turbulence flow (Gou et. Al., 2009), inlet and outlet design (Ahmadi, et. al., 2007), baffle used to flow control (Athanasia, et. al., 2008b), detention time (Athanasia, et al., 2008a).

Direct evaluation to performance and efficiency of disinfection tank require more costly and time consuming. Mathematical modeling was one of the alternative ways to determine of the flow field and hydrodynamics conditions in disinfection tanks. Many researchers have used mathematical modeling with same principles but in different methods (Lopez et.al. 2007; Kantoush, et.al. 2008). One of the mathematical model is Hydrodynamic

Pollutant Dispersion in River (HP2S). The model is based onconservationlaw of mass and energy, mathematicsstructureof differential partial through Leap Frog explicit finite difference numerical method that model visualized by using Mathlab computer program (Karnaningroem, 2005).

This current research used HPAd model to make formulation of mathematical model of flow velocity, NFr and Nre patterns in baffle channel disinfection tanks and to analyze the effect of hydrodynamic to the residual chlorine and distribution E.coli. It based on transport mechanism in pollutant dispersion was analogized to pollutant transport phenomenon in river.

## MATERIALS AND METHODS

### Optimizing coagulant dose

DPD method was the experimental to determine the optimum disinfectant dose, which it used chlorine and calcium hypochloride. The experimental consist of a coagulation tank and flocculation tank bothwith turbine mixer, a rectangular sedimentation tank and baffle channel disinfection tank

### Providing instrument

Scaled physical models were based on a similaritytheory, which used a series of dimensionless parameters that fully or at the least, partially characterize the physics. The choice of a scaling factor *n=Lp/Lm*, or length scale ratio, to be used in the experiments, was determined by the objectives of the research. According to the length of the tested section and laboratory constraints, the present laboratory model has been designed with horizontal and vertical scales of $n_h=n_v=25$. The selected flow rates were selected to take into account the tank dimensions according to Reynolds (NRe) and Froude numbers (NFr). Runs were carried out with injectionoptimumdisinfectant dose for 5 and 2.5 mg/L and running carried out with flow rates 1L/min, 2 L/min and 4L/min.

### Identification pattern

For identification of flow patterns, fluorescent was injected and the evolution of the color vein was observed. It is first step to the study hydrodynamic condition in baffle channel disinfection tanks, so that the observed phenomena (recirculation, preferential flow paths, etc.) could be used as a qualitative orientation in the comparison of quantitative models. For identify of distribution E.coli and residual chlorine, Smart Spectrophotometer took samples at 7 different points of surface basin into account E.coli and free chlorine.

### Mathematical formulation

Formulation for mathematical modeling based on formulation of mathematical in hydrodynamic model (Karnaningroem, 2005), which mathematical models are based onthe law of conservation of mass, conservation lawsand momentum transport phenomena. Results formulation visualized with Matlab program that obtained model patterns.

### Computer simulation

The HPAd model was prepared with visualization by Mathlab program after changed axis y as width of riverbecame axis z as depth of tank. Experimental data were used for simulation HPAsmodel. Next simulation conducted with length sedimentation tank variation to observed hydrodynamics condition. Outputs of running model were visualization of horizontal velocity flow, settling flocs pattern, turbidity, and NRe and NFr. Application of HPAd model have assumed sample was free chlorine, no back mixing, E.coli and disinfectant distributed along the tank, pH and temperature is constant.

### Theory and calculations

Mass conservation equation simplifies to Equation 1 because the mass flow changes resulting from changes to the length and depth of the basin and the runoff or the source of the mass inside, where the disinfection reactor is injected by disinfectant.

$$\left(\frac{\partial \rho}{\partial t}+\frac{\partial \rho u}{\partial x}+\frac{\partial \rho w}{\partial z}\right)=q \qquad \text{........(1)}$$

With the application Leap Frog method, then it becomes Eq.2

$$\rho_{i,k}^{n+1}=q_{i,k}^{n}+\rho_{i,k}^{n-1}-\frac{\Delta t}{\Delta x}\rho_{i,k}^{n}(u_{i+1,k}^{n}-u_{i-1,k}^{n})-\frac{\Delta t}{\Delta x}u_{i,k}^{n}(\rho_{i+1,k}^{n}-\rho_{i-1,k}^{n})-\frac{\Delta t}{\Delta z}\rho_{i,k}^{n}(w_{i,k+1}^{n}-w_{i,k-1}^{n})-\frac{\Delta t}{\Delta z}w_{i,k}^{n}(\rho_{i,k+1}^{n}-\rho_{i,k-1}^{n}) \qquad \text{....(2)}$$

Based on non-linear stability analysis [4], then it becomes Eq.3.

$$\rho_{i,k}^{n+1}=q_{0}+\rho_{i,k}^{n-1}-\frac{\Delta t}{\Delta x}\rho_{0}(u_{i+1,k}^{n}-u_{i-1,k}^{n})-\frac{\Delta t}{\Delta x}u_{0}(\rho_{i+1,k}^{n}-\rho_{i-1,k}^{n})-\frac{\Delta t}{\Delta z}\rho_{0}(w_{i,k+1}^{n}-w_{i,k-1}^{n})-\frac{\Delta t}{\Delta z}w_{0}(\rho_{i,k+1}^{n}-\rho_{i,k-1}^{n}) \quad . \qquad \text{....(3)}$$

Momentum conservation equation reduces to Eq.4 because there is a change of mass flow due tochanges in the length and depth of the basin, hydrostatic force, advection force

$$\left(\frac{\partial \rho U}{\partial t}+\frac{\partial \rho u U}{\partial x}+\frac{\partial \rho w U}{\partial z}\right)-(Po+\rho.g.h)\Delta z.\Delta y-\mu\frac{U.B}{\Delta x}=0 \quad \text{....(4)}$$

Because of the influence of velocity direction, then Eq.4 is converted into Eq.5, i.e the momentum equation on the x axis (length basin).

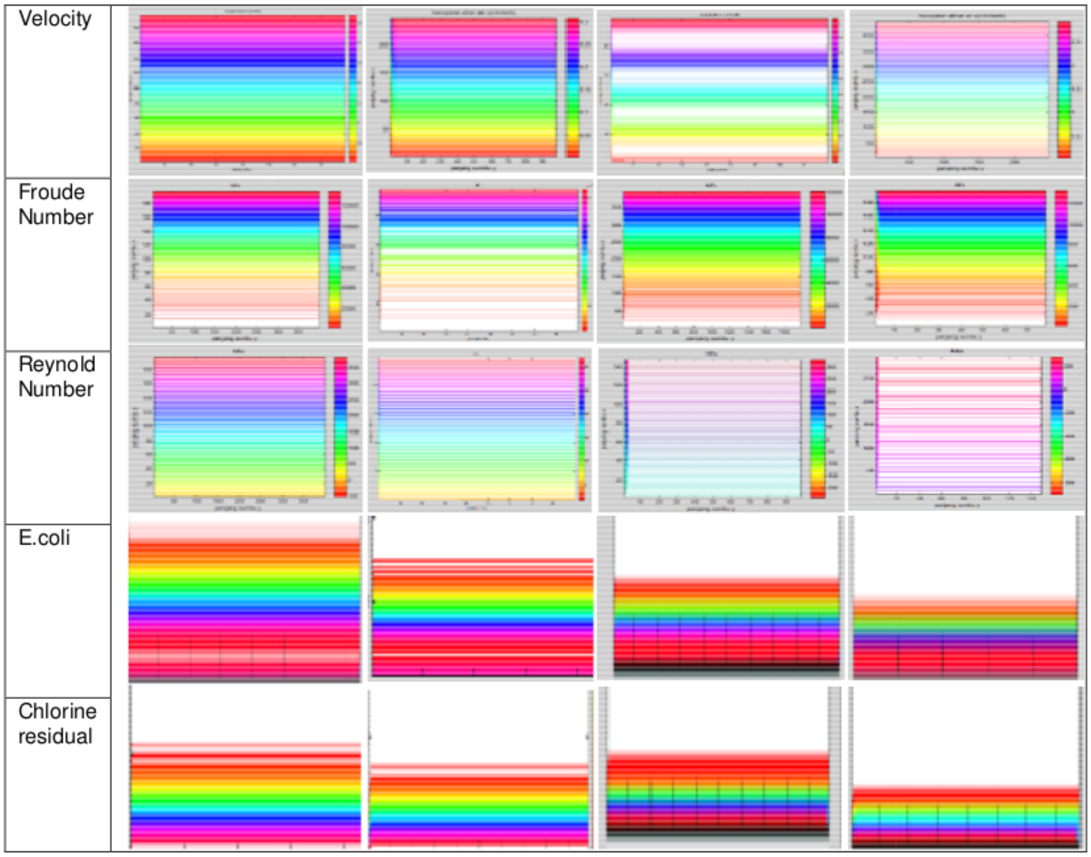


**Figure 1**.Visualization of mathlab program with flow rate 4 L/min in upstream

$$\rho\left(\frac{\partial u}{\partial t}+w\frac{\partial u}{\partial z}+u\frac{\partial u}{\partial x}\right)+u.q-(Po+\rho.g.h)\Delta z.\Delta y-\mu\frac{u.\Delta z}{\Delta x}=0 \quad ....(5)$$

With the application Leap Frog method, then Eq.5 is converted into Eq.6

$$u_{i,k}^{n+1}=u_{i,k}^{n-1}-\frac{\Delta t}{\Delta x}u_{i,k}^{n}(u_{i+1,k}^{n}-u_{i-1,k}^{n})-\frac{\Delta t}{\Delta z}w_{i,k}^{n}(u_{i,k+1}^{n}-u_{i,k-1}^{n})+\frac{2\Delta t}{\rho_{i,k}^{n}}[((Po+\rho.g.h)\Delta z.\Delta y)+(\mu\frac{u_{i,k}^{n}.\Delta z}{\Delta x})-(u_{i,k}^{n}.q_{i,k}^{n})] \quad ....(6)$$

Eq.4 was changed to Eq.7, namely the momentum equation on the y axis (width basin).

$$\rho\left(\frac{\partial w}{\partial t}+u\frac{\partial w}{\partial x}+w\frac{\partial w}{\partial y}\right)+w.q-(Po+\rho.g.h)\Delta x.\Delta y-\mu.w=0...(7)$$

With the application Leap Frog method, then Eq.7 to Eq.8

$$u_{i,k}^{n+1}=u_{i,k}^{n-1}-\frac{\Delta t}{\Delta x}u_{i,k}^{n}(w_{i+1,k}^{n}-w_{i-1,k}^{n})-\frac{\Delta t}{\Delta y}w_{i,k}^{n}(w_{i,k+1}^{n}-w_{i,k-1}^{n})+\frac{2\Delta t}{\rho_{i,k}^{n}}[((Po+\rho.g.h)\Delta x.\Delta y)+(\mu.w_{i,k}^{n})-(w_{i,k}^{n}.q_{i,k}^{n})] \quad .....(8)$$

Based on non-linear stability analysis then transformed into Eq.9.

$$u_{i,k}^{n+1}=u_{i,k}^{n-1}-\frac{\Delta t}{\Delta x}u_{0}(w_{i+1,k}^{n}-w_{i-1,k}^{n})-\frac{\Delta t}{\Delta y}w_{0}(w_{i,k+1}^{n}-w_{i,k-1}^{n})+\frac{2\Delta t}{\rho_{0}}[((Po+\rho.g.h)\Delta x.\Delta y)+(\mu.w_{0})-(w_{0}.q_{0})] \quad ...(9)$$

Transport phenomena equations reduces to Eq. 10 with the application Leap Frog Method.

$$C_{i,k}^{n+1}=\frac{\Delta t}{\Delta x}u_{i,k}^{n}(C_{i+1,k}^{n}-C_{i-1,k}^{n})+\frac{\Delta t}{\Delta x}w_{i,k}^{n}(C_{i,k+1}^{n}-C_{i,k-1}^{n})-C_{i,k}^{n-1} \quad ...(10)$$

Based on non-linear stability analysis [8] then transformed into Eq.11.

$$C_{i,k}^{n+1}=\frac{\Delta t}{\Delta x}u_{0}(C_{i+1,k}^{n}-C_{i-1,k}^{n})+\frac{\Delta t}{\Delta x}w_{0}(C_{i,k+1}^{n}-C_{i,k-1}^{n})-C_{i,k}^{n-1} \quad ....(11)$$

Formulation of mathematical models of settling flocsin the sedimentation basin that is Eq.3, Eq.6, Eq.9, Eq.11 was visualized using Mathlabprogram.

## RESULTS AND DISCUSSION

Physical model with length of basin=75 cm, width each

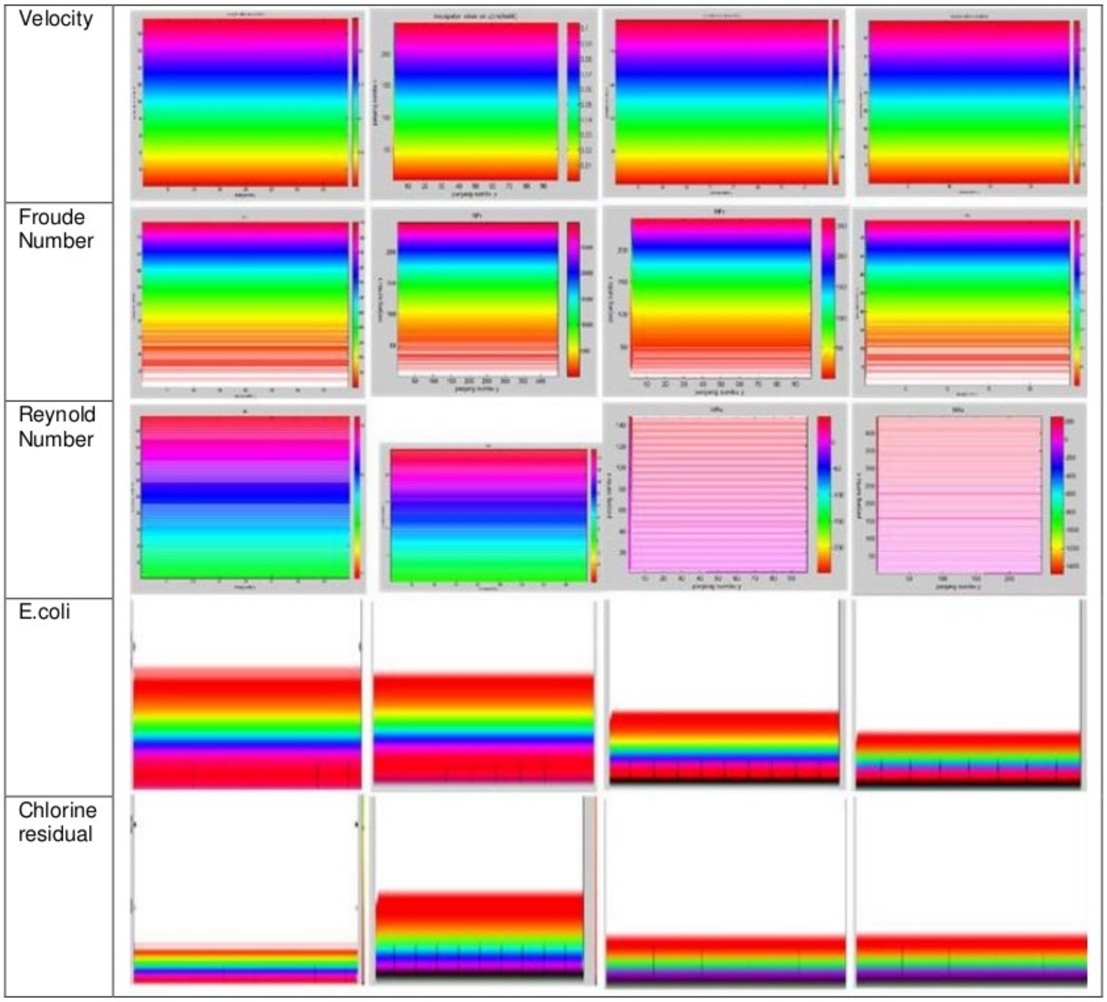


**Figure 2**.Visualization of mathlab program with flow rate 4 L/min in downstream

compartment = 10 cm and depth = 25 cm is used to identify the flow pattern, flow velocity measurements and the identification of distribution E.coli and residual chlorine. From the results of running by using physical models derived data, namely the horizontal flow velocity data, the value of E.coli and residual chlorine. The other data consists of: dimensional basin, detention time, flow rates, flow rates of runoff, velocity injection. These data are input to run the model in Mathlab. Running the model for all points, it has 7 points on the baffle channel disinfection tanks such as sampling at : inlet, outlet, 3 sampling on straight flow, and 2 sampling on turn flow.

Output running HPAd model of horizontal flow velocity pattern (u), the pattern of Froude Number (NFr), pattern of Reynold Number (NRe), the pattern of distribution E.coli concentration (c) and distribution residual chlorine (s) as a parameter to analyze the model. Output from running model are NRe showing turbulence flow conditions and NFr, which indicates stable flow conditions.

Simulation HPAd model in disinfection tank used only on the certain of horizontal flow velocity, Reynolds number, Froude number, residual chlorine concentration, E.coli concentration, retention times and depth of basin. It was happened because of influenced of a shear force, which fluid flow movement in each layer would be experience of mixing between layer in small scale and would be generated tension force then kinetic energy decreased (Van der Walt, 2008). While distribution velocity became increased in simulation. The organism and disinfectant interaction increased with increased of turbulence intensity.

Figure 1 and Figure 2 showed simulation of HPAd model with type and dosage of disinfectant variation to ensure that hydrodynamic conditions has same pattern to length basin constant. This paper showed sampling and result in theupstream or inlet and in the downstream or outlet. Behavior of hydrodynamics in baffle channel reactor was influenced by kinetic energy, which the biggest was on surface basin and dissipated along with length and depth of sedimentation basin. Therefore, velocity became increase and organism were distributed and contacted with disinfectant from upstream to downstream channel of the tank thereby dragging fluid along. The movement of fluid in turn affected to the disinfection of organism. It was mean that NRe, NFr, chlorine residual increased and velocity rate was increased due to turbulences. Based on simulation model experimental, decreasing E.coli didn't show significant results, only 30-50% compared with decreasing residual chlorine 50-80%. It was caused by disinfectant ability to react and to oxidize organism or others than E.coli. In other case, this research used dosage and type of disinfectant such as monocholramin and free chlorine in dosage 5 mg/L and 2.5 mg/L, respectively. This parameter will not influenced the pattern flow velocity and Froude Number. Dosage and type of disinfectant will influence the pattern of Reynold Number due to effect of acceleration and dragging flow correlated to dispersibility. While E.coli distribution and residual chlorine pattern will be influenced by dosage and type of disinfectant due to disinfectant was used for reducing E.coli and remaining chlorine as rest of product after chlorine reacted with organism.

## CONCLUSIONS

Formulation of mathematical model of disinfection patterns developed from HPAd model can be used in baffle channel tanks by using the parameters of the flow velocity pattern, the pattern of E.coli distribution, residual chlorine, Reynolds Numbers and Froude Numbers. Formulation of mathematical models of disinfection is still limited to the hydrodynamic model because the simulation has proved that dosage and disinfectant type will influence Reynold number, E.coli distribution and residual chlorine concentration. Behavior of hydro-dynamics in baffle channel tank was influenced by kinetic energy. Application of HPAd model have assumed sample was free chlorine, no back mixing, E.coli and disinfectant distributed along the tank, pH and temperature is constant. Implementation of the HPAd model still in laboratory scale and the research will continue to validate the model by using pilot scale implementation, such as in water works.

## ACKNOWLEDGEMENT

This research was granted by Directory of Research and Community Service, Ministry of National Educational Republic of Indonesia No.180/SP2H/PL/Dit.Litabmas/ V/2013

## REFERENCES

Ahmadi G, Tamayol AB, Firoozabadi B (2007). Effect of inlet position and baffle configuration on the hydraulic performance of primary settling tanks, J. Hydraulic Eng. ASCE, Vol. 133, No.6, pp.649-667.

Athanasia MG, Margaritis K, Khodiris DK, Anastasios IZ (2008a). A CFD methodology for the design of sedimentation tanks in potable water treatment, case study: the influence of a feed flow control baffle, Chem. Eng. J. Vol.140, pp.110-121

Athanasia MG, Margaritis K, Thodiris DK, Anastasios IZ (2008b). The effect of influent temperature variations in a sedimentation tank for potable water treatment-a computational fluid dynamics study, *Water Research*, Vol. 42, pp.3405-3414

Bond T, Templeton MR, Graham N (2012). Precursors of nitrogenous disinfection by-products in drinking water—A critical review and analysis,J. Hazardous Materials 235– 23, p.1-16

Boyle JN, Manas FI, Donald L (2005). Hydrodynamic analysis of the mechanisms of agglomerate dispersion, *Powder Technology*, Vol.153, No.2 , pp. 127–133.

Guo L, Zhang D, Xu D, Chen Y (2009). An experimental study of low concentration sludge settling velocity under turbulent condition, *Water Research*, Vol. 43, pp.2383–2390.

Haas CN, J Joffe, U Anmangandla, JG Jacangelo, M Heath (1996a). The effect of water quality on disinfection kinetics. J. AWWA, 88(3):95-103.

Hom LW (1972). Kinetics of Chlorine Disinfection of an Ecosystem. *Journal of the Sanitary Engineering Division, ASCE*, 98 (SA1):183-194.

Kantoush SA, Bollaert E, Schleiss AJ (2008). Experimental and numerical modeling of sedimentation in a rectangular shallow basin, Int. J. Sediment Res. Vol. 23, pp.212–232.

Karnaningroem N (2005). Mathematical modeling of hydrodynamics pollutant dispersion in river, Unpublished *Dissertation, Institute of Technology SepuluhNopember, Surabaya*. (in Indonesian).

Lopez PR, Lavın AG, Mahamud MM, de lasHeras JLB (2007). Flow models for rectangular sedimentation tanks, *Chemical Engineering and Processing*, Vol.47, pp.1705–1716.

Razmi A, Firoozabadi B, Ahmadi G (2009). Experimental and numerical approach to enlargement of performance of primary settling tanks, J. Appl. Fluid Mech. Vol.2, No.1, pp.1-12.

Sammarraee MA, Chan A, Salim SM, Mahabaleswar US (2009). Large-Eddy simulations of particle sedimentation in a longitudinal sedimentation basin of a water treatment plant. part I: particle settling performance, Chem. Eng. J. Vol.152, pp. 307–314

Van der Walt JJ (2008). The Modeling of water treatment process tanks, *Published Dissertation, University of Johannesburg.*

Wang H, RA Falconer (1998). Simulating disinfection processes in chlorine contact tanks using various turbulence models and high-order accurate difference schemes. *Water Research*, 5:1529-1543.

MR JEPAS_The pattern of hydrodynamic in water treatment disinfection to estimate organism removal

ORIGINALITY REPORT

| 10% | 4% | 9% | 4% |
|---|---|---|---|
| SIMILARITY INDEX | INTERNET SOURCES | PUBLICATIONS | STUDENT PAPERS |

PRIMARY SOURCES

| | | |
|---|---|---|
| 1 | Sameh A. KANTOUSH, Erik BOLLAERT, Anton J. SCHLEISS. "Experimental and numerical modelling of sedimentation in a rectangular shallow basin", International Journal of Sediment Research, 2008<br>Publication | 3% |
| 2 | Patricia Rodríguez López, Antonio Gutiérrez Lavín, Manuel M. Mahamud López, Julio L. Bueno de las Heras. "Flow models for rectangular sedimentation tanks", Chemical Engineering and Processing: Process Intensification, 2008<br>Publication | 2% |
| 3 | Yun Li, E. Rogers. "SYSTOLIC ARRAY INFORMATION PROCESSING STRATEGY FOR REAL-TIME AUTOMATIC CONTROL", Elsevier BV, 1990<br>Publication | 1% |
| 4 | Ramli, , Euis Sustini, Nurlaela Rauf, and Mitra Djamal. "Giant Magnetoresistance in | 1% |

FeMn/NiCoFe/Cu/NiCoFe Spin Valve Prepared by Opposed Target Magnetron Sputtering", Advanced Materials Research, 2014.
Publication

| | | |
|---|---|---|
| 5 | www.ict-fireworks.eu<br>Internet Source | 1% |
| 6 | H. Asgharzadeh, B. Firoozabadi, H. Afshin. "Experimental investigation of effects of baffle configurations on the performance of a secondary sedimentation tank", Scientia Iranica, 2011<br>Publication | 1% |
| 7 | Gediminas Adomavicius, Alok Gupta. "Toward Comprehensive Real-Time Bidder Support in Iterative Combinatorial Auctions", Information Systems Research, 2005<br>Publication | 1% |
| 8 | www.nicnas.gov.au<br>Internet Source | <1% |
| 9 | Submitted to Universiti Sains Malaysia<br>Student Paper | <1% |
| 10 | Decheng Wan. "Direct numerical simulation of particulate flow via multigrid FEM techniques and the fictitious boundary method", International Journal for Numerical Methods in Fluids, 06/20/2006<br>Publication | <1% |