Australian Journal of Basic and Applied Sciences, 9(33) October 2015, Pages: 122-126

ISSN:1991-8178

Australian Journal of Basic and Applied Sciences

Journal home page: www.ajbasweb.com

Experimental Study on Effect of Electro Chlorination System For Heat Transfer Enhancement In Plate Heat Exchanger

[1]E.Anandhi and [2]D. Prabhakaran

[1]*Department of Chemical Engineering, Coimbatore Institute of Technology, Tamilnadu, India.*
[2]*Associate Professor, Department of Chemical Engineering, Coimbatore Institute of Technology, Tamilnadu, India.*

ARTICLE INFO

Article history:
Received 3 August 2015
Accepted 28 October 2015
Available online 31 October 2015

Keywords:
bore well water, electro chlorinator, Plate heat exchanger.

ABSTRACT

The present study is to find the effect of electro chlorination system on the fouling mitigation and heat transfer enhancement in a plate heat exchanger (parallel flow). Bore well water (500 ppm hardness) was used for the study. The experiment in electro chlorination system was conducted using stainless steel as cathode and copper as anode and bore well water as an electrolyte at 2V and 4V. A series of experiments with and without an electro chlorinator were performed. For both cases effectiveness were calculated and compared.

To Cite This Article: E.Anandhi and D. Prabhakaran., Experimental Study on Effect of Electro Chlorination System For Heat Transfer Enhancement In Plate Heat Exchanger. ***Aust. J. Basic & Appl. Sci.,*** *9(33): 122-126, 2015*

INTRODUCTION

Plate heat exchanger (PHE) has been widely used in the fields of energy transport due to its constructive uniqueness, such as high heat transfer coefficient, compact size and ease to increase the heat transfer area (Guan-min Zhang, *et al*., 2013). The fouling is one of the main problems affecting Plate heat exchangers using water from natural sources (lakes, rivers and sea) as the cooling agent.

The presence of mineral salt in water when supersaturated usually precipitate out of the solution when exposed to high temperature because of their inverse solubility property and changes in pH of water (Leonard, D. *et al*., 2011; Cho, Y.I., *et al*., 2003). The continuous precipitation and hold of salt crystals on heat surfaces lead to decrease in area of pipe. In addition, scale deposits have very low thermal conductivity. Scaling problems lead to decreased operating efficiency, shortened equipment life, higher maintenance cost and increased energy consumption (Leonard, D. *et al*., 2011; Kazi, S.N., G.G. Duffy, X.D. Chen, 2010).

Various methods are available to clean scales formed in heat exchangers. The use of chemicals is commonly practiced in industries, but their high cost and the pollution concern require less costly and environmentally friendly clean means. The use of physical cleaning devices is a good alternative that is safe and effective. The physical treatment includes the application of electric or magnetic fields, catalytic surfaces, ultrasound (Tijing, L.D., *et al*., 2009).

This study focuses on an electro chlorination system, a new physical method. Sodium hypochlorite (NaClO) is used on a large scale for surface purification, odour removal and water disinfection. It has various advantages namely simple dosage and leaves no residual effluent. Electro synthesis of NaClO is preferred due to the environmental hazard associated with the storage and transportation of liquid chlorine (Asokan, K. and K. Subramanian, 2009).

MATERIALS AND METHOD

2.1. Electro chlorinator:

The electro chlorination system (for the preparation of water samples) consists of electrodes each has a dimension of 100 mm × 150 mm and thickness of 2.5 mm. The electrodes were immersed in the bore well water (hardness -500 ppm) and connected to a DC power supply. For each experimental run, a constant electrode spacing of 15 cm was maintained.

2.2 Plate heat exchanger:

Plate type heat exchanger consists of 5 plates and 2 end plates (arranged to form a network of parallel and counter flow channels), insulation asbestos, temperature scanner, geyser. The hot fluid is hot water which is obtained from an electric geyser

Corresponding Author: E.Anandhi, Department of Chemical Engineering, Coimbatore Institute of Technology, Tamilnadu, India
E-mail: anandhi17293@gmail.com

and it flow through one plate while the cold fluid is cold water flowing through other plate.

2.3 Principle:

NaClO is electrochemically produced by electrolyzing bore well water in batch electrolytic cell using copper as anode and Stainless Steel as cathode. Electrolysis leads to the generation of chlorine at the anode and sodium at the cathode. Chemical reaction between the chlorine gas and caustic solution results in the in – situ generation of NaClO (Asokan, K. and K. Subramanian, 2009).

At anode:

$NaCl \rightarrow Na^+ + Cl^-$; $2Cl^- - 2e^- \rightarrow Cl_2$ (1).

At cathode:

$H_2O \rightarrow H+ + OH-$;

$2 H+ +2e^- \rightarrow H_2$; $Na^+ + OH^- \rightarrow NaOH$ (2)

In the tank:

$NaOH+ Cl_2 \rightarrow NaClO +NaCl + H_2O$

2.4 Experimental procedure:

In each batch experiment, 6000 ml of bore well water was used and the temperature was maintained between 25 to 26 °C. When DC current was passed through electrolyte (bore well water), electrolysis occur. It leads to the production of chlorine at the anode and sodium at the cathode and finally sodium hypochlorite. Each experimental run was continued for at least 1 hour. Bore well water samples were collected from the electrolytic cell every 30 min and water analyses were made. After completion of electrolysis, the treated water was stored in a tank to conduct heat transfer test in plate heat exchanger.

In plate type heat exchanger, the temperature scanner was switched on .The flow of bore well water (treated) on hot water and cold water side was started. Geyser was put on. The flow rate was adjusted on hot and cold water side. The flow rate was maintained till steady state conditions were reached. The temperature on cold and hot water side and also flow rates were measured accurately. The same procedure was done for untreated case. The experiment was repeated by varying flow rates of hot and cold water in plate heat exchanger and voltages in electro chlorination. The effectiveness for treated and untreated water in all cases were calculated and compared.

RESULTS AND DISCUSSION

The various parameters of bore well water which were analyzed at different time intervals when electrolysis voltage 2V and 4V is shown in table 3.1and table 3.2 respectively.

Table 3.1: Water analyses for 2V:

Parameter	Initial (0 min)	30 min	Final (60 min)
pH	7.97	7.65	7.43
Conductivity(mS)	3.82	1.5	0.266
Salinity(ppt)	2.18	1.36	0.17
TDS(ppm)	2260	758	127
Hardness (ppm)	510	317	115

Table 3.2: Water analyses for 4V:

Parameter	Initial (0 min)	30 min	Final (60 min)
pH	7.97	7.78	7.51
Conductivity(mS)	3.82	2.1	0.76
Salinity(ppt)	2.18	1.54	0.35
TDS(ppm)	2260	1124	335
Hardness (ppm)	510	413	166

The experimental data for parallel flow plate heat exchanger for bore well water at 2V and 4V is shown in table 3.3 and table 3.4

Table 3.3: Parallel flow(2V):

	Hot water side				Cold water side				Effectiveness
	Flow rate (LPM)	Inlet temp T_{hi} °C	Outlet temp T_{ho}°C	N_{Re}	Flow rate (LPM)	Inlet temp T_{ci} °C	Outlet temp T_{co}°C	N_{Re}	
Treated	2	70	48	679	2	26	35	166.6	0.5
	4	70	53	1444	5.5	26	33	451.8	0.39
untreated	2	70	53	722	2	26	33	164.3	0.38
	4	70	57	1521	5.5	26	31	445.8	0.29

Table 3.4: Parallel flow (4V):

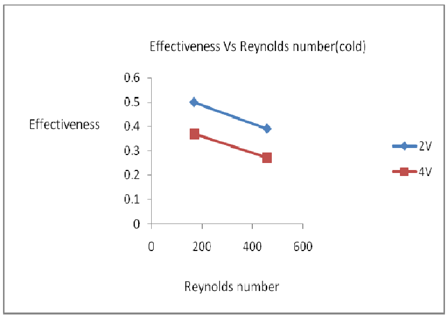
	Hot water side				Cold water side				Effectiveness
	Flow rate (LPM)	Inlet temp T_{hi} °C	Outlet temp T_{ho}°C	N_{Re}	Flow rate (LPM)	Inlet temp T_{ci} °C	Outlet temp T_{co}°C	N_{Re}	
Treated	2	70	50	695	2	26	33	168	0.45
	4	70	54	1549	5.5	26	32	458	0.36
untreated	2	70	54	735	2	26	31	170.1	0.37
	4	70	58	1554	5.5	26	30	451	0.27

The effectiveness was calculated by using the expression Effectiveness= $[m_c C_{pc}(T_{co}-T_{ci})/(m_h C_{ph}(T_{hi}-T_{ho})]$where C_{pc} and C_{ph} are specific heat of cold and hot fluid respectively.

The fouling tests were conducted in two cases: (a)the untreated and (b) the treated . The untreated test served as the reference test, where the treated test were compared to view any effects of electro chlorination on effectiveness and water chemistry is represented with respect to time.

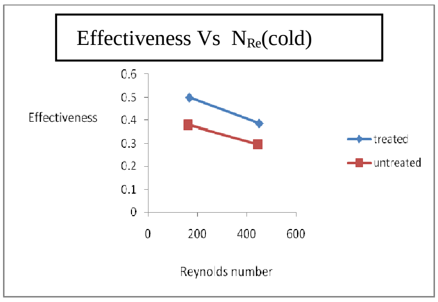
3.1 Effect of variation of voltage:

The Reynolds number (cold) for different voltages (2V and 4V) is plotted against effectiveness to find the effect of varying voltage on effectiveness which is shown in the graph below. From the graph, it is known that the effectiveness for 2V is higher compared to 4V



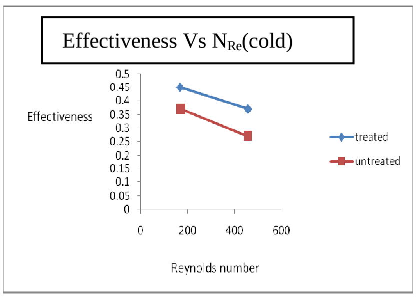
3.2 Effectiveness Vs Reynolds number (cold) (2V):

The Reynolds number (cold) for treated and untreated cases is plotted against effectiveness to find the effect of electro chlorination system on effectiveness at 2 V which is shown in the graph below. From the graph, it is known that the effectiveness varies linearly with Reynolds number(cold).



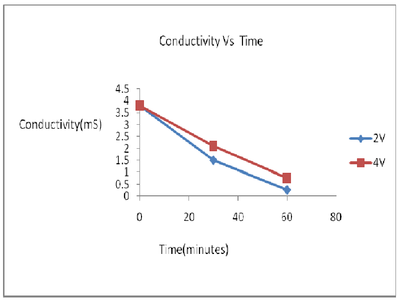
3.3 Effectiveness Vs Reynolds number (cold) (4 V):

The Reynolds number (cold) for treated and untreated cases is plotted against effectiveness to find the effect of electro chlorination system on effectiveness at 4V which is shown in the graph below



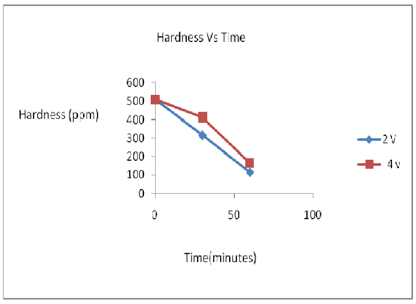
3.4 Effect of conductivity on time:

The conductivity of bore well water at different voltage (2 V and 4V) with respect to time is plotted. The effect of conductivity on different voltages is shown in the graph below



3.5 Effect of hardness on time:

The hardness of bore well water at different voltage (2 V and 4V) with respect to time is plotted. The effect of hardness on different voltages is shown in the graph below



Conclusion:

Experiments were conducted on plate type heat exchanger with different mass flow rate and voltage for electrolysis in parallel flow pattern. The effects of these parameters on cold outlet temperature, hot outlet temperature and individual heat transfer coefficients and effectiveness were studied. The comparison between voltage (2V and 4V) for electrolysis were made and it was found that maximum efficiency was obtained in case of 2V.

REFERENCES

Guan-min Zhang, Guan-qiu Li, Wei Li, Zhaoyan Zhang, Xue-li Leng, Mao-cheng Tian, 2013. Particulate fouling and composite fouling assessment in corrugated plate heat exchangers, International Journal of Heat and Mass Transfer, 60: 263-273.

Muhammad Saleem, Mohammed Harun Chakrabarti, Diya'uddeen Basheer Hasan, Md. Sakinul Islam, Rozita Yussof, Gazi Md. Arifuzzaman Khan and Brahim Si Ali, 2012. On site Electrochemical Production of Sodium Hypochlorite Disinfectant for a Power Plant utilizing Seawater Int. J. Electrochem. Sci., 7: 3929-3938.

Srbislav, B.G., J. Branislav, M. Dragan, P. Dragan, 2012. Experimental determination of fouling factor on plate heat exchangers in district heating system, Energy Build., 50: 204-211.

Chengwang Lei, Zhongxiao Peng, Thomas Day, Xinping Yan, Xiuqin Bai, Chengqin Yuan, 2011. Experimental observation of surface morphology effect on crystallization fouling in plate heat exchangers, Int. Commun. Heat Mass Transfer, 38: 25-30.

Leonard, D. Tijing, Dong-Hwan Lee, Dong-Won Kim, Young I. Cho, Cheol Sang Kim, 2011. Effect of high-frequency electric fields on calcium carbonate scaling, desalination., 279: 47-53.

Kazi, S.N., G.G. Duffy, X.D. Chen, 2010. Mineral scale formation and mitigation on metals and a polymeric heat exchanger surface, Appl. Therm. Eng., 30(14–15): 2236-2242.

Tijing, L.D., H.Y. Kim, D.H. Lee, C.S. Kim and Y.I. Cho, 2009. Use of an Oscillating Electric Field to Mitigate Mineral Fouling in a Heat Exchanger, Experimental Heat Transfer: A Journal of Thermal Energy Generation, Transport, Storage, and Conversion, 22(4): 257-270.

Asokan, K. and K. Subramanian, 2009. Design of a Tank Electrolyser for In-situ Generation of NaClO, Proceedings of the World Congress on Engineering and Computer Science, I.

Al-Mutairi, N.N., F.A. Aleem, M.I. Al-Ahmad, 2009. Effect of antiscalants for inhibition of calcium sulfate deposition in thermal desalination systems, Desalin. Water Treat., 10: 39-46.

Xiaokai, X., 2008. Research on the electromagnetic anti-fouling technology for heat transfer enhancement, Appl. Therm. Eng., 28: 889-894.

Tijing, L.D., B.C. Pak, D.H. Lee and Y.I. Cho, 2007. Heat-Treated Titanium Balls for the Mitigation of Mineral Fouling, Exp. Heat Transf., 21: 115-132.

Tijing, L.D., B.C. Pak, D.H. Lee, B.J. Baek and Y.I. Cho, 2007. An Experimental Study on the Bulk Precipitation Mechanism of Physical Water

Treatment for the Mitigation of Mineral Fouling, Int. Commun. Heat Mass Transf., 34: 673-681

Cho, Y.I., A.F. Fridman, S.H. Lee, W.T. Kim, 2004. Physical water treatment for fouling prevention in heat exchangers, Adv. Heat Transfer, 38: 1-71.

Macadam, J., S.A. Parsons, 2004. Calcium carbonate scale control, effect of material and inhibitors, Water Sci. Technol., 49(2): 153-159.

Bansal, B., X.D. Chen and H. Mullens-Steinhagen, 2003. Use of Non-Crystallising Particles to Mitigate Crystallization Fouling, Int. Commun. Heat Mass Transf., 30: 695-706.

Cho, Y.I., S.H. Lee and W. Kim, 2003. Physical Water Treatment for the Mitigation of Mineral Fouling in Cooling-Water Applications, ASHRAE Trans., 109: 346-357.

Panchal, C.B. and J.G. Knudsen, 1998. Mitigation of Water Fouling: Technology Status and Challenges, Adv. Heat Transf., 31: 431-474.

Cho, Y.I., B.-G. Choi and B.J. Drazner, 1998. Electronic Anti-Fouling Technology to Mitigate Precipitation Fouling in Plate-and-Frame Heat Exchangers, Int. J. Heat Mass Transf., 41: 2565-2571.

Melo, L.F., T.R. Bott, C.A. Bernardo, 1988. Fouling Science and Technology E: Applied Science, NATO ASI Series 145, Kluwer Academic Publishers, Netherlands.

Parsons, S.A., S.J. Judd, T. Stephenson, S. Udol and B.L. Wang, 1997. Magnetically Augmented Water Treatment, Inst. Chem. Eng., 75: 98-104.

Bott, T.R., 1997. Aspects of Crystallization Fouling, Exp. Thermal Fluid Sci., 14: 356-360.

Rajeshwar, K., J. Inanez, 1997. Environmental Electrochemistry: Fundamentals and Applications in Pollution Abetment. San Diego: Academic.

Baker, J.S., S.J. Judd, 1996. Magnetic amelioration of scale formation, Water Res., 30(2): 247-260.

Bansal, B., M. Steinhagen, 1993. Crystallisation fouling in plate heat exchangers, J. Heat Transfer, 115: 584-591.

Boxall, C., G.H. Kelsall, I. Chem. E. Symp, 1992. Electrochemical Engineering and the Environment", 127: 59.