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UNIVERSITI TEKNOLOGI PETRONAS

STUDY OF IRON REMOVAL FROM GROUNDWATER BY SULFIDE PRECIPITATION AND ELECTROCHEMICAL-COAGULATION METHOD

by

MUHAMMAD NOOR HISYAM BIN JUSOH

The undersigned certify that they have read, and recommend to the Postgraduate Studies Programme for acceptance this thesis for the fulfilment of the requirements for the degree stated.

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STUDY OF IRON REMOVAL FROM GROUNDWATER BY SULFIDE PRECIPITATION AND ELECTROCHEMICAL-COAGULATION METHOD

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MUHAMMAD NOOR HISYAM JUSOH

A Thesis
Submitted to the Postgraduate Studies Programme
as a Requirement for the Degree of

MASTER OF SCIENCE
CIVIL ENGINEERING DEPARTMENT
UNIVERSITI TEKNOLOGI PETRONAS
BANDAR SERI ISKANDAR,
PERAK

OCTOBER 2013

DECLARATION OF THESIS

Title of thesis	STUDY OF IRON REMOVAL FROM GROUNDWATER BY SULFIDE PRECIPITATION AND ELECTROCHEMICAL-COAGULATION METHOD

I _____MUHAMMAD NOOR HISYAM BIN JUSOH_____

hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UTP or other institutions.

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ACKNOWLEDGEMENTS

First and foremost, pray to God Al-Mighty for His bless and love, giving me all the strength to complete my research within the timeframe given. I would like to express the highest gratitude and love to my dear parents Jusoh Jaafar and Kamariah Che Soh and to my cherished brothers and sisters for their consistent support, guidance and encouragement throughout the study.

I would like to express the deepest appreciation to my supervisor, A.P. Dr Nasiman Sapari for his attention, guidance and advice throughout the completing of this research. I am extremely grateful and indebted to him for his expertise and encouragement extended to me. I place on record, my sincere gratitude to Prof. Malay Chaudhuri and Mrs. Raja Zainariah for their assistance and trust.

Lastly, I express very thankfulness to my friends who had shared ideas and knowledge that contributed to my writing. I also wish to thank all the technologists of Department of Civil Engineering generally and especialy to the Environmental Engineering Laboratory, Universiti Teknologi PETRONAS; Mr. Khairul Anuar, Mr. Zaaba, Ms. Yusmawati, Mr. Johan Ariff, Mr. Iskandar and Mr. Azran for their passions and help. Without them, this research could not be easier.

Last but not least, thank you to all for your contribution directly or indirectly. I will always keep them in my heart.

ABSTRACT

Groundwater usually contains dissolved mineral ions. Some of the dissolved minerals are essential for good health but others if abundant can cause problem such as odor and stain. This study investigated iron removal from groundwater using sulfide precipitation method and electrochemical-coagulation (EC) method. Different groundwater locations selected for this study are Universiti Teknologi PETRONAS (UTP) monitoring well Perak, groundwater treatment plants of Kampung Chicha, Tanjung Mas and Kampung Puteh, Kelantan. The efficiency of both methods was evaluated in batch study. In sulfide precipitation method, a hydrogen sulfide gas of 018 M concentration was purged into the sample while in EC method, aluminum electrode was used by flow the applied volts. A preliminary study was conducted with iron solution for both methods and the obtained optimum conditions applied to real groundwater. The parameters investigated in sulfide precipitation method include pH and contact time while the parameters investigated in electrochemical-coagulation include pH, voltage, contact time, inter-electrode distance, electrode surface area, initial concentration and sample volume. pH was of significant importance for both methods. Increase in pH resulted to increase in removal efficiency for both methods. pH 7 was optimum for both sulfide precipitation and electrochemical precipitation with a removal efficiency of 75% and 95% after 6 hours and 2 hours treatment time respectively. Increase in contact time increased removal efficiency for both methods. However, low contact time (2 hours) was required for EC treatment than sulfide precipitation (6 hours). Increase in electrode distance decreased removal efficiency and increased treatment time in EC process. The optimum electrode distance was observed at 1 cm with a residual iron concentration of 0.28 mg/L after 150 minutes. Increase in applied voltage resulted to increase in removal efficiency in electrochemical-coagulation. An optimum voltage of 20 volts was used in this study with a residual iron concentration of 0.24 mg/L after 150 minutes of treatment time. Increase in electrode surface area resulted to increase in removal efficiency. The optimum surface area was 90 cm^2 with a residual iron concentration of 0.28 mg/L below the permissible limit of 0.3 mg/L. Increase in iron concentration resulted to a decrease in removal efficiency. Increase in sample volume also resulted to a decrease

in removal efficiency. Application of obtained optimum conditions to the real groundwater samples showed that sulfide precipitation and electrochemical-coagulation are both effective in removing iron from groundwater. However, electrochemical-coagulation had a comparative advantage over sulfide precipitation with regards to treatment time and removal efficiency. While it is recommended that sulfide precipitation be applied to samples with low iron concentration due to slow reaction of sulfide and iron at inert atmosphere, electrochemical-coagulation can be effectively used for samples with high concentration. The structure and surface morphology of the sludge obtained from sulfide precipitation using FESEM showed the presence of pyrite (FeS_2) in cubic shape. For EC treatment, the roundness of the crystals is sub-angular compared to sulfide precipitation crystal indicating the presence of colloidal particles. The objective of this study was to remove iron from groundwater using sulfide precipitation and electrochemical-coagulation and evaluate the effects of the operating parameters.

ABSTRAK

Air bawah tanah kebiasaanya mengandungi mineral ion yang terlarut. Beberapa mineral terlarut adakalanya penting untuk kesihatan tetapi jika ianya berlebihan boleh mendatangkan masalah seperti bau dan lumur. Kajian ini menyiasat proses penyingkiran besi dari bawah air tanah menggunakan kaedah pemendapan sulfida dan pembekuan-elektrokimia (EC).Telaga pemantauan dari Universiti Teknologi PETRONAS (UTP), Perak dan loji rawatan air bawah tanah di Kampung Chicha, Tanjung Mas dan Kampung Puteh, Kelantan adalah lokasi berbeza yang dipilih untuk kajian ini. Kecekapan kedua-dua kaedah telah dinilai dalam kajian kumpulan. Dalam kaedah pemendakan sulfida, gas hidrogen sulfida yang mengandungi 018 M kepekatan telah dimasukkan ke dalam sampel manakala dalam kaedah EC, elektrod aluminium telah digunakan melalui aliran voltan. Kajian awal telah dijalankan untuk mengurangkan kandungan besi dengan menggunakan kedua-dua kaedah dan melalui optimum parameter yang diperolehi, ianya digunakan pula kepada air bawah tanah yang sebenar. Antara parameter yang dikaji dalam kaedah pemendakan sulfida adalah pH dan masa penuruan manakala unutk parameter elektrokimia-pembekuan pula termasuk pH, voltan, masa, jarak antara elektrod, keluasan permukaan elektrod dan kandungan terawal dan isipadu sampel. pH adalah amat penting bagi kedua-dua kaedah. Peningkatan dalam pH menyebabkan untuk meningkatkan kecekapan penyingkiran untuk kedua-dua kaedah. pH 7 adalah optimum bagi kedua-dua kaedah pemendapan sulfida dan pembekuan- elektrokimia dengan kecekapan penyingkiran masing-masing sebanyak 75% dan 95% selepas 6 jam dan 2 jam proses rawatan. Peningkatan dalam masa sentuhan telah meningkatkan kecekapan penyingkiran untuk kedua-dua kaedah. Walau bagaimanapun, masa sentuhan rendah (2 jam) telah diperlukan untuk rawatan EC dibandingkan dengan pemendapan sulfida (6 jam). Peningkatan dalam jarak elektrod telah mengurangkan kecekapan penyingkiran dan peningkatan masa rawatan dalam proses EC. Jarak optimum yang telah diperhatikan adalah pada 1 cm antara elektrod dengan kandungan besi berbaki 0.28 mg/L selepas 150 minit. Meningkatkan voltan yang digunakan menyebabkan peningkatkan kecekapan penyingkiran dalam elektrokimia-pembekuan. Voltan optimum 20 volt telah digunakan dalam kajian ini dengan baki kandungan besi 0.24 mg L selepas 150

minit masa rawatan. Peningkatan dalam kawasan permukaan elektrod menyebabkan untuk meningkatkan kecekapan penyingkiran. Luas permukaan yang optimum adalah 90 cm^2 dengan kandungan besi berkurang kepada 0.28 mg/L di bawah had yang telah dibenarkan iaitu 0.3mg/L. Peningkatkan kepekatan besi menyebabkan kepada penurunan dalam kecekapan dalam proses penyingkiran. Isipadu sampel yang tinggi juga telah menyebabkan kepada penurunan dalam kecekapan penyingkiran. Perolehan ciri-ciri optimum dan aplikasi untuk sampel air bawah tanah menunjukkan bahawa pemendapan melalui sulfida dan pebekuan-elektrokimia, kedua-duanya berkesan dalam membuang besi didalam air bawah tanah. Walau bagaimanapun, pembekuan-elektrokimia mempunyai kelebihan berbanding pemendapan sulfida dari segi masa rawatan dan kecekapan penyingkiran. Walaupun ia adalah disyorkan bahawa pemendapan sulfida digunakan untuk merawat air yang mempunyai kandungan besi yang rendah kerana tindak balas sulfida dan besi adalah perlahan dalam keadaan atmosfera yang lengai, manakala pembekuan-elektrokimia pula boleh digunakan dengan berkesan untuk sampel yang mempunyai kepekatan tinggi. Struktur dan morfologi permukaan lumpur yang diperolehi dari pemendapan sulfida menggunakan FESEM menunjukkan kehadiran pyrite (FeS_2) dalam bentuk padu atau kuboid. Untuk rawatan pembekuan-elektrokimia pulat, bentuk krisitalnya pula adalah sub-sudut berbanding pemendapan sulfida dan ia menunjukkan kehadiran zarah koloid. Objektif kajian ini adalah untuk mengurangkan kandungan besi dari air bawah tanah dengan menggunakan pemendapan sulfida dan pembekuan-elektrokimia dan menilai kesan-kesan operasi parameter.

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LIST OF ABBREVATIONS

Al^{+}	Aluminium
$Ca(OH)_2$	Calcium hydroxide
Ca^{2+}	Calcium
CD	Current Density
Cl^{-}	Chloride
DO	Dissolved Oxygen
EDAX	Energy Dispersive Analysis of X-Ray
Eh	Redox Potential
Fe^{2+}	Ferum / Iron
FeO(OH)	Ferric Oxide
FESEM	Field Emission Scanning Electron Microscopy
GW-K	Groundwater Treatment Plant from Kg. Chicha
GW-M	Groundwater Treatment Plant from Tanjung Mas
GW-P	Groundwater Treatment Plant from Kg. Puteh
GW-T	Groundwater Treatment Plant from UTP monitoring well
H^{+}	Hydrogen
H_2O	Water
H_2S	Hydrogen Sulfide H_2S
HCl^{-}	Hydrochloric Acid
HCO^{-}_3	Bicarbonate
HNO^{-}_3	Nitric Acid
K	Rate constant
K^{+}	Potassium
Mg^{2+}	Magnesium
Na^{+}	Sodium
NaOH	Sodium Hydroxide
NO^{-}_3	Nitrate
O_2	Oxygen
S^{2-}	Sulfide
SO^{2+}_4	Sulphate

TDS	Total Dissolved Solid
UTP	Universiti Teknologi PETRONAS
WHO	World Health Organization

LIST OF SYMBOLS

mg/L	milligram per liter
mV	milivolt
V	volt
$t_{1/2}$	half life
R^2	correlation coefficient
µg/L	microgram per liter
t	time