UNIVERSITI PUTRA MALAYSIA

EVALUATING THE POTENTIAL OF BANK INFILTRATION AS A SOURCE OF WATER SUPPLY IN JENDERAM HILIR, SELANGOR, MALAYSIA

MOHD KHAIRUL NIZAR BIN SHAMSUDDIN

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Master of Science

July 2014

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

EVALUATING THE POTENTIAL OF BANK INFILTRATION AS A SOURCE OF WATER SUPPLY IN JENDERAM HILIR, SELANGOR, MALAYSIA

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July 2014

Chairman : Wan Nor Azmin Sulaiman, PhD

Faculty : Environmental Studies

This study was inspired by the Klang Valley water crisis, for which Bank Infiltration (BI) was considered as a potential solution. Higher incidences of pollution to the rivers in Malaysia has lead to the decrease in resources for drinking water. Many developing countries like Malaysia, are faced with a big challenge to provide safe drinking water to the ever-increasing population. Currently, the treatment of river water uses chemicals to reduce several contaminants due to pollution. The chemical contents could give long term effects to the health of the consumers. However, there is hope in a more effective, but low-cost technology, known as Bank Infiltration (BI) or Riverbank Filtration (RBF). BI is a natural process using natural soil (aquifer) to treat river water and at the same time utilizes groundwater. Moreover, due to its ability to remove even the most persistent contaminants and microbes, BI can enhance treatment steps in a water treatment facilities, especially in a conventional water treatment. BI is a method that has long been known but it is still new and has not been practiced in Malaysia. Nevertheless, BI is site specific and requires thorough site investigations to assess its feasibility based on the local site characteristics. The study area was located in the southwest state of Selangor within the Langat Basin which covered an area of 10 km^2.

Besides, this study was specifically conducted to explore the possibility of using the BI systems to source the polluted surface water with groundwater. Three major factors were considered for evaluation: (i) an investigation on the contribution of surface water through BI, (ii) the input of local groundwater, and (iii) the water quality characteristics of water supply. In the earlier part of the investigations, the geophysical method was employed to define the subsurface geology and hydrogeology of the area. Isotope techniques were performed to identify the source of groundwater recharge and interaction between the surface water and the groundwater. A total of 25 monitoring wells and 2 test wells (DW1 and DW2) were constructed to circumscribe the BI system. The physicochemical and microbiological parameters of the local surface water bodies and groundwater were analysed before and during the water abstraction. The abstraction of water revealed a 5–98% decrease in turbidity, as well as HCO_3^-, SO_4^-, NO_3^-, Al, As and Ca concentrations reduction compared to the

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Langat River water. However, the water samples from test wells during pumping showed high concentrations of Fe^{2+} and Mn^{2+}. In addition, the amounts of *E. coli*, total coliform, and *Giardia* were significantly reduced (99.9%).The pumping test results indicated that the two test wells (DW1 and DW2) were able to sustain yields of 15.9 and 128 m^3/hr, respectively.

The BI method looks closely at surface water and groundwater interaction. The water quality interaction was assessed through multivariate statistical analyses based on analytical quantitative data. Multivariate statistical analyses were used, including discriminant analysis (DA) and principal component analysis (PCA), based on 36 water quality parameters from the rivers, lakes, and groundwater sites at Jenderam Hilir, which were collected from 2009 to 2011 (56 observations). The DA identified six significant parameters (pH, NO_2, NO_3, F, Fe, and Mn) from 36 variables to distinguish between the river, lake, and groundwater groups (classification accuracy = 98%). The PCA confirmed and identified 10 possible causes of variation in the groundwater quality with an eigenvalue greater than 1, which explained 82.931% of the total variance in the water quality data set: hydrochemistry; redox conditions; groundwater flow; surface runoff; groundwater contact with rock or weathered rock (Kenny Hills Formation); river water and groundwater interaction, discharge of untreated sewage and industrial wastes into the river; interaction between the river, lake, and groundwater; heavy metal pollution from past mining activities; and industrial pollution, such as dye or paint operations. Hence, in order to evaluate the effects of groundwater pumping and BI operation on the operations of wells, as well as to determine the effects of pumping rate on flow paths, travel time, size of pumping, and to capture zone delineation and groundwater mixing in a pumping well, numerical modelling simulation using MODFLOW and MODPATH were used. The simulation involved trying different scenarios by changing the variables to perform infiltration safely and to achieve the ideal pumping rate. The results indicated that the migration of river water into the aquifer has been generally slow and depended on the pumping rate and the distance from the pumping well to the river. Most water arrived at the well by the end of the pumping period of 1 to 5 days at 3072 m^3/day for test wells of DW1 and DW2, and during the simultaneous pumping for DW2 and PW1 for a well located 40 m and 20 m, respectively, from the river. During the 9.7-day pumping period, 33% of the water pumped from the DW1 well was river water, and 38% percent of the water pumped from DW2 throughout 4.6 days was river water. The models provided necessary information to water operators in the design, and the construction of pumping and sampling schedules of the BI practices. The detailed field investigation programmes obtained from this study can be used for preliminary BI system design and pilot construction by stakeholders, water operator or related agencies in Malaysia, as the study provided good methods and investigation (geophysical, isotope, grain size analysis, colloidal borescope systems and water quality analysis). The statistical and numerical methods to study the BI may also be used in other areas of similar hydrological characteristics and climate conditions.

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Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

MENILAI POTENSI SUSUPAN TEBING SEBAGAI SUMBER BEKALAN AIR DI JENDERAM HILIR, SELANGOR, MALAYSIA

Oleh

MOHD KHAIRUL NIZAR BIN SHAMSUDDIN

Julai 2014

Pengerusi : Wan Nor Azmin Sulaiman , PhD

Fakulti : Pengajian Alam Sekitar

ABSTRAK

Kajian ini diilhamkan oleh krisis air Lembah Klang, yang mana Susupan Tebing (BI) adalah dianggap sebagai penyelesaian yang berpotensi. Insiden yang lebih tinggi daripada pencemaran sungai di Malaysia boleh membawa kepada pengurangan dalam sumber untuk air minuman. Banyak negara-negara membangun, seperti Malaysia, berhadapan dengan cabaran yang besar untuk menyediakan air minuman yang selamat kepada penduduk yang semakin meningkat. Pada masa ini, rawatan air sungai menggunakan bahan kimia untuk mengurangkan beberapa bahan cemar akibat pencemaran. Kandungan kimia boleh memberi kesan jangka panjang kepada kesihatan pengguna. Bagaimanapun, teknologi terkini yang lebih berkesan yang menggunakan kos yang lebih rendah dikenali sebagai Susupan Tebing (BI) atau Sistem Penapisan Tebingan Sungai (RBF). BI adalah proses semulajadi menggunakan tanah (akuifer) untuk merawat air sungai dan pada masa yang sama menggunakan air tanah. Oleh kerana keupayaan untuk menyingkirkan bahan-bahan pencemar dan mikrob, BI sebagai sokongan kepada sebahagian skim rawatan air terutamanya dalam rawatan air secara konvensional. BI adalah kaedah yang telah lama diketahui tetapi masih baru dan tidak diamalkan di Malaysia. Walau bagaimanapun, BI adalah bergantung kepada kawasan yang spesifik dan memerlukan penyiasatan tapak secara terperinci bagi menilai kebolehkesanan ciri-ciri setempat. Kawasan kajian ini terlatak di baratdaya Negeri Selangor di dalam lembangan Sungai Langat yang meliputi kawasan seluas 10 km^2.

Di samping itu, kajian ini dijalankan khusus untuk mengkaji keupayaan penggunaan sistem BI sebagai penapis sumber air permukaan yang tercemar bersama-sama dengan air tanah. Tiga faktor utama yang telah dipertimbangkan untuk penilaian: (i) Kajian mengenai kaitan air permukaan melalui BI (ii) input air tanah tempatan, dan (iii) ciri-ciri kualiti air sebagai bekalan air. Sebagai permulaan kaijan, kaedah geofizik telah digunakan untuk menentukan geologi subpermukaan dan hidrogeologi di kawasan kajian. Teknik isotop telah dijalankan untuk mengenal pasti punca imbuhan air tanah dan interaksi di antara air permukaan dan air

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tanah. Sejumlah 25 telaga pemantauan dan 2 telaga ujian telah dibina dalam menentukan sistem BI. Parameter fizikokimia dan mikrobiologi air permukaan dan air tanah setempat telah dianalisis sebelum dan semasa abstraksi air. Abstraksi air menunjukkan penurunan kekeruhan sebanyak 5%-98%, serta pengurangan kepekatan HCO_3^-, SO_4^-, NO_3^-, Al, As, dan Ca berbanding dengan air Sungai Langat. Walau bagaimanapun, sampel air dari telaga ujian semasa ujian pengepaman dilakukan, menunjukkan kepekatan Fe^{2+} dan Mn^{2+} yang tinggi. Di samping itu, jumlah *E. coli*, koliform dan Giardia telah berkurangan dengan ketara (99.9 %). Keputusan ujian pengepaman menunjukkan bahawa kedua-dua telaga (DW1 dan DW2) mampu mencapai kadar mampan abstraksi air sebanyak 15.9 dan 128 m^3/jam.

Kaedah BI adalah interaksi yang begitu rapat antara air permukaan dan interaksi air tanah. Interaksi kualiti air telah dinilai melalui analisis statistik multivariat berdasarkan data kuantitatif analisis. Analisis statistik multivariat telah digunakan, termasuk analisis diskriminan (DA) dan analisis komponen utama (PCA), berdasarkan 36 parameter kualiti air dari sungai, tasik, dan air tanah di Jenderam Hilir yang dilakukan dari tahun 2009-2011 (56 cerapan). DA telah mengenal pasti enam parameter penting (pH, NO_2, NO_3, F, Fe dan Mn) daripada 36 pembolehubah untuk membezakan di antara sungai, tasik, dan air tanah (ketepatan pengelasan = 98%). PCA mengesahkan dan mengenal pasti sepuluh kemungkinan punca perubahan dalam kualiti air tanah dengan nilai *eigen* yang lebih besar daripada 1 yang menjelaskan 82.931 % daripada jumlah perbezaan dalam set data kualiti air: hidrokimia; keadaan redoks; aliran air tanah; air larian permukaan, sentuhan air tanah dengan batuan atau batuan terluluhawa (Formasi Kenny Hills); interaksi air sungai dan air tanah, serta pelepasan air kumbahan yang tidak dirawat dan sisa industri ke dalam sungai; interaksi antara sungai, tasik dan air tanah, pencemaran logam berat daripada aktiviti perlombongan; dan pencemaran industri seperti daripada aktiviti pembuatan cat atau pewarna. Dalam usaha untuk menilai kesan pengepaman air tanah dan operasi BI terhadap keupayaan telaga dan juga untuk menentukan kesan kadar pengepaman keatas arah aliran, masa pergerakan aliran air, kesan pengepaman didalam zon sempadan pemerangkapan dan zon campuran air tanah, simulasi numerikal menggunakan MODFLOW dan MODPATH digunakan. Simulasi ini terdiri daripada pelbagai senario yang berbeza dengan mengubah pembolehubah untuk menentukan nilai penyusupan yang selamat dan mencapai kadar pengepaman yang sesuai. Keputusan menunjukkan bahawa migrasi air sungai ke dalam akuifer umumnya perlahan dan bergantung kepada kadar pengepaman dan jarak dari telaga pengepaman ke sungai. Kebanyakan air sampai di telaga pada akhir tempoh pengepaman 1 hingga 5 hari pada kadar 3072 m^3/hari bagi telaga ujian DW1 dan DW2, dan semasa pengepaman serentak bagi DW2 dan PW1 yang terletak kira-kira 40m dan 20m dari sungai. Semasa tempoh pengepaman selama 9.7 hari, 33% daripada air yang dipam dari DW1 adalah air sungai, dan 38% peratus air yang dipam selama 4.6 hari bagi DW2, adalah air sungai. Pemodelan ini menyediakan maklumat yang diperlukan untuk operator air dalam mereka bentuk dan merancang jadual pengepaman dan persampelan ke atas sistem BI. Siasatan terperinci hasil yang diperolehi dari kajian ini boleh digunapakai untuk merekabentuk sistem BI dan pembinaan perintis ini oleh pihak berkepentingan seperti operator air atau agensi-agensi yang berkaitan di Malaysia, seperti kaedah kajian yang dilakukan ini amat sesuai digunakan dalam penyelidikan (geofizik, isotop, analisis saiz butiran, boroskopi koloid sistem dan analisis kualiti air). Kaedah statistik dan berangka untuk mengkaji BI boleh juga digunakan di kawasan-kawasan lain yang mempunyai ciri-ciri hidrologi dan keadaan iklim yang sama.

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APPROVAL

I certify that a Thesis Examination Committee has met on (17 July 2014) to conduct the final examination of Mohd Khairul Nizar Bin Shamsuddin on his thesis entitled "Evaluating the Potential of Bank Infiltration as A Source Of Water Supply In Jenderam Hilir, Selangor, Malaysia" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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