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EVALUATION OF GROUNDWATER VULNERABILITY TO CONTAMINATION AND GEOCHEMICAL CHARACTERISTICS IN AN ALLUVIAL AQUIFER OF ESHTEHARD PLAIN, IRAN

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LEILA KHODAPANAH

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

August 2012

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DEDICATION

To my Husband, Son, Father

And

In memory of my Mother

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Abstract of the thesis presented to the Senate of Universiti Putra Malaysia
infulfilment of the requirement for the Degree of Doctor of Philosophy

EVALUATION OF GROUNDWATER VULNERABILITY TO CONTAMINATION AND GEOCHEMICAL CHARACTERISTICS IN AN ALLUVIAL AQUIFER OF ESHTEHARD PLAIN, IRAN

By

LEILA KHODAPANAH

August 2012

ESTRACT

Chairman: Associate Professor Wan Nor Azmin B Sulaiman, PhD

Faculty: Environmental Studies

Amajority of the population in Eshtehard district depends upon the availability of quality groundwater from public or private sources. Eshtehard alluvial aquifer is the main source for irrigation, industrial and domestic uses. Recent anthropogenic activities, though, have created a potentially vulnerable environment as groundwater becomes exposed to contamination from municipal, industrial, and agricultural practices threatening the short and long term sustainability of high quality groundwater as a natural resource. Industrial discharge, waste disposal sites, application of pesticidesand fertilizers, poultry farms and municipal sewage are examples of potential source contamination in Eshtehard.

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Groundwater vulnerability to contamination from surface sources was evaluated for Eshtehard aquifer using a modified GIS based DRASTIC and GOD vulnerability methods. The study also evaluates groundwater quality and hydrochemistry. Chemical compositions of 114 groundwater samples were used to assess the groundwater quality in the study area and to validate the vulnerability mapsproduced by the two mentioned methods above.

Most water samples aregrouped into two categories: relatively low mineralizedof Ca–HCO_3 type and high mineralizedwaters of Na–Cl type,which indicate the intrusion of saline water and dissolution of carbonate minerals.Based onMANOVA test (*P=0.05)* on water samples collected during wet and dry seasons didn't show any significant difference. Concentrations of most of the groundwater quality indicators exceed the maximum allowable limits set by WHO drinking water standards. The chemical analysis also indicates strong affect of anthropogenic activities on the groundwater quality as implied by high nitrate, chloride, and sulfateconcentrations. High levels of salinity and sodium content suggest that the most of groundwater samples are of poor to medium quality for irrigation purposes.The factor analysis reveals that there are two sources of solutes: (1) saline water intrusion with high loading of Cl, Na, Ca, EC, TDS and K; (2) anthropogenic activities, characterizedby high loadings of NO_3, SO_4 and Mg.

For evaluating the groundwater vulnerability in Eshtehard area based on DRASTIC model, two challenging issues were encountered in this study: recharge estimation and alluvial media rating. Direct groundwater recharge from precipitation in semi-

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arid areas is generally small, usually less than about 5% of the average annual precipitation, with a high temporal and spatial variability. A combined groundwater balance and water table fluctuation method was applied to estimate the groundwater recharge in the research area. Original rating tables provide sufficient detail for mapping at theregional scale, where broad ranges of geologic material are present. However,modified rating tables improved spatial representation of input parameters atlocal scales, which is useful for local planning.

The DRASTIC and GOD's index values and maps for Eshtehard alluvial aquifer were generated in GIS environment. The Classic DRASIC was modified and optimized by incorporation of simple statistical and geostatistical techniques for the revision of the factor rating and weighting of all the parameter. The criterionfor these modifications was based on the correlation coefficientof each parameter with the nitrates concentration in groundwater.The correlation coefficient was obtained as r = 0.53, r = 0.42 and r = 0.68 ($p< 0.01$) for the original DRASTIC, GOD and modified DRASTIC methods, respectively. On the basis of their statistical significance, original ratings and weighting of the parameters werechanged in the DRASTIC equation. Following the above-mentioned modifications,the correlation coefficient between groundwater pollution potential and nitrates concentration was considerably improvedand rose to 15% higher than the original method. The results also showed that both GOD and modified DRASTIC indices values are relatively high and thus Eshtehard aquifer is considered vulnerable to pollution. However, the results indicated that the vulnerability prediction by DRASTIC proved superior to GOD in this particular hydrogeologic setting. These classification of the

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vulnerability index showed that central and downstream parts of the aquifer are most vulnerable to pollution. The salt flat in north and the alluvial fans of the southern heights yielded moderate scores. The aquifer in and around Eshtehard township, industrial zone and cultivation lands are highly susceptible to contamination.

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Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENILAIAN KETERDEDAHAN AIR BAWAH TANAH KEPADA PENCEMARAN DAN CIRI-CIRI GEOKIMIA DALAM AKUIFER ALUVIUM ESHTEHARD PLAIN, IRAN

Oleh

LEILA KHODAPANAH

August 2012

ABSTRAK

Pengerusi: Professor Madya Wan Nor Azmin B Sulaiman, PhD

Fakulti: Pengajian Alam Sekitar

Majoriti penduduk di daerah Eshtehard bergantung kepada kebersihan air bawah tanah dari sumber-sumber awam atau swasta. Eshtehard akuifer aluvium adalah sumber utama untuk pengairan, industri dan penggunaan domestik. Aktiviti antropogenik yang berlaku kebelakangan ini, walau bagaimanapun, telah mewujudkan persekitaran yang berpotensi terdedah kepada pencemaran hasil daripada amalan perbandaran, perindustrian, pertanian dan boleh mengancam kemapanan sebagai sumber air semula jadiyang berkualiti tinggi dalam jangka masa pendek dan panjang. Pelepasan perindustrian, tapak pelupusan sampah, permohonan racun perosak dan baja, ladang ternakan dan kumbahan perbandaran adalah sebahagian dari contoh sumber pencemaran yang berpotensi di Eshtehard.

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Keterdedahan air bawah tanah kepada pencemaran dari sumber permukaan telah dinilai bagi akuifer Eshtehard dengan menggunakan kaedah keterdedahanDRASTIC dan GOD diubahsuai dalam persekitaran GIS. Kajian ini juga menilai kualiti air bawah tanah dan sifat hidrokimia. Komposisi kimia mewakili 114 sampel air bawah tanah telah dianalisisbagi tujuan menilai kualiti air bawah tanah di kawasan kajian dan mengesahkan peta keterdedahan yang dihasilkan oleh dua kaedah tersebut.

Kebanyakan sampel air terkumpul kepada dua kategori: secara relatif agak rendah kandungan mineral jenis Ca-HCO_3 dan tinggi mineral jenis Na-Cl, yang menunjukkan pencerobohanair masin dan pembubaran mineral karbonat telah berlaku. Berdasarkan ujian statistik, MANOVA (P = 0.05) ke atas sampel air yang dikumpul semasa musim hujan dan panas tidak menunjukkan sebarang perbezaan yang signifikan. Kepekatan kebanyakan penunjuk kualiti air bawah tanah melebihi had maksima yang ditetapkan oleh piawaian bagi air minum, WHO. Analisis kimia juga menunjukkan kesan dari aktiviti antropogenik yang tinggi terhadap kualiti air bawah tanah sebagimana yang ditunjukkan oleh kepekatan kandungan nitrat, klorida, dan sulfat yang tinggi. Disamping itu, tahap kemasinan dan kandungan natrium yang tinggi mencadangkan bahawa kebanyakan sampel air bawah tanah terdiri dari kualiti sederhana hingga rendah tujuan pengairan. Analisis faktor menunjukkan terdapat dua sumber bahan larut: (1) pencerobohan air masin dengan muatan Cl, Na, Ca, EC, TDS dan K yang tinggi; (2) aktiviti antropogenik, dicirikan oleh beban NO_3, SO_4 dan Mg yang tinggi.

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Untuk menilai keterdedahan air bawah tanah kepada pencemaran di kawasan Eshtehard berdasarkan model DRASTIC, dua isu yang mencabar dihadapi dalam kajian ini: anggaran imbuhan dan pengkadaran media aluvium. Kadar imbuhan dari curahan hujan di kawasan separa gersang umumnya adalah kecil, biasanya kurang 5% daripada purata curahan hujantahunan, dengan ciri variasi ruang dan masa yang agak tinggi. Gabungan kaedah imbangan air bawah tanah dan pembuaian muka air tanah telah digunakan untuk menganggar imbuhan air bawah tanah di kawasan kajian. Jadual pengkadaranmedia asal menyediakan butir-butir yang mencukupi untuk pemetaan pada skala serantau, di mana julat luas bahan geologi hadir. Walau bagaimanapun, ubahsuai kepada jadual pengkadaran jadual tersebut telah meningkatkan perwakilan ruang parameter input pada skala tempatan, yang mana sangat berguna untuk perancang tempatan.

Indek DRASTIC dan GOD telah dihasilkan dalam persekitaran GIS. Kaedah DRASIC Classic telah diubahsuai dan dioptimumkan melalui penggabungan teknik statistik mudah dan geostatistik untuk semakan semula penarafan faktor pemberatan bagi semua parameter terlibat. Kriteria untuk pengubahsuaian ini adalah berdasarkan pekali korelasi setiap parameter dengan kepekatan nitrat dalam air bawah tanah. Pekali korelasi yang diperolehi sebagai $r = 0.53$, $r = 0,42$ dan $r = 0.68$ ($p < 0.01$) bagi kaedah DRASTIC asal, GOD dan kaedah DRASTIC yangdiubahsuai, secara berturutan. Atas dasar keertian statistik ini, penilaian asal dan wajaran bagi parameter telah diubah dalam persamaan DRASTIC. Berikutan pengubahsuaian di atas, pekali korelasi antara potensi pencemaran air bawah tanah dan kepekatan nitrat didapati telah jauh bertambah baik dan meningkat kepada 15% lebih tinggi daripada

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kaedah asal. Keputusan juga menunjukkan bahawa kedua-dua indek bagi kaedah GOD dan juga DRASTIC yang diubahsuai adalah agak tinggi dan seterusnya akuifer Eshtehard dianggap terdedah kepada pencemaran. Walau bagaimanapun, keputusan menunjukkan bahawa ramalan keterdedahan air bawah tanah kepada pencemaran oleh kaedah DRASTIC terbukti lebih tinggi berbanding kaedah GODbagi keadaan hidrogeologi berkenaan.Klasifikasi indeks keterdedahan ini jelas menunjukkan bahawa bahagian tengah dan hiliran akuifer Eshtehard paling terdedah kepada pencemaran. Garam rata di utara dan lapisan aluvium di bahagian ketinggian selatan telah mempengaruhi skor yang sederhana. Akuifer di bawah dan sekitar perbandaran Eshtehard, zon perindustrian dan tanah pertanian adalah sangat mudah terdedah kepada pencemaran.

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I certify that a Thesis Examination Committee has met on 16 August 2012 to conduct the final examination of Leila Khodapanah on her thesis entitled "Evaluation of Groundwater Vulnerability to Contamination and Geochemical Characteristics in an Alluvial Aquifer of Eshtehard Plain, Iran" 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 Doctor of Philosophy.

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Date: 23 January 2013

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee are as follows:

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DECLARATION

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

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