STUDY OF HYDROCHEMISTRY AND SEAWATER INTRUSION OF MANUKAN ISLAND, SABAH

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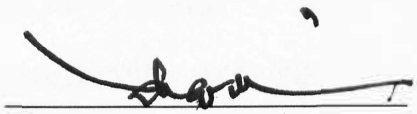

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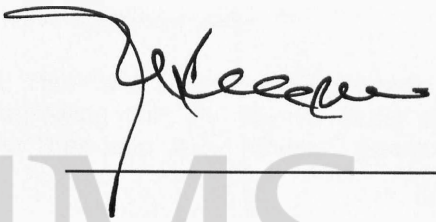

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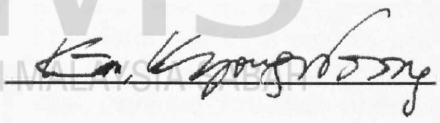

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ABSTRACT

STUDY OF HYDROCHEMISTRY AND SEAWATER INTRUSION OF MANUKAN ISLAND, SABAH

A detailed groundwater, seawater and sediment study were undertaken to examine the evolution of groundwater in the shallow aquifer of Manukan island, Sabah, Malaysia. Its aquifer is often exposed to heavy pumping and that could lead to seawater intrusion. The continuous pumping of groundwater on this island has contributed to enrichment of some constituents found in seawater. As a consequence of indiscriminate exploitation, the groundwater quality of this island has deteriorated. Major ion chemistry analysis shows that the groundwater quality of the island experiences some changes attributed to seawater intrusion. Simple mixing between seawater-freshwater is complicated by the cation exchange process and highly associated with groundwater withdrawal. This study indicates that the groundwater is classified as Na-Cl and Ca-Cl types. The groundwater has undergone a compositional change from Ca-rich to Na-rich which can be explained mostly by the cation exchange process. This study shows that the rise of Na and Cl composition in the groundwater is not only controlled by seawater intrusion, but also controlled by rapid cation exchange processes. Strong correlations exist among the major elements (Na, Mg, K, Cl and SO_4) and salinity with/or EC suggest that the impact of seawater intrusion to these major elements are more significant due to highly competitive relationship between ions. These relationships clearly identify the main elements contributing to the groundwater salinity and their tendency to depict a similar trend of salinization pattern. From the PHREEQC calculation, calcite, dolomite and aragonite solubility showed positive values of the saturation indices (SI), indicating supersaturation that lead to mineral precipitation condition of water by these minerals. Intensive exploitation of groundwater from Manukan Island's aquifer has disturbed the natural equilibrium between fresh and saline water, and has resulted in the increase of groundwater salinity and leap to the hydrochemical complexities of freshwater–seawater contact. It was observed that the mixing between freshwater–seawater created diversity in the geochemical processes of Manukan Island's aquifer and altered the freshwater and seawater mixture away from the theoretical composition line. This explained the most visible processes taking place during the displacement. The results from reactive transport modelling confirmed that the migration of seawater into the fresher parts of the aquifer apparently leads to a calcification of the aquifer despite the seawater being supersaturated for carbonate minerals and shows that the composition of the near coast zone and further landward area may vary and have a significant effect on the processes during the intrusion.

Keywords: groundwater, hydrochemistry, PHREEQC, seawater intrusion, small island

ABSTRAK

Satu kajian terperinci terhadap air bawah tanah, air laut dan sedimen telah dijalankan bagi mengenal pasti proses evolusi air bawah tanah yang berlaku di dalam akuifer cetek Pulau Manukan, Sabah, Malaysia. Akuifernya terdedah kepada proses pengepaman yang boleh membawa kepada penerobosan air laut. Proses pengepaman air bawah tanah yang berterusan telah menyebabkan komposisi elemen utama yang didapati daripada air laut telah meningkat. Akibat daripada ekploitasi yang keterlaluan, kualiti air bawah tanah telah menunjukkan status yang tercemar. Analisis kimia ion utama menunjukkan yang kualiti air bawah tanah pulau tersebut telah mengalami perubahan yang disebabkan oleh penerobosan air laut. Kajian ini menunjukkan air bawah tanah terdiri daripada jenis Na-Cl dan Ca-Cl. Percampuran antara air laut dan air tawar telah dirumitkan oleh proses penukargantian kation yang diburukkan lagi oleh pengepaman air bawa tanah. Air bawah tanah ini didapati telah melalui proses perubahan komposisi daripada jenis kaya-Ca ke kaya-Na yang dapat diterangkan secara jelas melalui proses penukargantian kation. Kajian menunjukkan sebab utama kepada peningkatan kepekatan Na dan Cl bukan sahaja disebabkan oleh penerobosan air laut tetapi juga dipengaruhi oleh proses penukargantian kation yang pantas. Pekali korelasi yang kuat wujud antara elemen utama (Na, Mg, K, Cl dan SO_4) dan parameter kemasinan antara/dengan kekonduksian elektrik (EC) menunjukkan kesan air laut ke atas elemen ini lebih signifikan disebabkan oleh wujudnya persaingan antara ion ini. Hubungkait ini membuktikan dengan jelas elemen utama yang menyumbang kepada kemasinan air bawah tanah dan kebolehannya untuk dipengaruhi kesan kemasinan yang sama. Daripada pengiraan PHREEQC, keterlarutan kalsit, dolomit dan aragonit menunjukkan nilai SI yang positif yang membawa kepada keadaan pembentukan mendakan oleh mineral tersebut. Eksploitasi yang berlebihan terhadap akuifer pulau Manukan telah mengubah keseimbangan semulajadi antara air tawar dan air laut dan menyebabkan peningkatan dalam kemasinannya dan seterusnya membawa kerumitan dalam hubungan antara air tawar dan air laut. Dapat diperhatikan juga bahawa percampuran air tawar dan air laut telah membawa kepada proses geokimia yang lebih kompleks serta telah mengubah percampuran proses percampuran air bawah tanah dan air laut jauh daripada teori percampuran. Ini menerangkan secara jelas proses yang mengambil tempat dalam penukargantian tersebut. Keputusan daripada simulasi pergerakkan reaktif mengesahkan bahawa pergerakkan air laut ke dalam akuifer air tawar telah membawa kepada proses pemendakan mineral-mineral karbonat. Keputusan simulasi juga menunjukkan bahawa komposisi keterlarutan ion-ion adalah berbeza antara kawasan yang hampir dengan persisir pantai dan jauh ke daratan yang mana mempengaruhi kesan penerobosan air laut ke atas komposisi akuifer.

Kata kunci: *air bawah tanah, hidrokimia, PHREEQC, penerobosan air laut, pulau kecil*

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LIST OF ABBREVIATIONS

1-D	one dimensional
3-D	three dimensional
a.m.s.l	above mean sea level
a.s.l	above sea level
APHA	American Public Health Association
CA	Cluster analysis
CEC	cation exchange capacity
CV	coefficient of variance
DGH	Dupuit Ghyben Herzberg
DO	dissolved oxygen
EC	electrical conductivity
Eh	redox potential
EIA	Environmental Impact Assessments
FA	factor analysis
FAAS	Flame Atomic Absorption Spectrometry
g.s.l	ground surface level
I.S	Ionic strength
IAP	ion activity product
ICP-MS	Inductively Couple Plasma – Mass Spectrometry
IWRM	Integrated Water Resources Management
KKIA	Kota Kinabalu International Airport
n	Number (number of samples)
NASA	National Aeronautics and Space Administration
NEMI	National Environmental Index

NIST	National Institute of Standards and Technology
ORP	oxidation reduction potential
PVC	polyvinyl chloride
R-mode	R-mode
rpm	rotation per minute
SD	standard deviation
SI	saturation index(ices)
SPSS	Statistical Analysis for Social Sciences
SRM	standard reference materials
SRTM	Shuttle Radar Topographic Mission
TDS	total dissolved solids
Temp.	temperature
UKM	Universiti Kebangsaan Malaysia
UMS	Universiti Malaysia Sabah
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
UPM	Universiti Putra Malaysia
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
USA	United States of America
WHO	World Health Organization

LIST OF SYMBOLS

-	negative / minus
%	percent
~	approximately
′	minute
+	positive / plus
<	not more than
=	equals to
>	more than
±	plus minus
≤	less or equal to
≥	more or equal to
°	degree
°C	degree celcius
µg/l	microgram per liter
µm	micrometer
µS/cm	microsiemens per centimeter
atm	atmosphere
cm	centimeter
E	East
ET	evapotranspiration
g	gram
g/cm^3	gram per cubic centimeter
g/kg	gram per kilogram
J/mol K	Joule per molality Kelvin

K	hydraulic conductivity
km	kilometer
m	meter
M	molar
m^2	square meter
m^2/s	square meter per second
meq/100 g	milliequivalent per hundred gram
mg/l	milligram per liter
ml	milliliter
mm	millimeter
mmol/l	milimolar per liter
mol/kg	molality per kilogram
mS/cm	millisiemens per centimeter
mV	Milivolt
N	North
P	precipitation
p	singinificant value
ppt	part per thousand
R	recharge
r	correlation value
V	voltan
yr	year
β	equivalent fraction
ρ	density
Σ	Sum