GROUNDWATER CHEMISTRY OF MABUL AND SIPADAN ISLANDS, SABAH

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I hereby declare that this dissertation is an effort of my own except for the quoting and references whereby its sources were clarified and stated clearly.

31st March 2005

[Signature]

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AHMAD ZAHARIN ARIS
ABSTRACT

Groundwater samples were collected from seven wells on Mabul island and two wells on Sipadan island to understand the groundwater chemistry based on various ion composition (Ca$^{2+}$, Mg$^{2+}$, Na$^{+}$, K$^{+}$, HCO$_3^-$, SO$_4^{2-}$, Cl$^-$) and in situ parameters such as DO, EC, TDS, pH and temperature. The result of analyses indicates that in general the groundwater of the study areas were highly enriched with Na$^+$, HCO$_3^-$ and Cl$^-$. At some sampling sites for both islands, the concentration of these ions (Na$^+$, Ca$^{2+}$, HCO$_3^-$, SO$_4^{2-}$, Cl$^-$), as well as other parameters such as total dissolved solids were above the World Health Organization standards for drinking water. The high concentration of ions such as Na$^+$, Mg$^{2+}$ and Cl$^-$ in the groundwater at some locations indicates some encroachment of seawater into the aquifer. The groundwater facies range from Na-HCO$_3$ to Na-Cl waters type. In order to gain an understanding of the hydrochemical process of the groundwater in the Mabul and Sipadan islands, descriptive statistics and correlation matrices were used. The main process influencing the groundwater chemistry are dissolution of minerals, cation exchange processes and simple mixing between two types of waters.

Keywords: Groundwater, Small Oceanic Islands, Mabul, Sipadan, Hydrochemical, Hydrochemical Facies, Salt water intrusion.
SAMPEL AIR BAWAH TANAH TELAH DIAMBIL DARIPADA TUJUH PERIGI YANG TERDAPAT DI PULAU MABUL DAN DUA PERIGI DARIPADA PULAU SIPADAN UNTUK MEMAHAMI KIMIA AIR BAWAH TANAH BERDASARKAN KEPELBAGAIAHAN ION YANG WUJUD (Ca^{2+}, Mg^{2+}, Na^+, K^+, HCO_3^-, SO_4^{2-}, Cl^-) DAN JUGA PARAMETER YANG DIUKUR SECARA IN SITU SEPERTI OKSIGEN TERLARUT (DO), KONDUKTIVITI (EC), JUMLAH PEPEJAL TERLARUT (TDS), pH DAN JUGA SUHU. SECARA AMNYA, KEPUTUSAN ANALISIS TERHADAP SAMPEL AIR BAWAH TANAH DARIPADA KEDUA-DUA KAWASAN KAJIAN MENJUKKAN BAHAWA KEPKEKATAN ION TERTENTU (Na^+, Ca^{2+}, HCO_3^-, SO_4^{2-}, Cl^-) DAN JUGA PARAMETER LAIN SEPERTI JUMLAH PEPEJAL TERLARUT (TDS) ADALAH MELEBIHI PARAS KEPKEKATAN YANG DIBENARKAN OLEH PIAWAIAN PERTUBUHAN KESIHATAN SEDUNIA (WHO) UNTUK AIR YANG BOLEH DIMINUM. KEPEKATAN YANG TINGGI BAGI ION SEPTI Na^+, Mg^{2+} AND Cl^- DI DALAM AIR BAWAH TANAH DI SESETENGH KAWASAN MENJUKKAN PENEROBOSAN AIR LAUT KE DALAM AKUIFERNYA. AIR BAWAH TANAH DIAPTI ADALAH DARIPADA JENIS Na-HCO_3 DAN Na-Cl. DALAM UNTUK MEMAHAMI PROSES HIDROKIMIA AIR BAWAH TANAH PULAU MABUL DAN PULAU SIPADAN, ANALISIS DISKRIPITIF DAN JUGA HUBUNGAN KOLERASI DIGUNAKAN. DIDAPATI BAHAWA PROSES YANG PEMPENGARUH HI KIMIA AIR BAWAH TANAH ADALAH PEMERLASAN MINERAL, PROSES PERTUKARAN KATION DAN JUGA PERCAMPURAN SEDERHANA ANTARA DUA JENIS AIR.

Kata Kunci: Air bawah tanah, pulau laut kecil, Mabul, Sipadan, hidrokimia, jenis air, penerobosan air laut.
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<td>atomic absorption spectrometry</td>
</tr>
<tr>
<td>AMSL</td>
<td>above mean sea level</td>
</tr>
<tr>
<td>APHA</td>
<td>American Public Health Association</td>
</tr>
<tr>
<td>BGL</td>
<td>below ground level</td>
</tr>
<tr>
<td>CEC</td>
<td>cation exchange capacity</td>
</tr>
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<td>CMR</td>
<td>cation exchange ratio</td>
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<td>DO</td>
<td>dissolved oxygen</td>
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<td>EC</td>
<td>electrical conductivity / conductivity</td>
</tr>
<tr>
<td>EIA</td>
<td>environmental impact assessment</td>
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<tr>
<td>MHWN</td>
<td>mean high water neap</td>
</tr>
<tr>
<td>MHWS</td>
<td>mean high water spring</td>
</tr>
<tr>
<td>MLWN</td>
<td>mean low water neap</td>
</tr>
<tr>
<td>MLWS</td>
<td>mean low water spring</td>
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<tr>
<td>SIDS</td>
<td>Small Island Developing States</td>
</tr>
<tr>
<td>SIWIN</td>
<td>Small Island Water Information Network</td>
</tr>
<tr>
<td>TDS</td>
<td>total dissolved solids</td>
</tr>
<tr>
<td>TSS</td>
<td>total suspended solids</td>
</tr>
<tr>
<td>UKM</td>
<td>Universiti Kebangsaan Malaysia</td>
</tr>
<tr>
<td>UMS</td>
<td>Universiti Malaysia Sabah</td>
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<tr>
<td>UNEP</td>
<td>United Nations Environmental Programme</td>
</tr>
<tr>
<td>UNESCO</td>
<td>United Nations Educational, Scientific and Cultural Organization</td>
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<tr>
<td>USGS</td>
<td>United States Geological Survey</td>
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<tr>
<td>UV</td>
<td>ultraviolet</td>
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<td>WHO</td>
<td>World Health Organization</td>
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<td>World Wild Life Foundation</td>
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\%
< 

\( > \)

\( \pm \)

\( \leq \)

\( \geq \)

\( ^{\circ} \text{C} \)

\( \mu \text{l} \)

\( \mu \text{m} \)

\( \mu \text{Scm}^{-1} \)

\( \text{E} \)

\( \text{gl}^{-1} \)

\( \text{km} \)

\( \text{km}^{2} \)

\( \text{km}^{3} \)

\( \text{m} \)

\( \text{m}^{2} \)

\( \text{m}^{3} \)

\( \text{meq}l^{-1} \)

\( \text{mg}l^{-1} \)

\( \text{ml} \)

\( \text{mm} \)

\( \text{N} \)

\( \text{nm} \)

\( p \)

\( r \)

percent
not more than
more than
plus minus
not more or equal to
more or equal to
degree celsius
micro liter
micro meter
micro siemens per centimeter
East
gram per liter
kilometer
square meter
cubic kilometer
meter
square meter
cubic meter
milliequivalent per liter
milligram per liter
milliliter
millimeter
north
nanometer
significant value
correlation value
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CHAPTER 1

INTRODUCTION

Water is essential for life where it exists in the environment and plays a vital role for the living things in the ecosystem. Water is distributed all over the world by the hydrological cycle. The hydrologic cycle happens all the times even there are no living things. When water hits the earth's surface, it either runs into streams and ends up in oceans or lakes, or seeps into the soil. The water that seeps into the soil is then either absorbed by the roots of vegetation, or it sinks into the groundwater reservoir.

Groundwater can be found almost everywhere including small islands. According to Dijon (1984) a very small island would generally have an area of not greater than 100 km$^2$ or a width that is not greater than 3 km. One of the major problems faced by small islands is the water resources. Generally, inhabitants of small islands rely on groundwater and rain collection as their water resources. According to UNESCO (2001), most small islands rely on groundwater resources for their water needs. The quantities of the groundwater that can be stored up in a small island in the groundwater reservoir depend on its aquifer type.

According to Herman (1978), aquifer is the name given to underground soil or rock through which groundwater can easily move. Terence (1991) stated that, aquifer
is a groundwater bearing formation which is sufficiently permeable to yield usable quantities of water. According to Mandel and Shiftan (1981) there are about six types of aquifers: alluvial aquifers, sandstone-shale aquifers, carbonate / limestone aquifers, volcanic terrains, crystalline rocks and coastal aquifers. The aquifers types are classified by their climatic and geologic conditions.

Different types of aquifers, may contribute to the different types of the groundwater. Different types of aquifers mean different geochemistry of groundwater. The geochemistry of groundwater may influence the utility of aquifer system as sources of water. The type and concentration of dissolved constituents in the water of an aquifer system will determine whether the resource, is suitable for drinking-water supplies, industrial purpose or other uses. The changes in the aquifer system, either attribute to natural causes or anthropogenic causes, may alter the suitability of the aquifer system as a source of water (Hudak, 2000). Assessing ground water quality and developing a strategic plan to protect aquifers from contamination are necessary aspects of water-resource management and planning.

It is important to characterize the natural ground water chemistry of the aquifer of islands, particularly touristic islands such as Sipadan island and Mabul island of Sabah, Malaysia. The current groundwater quality of both islands may serves as future reference and in defining the type of aquifer system that exist in the two small islands.

Usually, the main things to be considered while doing an assessment of the groundwater quality are the major dissolved constituents that exist in the groundwater basin (Deutsch, 1997). The major constituents in groundwater basin include calcium,
magnesium, sodium, potassium, bicarbonate, chloride and sulfate. Other chemical characteristics in the assessment of the groundwater quality include pH, dissolved oxygen (DO), alkalinity, hardness and total dissolved solids (TDS). The quality of water (physical, chemical and biological) does not only depend on the quantity and types of the chemical constituents that exist in the water but is also on the influenced by the geological and biological processes that might occur in the water body (Udosen, 2000).

Graphical and statistical techniques are usually used to analyze the data taken from the field. There are two main methods in reporting groundwater chemistry where the regional trends in groundwater chemistry can be analyzed. Piper Trilinear diagram are the most commonly used ones, and Stiff diagram, which are useful on maps to display several water types by its location. The graphical analyses are used to display the areal distribution of dissolved constituents throughout the basin, and to describe the general chemical character of the groundwater of each aquifer (Drever, 1997).

It is necessary to do an assessment and analyses so that the precious groundwater resource can be used wisely. The assessment of the groundwater quality is very important as it characterizes the groundwater types and determines the major dissolved constituents in the groundwater of the Sipadan and Mabul Islands. Currently there are limited number of researches that has been done on both islands.
2.1 SMALL ISLANDS

UNESCO (2001) study on the hydrology and water resources of islands classifies that any island larger than 2,000 km² to be in the large category. The definition of a small island is one where the area is not greater than 200 km² in area or where the width that is not greater than 10 km. In a special cases, islands larger than 2,000 km² could be considered as a small island in term of hydrological viewpoint (Franca & Falkland, 1991). Although it is not intended to apply a rigid definition, a very small island would generally that have an area of not greater than 100 km² or a width that is not greater than 3 km (Dijon, 1984).

Waterhouse (1984), Mink (1986) and Yang Qinyi et al. (1988), classify small islands based on the island origin, dominant lithology, permeability distribution, saltwater penetration and the small islands altitude itself.

Small islands that are situated in the humid tropics may be classified according to their geology and topography (Falkland, 1999). These two factors have an intense
influence on the type and quantity of fresh water resources on the island. Other major
determining factors include the local climate, the vegetation and the soil conditions.

In geological conditions, all small islands can be described as being either,
volcanic rock, carbonate or limestone, bedrock, unconsolidated or in a mixed nature
(Franca & Falkland, 1991).

2.1.1 Volcanic Islands

Volcanic islands are common in tropical regions of the Pacific Ocean and in the
Atlantic Oceans (Franka & Falkland, 1991) and also, occur in Caribbean Sea and
Indian Oceans (Falkland, 1992). Volcanic islands, even the very small ones, are
typically high islands, generally hundreds and even thousands of meters in elevation.
According to Custodio (1991), there are several types of islands under the volcanic
island types depending on the type of volcanism, age and frequent of eruptions, and
also on other associated sedimentary formations. Custodio (1991), has categorized the
volcanic island in two main groups which (a) those that are typically oceanic and (b)
those that are typically associated with plate subduction belts.

(a) Typically Oceanic

These types of islands rise from the deep ocean or on the ocean sides of ditch dug in
the ground or subduction zones. These islands are mainly of basaltic nature, although
there are periods in which more salic materials such as phonolites and thrachytes,
were emitted, resulting from the periods of magma chemical differentiation (Custodio, 1991).

(b) Typically Associated With Plate Subduction Belts

In these types of islands, in which more acidic viscous materials are emitted, generally in a more explosive form. These types of islands occur on the continent side of trenches or subduction zones, forming the islands, which the typical volcano island forms in less than two million years if the activity is due to the intermittent effect of a hot spot below it. Volcanic materials are highly heterogeneous due to the formation. Porosity and permeability change dramatically, although areal values cannot be assigned for island scale calculations and generally, permeability decreases conspicuously with increasing age (Custodio, 1991; Falkland, 1991).

Some other factors that play an important role in permeability changes over time such as the degree of weathering by flowing water, hot water of gases, the exposed surface of the rock to weathering agents and the grain size of clastics and minerals (Custodio, 1991). In fact many small volcanic islands can be considered practically impermeable and exploitable groundwater is found only in associated formations.

Volcanic aquifers of small islands in a macroscopic term have a simple watertable aquifers which for some areas may behave almost independently from others at some layers can be considered as confined or semi confined in a short term (Todd Meyer, 1971)
REFERENCES


