INVESTIGATION OF GROUND WATER QUALAITY USING REMOTE SENSING AND GIS TECHNIQUE

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KEY WORDS: Groundwater quality, Remote Sensing, GIS, land use, water quality index

Abstract: Ground water is one of the natural clean water sources. However, surface water resources from river, lakes and rainfall are more exploited rather than groundwater. Recently there are a lot of problems related to surface water resources such as degradation in water quality and quantity. Groundwater become important and can be one of the alternatives sources of clean water for various uses such as drinking purpose, residential water supply and industrial use. The main objective of this study is to investigate the impact of land use on groundwater quality by using remote sensing and GIS technique. This study carried out in the district of Johor Bahru, Pontian kecil and Kota Tinggi. The main satellite data used in this study is Landsat 5 TM on 2005 obtained Malaysian Remote Sensing Agency. Other ancillary data such as topographic map, landuse map, groundwater quality data, and well map supporting data. All these data were then import into GIS database to analyse and were used to analyse the groundwater quality in the study area. The inverse distance weigh technique (IDW) was used to obtain the spatial distribution of ground water quality parameter. Result shows that most of the location gives the index value less than 50.

INTRODUCTION

Groundwater has become one of the important sources of clean water since past few decades. This is mainly due to an increase demand on clean water for drinking, residential water supply and industrial. However, surface water resources from perennial river, lakes and rainfall are more exploited rather than groundwater. In Malaysia there are many potential area of ground water that can be explored for alternative to clean water resources. The issue that may arise is the quality of the groundwater to be consumed daily.

Generally the groundwater quality consists of the physical, chemical and biological qualities. Temperature, turbidity, color and taste are the physical parameter of water quality. The attention is more to chemical and biological parameters since the water are colorless and odorless. Naturally, groundwater contains mineral ions. These ions slowly dissolve from soil particle, sediments, and rock as the water travels along mineral surface in the pores or fractures of the unsaturated zone and aquifer. They are referred as dissolved solid. Some dissolved solids may have originated from the precipitation water or river water that recharges the aquifer (harter, 2003)

GIS and remote sensing are effective tools for water quality mapping and land cover mapping essential for monitoring, modeling and environmental change detection (Asadi*et al.*, 2007). GIS is potentially powerful tools to developed a total solution of water resources problems such as evaluating the water quality, flood preventation, understanding the nature and managing the water resources in local or regional scale. With the integration of remote sensing, GIS and field assessment, the groundwater quality evaluation can be made with the relation to the impact of land use change.

The study area comprises most of the Johor Bahru district and some small parts of Kota Tinggi and Pontian district. The total area is about 2097 km^2.

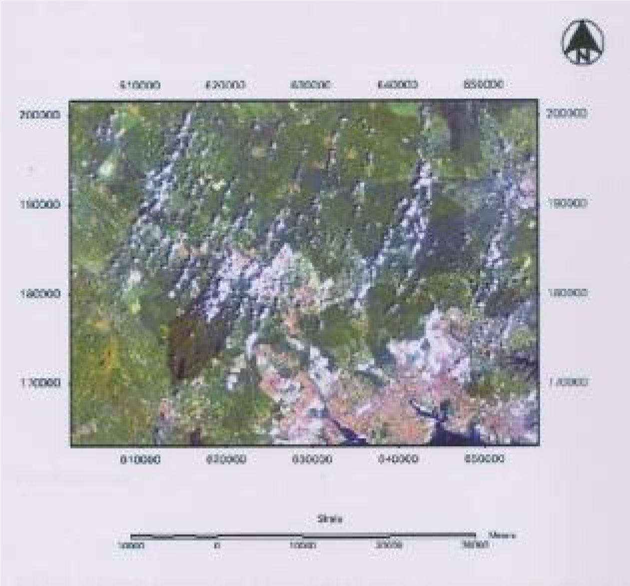

Figure 1: Study Area.

MATERIALS AND METHOD

The Landsat 5 satellite data is being used as the main data that obtained from Malaysia Remote Sensing Agency followed by some supporting data which are topographic map, land use map and field data of groundwater quality parameter from Department of Geoscience and Mineral, Johor.

The water quality parameter such as pH, sulphates, nitrates, fluorides, ferum, total dissolved solid (TDS) and water quality index (WQI) were overlaid on the Landsat 5 imagery. The inverse distance weighted (IDW) approach has been used in the present study to delineate the location distribution of water pollutants or constituents. This methods use a defined or selected set of sample point for estimating the output gris cell value. It determines the cell values using a linearly weighted combination of a set of sample points and controls the significance of knowns point upon the interpolated values based upon their distance from the output point thereby generating a surface grid well as thematic isolines.

Estimation of Water Quality Index (WQI)

Water Quality Index (WQI) is a very useful tool for communicating the information on overall quality of water. To determine the suitability of the groundwater for drinking purpose, WQI is computed adopting the following formula:

$$WQI = \text{Antilog}\,[\Sigma W^{n}{}_{n=1} \log10 q_n] \qquad (1)$$

Where,

W, Weightage factor (W) is computed using the following equation, (Table 2)

$$W_n = K/S_n \qquad (2)$$

and K, Propotionality constant is derived from,

$$K = [1/(\Sigma^{n}{}_{n=1}\ 1/S_i) \qquad (3)$$

S_n and S_i are the Malaysia Ministry of Health/ WHO standard values of the water quality parameter.

Table 1: Water quality parameter, their Ministry of Health/WHO standard and assigned unit weight.

Parameter	Standard (S_n & S_i)	Weightage (W_n)
pH	8.5	0.0176
Chlorides	250	0.0006
Fluoride	0.9	0.1667
Sulphates	400	0.0004
Nitrates	10	0.015
Ferum	0.3	0.5
TDS	1000	0.0002

Quality rating (q) is calculated using the formula,

$$q_{ni} = \{[(V_{actual} - V_{ideal})/(V_{standard} - V_{ideal})]*100\} \qquad (4)$$

where,

q_{ni} = Quality rating of i^{th} parameter for a total of n water quality parameters.

V_{actual} = Value of the water quality parameter obtained from laboratory analysis.

V_{ideal} = Value of that water quality parameter can be obtained from the standard tables.

V_{ideal} for pH = 7 and for other parameter it is equalent to zero.

$V_{standard}$ = WHO/Ministry of Health standard of the water quality parameter.

Based on the above WQI values, the ground water quality is rated as excellent, good, poor, very poor and unfit for human consumption (Table 2).

Table 2: Water Quality Index Categories

Water Quality Index	Description
0 – 25	Excellent
26 – 50	Good
51 – 75	Poor
76 – 100	Very poor
> 100	Unfit for drinking

RESULT AND DISCUSSION

Variation of Groundewater Quality

The pH of the water sample in the study area ranged in between 7.1 to 8.5. The concentration of chlorine in many locations is within the permissible limits.

Fluoride, the most commonly occurring form of fluorine, is the common natural contaminant of water. Groundwater usually contains fluoride dissolved by geological formation. The concentration of fluoride was observed to be above permissible limits was seen at Kulai Evergreen Mineral Water which is 13mg/l (Figure 2).

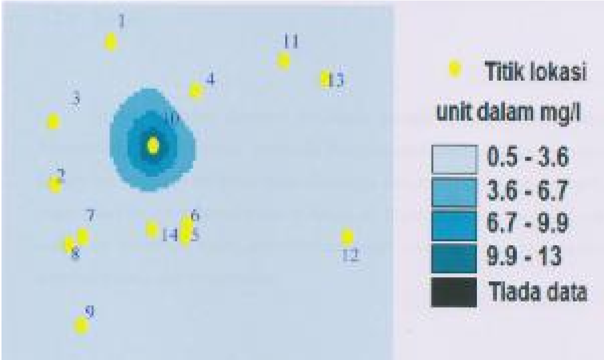

Figure 2: Spatial Distribution of Fluoride.

Permissible limits as standard by Malaysia Ministry of Health/WHO for sulphates concentration in water is 400 mg/l. All the sampling points showed that the amount of sulphates is within the permissible limits. As for nitrates, only area near Ocean Mineral Water was found to have high concentration of nitrates which is beyond the permissible limit (13mg/l). Figure 3 shows the spatial distribution of nitrates distribution.

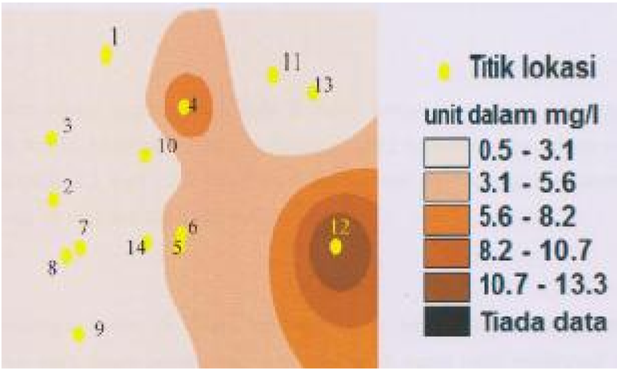

Figure 3: Spatial Distribution of Nitrate Concentration

The concentration of Ferum in the groundwater in the study area are ranged from 0.1 to 1.9 mg/l. Six location were found beyond the permissible limits of ferum concentration. Highest concentration of ferum was found a Kulai Besar Oil Mill which is 1.9mg/l. For the TDS, all location show the concentration was within the permissible limits.

Water Quality Index

Water quality index is calculated to determine the suitability of water for drinking purpose. Water quality index revealed that the groundwater quality of the study area are suitable whether for drinking, domestic use or even for industrial. Most of the monitoring well location shows the index value less than 50. Except for Kulai Besar Oil Mill, the index shown the value of 51 which indicated the quality is poor. The WQI map is shown in Figure 4.

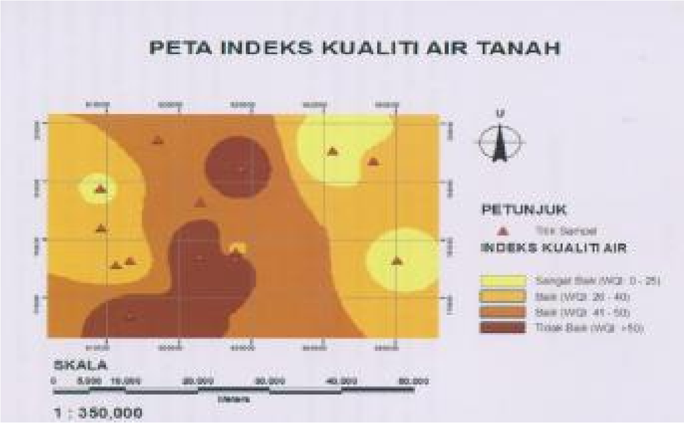

Figure 4: Water Quality Index Map

Land use vs Groundwater Quality

In the present study area, based from the land use map in Figure 5, the agriculture cover 43% of the study area. The residential and urban comprise 27% of the total study area and the same percentage goes to the forested land use. The percentage goes of the area is based on the classification of the satellite imagery so there are areas which convered with clouds which comprises 2%.

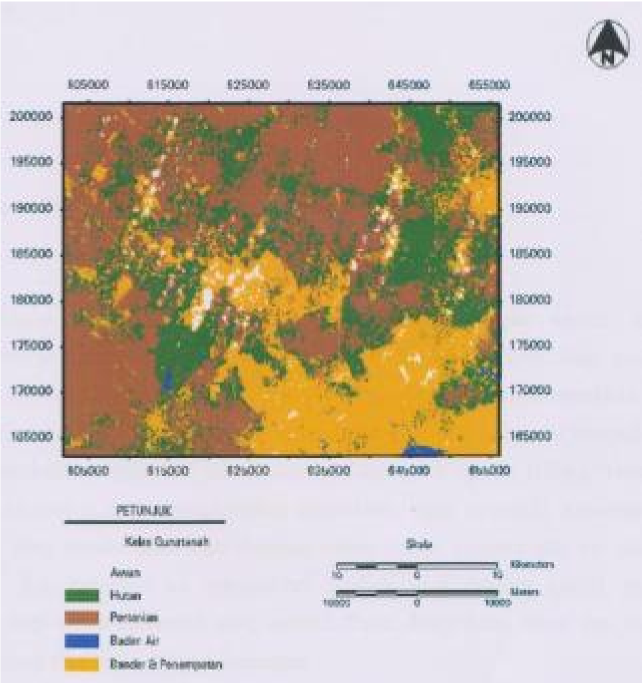

Figure 5: Land use Map

Another 1% of the study area is the water bodies. Figure 5 above and Figure 6 below shows the land use distribution in the study area.

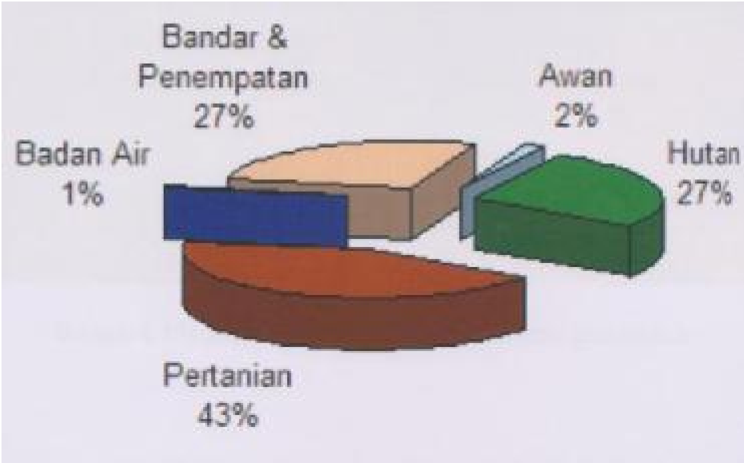

Figure 6: Land use distribution in the study area.

Major portion of the groundwater sample collected from agricultural category. The correlation of water quality to land use depicted in Table 3.

Table 3: correlation of Water Quality with Land use

Water Quality Index	Land use		
	Forest	Agriculture	Residential & urban
Excellent	2	4	3
Good	0	2	2
Poor	0	1	0
Very poor	0	0	0
Unfit for drinking	0	0	0

From the total of 14 samples, 64.3% are rated *Excellent*, 28.6% are rated as *Good* and remaining 7.1% are rated *Poor*. None of the sample ware rated *Very Poor* and *Unfit for Drinking*. Figure 7 shows the percentage of the sample to the distribution of the land use.

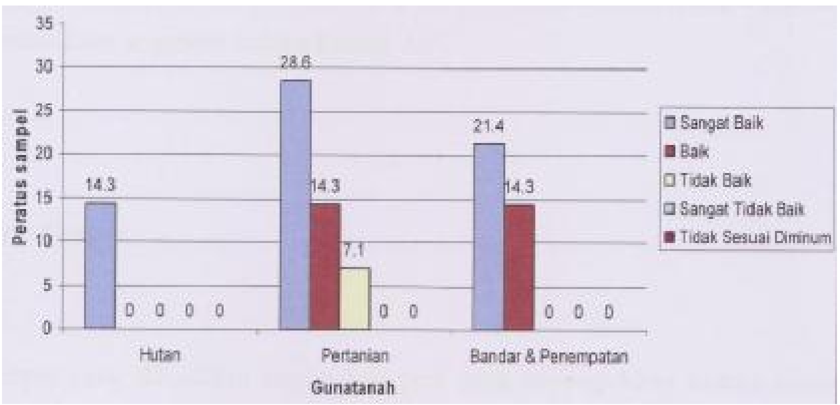

Figure 7 : Samples percentage to the land use distribution

CONCLUSIONS & RECOMMENDATIONS

The result indicate that certain parameter such as nitrates, chlorides, fluorides and ferum were beyond permissible limits which are some of them were in the agricultural area. The overall view of the water quality index in the study area is quite excellent. This is shown by 9 out of 14 sample have the WQI rated *Excellent.*

The analysis of the result drawn at various stages of the work shown that the integration of remote sensing and GIS are effective tools for monitoring the groundwater quality for local or regional scale. Spatial distribution maps of various pollution parameters are used to indicate the location distribution of water pollutants in a comprehensive manner.

In order to improve this study, it is more significant to sample more groundwater of various locations. It is also meaningful if the samples are taken from shallow aquifer, aquifer that is near to the surface. In fact, it will give more variation to the result that will be obtained.

REFERENCES

Abassi, S. A.: Water Quality Indices, State-of-the art. J.IPHE. 1999, No.1.

Foster, S.S.D., Lawrence, A. & Morris, B.,(1998). Groundwater in Urban Development: Assessing management needs and formulating policy strategies. World Bank Technical Paper No. 390, 55p.

Llamas, R., Back, W. and margat, J., (1992). Groundwater Use: Equilibrium Between Social Benefits and Potential Environmental Costs. Applied Hydrogeology, 2, p3-14. National Economic Action Council (1998).

Thomas Harter (2003). "Groundwater Quality and Groundwater Pollution" FWQP Reference sheet. (Online) Available http://www.anrcatalog.ucdavis.edu 16 ogos 2007

S.Mandel, Z.L. Shiftan (1981). "Groundwater as Part of the Hydrologic Cycle". Groundwater Resources, Investigation and Development. Academic Press pp. 1-3

S. S. Asadil, Padmaja Vuppala and M. Anji Reddy (2007). "Remote Sensing and GIS Techniques for Evaluation of Groundwater Quality in Municipal Corporation of Hyderabad (Zone-V), India", (Online) Available http://www.ijerph.org 15 ogos 2007

The Groundwater Foundation (2001). "Groundwater basics", (Online) Available http://www.groundwater.org 16 ogos 2007

WHO Fluorine and Fluorides. Environmental Health Criteria. World Health Organization. Geneva. 1984.