JOURNAL OF
ENVIRONMENTAL HYDROLOGY
The Electronic Journal of the International Association for Environmental Hydrology
On the World Wide Web at http://www.hydroweb.com
VOLUME 15 2007

SEAWATER INTRUSION INTO GROUNDWATER, PENINSULAR MALAYSIA

Z. Ismail
N.A. Aziz
R. Hashim

Civil Engineering Department
University of Malaya
Kuala Lumpur, Malaysia

Industrialization has led to the contamination of the environment including groundwater in the form of chemical and mineral waste. Monitoring of important parameters is essential in order to evaluate the situation and be in a position to intervene if necessary. In this study the parameters monitored were pH, temperature, conductivity and turbidity. Total organics, volatile organic compounds, metals, total hardness, total dissolved solids, anions, phenols, bacteria and radioactivity were also analyzed. This paper focuses mainly on anions with special reference to chlorides, based on data collected from sixty-two monitoring wells throughout the country over a period of three years. The yearly and regional trends were determined, and a course of action is recommended. From the results gathered so far, chlorides have the highest values among the anionic contaminants. This is an indication that perhaps there is seawater intrusion into the groundwater system. However, the levels were not yet critical.

INTRODUCTION

Groundwater is an important source of water supply for domestic, agricultural and industrial purposes. Groundwater contributes to about 95% of the fresh water supply of the world. In the late seventies, groundwater contamination and degradation of groundwater quality became big issues with the discoveries of numerous leaking hazardous waste sites. Contaminated land problems are increasing rapidly. Previously neglected, such lands are now becoming central to environmental problems. Such land can be found in many places such as motor workshops, petrol stations, fuel depots, railway yards, landfills, industrial sites and ex-mining land. Many contaminated lands remain hidden including abandoned landfills and refuse dumping sites. The Department of Environment implemented a program referred to as the Groundwater Control Activity in 1996 and the monitoring program proceeded through 1997. The water quality was monitored through sixty-two wells throughout the country. The objective of this study is to analyze available data on the contamination of groundwater in West Malaysia; with special focus on chlorides, and propose the most practical approach for remediation.

BACKGROUND

Sources of Contaminants

Waste will eventually be exposed to the soil and it is crucial to evaluate the need to decontaminate in order to mitigate toxic impacts and prevent further migration of contamination. There is a multitude of sources of groundwater contamination as a result of human and some natural activities as indicated by Raymond (1996).

Septic tanks are used to transfer and contain household sewage directly to the ground for anaerobic decay. Water from toilets, sinks and showers, dishwashers and washing machines goes into the septic tank where it undergoes settling and decomposition. Liquid wastes are sometimes discharged into waterways thus posing a threat and the possibility of contaminating surface water. There are also liquids which are discharged through injection wells into subsurface zones below the water table. Such liquids are those used in the process of enhanced oil recovery, treated water intended for artificial aquifer recharge, and fluids used in the mining industry. Injection wells can cause groundwater contamination if the fluids being injected accidentally enter a drinking water aquifer. Spray irrigation systems using municipal and industrial wastewater can also contaminate the groundwater. While some organic matter can be biodegraded or be made to be biodegradable, nitrates, phosphates, heavy metals and some organic compounds remain as potential threats through the process of leaching from the soil.

Landfills are designed to minimize the adverse effects of waste disposal. However, poor design and maintenance are common causes of leakage of leachates into the groundwater. Nonhazardous as well as hazardous waste materials such as municipal garbage, construction debris, sludge, incinerator ash, and foundry wastes are found in landfills. Open dumps are unregulated and receive all kinds of waste. They are unlined and have no leachate collection systems. Mining wastes and tailings may be piled on the land surface, used to fill low areas, used to restore the land to pre-mining contours or placed in landfills, all of which pose a threat to groundwater contamination. Contents of underground tanks can seep into the groundwater through holes and cracks of the tanks and failure of the piping and fittings. Petroleum products, agri-chemicals and other chemicals stored in ground tanks can also enter the ground after ruptures and spills.

Sewers to transport wastewater, and pipelines to transport crude petroleum, as well as petroleum, petrochemical and chemical products are also potential sources of contaminants. Any leakage of the materials due to ruptures, corrosion and faulty joints posed a potential hazard to the groundwater. Road and rail transportation, as well as the associated loading and unloading facilities are also potential sources of soil contamination following accidents and spills. This becomes more severe when the cleanup efforts are not carried out properly.

When crops are irrigated, more water is commonly applied to the field than is actually needed. The return flow of excess water which usually contains chemical fertilizers and toxic pesticides can percolate through the soil to the water table. Pesticide application has extensive potential for contaminating the groundwater as described by Waldron (1992). Nowadays more biodegradable pesticides are being used, but sometimes the breakdown products can also act as contaminants. Application of chemical fertilizers is another potential for groundwater contamination. Phosphates are not very mobile in soil and the threat is insignificant, and the application of potash is generally low and not of any serious significance. The problem comes from nitrates. Urban runoff contains high amounts of dissolved and suspended solids from auto emissions, vehicle leaks, home gardening, refuse and animal faeces. For the most part, the urban runoff is carried into surface ponds, but it may recharge the water table from leaking storm drains. Surface and underground mining may expose rocks containing pyrite to oxygenated water resulting in the production of acidic water which drains from the mine.

Wells are drilled for the production of oil, gas and water. A conduit for the flow of contaminated surface water into the ground or the movement of contaminated groundwater from one aquifer into another can result from improperly constructed wells, corroded well casings, and improperly abandoned wells.

Types of Contaminants

Pollutants are basically organic or inorganic compounds which are either toxic/mutagenic or carcinogenic or both. Municipal solid waste or domestic waste is also a major problem in most countries. These include food waste, packaging, yard waste and construction debris.

Hydrogeologic Site Investigation

In order to arrive at a cost-effective corrective action program to combat groundwater contamination, adequate data on the physical and chemical properties of the soil and groundwater have to be obtained. This may be achieved by utilizing well-designed, well-constructed and properly operated monitoring wells for the hydrogeologic investigations.

Contaminant Transport Mechanisms

The main transport and other processes of concern in groundwater studies include advection, diffusion, dispersion, adsorption, biodegradation and chemical reaction. The incorporation of the said mechanisms into groundwater models for the prediction and evaluation of waste sites have been introduced by several authors including Bedient et al. (1994), Fetter (1993), and Freeze and Cherry (1979).

Remediation Approaches

Choosing a remedial approach depends on the type of contaminant, site hydrogeology, source characteristics and the contaminant in the subsurface. The accepted approaches are complete source removal, containment, mass reduction including bioremediation and extraction as described by workers like Evanko and Dzombak (2004), Khan et al. (2004), Reddy and Chinthamreddy (1999), Rivett et al. (2002) and Virkutyte et al. (2002).

METHODOLOGY

For the purpose of this study, Peninsular Malaysia was divided into four regions: the Northern Region comprising of the states of Perak, Pulau Pinang, Kedah and Perlis; the Western Region of Selangor and Negri Sembilan; the Southern Region of Melaka and Johor; and the Eastern Region of Pahang, Trengganu and Kelantan. The map of Peninsular Malaysia showing these regions and the locations of the monitoring wells is given in Figure 1. The study was done through interviews, data collection and statistical analysis. Officers from the Department of Environment were interviewed to obtain the general overview of the project. Supplementary data were gathered from literature. Available commercial softwares were utilized for the data analysis. The data are summarized in Table 1.

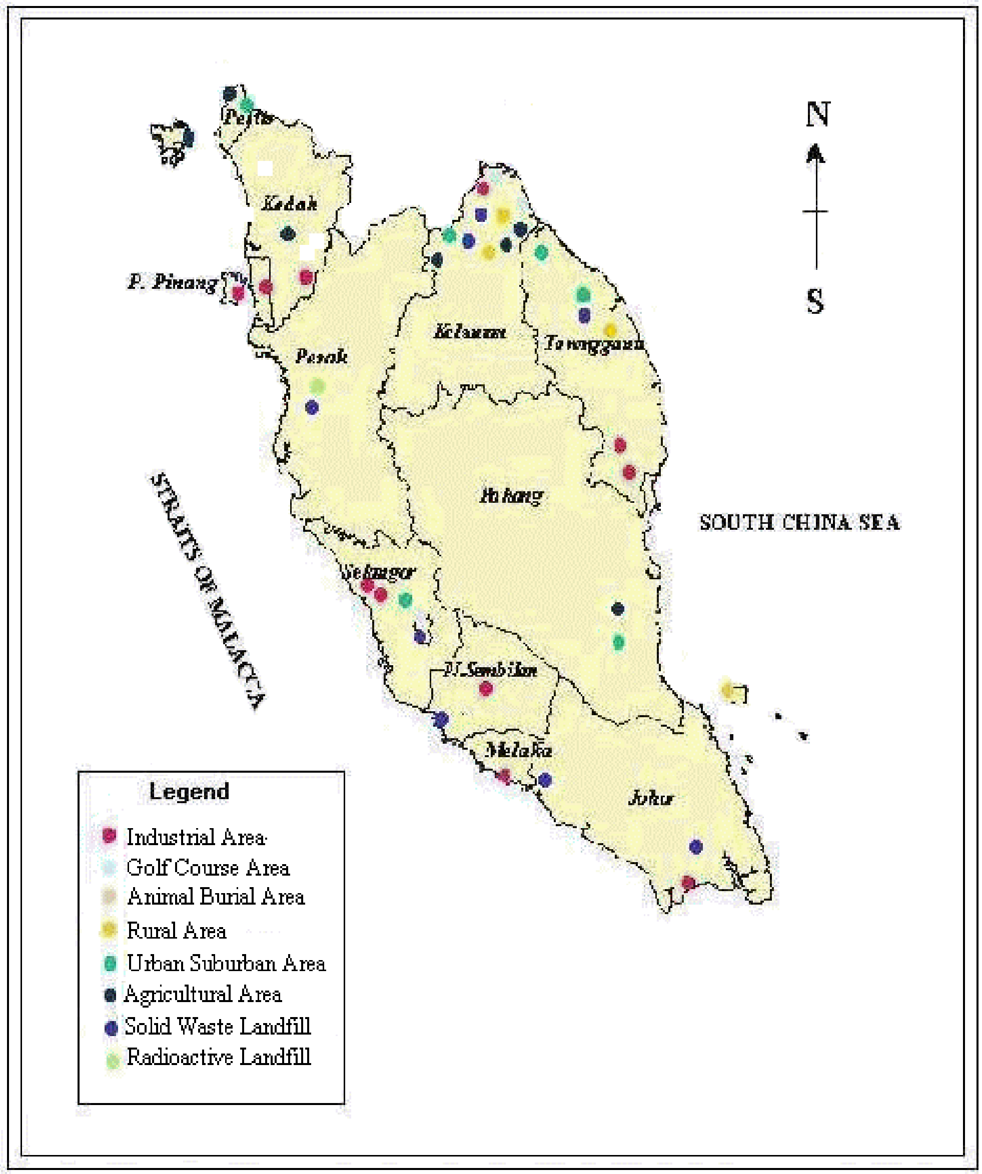

Figure 1. Peninsular Malaysia - groundwater quality monitoring locations.

Table 1. Anion analysis for 2003 (mg/L).

Location	**Min. Conc.**	**Max. Conc.**	**Mean**
Perlis	0.00	42.97	14.1
Kedah	0.00	18.25	7.3
Langkawi	0.00	10.28	3.3
Penang	0.00	7532.23	1978.8
Perak	0.00	1.66	0.9
K. Lumpur	0.00	10.40	5.9
Selangor	0.00	164.90	49.1
N. Sembilan	0.00	39.10	14.9
Melaka	0.00	13.00	3.8
Johor	0.00	2740.50	710.2
Pahang	0.00	161.96	40.9
Trengganu	0.05	164.28	44.6
Kelantan	0.11	181.57	52.9

RESULTS AND DISCUSSION

Regional Trends

For the Northern Region of Perak, Pulau Pinang, Kedah and Perlis, the value for anions was highest in Pulau Pinang with 1978.8 mg/L followed by Perlis with 14.1 mg/L; with a maximum concentration of 7532.2 mg/L for a location in Pulau Pinang. Attention has to be given to some areas of high concentration.

For the Western Region of Selangor and Negri Sembilan, the mean value for anions was highest in Selangor with 49.1 mg/L followed by Negri Sembilan with 14.9 mg/L and Kuala Lumpur with 5.9 mg/L. The maximum concentration was 164.9 mg/L which was acceptable.

For the Southern Region of Melaka and Johor, the mean value for anion is higher in Johor with 710.2 mg/L than in Melaka with 3.8 mg/L; with a maximum value of 2740.5 mg/L at a location in Johor. This value is on the high side.

For the Eastern Region of Pahang, Trengganu and Kelantan, the mean value for anions was highest in Kelantan with 52.9 mg/L, followed by Trengganu with 44.6 mg/L and Pahang with 40.9 mg/L; with a maximum concentration of 181.5 mg/L at a location in Kelantan. The levels should give some concern.

Yearly Trends

For the year 2001, chlorides made up the majority of anions at 92% and the remainder was sulfates. For the year 2002, chlorides still made up 92% with sulfates at 6% and nitrates making up the rest. For the year 2003, chlorides were 91%, sulfates at 8% and nitrates with 1%. The results showed that the anion levels did not vary much over the years. The concentrations of anions in 2003 at various locations in the country were recorded. It was apparent that several locations indicated high levels of anions especially chlorides as shown in Table 1.

The highest levels of anions were found in the northern region followed by the southern region, eastern region and western region. Chlorides formed 92% of anions for 2001 and 2002, and 91% for 2003; while sulfates formed the main bulk of the remainder. The overall level of groundwater contamination was found to be worst for the northern region followed by the eastern region, the southern region and the western region. In most cases, however, the levels were still within recommended limits, and were not considered to be critical. Levels for chlorides are high and this could be from seawater intrusion. Methods such as soil flushing and ion-exchange are available to treat chlorides.

CONCLUSION

The high levels of chlorides in some areas indicate that there is a possibility of seawater intrusion into the groundwater systems. Although the levels look high, it is not yet considered to be critical. However, because of the low area density of point data gathered, it is difficult to arrive at any regional characteristics from these isolated point data, and at best this can only be regarded as preliminary information. There is, however, a need to continue monitoring the situation to determine whether the trend is worsening and spreading to other locations or stabilizing. Any need for remediation work has to select a suitable approach which depends on the site hydrogeological conditions.

ACKNOWLEDGMENTS

The authors wish to express their gratitude to the staff of the Water and Marine Division, Department of Environment, Putrajaya and Kuala Lumpur, for their assistance in providing the data. They also wish to thank Professor Dr. A. M. Baki from the Civil Engineering Faculty, University Technology MARA and Professor Dr. F. Putuhena from the Civil Engineering Department, University Malaysia Sarawak, who have kindly made constructive comments in reviewing this article.

REFERENCES

Bedient, P.B., H.S. Rifai, and C.J. Newell. 1994. Groundwater Contamination, Transport and Remediation. NJ, Prentice Hall.

Evanko, C.R., and D.A. Dzombak. 2004. Remediation of metals-contaminated soilsand groundwater, Technology Evaluation Report, Carnegie Mellon University.

Fetter, C.W. 1993. Contaminant Hydrogeology. New York, Macmillan.

Freeze, R.A., and J.A. Cherry. 1979. Groundwater, NJ, Prentice Hall.

Khan, F.I., T. Husain, and R. Hejazi. 2004. An overview and analysis of site remediationtechnologies. J.Env. Mgt., Vol. 71, pp. 95-122.

Raymond, L.S. 1996. Groundwater Contamination, University of Minnesota.

Reddy, K.R., and S. Chinthamreddy. 1999. Electrokinetic remediation of heavy metal contaminated soils under reducing environments. Waste Mgt, Vol. 19(4), pp. 269-282.

Rivett, M.O., J. Petts, B. Butler, and I. Martin. 2002. Remediation of contaminated land and groundwater: experience in England and Wales. J.Env. Mgt, Vol. 65, pp. 251-268.

Waldron, A.C. 1992. Pesticides and Groundwater Contamination, The Ohio State University.

Virkutyte, J., M. Sillanpaa, and P. Latostenmaa. 2002. Electrokinetic soil remediation: critical review. Sci.Total Env., Vol. 289, pp. 97-121.

ADDRESS FOR CORRESPONDENCE
Z. Ismail
Civil Engineering Department
University of Malaya
Kuala Lumpur, Malaysia

Email: zu_ismail@um.edu.my