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MONITORING VOC CONTAMINATION IN GROUNDWATER: PENINSULAR MALAYSIA

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The country's industrialization leads to contamination of the environment including groundwater in the form of chemical and mineral waste and microorganisms. Monitoring of important parameters is essential in order to evaluate the situation and be in a position to intervene. The focus of this study is on volatile organic compounds. From the analysis of results so far obtained based on data collected from sixty-two monitoring wells throughout the country, the level of volatile organic compounds contamination in groundwater in Peninsular Malaysia is not yet critical. However, new contaminants are starting to appear. A future course of action needs to be planned.

INTRODUCTION

Petroleum operations offshore of the East Coast of Peninsular Malaysia started over thirty years ago but really got into full swing these last twenty years or so. The impact on the environment is just beginning to become apparent. As an example, there are already some indications that the groundwater is being contaminated by pollutants like volatile organic compounds (VOCs). Groundwater is an important source of water supply for domestic, agricultural and industrial purposes. It contributes to about ninety-five percent 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 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. All these contribute to the contamination of groundwater. The Department of Environment implemented a program referred to as the Groundwater Control Activity in 1996 and the monitoring program proceeded through 1997. 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 a special focus on VOCs, identify any critical contaminants, and propose the most practical approach for remediation.

BACKGROUND

Types of contaminants

Contaminants are basically organic or inorganic compounds which are either toxic/mutagenic or carcinogenic or both. Examples are heavy metals, inorganic fertilizers, VOCs, microorganisms, and radioactivity. Municipal solid waste or domestic waste is also a major problem in most countries. These include food waste, packaging materials, garden waste and construction debris.

Causes of contamination

There are several sources of groundwater contamination as a result of some natural and some industrial activities. Imperfect systems, imperfect operations and imperfect processes result in ruptures and spillages, waste and unwanted by-products which will eventually be exposed to the soil. Several of these substances are toxic to the environment, and it is crucial to evaluate the need to decontaminate them in order to mitigate toxicological effects and prevent further migration of the contaminants. Some of the causes mentioned may be summarized and classified as follows:

Poor Design

Septic tanks are used to transfer household sewage directly to the ground after 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 discharged through injection wells into subsurface zones below the water table. Such liquids are those used in enhanced oil recovery, treated water intended for artificial aquifer recharge, and fluids used in mining. Injection wells can cause groundwater contamination if the fluid being injected accidentally enters a drinking water aquifer**.** 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, foundry wastes are found in landfills.

Inefficient Process

Optimum process design will achieve energy efficiency at the same time maximizing yield of desired products. There are, however, cases of processes where the excessive production of unwanted by-products is inevitable. They are difficult to dispose of and may end up unattended and become environmental pollutants.

Unsound Practices

Spray irrigation systems using municipal and industrial wastewater can also contaminate the groundwater. While some organic matter can be biodegraded, nitrates, phosphates, heavy metals and some organic compounds remain a potential threat leaching from the soil**.** 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. When crops are irrigated, more water is applied to the field than needed. The return flow of excess water containing fertilizers and pesticides percolates through the soil to the water table. Pesticide application has extensive potential for contaminating the groundwater. Nowadays more biodegradable pesticides are being used, but sometimes the breakdown products could also act as contaminants. Application of NPK fertilizers is another potential for groundwater contamination. Phosphates are not very mobile in soil and the threat is insignificant, and the application potash is generally low to be 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 feces. Surface and underground mining may expose rocks containing pyrite to oxygenated water resulting in the production of acidic water which drains from the mine.

Poor Maintenance

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, agrochemicals and other chemicals stored in in-ground tanks can also enter the ground after ruptures and spills. Included in this class are sewers to transport wastewater, and pipelines to transmit petroleum, petrochemical and chemical products. Any leakage of the materials due to ruptures, corrosion and faulty joints pose as a potential hazard to the groundwater. For the most part, the urban runoff is carried into surface ponds, but it may recharge the water table from leaking storm drains. 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.

Maloperation

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 could be due to human error or unfriendly operating procedures. The whole matter becomes more serious when the cleanup efforts are not carried out properly. 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.

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 Evanko and Dzombak (1997), Khan et al. (2004), Virkutyte et al. (2004), Reddy and Chinthamreddy (1999), and Rivett et al. (2002).

Hydrogeologic site investigations

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 Fetter (1993), Freeze and Cherry (1979), and Bedient et al. (1994).

METHODOLOGY

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 software were utilized for the data analysis.

RESULTS AND DISCUSSION

Regional trends

For the Northern Region of Perak, Pulau Pinang, Kedah and Perlis, the value for VOCs had a mean of about 0.0012 mg/L with a maximum concentration of 0.0034 mg/L. These levels were found to be acceptable. For the Western Region of Selangor and Negri Sembilan, the value for VOCs had a mean of about 0.001 mg/L, and a maximum concentration of 0.0023 mg/L. These levels were considered acceptable. For the Southern Region of Melaka and Johor, the mean value for VOCs was 0.001 mg/L; and the maximum concentration was also 0.001 mg/L. For the Eastern Region of Pahang, Trengganu and Kelantan, the mean value for VOCs for Trengganu was 0.01 mg/L and the values for both Pahang and Kelantan were 0.001 mg/L; with a maximum concentration of 0.0943 mg/L for a location in Trengganu. The levels for Trengganu were seen to be higher than the rest but they were still within limits.

Yearly trends

The constituents of VOCs are typically chlorobenzene, 1,2-dichlorobenzene, 1,3-dichlorobenzene, 1,4-dichlorobenzene, bromodichloromethane, dibromochloromethane, bromoform, chloroform, benzene, toluene, o-xylene, m-xylene and p-xylene. It was found that the constituents making up the VOCs in 2001 were mainly 1.2-dichlorobenzene (91%) with some m- and p-xylene (4%), toluene (2%), 1,4-dichlorobenzene (2%) and o-xylene (1%). Although there was a noticeable reduction in 1,2-dichlorobenzene (63%) for the year 2003, there were, however, more types of constituents appearing, for example, 1,3-dichlorobenzene (15%), toluene (13%), chloroform (4%), 1,4-dichlorobenzene (2%), bromodichloromethane, dibromochloromethane (1%) and bromoform (1%)

Table 1 shows the VOC concentrations for 2003 at various locations in the country. The concentrations were found to be generally low at 0.0010 mg/L for all locations except in Trengganu where the values have a mean of 0.010 mg/L with a maximum of 0.0943 mg/L.

Table 1. VOC Analysis for 2003 (mg/L).

Location	Min Conc	Max Conc	Mean
Perlis	0.0010	0.0034	0.0012
Kedah	0.0010	0.0010	0.0010
P Langkawi	0.0010	0.0010	0.0010
Penang	0.0010	0.0010	0.0010
Perak	0.0010	0.0010	0.0010
K Lumpur	0.0010	0.0010	0.0010
Selangor	0.0010	0.0010	0.0010
N Sembilan	0.0010	0.0023	0.0011
Melaka	0.0010	0.0010	0.0010
Johor	0.0010	0.0010	0.0010
Pahang	0.0010	0.0010	0.0010
Trengganu	0.0010	0.0943	0.0100
Kelantan	0.0010	0.0010	0.0010

CONCLUSIONS AND RECOMMENDATIONS

The general levels of VOCs were found to be highest in the Eastern region followed by Northern region, Western region and Southern region. 1,2-dichlorobenzene made up 91% of the VOCs for the year 2001 reducing to 63% for the year 2003 with some new compounds appearing. Concentration levels of VOCs in Malaysian groundwater are still at insignificant levels but there is a need for a close monitoring of the levels in the Eastern region due to the very fast development of the petrochemical industry there.

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