EVALUATION OF GROUNDWATER POLLUTION NITROGEN FERTILIZER USING EXPERT SYSTEM

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ABSTRACT

An expert system was used to correlate the availability of nitrogen fertilizer with the vulnerability of groundwater to pollution in Peninsula Malaysia to identify potential groundwater quality problems. The expert system could predict the groundwater pollution potential under several conditions of agricultural activities and exiting environments. Four categories of groundwater pollution potential were identified base on an N-fertilizer groundwater pollution potential index. A groundwater pollution expert system developed can be use as a tool for the implementation of groundwater pollution potential approach. This facilitated the identification of priority areas for future on site sampling and quantification of groundwater quality. Current cropping patterns and practice need to be evaluated in areas with high susceptibility to groundwater pollution and availability of nitrogen fertilizer. This study indicated that the cultivation of crops requiring high nitrogen fertilizer application rates have the potential to impact groundwater quality. This impact will vary from study area to area on the specific crops grown and their distribution over vulnerable areas.

INTRODUCTION

The intensification of agricultural production can lead to serious deterioration in groundwater quality in some pedological, geological and climatic conditions. Agriculture production has a great potential to adversely affect the environment, most particularly from nonpoint sources, hazardous waste disposal, habitat destruction and inlocalized areas, nuisance odours. Nonpoint source pollution of groundwater by agricultural chemicals is an increasing environmental problem. According to the congressional research service (Feliciano, 1996) agricultural activity are the most pervasive contributors to nonpoint source pollution of groundwater. The two most commonly determined pollutants are nitrates and pesticides, probably because of their adverse effects on human health (US.EPA, 1984). Substantial increases in groundwater nitrate nitrogen are of particular concern on intensively cropped irrigated sandy soil. A study was conducted by Hubbard, et al. (1984) to compare shallow groundwater nitrate nitrogen concentrations under intensive multiple cropping system with those from under nearly non agricultural site. The result indicated that, nitrate nitrogen concentration range from less than 0.1 mg/l. The study raise concern about shallow groundwater quality under intense multiple cropping system on sandy soils. Agricultural application of nitrogen fertilizer is being increasingly recognized as significant source of nitrate nitrogen groundwater pollution. A number of factors influence the movement of nitrogen from applied fertilizers to groundwater systems. From example, heavy rainfalls occurring shortly after fertilizer application can greatly increase losses of nitrogen through a subsurface drainage system. Additional influencing factors include soil and crop type, and fertilizer application practices. The objective of this study was to predict potential groundwater quality problems resulting from application of nitrogen fertilizers to crop in Peninsula Malaysia by combining information on the availability of the potential pollutant (nitrogen fertilizer) with assessment of the vulnerability of an area to pollution which using an expert system.

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APPROACH

Expert system are typically classified according to the type of problem to which they are applied. Categories of expert system include interpretation, diagnostic, prediction, design, planning, control, repair, debugging, monitoring, and instruction. The three most common applications for expert system in groundwater contamination studies are interpretation, diagnostic and prediction (Crowe, 1994). AN-fertilizer groundwater pollution potential index, produced by using groundwater vulnerability methodology was combined with information on cropped areas, recommended nitrogen fertilizer application rates with in the peninsula Malaysia, these processes are applied by groundwater pollution expert system. A study will be carried out from field study, several sources of established literature, and domain experts to get knowledge base or rule for expert system.

METHODOLOGY

A study was carried out from several sources of established literature and domain expert to get knowledge base and rule for expert system. The detail of methodology are following :

- An expert system for predicting the impact of nitrogen fertilizer on groundwater pollution potential was developed by using CLIPS (C Language Integrated Production System), a computer software developed by NASA/Lyndon B.Johnson Space Center in 1984 (Giarratano and Riley, 1994).
- A nitrogen fertilizer groundwater pollution potential index, produced by using groundwater vulnerability methodology was combined with information on cropped areas, recommended nitrogen fertilizer application rates with in the peninsula Malaysia. Data from the Soil and Analytical Service Branch Division of Agriculture, Ministry of Agriculture and Rural Development Malaysia for the following nine crops were used in this study and Recommended nitrogen fertilizer application rates for the nine crops : rice, oil palm, coconut, maize, sorghum, pasture folder grasses, ground nuts, soy bean and sugar cane. These publications list

recommended fertilizer application rates for the 8 agricultural districts or state of Peninsula Malaysia.

- To minimize and compensate groundwater pollution will be introduced by using the knowledge base from environmental impact assessment (EIA) reports submitted to Department of Environmental (DOE), FAO reports, established literature's and domain expert.

ANALYSIS

Groundwater pollution expert system, computer software, is developed from CLIPS program. It has the capability of decision making in predicting groundwater pollution potential from the use of nitrogen fertilizer in agricultural activities. This system combines the knowledge base or static data base which is composed of facts and rule base from the information about the existing environment, and then projecting into the future. The information is composed of data from the physical framework, the hydrological framework, model and expert system framework and development framework. The system has interaction among all of data interfacing with user by programming and inference engine, drawing from information about the existing environment or the question and answers. It is and occurrence of dynamic database, until the expert system is able to make the necessary conclusions, or until it fails to do so, if there is not enough data. Groundwater vulnerability model was incorporated in the expert system, which is the model that uses equation 1 as shown below. It is a method of empirical models and consist of several factors for determining relative aquifer vulnerability. All factors involve scoring soil column on the basis of a set of factors known to be related to groundwater contamination. The groundwater pollution potential can be presented as follows :

$$Potential\ pollution = D_wD_s + R_wR_s + A_wA_s + S_wS_s + T_wT_s + C_wC_s \quad (1)$$

where, D is depth to water table, R is net water recharge, A is aquifer medium, S is soil medium, T is topography, I is impact of vadose zone medium, C is hydraulic conductivity. The vulnerability of groundwater in a soil column is determined by assigning a score based on the observed range of each factor. The score is multiplied by an associated weight, and the results are summed to obtain an index. The subscript w indicates feature weights, and the subscript s indicates feature scores (Baum, 1994). Data from the Soil and Analytic Service Branch Division of Agriculture, Ministry of Agriculture and Rural Development Malaysia , including recommended nitrogen fertilizer application rates for the nine crops, i.e. rice, oil palm, maize, sorghum, pasture folder grasses, ground nuts, soy bean and sugar were used in this study. These publications list of recommended fertilizer application rates for 8 agricultural districts or state of Peninsula Malaysia. The information on cropped areas and recommended nitrogen fertilizer application rates with in the study area, which is predicated were summed to give the total acre of planted crop land within the study area. The total amount of nitrogen fertilizer applied to a specific crop within a study area was computed as :

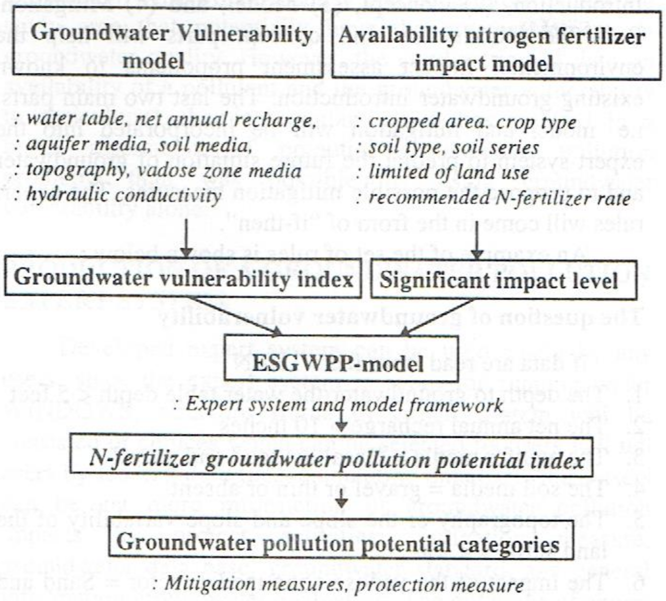

Figure 1. Flow chart of groundwater pollution expert system for evaluating groundwater

$$Ni = Ci \times Fi \quad (2)$$

Ni is the nitrogen fertilizer applied to crop (I) in study area = kg.

Ci is the area of crop (I) planted in the study area = acre.

Fi is the recommended nitrogen fertilizer application rate for crop (I) in agricultural district or in the study area = kg/ha. The results were summed to give the estimated total nitrogen fertilizer (kg) applied to the study area for nine crops investigated/in existing environment of the study area. This estimation for the study area was divided by the total acres planted in that study area to yield the estimate average nitrogen fertilizer application rate for the study area in kg/planted acre. This estimate of nitrogen fertilizer application rate represents an average for the study area and does not account for spatial variability in cropping patterns within individual study area. The resulting data represent the estimated average nitrogen fertilizer application rate of the study area. General data were created using groundwater pollution expert system tool. The steps are summarized in Figure 1. An N-fertilizer groundwater pollution potential index defined as the intersection of the groundwater vulnerability index and the recommended nitrogen fertilizer applied (kg/planted acre), was created using the groundwater expert system. This procedure linked the availability of a potential pollutant (nitrogen fertilizer) with the groundwater vulnerability to pollution. This approach was modified from the used by Alexander, et al. (1986) and Halliday Wolfe (1991).

EXPERT SYSTEM SKELETON

The expert system skeleton for predicting groundwater pollution potential can be presented as the main flowchart shown in Figure 2. The skeleton of the expert system for groundwater is divided into four main parts : (1)

Introduction, (2) Concept, (3) Model, and (4) Mitigation. Both the introduction and concept parts will help the environmental impact assessment proponents to known existing groundwater introduction. The last two main parts; i.e. model and mitigation will be incorporated into the expert system to predict the future situation of groundwater and to propose the possible mitigation measures. The expert rules will come in the from of "if-then".

An example of the set of rules is shown below :

The question of groundwater vulnerability

If data are read from facts THEN

1. The depth to groundwater/the water table depth < 5 feet
2. The net annual recharge > 10 inches
3. The aquifer media = Basalt or sand and gravel
4. The soil media = gravel or thin or absent
5. The topography or the slope and slope variability of the land surface < 2%
6. The impact of the vadose zone media factor = Sand and gravel
7. The hydraulic conductivity of the aquifer = > 2000 gpd/ft2

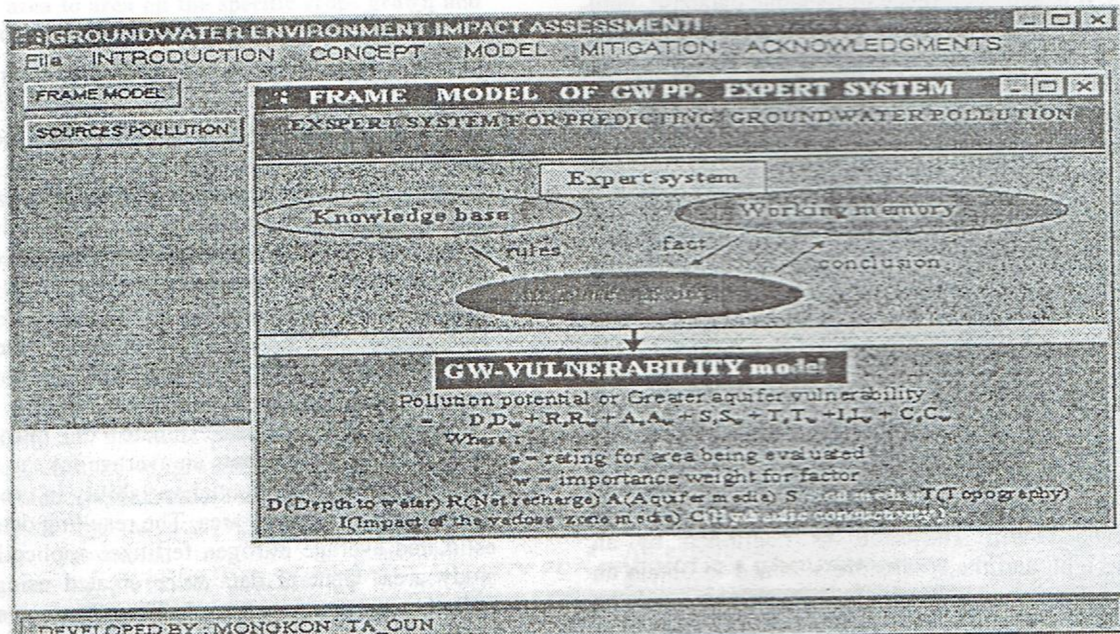

Figure 2. The main of a groundwater pollution expert system skeleton

Result groundwater pollution potential = 221 score

IF groundwater vulnerability index ≥ 183 score

THEN groundwater pollution potential = very high

The question of availability of nitrogen fertilizer

1. How big is total study area to predict groundwater pollution potential due to nitrogen fertilizer application of agriculture activities ? (acre)
2. Is the study area used for oil palm plantation ?
3. What is the soil type used for oil palm plantation ?
4. How big is unique area of oil palm plantation (acre) ?
5. Is the study area used for coconut plantation ?
6. etc. (6-29 question).

These rules eventually be detailed out when the knowledge from all three sources (domain experts, established literature, and field research) are made to complement each other.

EXPERT SYSTEM FOR APPLICATION TO GROUNDWATER PROBLEMS

The cropping data and recommended nitrogen fertilizer application rates are summarized. Data from the Soil and Analytical Services branch Division of Agriculture, Ministry of Agriculture and Rural Development Malaysia and the recommended nitrogen fertilizer application rates for the nine crops, i.e. rice, oil palm, coconut, maize, sorghum, pasture folder grasses, ground nuts, soy bean and sugar cane were used in this study. These publications list recommended fertilizer application rates for the 8 agricultural districts or state of Peninsula Malaysia. The value for each agricultural district/state of Peninsula Malaysia in which the particular crop was grown was around 50 to 368 kg/acre (FAO, 1983; Kanapathy, 1976; Maximizing, 1983; and Nikm Mohdm Kamil and Librero, 1988). An N-fertilizer groundwater pollution potential index were grouped into 4 pollution potential categories for nitrogen fertilizer. The use of a relatively large percentage for the moderate category minimized the likelihood of the study area being mis-classified between the high and low pollution potential categories (Alexander, et al., 1986). However, this does mean that some study area identified on the upper and lower bounds of the moderate pollution potential category could be considered of high or low pollution potential, respectively. The basis for the approach used in this study was the hypothesis that a better screening tool for identifying potential pollution problems would result from the correlation of pollutant availability with groundwater vulnerability rather than considering just groundwater vulnerability. If groundwater vulnerability index alone was used for screening, this land would be high on the priority list for monitoring. When using the additional information on nitrogen fertilizer eliminates this same land from the priority list for potential contamination from nitrogen fertilizer. The N-fertilizer groundwater pollution potential index used in this analysis represented average data for study area and did not include the spatial variability within study area. After identifying high pollution potential study area from an N-fertilizer groundwater pollution potential index a detailed screening within these study area could be conducted based on the spatial distribution of crops within individual study area. This may eliminate some additional areas from top priority. For example, the study area typically have less intensive cropping due to shallow soils and rock out crops. The lack of crops in these areas would reduce the N-fertilizer groundwater pollution potential index to the very low category, although the groundwater vulnerability index would be likely to assign in areas with high values. The results of this study indicated that present cropping patterns and practices in areas with high groundwater vulnerability and availability of nitrogen fertilizer have a potentially negative impact on groundwater quality. To assess which crops have the greatest impact on groundwater quality in high an N-fertilizer groundwater pollution potential index of study area, a more detailed investigation of the distribution of cropland needs to be undertaken. This would identify individual crops within the study area that potentially have the greatest impact on groundwater quality. However, the combination of data on availability of a pollutant and the groundwater vulnerability to agricultural chemical contamination has resulted in a better assessment of potential groundwater pollution problems than was possible by using groundwater vulnerability alone.

PRODUCTION OF A GROUNDWATER POLLUTION EXPERT SYSTEM

Developed expert system can be used easily by any users, since the expert system is setup for running under WINDOWS, structure frame of expert system will be consisted of choices which can be selected by users will tell users by loading data files, calculating data base, thus, users can be get more information of groundwater pollution impacts by project activities, mitigation measure, groundwater data base, groundwater standard, and general information groundwater evaluation. The out come of expert system will present on monitor in forms of file output, picture, graphics, sound and printed out details. Using expert system for predicting groundwater pollution potential will have the question and possible answer to choose. Just key in the answer number of derived question as shown in Figure 3-4. After putting in the answer numbers of the questions, then the expert system will evaluate the data by the combination of these question. Thus, the results of the evaluation are shown in Figure 5 and mitigation measures and management control are shown in Figure 6 when the evaluation of groundwater pollution potential is high risk.

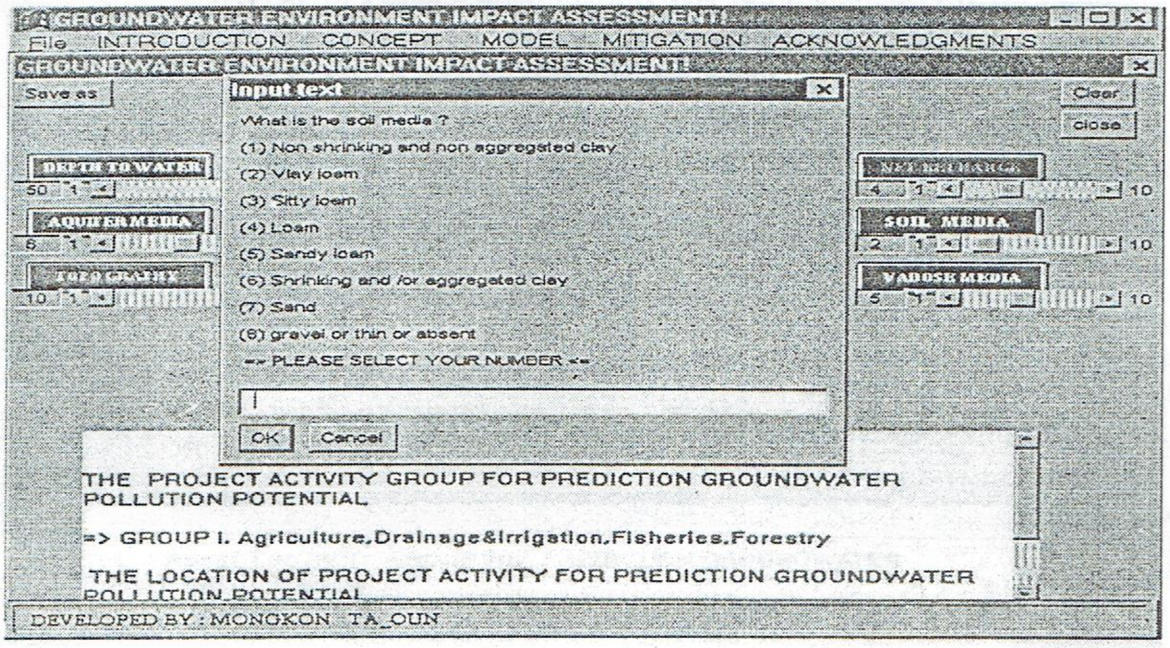

Figure 3. An Example question in groundwater vulnerability model : What is soil media tending to affect on groundwater pollution ? (possible answers are shown as choices on screen)

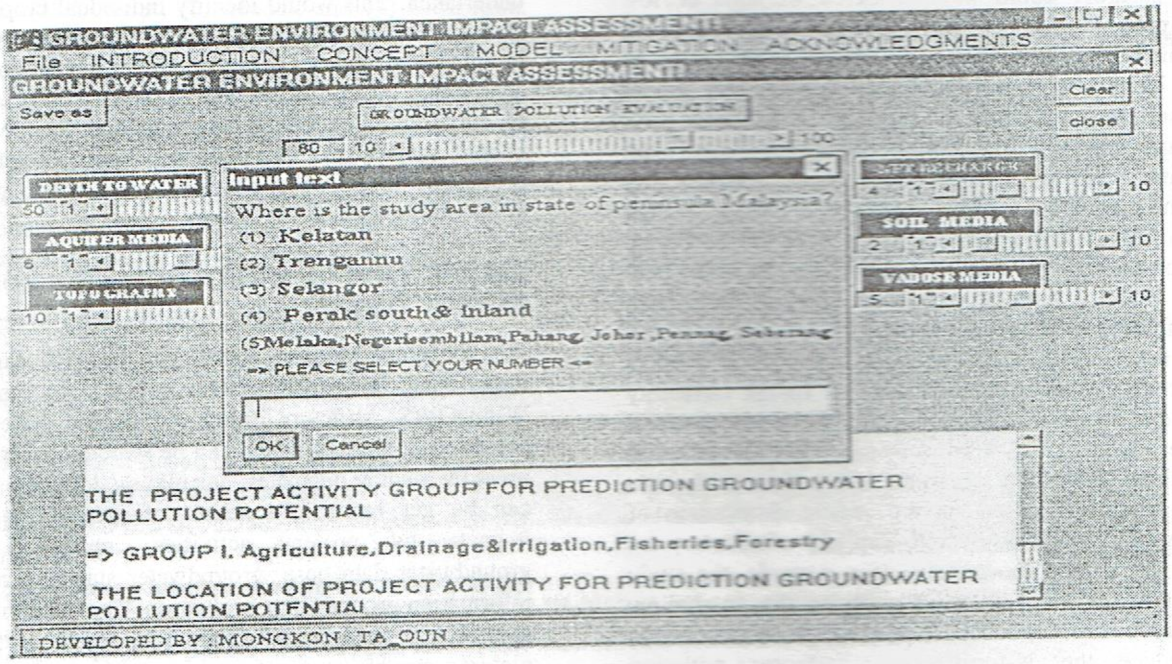

Figure 4 An Example question in availability of nitrogen fertilizer model : Where is the study area in state of peninsula for rice plantation ?

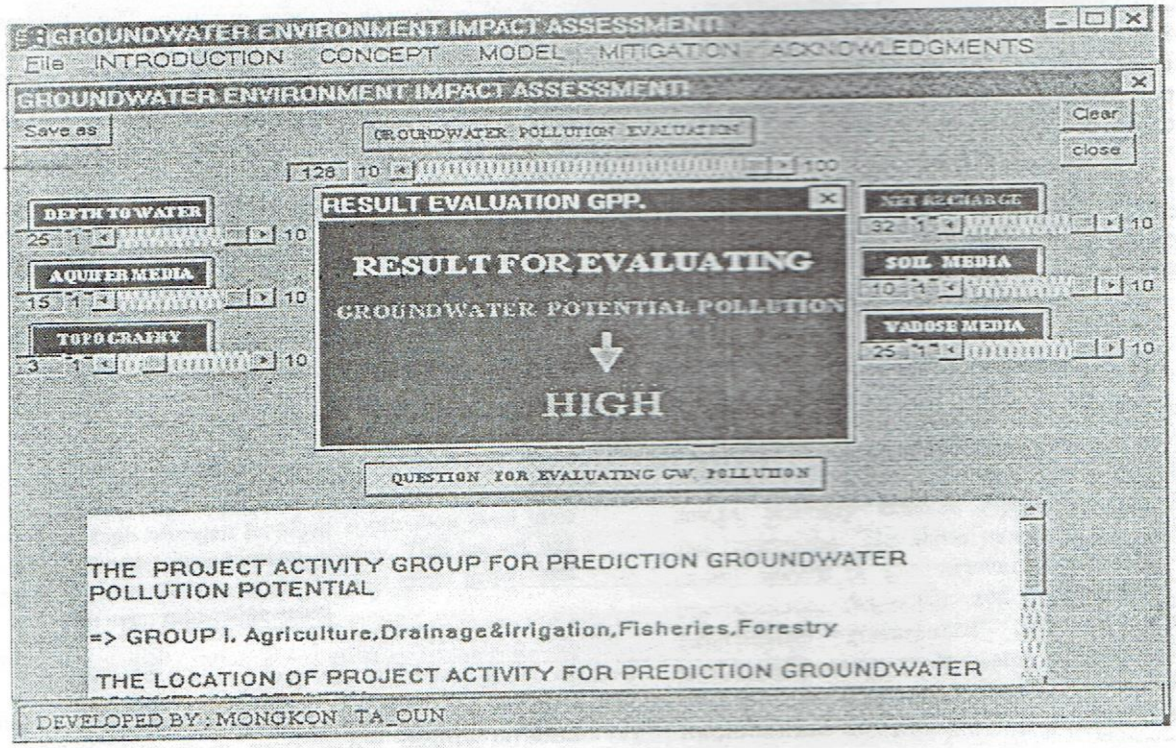

Figure 5 Example of results of evaluating groundwater pollution potential. (High)

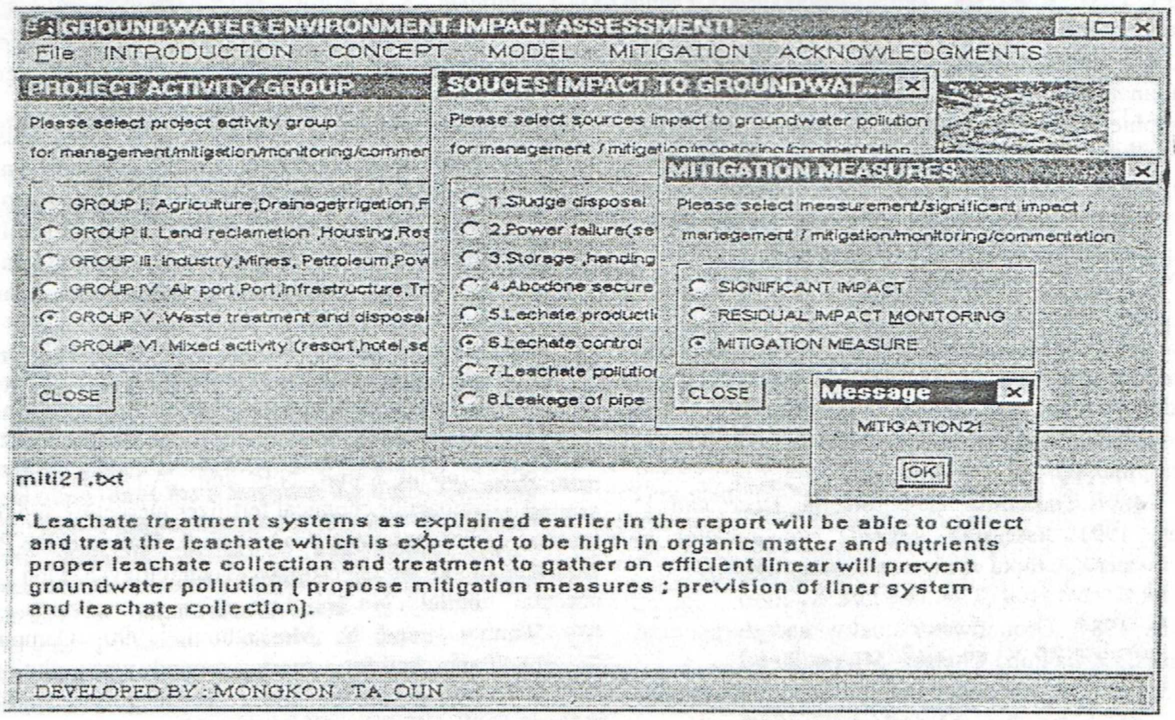

Figure 6 An example of mitigation measure for minimizing groundwater pollution

CONCLUSION

The basis for the approach used in this study was hypothesis that a better screening tool for identifying potential pollution problems would result from the correlation of pollutant availability with groundwater vulnerability rather than considering just groundwater vulnerability.

The skeleton of an expert system for predicting the impact of nitrogen fertilizer from agriculture activities on groundwater pollution potential is divided into four main parts. Both introduction and concept parts will help to produce existing groundwater introduction. The last two main parts; i.e. model and mitigation will be incorporated into the expert system to predict the future situation of groundwater and to propose the possible mitigation measures. The expert rules will come in the form of "if-then". Knowledge base extracted from FAO reports, Ministry of Agriculture and Rural Development Malaysia, several sources of established literature and domain expert were used in preparing the expert system skeleton. A groundwater pollution expert system was used to assess the groundwater pollution potential from nitrogen fertilizer applied to cropped area in Peninsula Malaysia. An N-fertilizer groundwater pollution potential index was generated by combining groundwater vulnerability index (the vulnerability of a study area) with the recommended rate of nitrogen fertilizer application to the planted area of nine crops. Four categories of groundwater pollution potential were identified base on the N-fertilizer groundwater pollution potential index as follow very low, low, moderate and high. The results of prediction, generally, indicate that groundwater is most vulnerable to nitrate leaching where : the soil and unsaturated zone are thin and permeable, several crops a year are grown, fertilizer inputs are high.

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