Evaluation of waste disposal site using the DRASTIC system in Southern Korea

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Abstract: As a systematic approach to waste disposal site screening for groundwater pollution protection, the DRASTIC system developed by the US Environmental Protection Agency (USEPA) was introduced at Younggwang County in Korea. Hydrogeologic spatial databases for the system include information on depth to water, net recharge, aquifer media, soil media, topographic slope, hydraulic conductivity and lineament. Using the databases, the DRASTIC system and a GIS, the regional groundwater pollution vulnerability of the study area was assessed. The fracture density extracted from lineament maps was added to the DRASTIC system to take into account the preferential migration of contaminants through fractures. From the results of the study, a degree of groundwater pollution vulnerability through the study area was easily interpreted, and waste disposal sites could be screened for groundwater protection

Keywords: DRASTIC, GIS, Waste disposal site, Groundwater vulnerability, Korea.

1. Introduction

Because hazardous polluting material can be spread widely by groundwater near a landfill site, groundwater pollution protection is a very important factor in waste disposal site location. The waste site, especially for hazardous and solid waste disposal, must be in an area with a low vulnerability to groundwater pollution, to prevent easy movement by the groundwater. Thus, the objective of this study is to screen for waste disposal sitting with respect to groundwater protection by performing a groundwater vulnerability assessment using a modified DRASTIC (Aller and others 1987) approach combined with a Geographic Information System (GIS). The hydrogeologic factors that affect the potential for groundwater pollution, defined in the DRASTIC system are follows; D = Depth to water, R = net Recharge, A = Aquifer media, S = Soil media, T = Topography or slope, I = Impact of vadose zone media, and C = hydraulic Conductivity. In this study, the procedure for implementing the DRASTIC method and screening for waste disposal sitting using GIS involves: (1) collecting hydrogeologic and geologic data, (2) standardizing and digitizing source data, (3) constructing an environmental database, (4) analyzing the DRASTIC factors, (5) calculating the DRASTIC index for the hydrogeologic settings, (6) rating these areas as to their vulnerability to contamination, and (7) screening for waste disposal siting.

2. Groundwater pollution vulnerability assessment system

The DRASTIC system is composed of two major parts: (1) the designation of mappable units, termed hydrogeologic setting; and (2) the application of a numerical scheme of relative ranking of hydrogeologic factors, which helps to evaluate the relative groundwater pollution potential of any hydrogeologic setting. Hydrogeologic setting is a composite description of all the geologic and hydrologic factors controlling groundwater flow into, through, and out of an area (Kim and Hamm 1999). Hydrogeologic factors of the study area were obtained from the Hydrogeologic Maps of Younggang-Gun Province (Choi and others 1997).

Each DRASTIC factor has been evaluated with respect to the others to determine their relative importance so that a relative weight ranging from one to five could be assigned to each factor. Each factor was further divided into either ranges or significant media types and a rating representing the relative significance of pollution vulnerability was assigned to each range. The DRASTIC system allows the user to determine a numerical value that shows areas more likely to be susceptible to groundwater contamination relative to others. The higher the DRASTIC index, the greater the groundwater pollution vulnerability. There are two types of DRASTIC systems. One is a general DRASTIC system and the other is a pesticide DRASTIC system. The pesticide DRASTIC system is designed to be used where the activity of concern is the application of pesticides to an area and differs in the assignment of weights. The equation for determining the DRASTIC Index is:

$$\text{DRASTIC Index (Pollution vulnerability)} = DrDw + RrRw + ArA + SrSw + TrTw + IrIw + CrCw \quad (1)$$

(r = rating, w = weight, D = depth to water, R = net Recharge, A = Aquifer media, S = Soil media, T = topography, I = Impact of vadose zone media, C = hydraulic Conductivity).

Once the DRASTIC Index has been computed, it is possible to identify areas that are susceptible to groundwater pollution. A modified DRASTIC system is developed in this study. The system combines the DRASTIC system and the lineament density. Lineament refers to numerous linear features of the land surface. However, in this study, it only represents geologic structures such as fractures and joints. Lineament is closely related to groundwater flow and contaminants migration resource;

therefore, higher lineament density values may mean more potential groundwater contamination. Particularly in Korea, most of the aquifers are developed in fractured rock as groundwater mainly moves through faults and fractures. The lineament density is similar to the aquifer media, but the aquifer media only takes into consideration lithology, not fault and fracture. Therefore, by applying an analysis of lineament density to the DRASTIC system, groundwater pollution vulnerability can be assessed more accurately. Using the lineament database, lineament density is obtained from the photolineament value (Hardcastle 1995). When considering lineament frequency, the obtained lineament density was rated in 10 equal areas (about 10%). Then, the chosen range and rating was assigned to lineament density and overlaid with the DRASTIC system. The weighting of the lineament density was set to five, i.e., the highest of the DRASTIC system weighting values, because of the importance of the lineament density. The modified DRASTIC system index was thus calculated using Eq. 2.

$$\text{Modified DRASTIC index} = \text{DRASTIC index} + L_rL_w \quad (2)$$

(r = rating, w = weight, L = lineament density)

3. Study area and spatial database

The study area is Younggwang County in Korea. The site lies between latitudes 35°10' N and 35°27' N, and longitudes 126°20' E and 126°40' E, and covers an area of 460 km^2. The geology of the study area consists of Pre-Cambrian gneiss, metasedimentary rock of an unknown age, Jurassic granite, Cretaceous volcanic rock, dikes and Quaternary alluvium. The study area has a population of a half million. Efficient development and management of groundwater are needed in the study area because of the increasing demand for groundwater and the existence of various potential sources of groundwater pollution, including agricultural activities, industrialization, and seawater intrusion. Also, waste disposal sitting is needed because of increasing amounts of hazardous solid waste.

Topographic, geologic and groundwater related data were collected through the study area. The data were formed into a spatial database using GIS, for groundwater pollution vulnerability assessment. The topographic database was constructed using a 1:50,000 scale topographic map (contour interval of 20m). This database has line attributes (vectors). The vector coverage was interpolated into a digital elevation model (DEM) with 30m resolution, then a height distribution map, slope map, aspect map, hillshaded map, surface water flow map and basin map were made using the DEM. These are needed to detect overall topography and surface water flow. A drainage database was constructed using the 1:50,000 scale topographic map. The drainage database has line and point attributes. The line attributes represent rivers and streams and the polygon attributes represent reservoirs, lakes and large rivers. The well database includes information about wells and groundwater. A well inventory was made 6 times for 252 well sites. The data from the inventory are well location, owner, address, phone number, installation year, use, depth, diameter, static water table, survey date, depth to water level, temperate, pH, EC and TDS; and they were formed to spatial database using GIS. The well database has point attributes. The geologic database was constructed using a 1:50,000 scale geologic map. The geologic database has polygon attributes and includes lithology and fault data. The soil database was constructed using a 1: 25,000 scale detailed soil map. The soil database has polygon attributes and includes soil texture, material. The land-use database has polygon attributes. It was constructed by converting the results of image processing of LANDSAT TM imagery (acquired in 1995. 3. 17) and was used for water budget analysis. The lineament database has line attributes. It was obtained from aerial photo interpretation and used for calculating lineament density.

4. Assessment of groundwater pollution vulnerability and screening waste disposal site

(2)

General pesticide and modified DRASTIC maps were produced. The modified DRASTIC map was made by overlaying the general DRASTIC map and the lineament density map. Using this DRASTIC methodology to perform the aquifer vulnerability assessment of the study area resulted in a pollution potential map of the study area. The steps for producing the maps were: (1) data collection on the study area, (2) database construction using the collected data, (3) extraction of hydrogeologic factors from the database, and (4) overlay analysis of the factors. The impact of the vadose zone is excluded because of insufficient data. The resultant values from Eq 1 are as follows: the minimum DRASTIC index is 55 and the maximum DRASTIC index is 141; the minimum pesticide DRASTIC index is 66 and the maximum pesticide DRASTIC index is 187; and the minimum modified DRASTIC index is 68 and the maximum modified DRASTIC index is 191.The final DRASTIC values have been grouped together into very low, low, moderate, high, and very high pollution potential classes. These classes represent the relative pollution potential within the study area. In terms of index extent, 55–97 is classified as indicating a very low pollution potential, 98–102 is classified as indicating a low pollution potential, 103–110 is classified as having a moderate pollution potential, 111–120 is classified as having a high pollution potential, and 121–141 is classified as indicating a very high pollution potential. The criterion of classification is the distribution of the index value with equal area (about 20% for each range). The pesticide DRASTIC map is similar to the general DRASTIC map except for the range of the indexes, 66–118, 119–124, 125–140, 141–150 and 151–187 for very low, low, moderate, high and very high. However, the modified DRASTIC map is different to the general and pesticide DRASTIC maps. The south-middle part of the study area has very high values with the index value above 152 because of lineament density. The modified DRASTIC index is divided into five ranges: 68–114, 115–129, 130–139, 140–151 and 151–191, representing very low, low, moderate, high and very high values, respectively. The site was selected by the criterion that the modified index value is very low, 68–114. Roughly, compared with satellite image of study area, the middle and upper-middle sections of the study area are suitable for waste disposal sites because they have a low level and slope. However, the middle-left area and lower-right sections of the study area are mountainous areas and have a high slope.

5. Conclusion and discussion

Regional groundwater pollution vulnerability was analyzed accurately, quickly and easily using the DRASTIC system and GIS. The groundwater pollution vulnerability map is ideal for use in future land-use planning studies, where potential contamination may occur. To aid in avoiding future contamination of the groundwater by considering the vulnerability of an area before high-risk activities were allowed to take place. Information of non-point and point sources of potential pollutants, including population, livestock, pesticide usage, and industries, will be needed for the risk analysis of groundwater pollution. In the regional screening process for the waste disposal site selection, only the pollution problem was considered. However, in the waste disposal siting, other factors that have not been considered, such as surface water, environmentally sensitive lands and population, must be considered.

The role of a Geographic Information Systems (GIS) in waste management is very significant, as many aspects of planning and operations are highly dependent on spatial data. In general, GIS plays a key role in maintaining account data to facilitate collection operations; customer service; analyzing optimal locations for transfer stations; planning routes for vehicles transporting waste from residential, commercial and industrial customers to transfer stations and from transfer stations to landfills; locating new landfills and monitoring the landfill. GIS is a tool that not only reduces the time and cost of site selection, but also provides a database for future monitoring programs for the site.

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