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Groundwater Pollution Vulnerability by Drastic Method in Ja-Ela Divisional Secretorial Division, Sri Lanka

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Abstract. Groundwater contamination occurs when man-made products such as gasoline, oil, road salts and chemicals get into the groundwater and cause it to become unsafe and unfit for human use. Materials from the land's surface can move through the soil and end up in the groundwater. Ja-Ela Divisional Secretariat Division is one of most populated Division in Gampaha District at Western Province Sri Lanka. The land area is 64 km^2 and it is occupied by 210,294 people with 59,067 house units in 2011. This is high industrialized area occupied by 403 industries in 2017 and bounded to environment sensitive areas like Dandugama River, Muthurajawela wetland and several threaten marshy lands. The main objective of this study is to assess pollution vulnerability of the groundwater in Ja-Ela DSD by using the most commonly used overlay and index method; the DRASTIC method which is developed by United States Environmental Protection Agency (USEPA). Assessment of groundwater vulnerability was done by using a modified DRASTIC model. Evaluation of groundwater vulnerability was done by using computer programs based on Geographical Information System (GIS) in order to facilitate data management and spatial analysis. The most important mappable factors that regulate the groundwater potential are depth of water, net recharge, aquifer media, soil media, topography, impact of vadose zone and hydraulic conductivity of the aquifer. Assessment of DRASTIC Index involves multiplying each parameter weight by its rating corresponding to its study area and summing the total. The monthly average rain fall in this area was 190mm and four main soil types were existed. The land elevation was ranged from sea level to 55m and the depth to groundwater table was varied between 0 to 13m. DRASTIC indexes were ranged from 70 to 195 and the mean DRASTIC index value was 147. According to obtained vulnerability map, negligible vulnerable zones; <80 was exhibited by 0.047% of geographical area; low vulnerable zones ranging from 80 to 120 with 19.6% geographical area; moderate vulnerable zones ranging from 120 to 160 with 46.4 % geographical area; high vulnerable zones ranging from 160 to 200 with 33.2 % geographical area and extreme vulnerable zone with greater DRASTIC index value higher than 200 with 0.6% area from total land extend of Ja-Ela DSD. Generally this was higher potential for pollution. The water quality assessment was done by using 30 sample points. The pH, COD, PO_4^{-3} level, SO_4-^{2} level and NO_3^{-1} level were analyzed. The validation of DRASTIC method was done with comparing water quality values with DRASTIC index value. According to the validation of DRASTIC method with using statistical analysis, measurements, the pH level, SO_4-^{2} level and NO_3^{-1} level were identified as good indicators. The PO_4^{-3} SO_4^{-2} and NO_3^{-1} concentrations of 30 sample points were varied from 0 to 1.5mg/L, 0-64mg/L and 0.4-4.4mg/L respectively. The pH level was acidic and it was ranged from 3.5 to 6.3. The COD level is very less among all points. The DRASTIC index value was shown a positive strong relationship with above mentioned parameters. The results provide important information for the local authorities and decision making personals for effective management of ground water resource.

Key words: aquifer, rain fall, GIS, topography, soil

Introduction

Contamination of ground water can result in poor drinking water quality, loss of water supply, degraded surface water systems, high cleanup costs, high costs for alternative water supplies, and/or potential health problems. The consequences of contaminated ground water or degraded surface water are often serious. When polluted groundwater reaches drinking water systems it can pose serious public health threats. Nutrient pollution can affect vital ground water and drinking water sources. The vulnerability of the groundwater for the pollutant has become an important element for water resource management and land use planning. Hence, maps of groundwater vulnerability to pollution are becoming more in demand because this essential resource for life represents the main source of drinking water in many parts of the world. Water quality assessment and monitoring is one of the first steps required in the rational development and management of water resources. An assessment of groundwater vulnerability is the most feasible step regarding these purposes. The main concept of groundwater vulnerability assessment is the areas which are more vulnerable to pollution than others.

Even though different methods such as hydrological setting methods, parametric methods are existed to assess the groundwater vulnerability, the Overlay & index methods are the most populated and convenience. Some common overlay & index methods are DRASTIC, SEEPAGE, SINTACS, GOD, and EPIK, in which the DRASTIC method is the most accepted worldwide for groundwater vulnerability assessment (Singh *et al.*, 2015).

In this study the DRASTIC model has used (Shirazi *et al*., 2012). The DRASTIC method has been used since 1987 to determine the pollution vulnerability of groundwater (Piscopo, 2001). DRASTIC has an outstanding advantage of permitting a simplicity and flexibility criteria structure to realize the estimation. However, the weights and rates are originally given or dependent on the experiences of assessment experts, which is the major drawback of this method. In order to deal with this issue, some studies have proposed various techniques, such as changing the weights and/or rates of the structure, subtracting or adding additional factors, using sensitivity analyses and calibration approaches, and combining with the analytic hierarchy process (Secunda, Collin, & Melloul, 1998; Huan, Wang, & Teng, 2012; Thapa *et al.*, 2018). Actually these kinds of analysis are much essential at the digitalized and industrialized era like this. As a developing country, Sri Lanka needs to achieve more development goals. But the trouble is these achievements have to be done without compromising of ability of future generation to consume the environment in a sustainable way.

Research Problem

Many Divisional Secretarial Divisions in Gampaha District including Ja-ela DS Division have been suffered from the lacking of groundwater during extreme weather conditions and water quality deterioration. But there are no any clear idea about existing groundwater level, its quality and pollution potential in Ja-ela DS Division. The clear detailed map about the quality, availability and pollution vulnerability of the groundwater in Ja-ela DS Division had still not been evaluated. The decision-making, industrial development planning, policy making and groundwater management are based on water quality data and vulnerability assessment of groundwater.

In 2015, around 403 industries under various scales are located in this study area (CEA, 2015). According to the Census and Statistics Department of Sri Lanka, the total population of Ja-Ela DSD was 201,521 in 2011. According to those data, the pollution potential of ground water is assumed as very high in this area. This area is more vulnerable to groundwater pollution due to the high population density, industrialization, urbanization and land use pattern. The obtained groundwater vulnerability map and DRASTIC index will be provided concepts about high sensitive and high pollution potential areas. The vulnerability map thus generated helps in identifying areas which are more likely to be susceptible to groundwater contamination relative to one another.

Study Area

Ja-Ela Divisional Secretariat Division is one of most populated Division in Gampaha District at Western Province Sri Lanka. This research was conducted within Ja-ela area. Study area is located in Gampaha District at Western Province in Sri Lanka. Geographically it lies between 776000-788000(UTM) N latitude and 374000-384000 (UTM) E longitude. It is bounded on the north by Katunayeka- Seeduwa DS and west by the sea and DSD area of Wattala, on the east by Gampaha DSD, and on the south by Wattala DSD area.

The land area is 64 Km^2 and it is occupied by 210294 people with 59067 house units (Ja-Ela Divisional Secretariat, 2011). Other than to high density of population, numerous industries in various scales are also located here. According to the CEA 2017, 403 of industries which belong to several categories are operated within Ja-Ela DSD including Ekala Industrial Zone. Ja-Ela DSD also linked with Muthurajawela Marsh- Negombo Lagoon environmental sensitive area as well as estuary of Aththanagalu Oya. Other than to these special environmental characteristics, heaps of wetlands are located here. Therefore this study area can be identified as an environmental sensitive area.

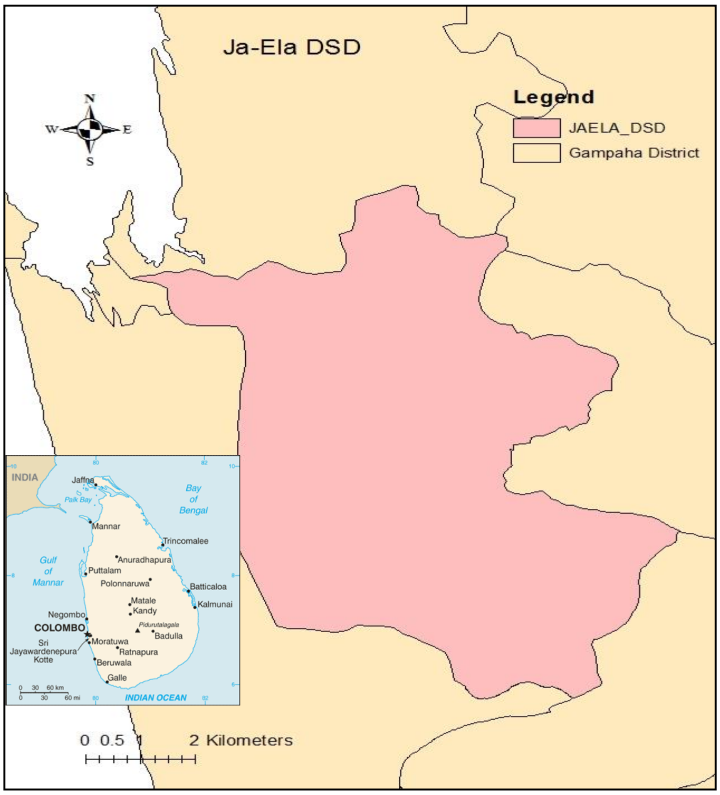

Figure 1: The map of Ja-Ela DSD

Source: made by author with referring the map taken from Department of survey, 2012

Research Method

Main three types of methods are available to analyze the pollution vulnerability. There are index and overlay method, process-based computer simulations and statistical analyses. In this study, the most practiced method; the index and overlay method had used. Even though several types of index and overlay methods are existed, the most popular DRASTIC method which was proposed by Aller *et al*. (1987) was used here.

The reasons for the popularity of the DRASTIC method are it's relatively inexpensiveness, straightforwardness, and ability to uses data that are commonly available or estimated, and produces an end product that is easily interpreted and incorporated into the decision-making process. The most significant factors that regulate the groundwater potential are given in following table.

Table 1. DRASTIC standard weight

Criteria	Weight
Depth to groundwater (D)	5
Recharge (R)	4
Aquifer type (A)	3
Soil properties (S)	2
Topography (T)	1
Impact of the vadose zone (I)	5
Hydraulic conductivity (C)	3

Those parameters were assigned with relative weight ranging from 1 to 5 and all factors were divided into either ranges or significant media types which have an impact on pollution potential. The range for each DRASTIC factor has been assigned a rating which varies between 1 (least pollution potential) and 10 (highest pollution potential). The equation for determining the DRASTIC index was:

$$DI = DR\ DW + RR\ RW + AR\ AW + SR\ SW + TR\ TW + IR\ IW + CR\ CW$$

Where D, R, A, S, T, I and C were the DRASTIC parameters as D-Depth to water, R-Net recharge, A-Aquifer media, S-Soil media, T-Topography, I-Impact of Vadose zone and C-Hydraulic conductivity of the aquifer, R was the rating of each parameter for the study area and W was the importance weight parameter. Seven digital maps were evaluated by using Arc GIS software. The final DRASTIC map was prepared by overlaying the raster formats of those seven maps. The area with higher DRASTIC Index values were indicated the most vulnerable areas for pollutant.

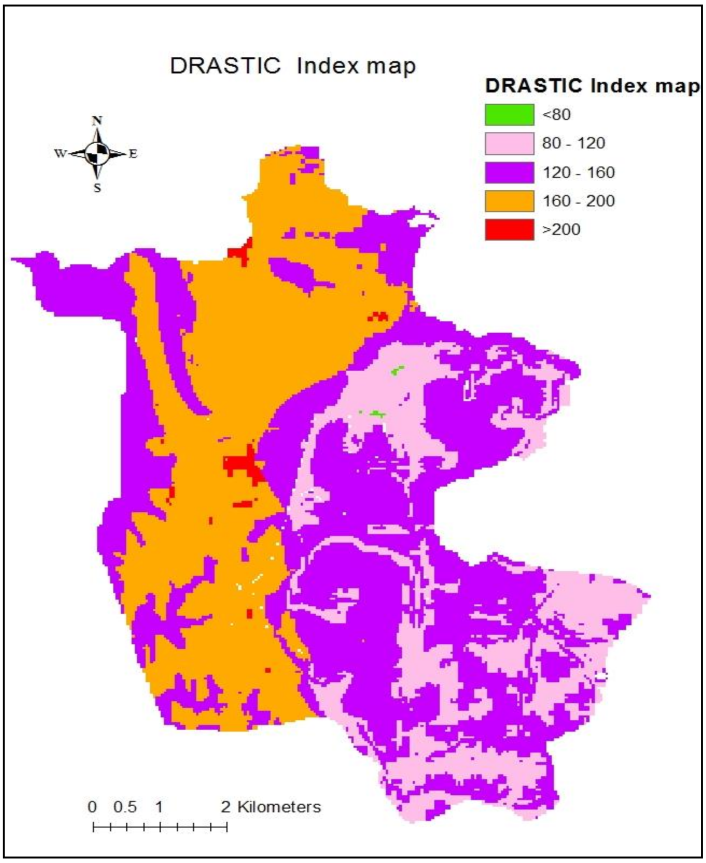

Figure 2: Groundwater pollution vulnerability map of Ja-Ela DSD
Source: evaluated by Author using Arc-GIS software with referring maps taken from GSMB, Department of Survey, Department of Irrigation, 2017

Validation of DRASTIC Method

The accuracy of the DRASTIC method was assessed by investigating the quality of ground water parameters. The measured parameters were pH, COD, PO_4^-, NO_3^- and SO_4^{3-} and certain parameters was measured within 30 sites. The obtained DRASTIC index values for certain 30 points were compared with measured pH, COD, PO_4^-, NO_3^- and SO_4^3 variations. The bivariate correlation under SPSS software was used to determine the validation of DRASTIC method by comparing the DRASTIC index with measured certain parameters.

Conclusion

DRASTIC indexes were ranged from 70 to 195 and the mean DRASTIC index value was147. According to obtained vulnerability map, negligible vulnerable zones; <80 was exhibited by 0.047% of geographical area; low vulnerable zones ranging from 80 to 120 with 19.6% geographical area; moderate vulnerable zones ranging from 120 to 160 with 46.4 %.geographical area; high vulnerable zones ranging from 160 to 200 with 33.2 % geographical area and extreme vulnerable zone with greater DRASTIC index value higher than 200 with 0.6% area from total land extend of Ja-Ela DSD. Generally this was higher potential for pollution. The PO_4^{-3} SO_4^{-2} and NO_3^{-1} concentrations of 30 sample points were varied from 0 to 1.5mg/L, 0- 64mg/L 0.4-4.4mg/L and respectively. The COD level is very less among all points. Ja-Ela DSD is classified as the medium vulnerable zone. However areas like Kandana, Ekala and Ja-Ela are located within the area of high vulnerability zone.

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