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GIS based modelling of groundwater vulnerability: a case study of Birmingham urban unconfined aquifer, United Kingdom

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The present paper presents results obtained for ground water vulnerability assessment of Birmingham urban unconfined aquifer for conservative contaminants and volatile organic pollutants, viz. Benzene, Toluene, Ethyl benzene and Xylene (known as BTEX) and pesticides (e.g., Atrazine) using process based approaches implemented in GIS based UGIf model. UGIf is a GIS based urban recharge pollutant flux model, developed in 2001 using ArcView GIS (ver. 3.x) for estimating groundwater recharge and pollutant fluxes of nitrate, chloride and BTEX in UK urban environments [1]. This model was further modified with the incorporation of three screening level groundwater vulnerability models viz. 1) the Attenuation Factor (AF) model, 2) Leaching Potential Index (LPI) model and 3) Ranking Index (RI) model and a simple approach to assess intrinsic vulnerability of conservative contaminants (chloride) based on the evaluation of vertical travel time from the surface to aquifer.

The input data used in this modelling work for the area covering Birmingham unconfined aquifer are the following: meteorological data (rainfall, evapotranspiration and soil moisture deficits), land use / land cover map, soil map/hydrologic soil group map, geological map with lithology, hydraulic and geochemical attributes for the lithological units; topographic elevation and water table depth data. The steps followed in vulnerability assessments using the UGIf model were the following: 1) estimation of average direct recharge during winter and autumn period, 2) preparation of Vadose Zone Depth (VZD) map, 3) combining grids of recharge, geology (lithology) and VZD, 4) assigning of soil textures, Hornberger constants, porosity and saturated hydraulic conductivity to the lithological units, 5) calculation of vadose zone volumetric water content using the Clapp and Hornberger method, 6) assigning of bulk density and fraction of organic carbon content, 7) calculation of soil-water partitioning coefficient values and vadoze zone retardation factors for BTEX and Atrazine, and 8) vulnerability assessments (calculation of 3 indices of ground water vulnerability and vadose zone travel time for BTEX & pesticides, and calculation of travel time for conservative pollutants).

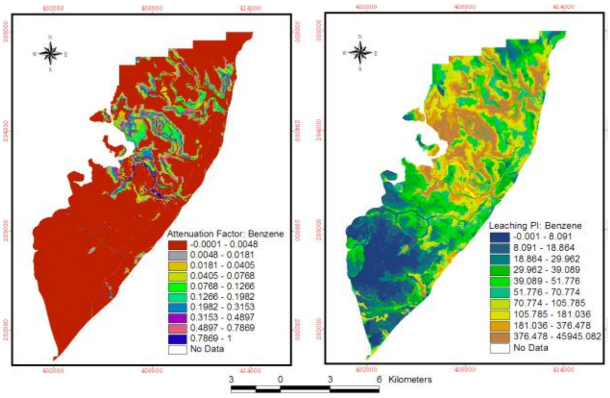

Figure 1: Attenuation Factor & Leaching Potential Index for Benzene in Birmingham.

Areas showing higher AF & LPI and lower RI and vadose zone travel times for a specific pollutant have more likelihood of contamination to groundwater. Higher AF values for benzene are observed in areas having low VZDs (areas underlain by/adjacent to River Tame). The extent of area showing positive AF values is higher for Benzene than the other contaminants. Higher LPI values (Benzene: 181-45,945, Toluene: 18-895, Ethyl benzene: 31-2,586, Xylene: 65-5,242, Atrazine: 10-562) are seen in certain portions of the central and northern parts of the aquifer.

The maximum value of RI for benzene is much lower (<340) when compared to other modelled contaminants. On comparing the travel time values for BTEX & Atrazine, much higher values (2,477 - 10,247 years) are predicted for Ethyl benzene in the southern part of the aquifer indicating lesser susceptibility to contamination due to higher VZDs. The travel time of chloride ranges from 0-294 years (0 – 4.5 years in areas of low VZDs). The indices obtained for BTEX and Atrazine suggest that most of the study area is not vulnerable except the portion underlain by / adjacent to River Tame.

References:

[1] Thomas A and Tellam J H (2006) Science of the Total Environment 360: 158-179.