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Assessment of shallow and deep aquifers susceptibility to point source contamination using the Weights of Evidence method

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In densely urbanized areas groundwater represents a valuable resource for the public, agricultural and industrial supply and, thus, for the socio-economic development. In this context, the high presence of anthropogenic activities together with the use of inadequate groundwater protection measures have a severe impact on the qualitative status of water bodies. Pollution in urban groundwater is caused by various sources including point sources commonly related to landfills and industrial spillages and responsible, for example, for chlorinated solvents and chromium contamination.
To cope with this problem, statistical methods can be considered effective tools to provide key information for environmental planning and management. Among the various techniques, the Weights of Evidence (WofE) has proved to be a reliable method to assess the qualitative deterioration of the unconfined shallow aquifer due to non-point sources, typically related to nitrate contamination.
This study provides the first application of the WofE methodology for estimating the susceptibility of both unconfined shallow and confined deep aquifers due to point source pollutants, as PCE+TCE and chromium, in the Province of Milan (northern Italy). The advantage of this technique consists in the possibility of identifying, for each pollutant, the hydrogeological and land use conditions that contribute to the development of contamination phenomena. This result is achieved by quantitatively evaluating the spatial correlation between pollutants occurrence and natural and anthropogenic factors potentially influencing the contamination in each aquifer.
For the shallow aquifer analyses, the selected factors include: i) groundwater depth, ii) hydraulic conductivity of the unsaturated zone, iii) groundwater velocity, iv) degree of confinement and v) the distribution of industrial, artisanal and commercial settlements, representing potential sources of PCE+TCE and chromium contaminations.
For the deep aquifer analyses, we selected: i) thickness of the fine sediments between shallow and deep aquifers, ii) distribution of pollutant concentrations in the shallow aquifer and iii) potential leakages from the shallow aquifer system to the deep one represented by the presence of wells screened in both aquifers (multi-aquifer wells).
Results show that geological, hydrogeological and anthropogenic conditions influence the contamination of the shallow aquifer as expected in groundwater susceptibility studies. Moreover, results highlight that the shallow aquifer can easily represent a secondary source of contamination for the deep aquifer due to local heterogeneities of the fine sediments and the inappropriate design of multi-aquifer wells.
All the investigated variables are combined to generate the aquifer susceptibility maps for the shallow and deep aquifers to PCE+TCE and chromium pollutions. These maps are a reliable support tool to be used by stakeholders and decision makers for an appropriate management and protection of the groundwater resource.