A Bayesian approach for the assessment of shallow and deep aquifers susceptibility to point sources contamination in the Province of Milan, Italy

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ABSTRACT
In densely populated areas, urban and industrial activities are responsible for groundwater quality deterioration due to point sources contamination (Kuroda and Fukushi, 2008). In the Province of Milan (Northern Italy), the available water-quality data indicate the occurrence of high PCE+TCE and chromium concentrations in the unconfined shallow as well as in the confined deep aquifers. To cope with this problem, statistical methods can represent reliable tools to provide key information for groundwater management and protection.

Keywords: shallow and deep aquifers, point sources contaminants, urban areas, statistical methods

METHODS

Among the various techniques, the Weights of Evidence (WofE; Bonham-Carter, 1994) technique was identified as one the most appropriate method to assess the susceptibility of aquifers to contamination (Sorichetta et al., 2011). In this study, the WofE technique was used to assess aquifer susceptibility to PCE+TCE and chromium contamination of the shallow and deep aquifers in the Province of Milan (Northern Italy).WofE was used to quantitatively evaluate the degree of spatial correlation (i.e., weights) between pollutants occurrence and factors potentially controlling the qualitative status of the aquifers.
For the shallow aquifer analyses, the investigated 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 settlements, representing potential sources of PCE+TCE and chromium contaminations.
For the deep aquifer analyses, the examined factors include: 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).
The investigated factors, resulting statistically and physically significant, were combined to generate four maps representing the shallow and deep aquifers susceptibility to PCE+TCE and chromium pollution (Fig. 1). Each map was validated using a series of validation procedures proposed by Sorichetta et al., 2011.

RESULTS

The WofE analysis performed on shallow aquifer showed a direct correlation between point sources contamination and i) high values of both groundwater velocity and hydraulic conductivity of the unsaturated zone, ii) low values of groundwater depth, iii) a medium or medium-high degree of confinement, iv) a high presence of industrial activities.

The WofE analysis carried out on deep aquifer outlined a direct correlation between point sources contamination and i) a limited thickness of the fine sediments layer between shallow and deep aquifers, ii) areas with high PCE+TCE and chromium concentrations in the shallow aquifer, iii) a high presence of multi-aquifer wells.

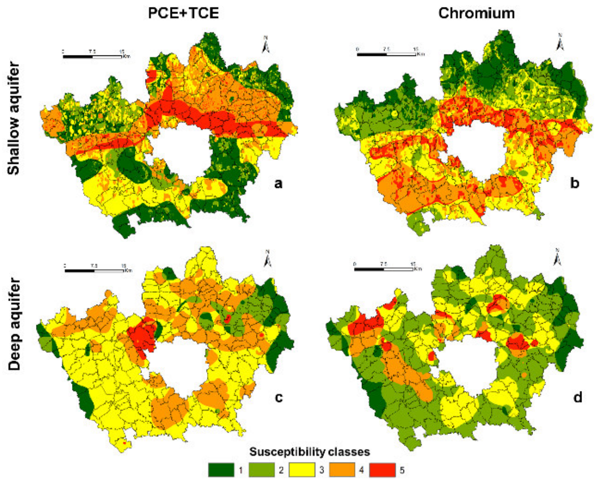

Fig. 3 - Susceptibility maps.

CONCLUSIONS

Although the WofE method has been widely used in shallow aquifer vulnerability analyses to non-point sources (e.g., Stevenazzi et al., 2017 and included references), it has also proved to be effective for evaluating the quality deterioration of both shallow and deep aquifers due to point sources pollutants.

The WofE technique has allowed defining the hydrological and land use conditions that have a high impact on groundwater pollution by identifying the range of factor values that strongly influence the occurrence of point sources contamination in each aquifer.

Moreover, the results have highlighted that the shallow aquifer can be considered as a secondary source responsible for the development of contamination phenomena within the confined deep aquifer. In particular, heterogeneities in the fine sediment separating the two aquifers and inappropriate design of wells (multi-aquifer wells) can favour the vertical movement of the pollutants towards the deep aquifer.

Those results together with the final susceptibility maps can represent an extremely useful support to be used by stakeholders and decision makers for an appropriate management and protection of the groundwater resource.

References

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