A geostatistical approach to investigate the fate of nitrates in groundwater: a study case in the Friuli-Venezia Giulia Region

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Abstract

In the European Union, the presence of nitrates in drinking water from groundwater sources has been regulated by the 91/676/CEE Directory, which limited nitrate concentration in drinking water to 50 mg l^{-1} and termed "vulnerable" those areas that drain surface water to contaminated groundwater. The delineation of a sharp boundary between vulnerable and non-vulnerable areas is however difficult because soil, subsoil and groundwater are always characterized by a continuous variation of chemical properties. Moreover, groundwater monitoring can be carried out in a limited number of wells, and results must be extended to unsampled locations through predictions which accuracy strongly depend on the interpolation method adopted. The present study was aimed at assessing the usefulness of geostatistical techniques in the delineation of areas that, according to the cited Directory, may be vulnerable to nitrates. Data of the years 1980, 1986, 1992 and 1997 came from the groundwater monitoring network of the del Friuli-Venezia Giulia Region. After 1986, nitrates did not longer exceed the 50 mg L^{-1} threshold and the lower threshold of a 10 mg L^{-1} was considered as symptomatic of an agricultural origin of groundwater contamination. Geostatistical analysis was performed using the indicator kriging technique, which is specifically devoted to the spatial distribution of contamination thresholds. Raw data are transformed into an indicator variable giving value 1 to the observation when it exceeds the threshold, and 0 otherwise. Once the variable has been transformed, the indicator kriging interpolates the probability that the threshold has been exceed. The interpolation map will display vulnerable areas with smoothed boundaries that should help policy makers to take management decisions on the basis of the uncertainty associated to the phenomenon of contamination. In the study case, variograms showed two different spatial structures, symptom of different environmental processes affecting nitrate contamination. The short-range structure was possibly related to the vertical movement of nitrate from the soil surface to groundwater, and its range suggested the influence of rather localized factors like soil fertilization. The longest structure, on the contrary, displayed a range comparable to the extension of aquifers along their maximum slope gradient, explainable with the horizontal movement of water and solutes. Probability maps, in the end, delineated the areas in those years vulnerable to nitrates and recorded a gradual attenuation of groundwater contamination over the years.

Key words: geostatistics, groundwater, indicator kriging, nitrate contamination