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Groundwater contamination by nitrates in the city of Konya, (Turkey): A GIS perspective

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Abstract

Groundwater is an essential drinking water source in the city of Konya, Turkey. Approximately 75% of the city's water consumption has been supplied from 198 groundwater wells for the last six years. Nitrate (NO_3^-) is one of the important water quality parameters and was measured in the water samples taken from 139 wells in 1998 and from 156 wells in 2001 within the study area of 427.5 km^2.

To evaluate the nitrate data, a vector-based GIS software package ArcView GIS 3.2 was used. A hardcopy map of the city was digitized in the UTM projection system. The locations of the wells were obtained by a hand-held Global Positioning System (GPS) receiver.

According to the maps produced, nitrate concentrations generally tend to increase in the city center, the average concentrations being 2.2 and 16.1 mg/L for the years of 1998 and 2001, respectively. A statistical correlation procedure was also applied to well depths and nitrate concentrations. As a result, correlation coefficients of 0.259 and 0.261 were obtained for data collected in 1998 and 2001. It is concluded that the distribution of nitrate concentrations is not correlated with well depths within the study area.

Keywords: GIS; Groundwater; Nitrate; Wells

1. Introduction

Groundwater is the source of drinking water for many people around the world, especially in rural areas. Groundwater can become contaminated naturally or because of numerous types of human activities. Residential, municipal, commercial, industrial, and agricultural activities can all affect groundwater quality (U.S. EPA, 1993).

Contamination of groundwater can result in poor drinking water quality, loss of water supply, high clean-up costs, high costs for alternative water supplies, and/or potential health problems.

A wide variety of materials have been identified as contaminants found in groundwater. These include synthetic organic chemicals, hydrocarbons, inorganic cations, inorganic anions, pathogens, and radionuclides (Fetter, 1999).

Nitrate and nitrite are naturally occurring ions that are part of the nitrogen cycle. The nitrate ion (NO_3^-) is the stable form of combined nitrogen for oxygenated systems. Although chemically unreactive, it can be reduced by microbial action. The nitrite ion (NO_2^-) contains nitrogen in a relatively unstable oxidation state. Chemical and biological processes can further reduce nitrite to various compounds or oxidize it to nitrate (ICAIR Life Systems, Inc., 1987). Because of its solubility and its anionic form, nitrate is very mobile in groundwater (Fytianos and Christophoridis, 2003). It tends not to adsorb or precipitate on aquifer solids (Hem, 1985).

The nitrate concentration in groundwater and surface water is normally low but can reach high levels as a result of agricultural runoff, refuse dump runoff, or contamination with human or animal wastes (World Health Organization, 1998). Groundwater contamination by nitrates is a worldwide problem mainly related to the excessive use of fertilizers in intensive agriculture (World Health Organization, 1985; U.S. EPA, 1993). Previous studies have shown that rural land uses, especially agricultural practices, can contribute nitrate to groundwater. Non-agricultural sources of nitrogen, such as

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septic systems and leaking municipal sewers, are generally less significant regionally but may affect groundwater locally (Hudak, 1999; Fetter, 1999).

According to the Turkish Standards Institute (TSE-266), the World Health Organization (WHO) and the European Community (EC), the maximum contaminant level (MCL) of nitrate is given to be 50 mg/L whereas the US Environmental Protection Agency (EPA) allows for only 44.27 mg/L in drinking water. On the other hand, both Turkish Standards Institute (TSE-266) and European Community (EC) describe the guide level (GL) of nitrate as 25 mg/L. (TSE, 1997; World Health Organization, 1998; U.S.EPA, 2001).

Recently, many research projects have examined the relationship between nitrate levels and well depths (Hudak, 1999, 2000; Lee et al., 2003; Lake et al., 2003).

In Konya, the main sources of drinking water are groundwater aquifers, therefore excessive nitrate concentrations in groundwater may be a health hazard for consumers. The aims of this research are: (1) to determine the spatial distribution of nitrate concentration (2) to assess nitrate pollution and (3) to evaluate the correlation between well depth and nitrate concentrations in Konya and area based on 1998 and 2001 data using Geographic Information System (GIS) technology.

2. GIS approach

GIS is a powerful tool and has great promise for use in environmental problem solving. Most environmental problems have an obvious spatial dimension and spatially distributed models can interact with GIS (Goodchild, 1993). Troge (1994) reported that this computer-based tool has allowed successful integration of water quality variables into a comprehensible format.

Lasserre et al. (1999) developed a simple GIS-linked model for groundwater nitrate transport in the IDRISI GIS environment. Hudak (1999) described chloride and nitrate concentrations in groundwater from the measurements of 53 water wells. ArcView GIS was used to map, query, and analyze the data. Spearman's rank correlation coefficient was employed to illustrate and measure associations between variables. There was a statistically significant correlation between nitrate and well depth (−0.637). Similarly, Hudak (2000) documented regional trends in the nitrate content of Texas groundwater and identified probable causes of state-wide groundwater nitrate variability. ArcView GIS was used in that study. Statistically significant, inverse associations between nitrate and well depth were computed.

Another example of using GIS for the benefit of environmental problem-solving was when Vinten and Dunn (2001) studied the effects of land use on temporal changes in well water quality. The nitrate concentration in discharge from the Balmalcolm borehole in Scotland was reported to have steadily increased from 19.2 mg/L in the early 1970s to 47 mg/L in 1998. Levallois et al. (1998) studied groundwater contamination through nitrates associated with intensive potato culture in Québec, Canada. The data analysis was carried out by combining GIS (MapInfo) and statistical methods (SAS) to test hypotheses about the spatial relationship between measured nitrate concentrations and their immediate environment. D'Agostino et al. (1998) described a spatial and temporal study of nitrate concentration in the aquifer of the Lucca Plain, central Italy. Cokriging and ordinary kriging were used as geostatistics methods within an area of about 110 km^2.

Lee et al. (2003) developed statistical models for groundwater quality using GIS. The NO_3–N concentrations were higher in shallow wells (less than 40 m) than in deep wells (deeper than 40 m) in both the dry and rainy seasons. Correlation results between NO_3–N concentration and land uses were generally low and weak. Lake et al. (2003) described the creation of models of groundwater vulnerability using a GIS to combine spatial information on surface leaching, soil characteristics, low permeability superficial (drift) deposits and aquifer type. There was only a weak relationship between vulnerability class and borehole depth and, furthermore, vulnerability class was a much more important factor in accounting for borehole nitrate concentrations than depth.

3. Study area

The city of Konya is located at between 36.5–39.5° north latitude and 31.5–34.5° east longitude and is the largest province of Turkey with a surface area of 38,183 km^2. The population of the city is approximately 850,000. Fig. 1 shows the location of Konya city. The study area is about 17.1 km wide from east to west and 25 km long from north to south, which yields a total area of 427.5 km^2.

Until 1956, drinking water requirements of the city were supplied from 4 springs located southwest of the city. Drilling of the deep-wells was started in 1956 in the north, south and west of the city after the population increased. Drinking water supplied from underground is connected directly to a water distribution network by means of pumping.

In 1995, a drinking water treatment plant was put into operation. The treatment plant was constructed to treat water from Altinapa Dam and it was supposed to supply 43% of the total water requirements of the city. However, the treatment plant supplied only 3.2% of the total water requirements by the year 2001 because of the drought. Therefore, the treatment plant was taken out of operation in 2001 due to the fact that the water level in the dam was too low (Water Authority, 2001).

Presently, new deep wells are still being drilled and operated by the Water Authority of Konya City Municipality (WAKCM), as the water requirements of the city