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Occurrence of Nitrate and Arsenic in Alluvium and Bolson Aquifers of West Texas, USA

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Nitrate and arsenic in drinking water pose significant health risks. Nitrate has been linked to potentially fatal methemoglobinemia and non Hodgkin's lymphoma (Johnson et al. 1987; Ward et al. 1994). Various agricultural sources contribute nitrate to soil and groundwater, including fertilizer, crop residue, animal waste, and mineralization of soil organic nitrogen. Nonagricultural sources of nitrate include septic systems, lawn fertilizer, muncipal and industrial discharges containing nitrogen-bearing effluent, nitrogen fixation by legumes, and atmospheric deposition. Nitrogen compounds in these sources are oxidized in aerated soils to soluble nitrate, which can percolate to groundwater. Once in groundwater, nitrate has a low tendency to filter out of solution. Worldwide, nitrate is one of the most common contaminants in groundwater (WHO 1999). The U.S. maximum contaminant level (MCL) for nitrate in drinking water is 44.3 mg/L (as NO_3) (EPA 2000).

Arsenic is harmful at much lower concentrations. Recently, the U.S. EPA set a 10 ug/L MCL for arsenic in drinking water (EPA 2002). Arsenic uptake can lead to cancer, nervous system disorders, cardiovascular problems, kidney and liver disease, diabetes, and respiratory problems (EPA 2000). Recent studies (Bae et al. 2001) suggest that arsenic may have growth stimulatory (hormetic) effects at very low doses. The World Health Organization (WHO) compiled reports of arsenic in drinking water in several countries, including Argentina, Bangladesh, China, Chile, Ghana, Hungary, India, Mexico, Thailand, and the U.S. (WHO 1999). Arsenic is prevalent in groundwater of the southwestern U.S., including parts of west Texas (Welch et al. 2000).

Of several industrial applications for arsenic (Weast 1992), wood preservation (current) and agriculture (pre 1980) are the largest in the U.S. (Welch et al. 2000). Arsenic has been applied extensively to cropland, especially cotton fields, as a pesticide and defoliant (Piltz 1987). Arsenic also occurs naturally in rock, especially in association with metal sulfide and oxide deposits (Korte and Fernando 1991).

Agricultural practices, including pesticide and fertilizer applications, and urban wastewater are potential sources of groundwater pollution in west Texas. The objective of this study was to compile, map, and evaluate nitrate and arsenic levels in groundwater within alluvium and bolson aquifers beneath a two-county area of west Texas.

El Paso and Hudspeth Counties are located in far west Texas, bordering the Rio Grande to the south and New Mexico to the north (Figure 1). El Paso is the only large city in the predominantly rural study area. Fault block mountains and intervening, sediment-filled basins characterize the region's physiography. Soils range from fine sandy loam and clay on the Rio Grande floodplain to gravely in the foothills. Desert scrub, desert grassland, and pinon-oak-juniper woodland dominate native flora of the region (El-Hage and Moulton 1998). Over the entire study area, annual precipitation and gross lake evaporation average approximately 23 cm and 208 cm, respectively.

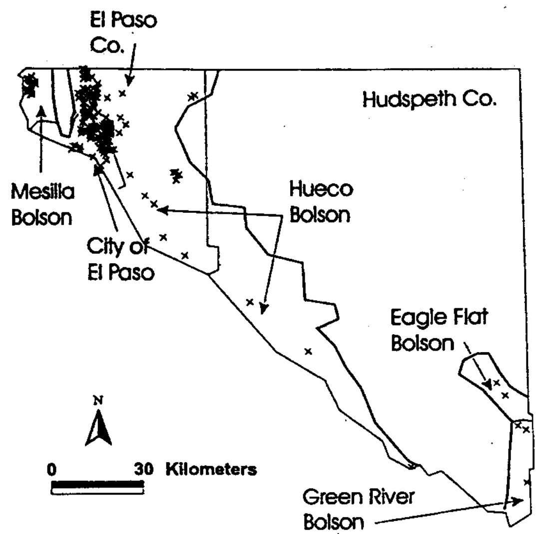

Figure 1. Study area, sampled water wells (X), and aquifer boundaries.

Groundwater supplies about half of the total water consumed in the study area (Mace 2001). Most of this groundwater supplies municipal demands, including public drinking water, in the El Paso metropolitan area and irrigated agriculture (Ashworth and Hopkins 1995). Farming, ranching, and recreation are the predominant land uses outside the El Paso area. Much of the cropland occupies the Rio Grande flood plain. Principle crops grown in the study area include cotton, hay, wheat, and sorghum (USDA 1997). The study area also produces significant quantities of pecans and vegetables, such as tomatoes, onions, and chiles. Pesticides and fertilizers have been applied to cropland and pasture throughout the study area over the past 70 years. Arsenic-bearing pesticides have been used in cotton fields. Native landscapes in the study area consist mainly of shrubland and grassland.

Valley fill (bolson) and alluvial deposits of clay, silt, sand, and gravel yield fresh to slightly saline groundwater in the study area. Five such aquifers were evaluated in this study: the Hueco, Mesilla, Eagle Flat, and Green River bolsons, and alluvium along the Rio Grande (Figure 1). The Hueco bolson comprises the thickest accumulation of sediment, reaching a maximum of 2700 m, although fresh to slightly saline water occupies only the upper 370 m of this sequence (TWC 1989). Alluvium overlies bolson deposits along the Rio Grande. The Hueco and Mesilla bolsons are principle water sources for the El Paso metropolitan area.

Precipitation, stream seepage, and irrigation return flow recharge the aquifers. Most of the recharge occurs in foothills at basin margins (Ashworth and Hopkins 1995). Though interrupted by pumping, groundwater flows generally toward topographically lower parts of the basins. Groundwater in the aquifers discharges to wells, streams, and evaporation. Over the past century, pumping has substantially depleted groundwater supplies in the Hueco and Mesilla bolsons (Ashworth and Hopkins 1995). Overpumping has induced migration of poorer quality water, from both deeper saturated intervals and the overlying Rio Grande, into fresh groundwater zones.

Since 1985, the City of El Paso has injected treated wastewater into the bottom of the Hueco bolson's freshwater zone to augment dwindling groundwater supplies (Buszka 1994). In 1998-1999, nitrate concentrations (as NO_3) in the injected wastewater ranged from approximately 22 to 31 mg/L (EPA 1999). The wastewater treatment plant and injection wells are located near the city's northeast boundary (Figure 1). Abandoned water wells in the El Paso area also constitute potential avenues for contaminant migration (White 1987).

MATERIALS AND METHODS

Water quality and well data were obtained from the Texas Water Development Board. Wells were pumped until temperature, conductivity, and pH stabilized (TWDB 1999). Samples were taken directly from each well, filtered, preserved, and delivered to an analytical laboratory within 24 hours. Analyses were completed using automated colorimetry or ion chromatography. Data used in this study were collected from 1997 to 2001. The most recent measurement was retained at wells sampled more than once during this time interval.

Concentrations of nitrate and arsenic were compiled at 174 wells in five aquifers (Table 1). All 11 wells in the Rio Grande alluvium are within the cluster of wells in the northwestern corner of El Paso County (Figure 1). The remaining 163 wells tap bolson deposits. The wells were used for public (148 wells), stock (4 wells), domestic (3 wells), irrigation (3 wells), industrial (1 well), and recreation (1 well) purposes. The remaining 14 wells were used only for monitoring purposes. Many of the public water supply wells tap the Hueco and Mesilla bolsons in central El Paso County (Figure 1).

MINITAB (Ryan et al. 1992) computed summary statistics for each solute and correlations between solutes and well depth, and compared solute concentrations between aquifers. ArcView (ESRI 1994) mapped well locations and solute concentrations.

RESULTS AND DISCUSSION

Solute concentration distributions were skewed with a right-hand tail. This pattern, typical of water quality data, results from a large number of observations at low concentrations and fewer observations at high concentrations. Median concentrations were closer to the minimum than the maximum value (Table 1). The distribution of well depths showed a similar pattern. Based upon observed, non-normal solute-concentration and well-depth distributions, non-parametric tests were used to compare and evaluate associations between study variables.

Table 1. Summary of well depth and solute concentrations for Hueco (H), Mesilla (M), Eagle Flat (E), Green River (G), and Rio Grande (R) Aquifers.

	Well Depth (m)					Nitrate (mg/L)					Arsenic (ug/L)
	H	M	E	G	R	H	M	E	G	R	H
N	136	20	2	3	11	137	20	3	3	11	5
Mn	23	85	49	28	37	<0.3	<0.3	0.4	1.8	<0.3	8.8
Md	229	168	58	152	49	7.5	1.8	3.1	7.0	2.7	15
Mx	367	368	67	162	67	28.6	2.9	15.5	51.8	3.8	29.2

N=number of observations; Mn=minimum; Md=median; Mx=maximum.

Kruskal-Wallis tests comparing well depth and nitrate concentrations between aquifers (with at least five observations) were statistically significant ($p=0.000$). The Hueco bolson had the highest median nitrate concentration, whereas the Mesilla bolson and Rio Grande alluvium had the lowest median nitrate concentrations (Table 1). The Hueco bolson also had the highest median well depth.

Rank correlations between nitrate and arsenic, nitrate and well depth, and arsenic and well depth were 0.586, 0.266, and 0.117, respectively. Taking into account the number of observations in each computation, only the nitrate and well depth correlation was statistically signficant at $\alpha = 0.05$. A statistically significant, direct correlation between nitrate and well depth suggests deep wastewater injection wells in the El Paso area may have impacted groundwater quality in the study area. Several nitrate observations above 10 mg/L occupied the well field

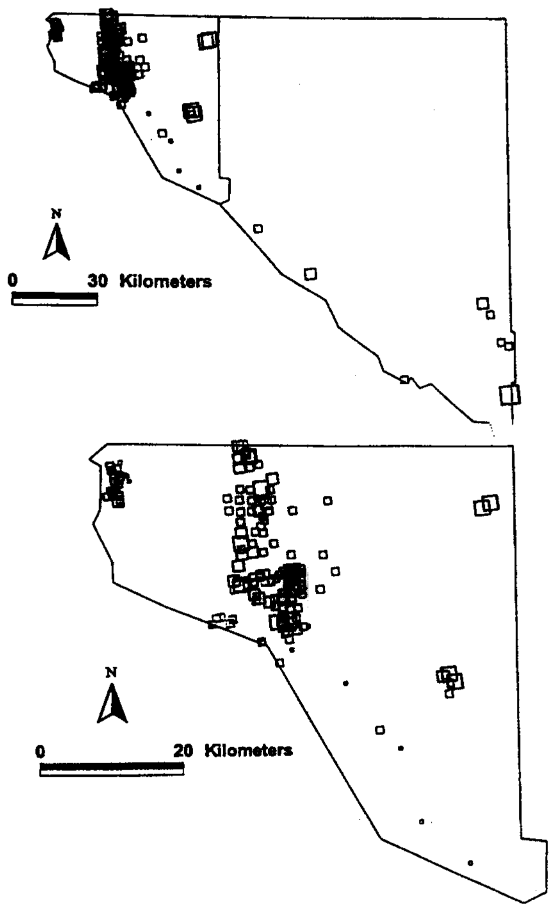

Figure 2. Nitrate levels in study area (top) and El Paso County (bottom); from smallest to largest, squares represent <0.3, 0.3-10.0, 10.1-20.0, 20.1-44.3, and >44.3 mg/L.

tapping the Hueco bolson east of El Paso (Figures 1 and 2). If derived principally from surface applications, correlations between nitrate and well depth would likely be inverse rather than direct. Throughout the study area, sparse rainfall and deep wells, with a median depth of 209 m, curtail pollution from surface sources. However, surface sources such as fertilizer applications have likely impacted groundwater in parts of the study area. For example, relatively high nitrate observations outside the El Paso area cannot be explained by municipal wastewater injection (Figure 2). The highest nitrate observation, in the Green River bolson at the southeast corner of the study area, exceeded 44.3 mg/L.

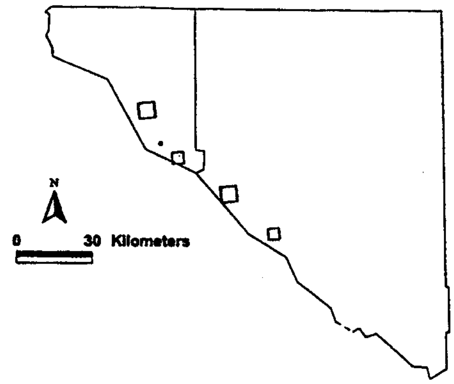

Figure 3. Arsenic levels in study area; from smallest to largest, squares represent 8.8, 10.1-20.0, and 20.1-29.2 ug/L.

Arsenic concentrations were generally high in wells with high nitrate concentrations, although this association was statistically insignificant given the small number of arsenic observations (Table 1). A direct correlation between arsenic and nitrate would substantiate a common origin, such as agricultural activity, for wells impacted by those contaminants.

Although only five arsenic observations were available for the study period, arsenic was consistently detected where measured in groundwater (Figure 3). All of the arsenic data were from wells near cropland along the Rio Grande, but tapping the deeper Hueco bolson. Arsenic pesticides applied to cotton fields in this area may have impacted underlying aquifers. Three of the five arsenic observations exceeded the 10 ug/L standard. This result points to the need for future monitoring, throughout the study area, to further characterize arsenic levels. Arsenic and nitrate are not routinely removed from household wells or community water supplies. Communities in the study area could reduce their risk to nitrate and arsenic exposure by regularly testing and filtering tap water and avoiding adverse land uses near water production wells.

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