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GROUNDWATER URANIUM CONCENTRATIONS--HOW HIGH IS HIGH?

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ABSTRACT

Twelve groundwater samples collected from Platte River bottomlands contained from 22.1 to 257.7 μg/ℓ U. Highest uranium levels occurred in the shallow wells downgradient from irrigated cropland, as did highest levels of TDS and NO_3-N. Fourteen groundwater samples collected from the terrace contained 0.4 to 549 μg/ℓ U. The highest uranium levels occurred in wells screened at the bottom of the Pleistocene sands and gravels. The opposite vertical trend was observed for TDS and NO_3-N. In several of the wells α activity from U was considerably greater than the 15 ρCi/ℓ permissible level for total α activity.

INTRODUCTION

Uranium (U) in the hydrologic environment is of special interest because of its economic importance and its chemical and radiotoxicity and that of some of its daughter nuclides.

Worldwide soluble U concentrations generally range from 0.1 to 10.0 μg/ℓ in rivers (refs. 1-4), lakes (5), and groundwater (5). No maximum permissible U concentration in drinking water has been established in the USA and in terms of activity most USA waters would contain considerably less total α activity than the 15 ρCi/ℓ drinking water standard (6). However, anomalously high U levels do occur. In the Helsinki, Finland area 14 drilled wells had concentrations in excess of 1 mg/ℓ (7) and in the USA concentrations from 10-88 μg/ℓ were observed in the groundwater from the Ogallala Formation (8) and in shallow wells in the Arkansas River valley of western Kansas (9). Recently high U levels (>100 μg/ℓ) have been reported in shallow groundwater in the Platte Valley of Nebraska (10) and the Nebraska State Health Department (11) has warned several municipalities in the Platte River valley that their drinking water supplies exceed the 15 ρCi/ℓ limit.

The purpose of this investigation is to determine the range of U concentrations and activities in groundwater from the Central Platte valley and to determine the likely source or sources of U.

INVESTIGATED AREA

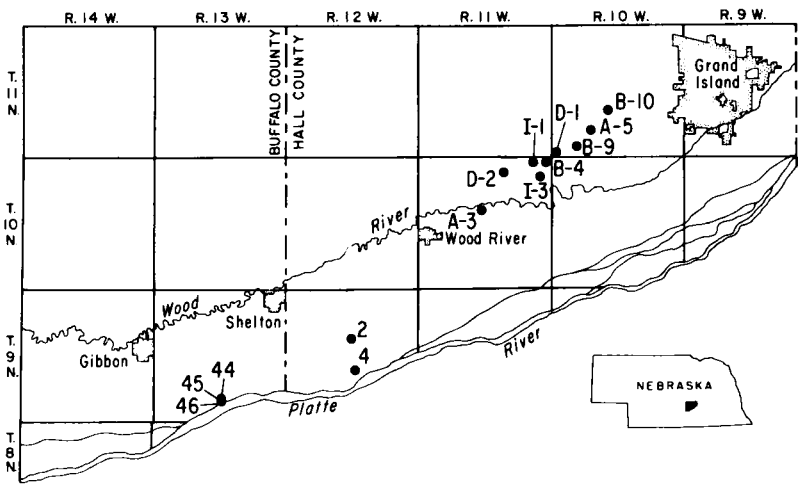

Fig. 1. Investigated area.

The investigated area occupies approximately 275 km^2 on the north side of the Platte River in south-central Nebraska (Fig. 1).

The geology, hydrology, hydrochemistry, and landuse in this intensively farmed area are detailed elsewhere (12, 13) as is the installation procedure for most of the wells (14). With the exception of private irrigation (I-1 and I-3) and domestic (D-1 and D-2) wells, the wells were augered or drilled and cased with 10.2 cm polyvinyl chloride. Several of the wells are in clusters of 3 with each screened at a different depth in the saturated layer. All but wells 1D and 2D are slotted in the primary aquifer--the Pleistocene sands and gravels. Well 2D is screened in a secondary aquifer of fine sands to medium gravels and well 1D is in the Ogallala Formation, a lime-cemented silty sandstone of Tertiary age.

MATERIALS AND METHODS

Isotope dilution (15) was used to determine U concentrations and activity ratios. Sample collection and analytical methods for major ions and nitrate-nitrogen are described in an earlier paper (16).

RESULT AND DISCUSSION

Bottomland well clusters sampled in this study were chosen on the basis of previous hydrochemical investigations (16) which indicated that groundwater in

these clusters ranged from predominately pristine at cluster 4 to moderately contaminated at clusters 44 and 45 to highly contaminated groundwater at cluster 2. Leachates from upgradient irrigated fields were the only apparent upgradient source of contamination for the groundwater because the Platte River forms a shallow water table divide in this area. In all contaminated well clusters the leachate was most obvious in the shallow groundwater, which has become the immediate sink for vertical fluxes of solutes originating in the soils.

TABLE 1
Summary of analytical data

Identification	TDS (mg/ℓ)	NO_3-N (mg/ℓ)	U (μg/ℓ)	Depth slotted below water table (m)
		Bottomland Groundwater		
46S	695	0.6	24.7±0.3	1.2-1.8
45S	1328	26.0	57.1±1.7	1.2-1.8
45M	853	2.4	26.0±0.2	9.1-9.8
45D	629	0.2	21.1±0.2	19.2-19.8
44S	1260	21.0	120.5±1.4	1.2-1.8
44M	906	4.8	44.7±0.5	9.1-9.8
44D	645	0.3	18.4±0.2	19.2-19.8
4S	682	0.1	22.1±0.3	1.2-1.8
4M	694	0.0	22.9±0.2	9.1-9.8
4D	683	0.0	22.6±0.2	19.2-19.8
2S	2277	22.0	257.7±2.3	1.2-1.8
2M	1211	11.0	94.4±0.9	9.1-9.8
		Terrace Groundwater		
A3-S	1117	51	33.2±.2	0.0-2.4
A3-M	691	22.3	16.5±0.2	6.4-9.5
A3-D	848	BDL	42.8±0.3	9.8-12.9
B4-S	1191	57.9	39.8±0.5	0-2.1
B4-M	784	9.0	158.4±1.5	3.6-6.6
B4-D	723	BDL	549±3.3	8.1-11.1
B-9	793	19.6	56.9±0.6	3.5-6.5;8.2-11.2
A5-S	265	0.5	9.2±0.1	0.0-2.1
A5-M	302	0.2	4.8±0.1	3.6-6.7
A5-D	280	0.3	6.2±0.1	8.5-11.6
B-10	337	BDL	0.4±0.02	2.2-5.7;8.7-11.7
I-1	575	26.0	172±1.3	2.5-13.7
I-3	419	15.6	82±0.8	2.5-13.7;27-32
D-1	571	2.3	239±2.4	8.2-11.2
D-2	625	18.4	18.7±0.3	5.0-11.0

S=shallow, M=medium, D=deep, BDL=below detectable limits

As in the previous study (16) the total dissolved solids (TDS) and NO_3-N levels at cluster 4 (Table 1) showed little vertical variation. These concentrations are essentially equal to those of the Platte River (unpublished data), the line source of seepage water in this area.

In the remaining clusters 44, 45, and 2, all of which are downgradient from irrigated cropland, TDS, NO_3-N and U were observed to be stratified (Table 1).

A high degree of association between U and TDS in these wells (r=+0.96) indicates that U and TDS have the same origin. The source of TDS appears to be the accelerated dissolution of evaporite deposits which are common to river bottomlands in the western Great Plains and probably originate from evaporation of receding river water after flooding. Dissolution of evaporites are also the apparent source of elevated U levels in groundwater of the Arkansas River bottomland in Kansas (9). The highest observed major ion and U concentrations in the bottomland are in well cluster 2, which is influenced by the additive effects of leachates from ∿6 km of upgradient cultivated and irrigated fields.

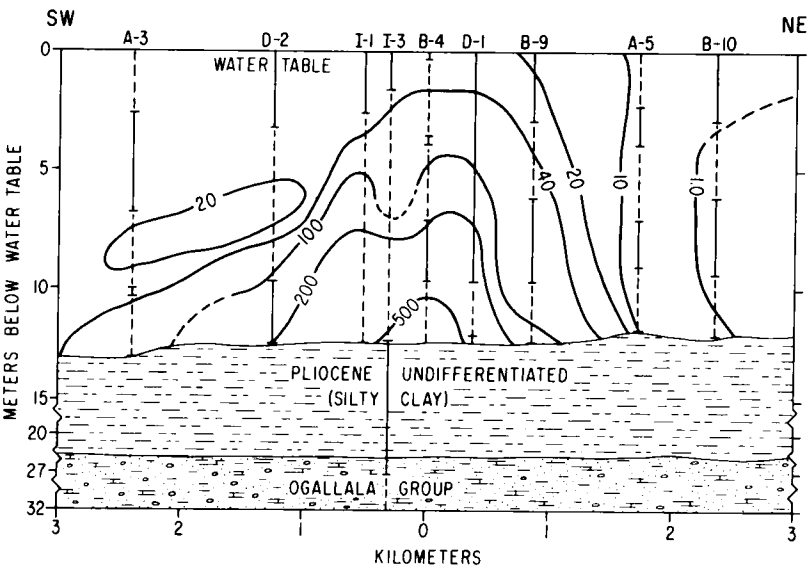

Fig. 2. Vertical distribution of U in terrace wells

The highest U concentrations were located in terrace wells screened at the bottom of the primary aquifer (Fig. 2). These high concentrations, however, are not correlated with TDS and in several of the samples NO_3-N showed opposing vertical trends with uranium (Table 1). These high U concentrations do not appear to result from the northeasterly transport of bottomland groundwater; thus, a second source of U has been mobilized. Deep irrigation wells in the immediate area of cluster B-4 may have induced the remobilization of uranium from low grade deposits at the Plio-Pleistocene interface (Table 1) or from potentially higher grade traps in the Tertiary. Since two irrigation wells upgradient from the high uranium zone are drilled into the Ogallala Formation, it is possible that aeration during pumping has oxidized previously immobilized uranium within the secondary aquifer from the

+4 to the +6 state, thereby mobilizing it. If the above contention is correct, it may explain why elevated groundwater U concentrations were observed to occur along the eastern boundary of the Ogallala Formation in the Grand Island quadrangle (10).

In order to relate U-234 activity to water quality, uranium disequilibrium will be discussed primarily in terms of total α activity. U disequilibrium ratios are thought to result primarily from α recoil transfer (5). This generally results in a positive fractionation of the U-234/U-238 activity ratios in most, but not all, groundwater systems. Disequilibrium values in the groundwater of the central Platte ranged from 1.16 to 1.66 and averaged slightly less than 1.5. Therefore, in terms of total α activity from U in groundwater there is a contribution of about 1.5 ρCi U-234 for each ρCi from U-238. The average concentration in the Platte River was observed to be 24 μg/ℓ and the total α activity from U is $\sim$20 ρCi/ℓ. Thus, it is not surprising that several communities with wells in the Platte bottomland would have water with slightly more than 15 ρCi/ℓ limit.

CONCLUSIONS

Elevated groundwater U concentrations in the bottomland were caused by nonpoint leachates from upgradient irrigated cropland. These U leachates probably are the major cause of elevated total α activity in shallow bottomland groundwater throughout much of the western Great Plains.

Higher levels of uranium in deep terrace wells are from localized mobilization of pre-Pleistocene strata. If the mechanism of this mobilization is increased by deep bedrock irrigation wells, their construction will become a source of future water quality concern.

Injected U compounds are very toxic; however, U ingested by rats at the 400 mg level showed no adverse effect (17). The only potential health problem associated with anomalously high U levels in drinking water appears to be from higher total α radiation exposure. Water containing 30 μg/l U-238 with a U-234/U-238 activity ratio of 1.5 would contribute an accumulated dose of $\sim$375 mrems/year for an individual ingesting 2 ℓ/day. Although the individual is receiving more than normal exposure from his drinking water, his total annual exposure including natural ionizing radiation from cosmic rays ($\sim$100 mrem/year) would still be below the 500 mrem/year limit for total radiation exposure from man-made sources (18). In conclusion, the suggested water quality limit of 10 ρCi/ℓ for uranium (18) would result in economic hardship for many communities in the Platte Valley. Today, in terms of health effects, this limit appears unwarranted.

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