

Use of a geographic information system (GIS) for targeting radon screening programs in South Dakota

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ABSTRACT

Because ²²²Rn is a progeny of ²³⁸U, the relative abundance of uranium may be used to predict the areas that have the potential for high indoor radon concentration and therefore determine the best areas to conduct future surveys. Geographic Information System (GIS) mapping software was used to construct maps of South Dakota that included levels of uranium concentrations in soil and stream water and uranium deposits. Maps of existing populations and the types of land were also generated. Existing data about average indoor radon levels by county taken from a databank were included for consideration. Although the soil and stream data and existing recorded average indoor radon levels were sparse, it was determined that the most likely locations of elevated indoor radon would be in the northwest and southwest corners of the state. Indoor radon levels were only available for 9 out of 66 counties in South Dakota. This sparsity of data precluded a study of correlation of radon to geological features, but further motivates the need for more testing in the state. Only actual measurements should be used to determine levels of indoor radon because of the strong roles home construction and localized geology play in radon concentration. However, the data visualization method demonstrated here is potentially useful for directing resources relating to radon screening campaigns.

KEYWORDS: Geographic Information System, uranium concentration, indoor radon, high-risk areas, mapping

INTRODUCTION

Radon gas is found in buildings throughout the world. It is naturally occurring, colorless and odorless, and if its progeny are chronically inhaled in high concentrations, they can cause lung cancer. Because of radon's carcinogenic nature and the identification of occupied dwellings with indoor radon concentrations as high as 410 kBq m⁻³ [1], many researchers across the globe focused their efforts on measurement methods, surveys, and mitigation techniques [2–25].

²²²Radon is a progeny of ²³⁸U, which comprises over 99% of natural uranium. Therefore, locations containing the highest concentrations of uranium may potentially contain high radon levels. Previous research has documented indoor radon in various areas of the USA [26]. Unfortunately, the amount of data for South Dakota, as well as for Native American lands in general, is small, likely because of their exclusion from early surveys, low population densities, and lack of resources. It is hypothesized that by analyzing the intersection of regions of elevated environmental uranium concentrations with

densely populated areas, regions that potentially have very high indoor radon concentrations could be identified. Testing could be concentrated on areas with elevated uranium, and steps taken to reduce exposure when significant concentrations are found. In some countries, enhanced geographical concentrations of pollutants, which may additionally be coupled with lowered testing, may disproportionately affect specific minority races or cultures, causing 'environmental justice' concerns [27]. While the identification of dangerous indoor radon levels and efficient uses of scarce public health resources are the primary motivators for the design of radon screening campaigns, historical environmental justice considerations are of particular concern in South Dakota because of its large Native American population. In the Four Corners Region of a nearby state, there exists a compelling historical relationship between the Navajo tribe and underground uranium mining, which may be partially motivating enhanced specific concerns about radiation by native people [28]. Mapping may also help to identify regions of special concern from that viewpoint.

METHODS

A Geographic Information System (GIS) mapping program (ArcMap 9.1, ESRI Inc., 380 New York Street, Redlands, CA 92373-8100, 1-909-793-2853, <http://www.esri.com>) was used to map several datasets relating to uranium deposits and radon concentrations in South Dakota. To begin, a base map of the central USA was obtained from the program's library files. This included freeways, water systems, major cities, state and county outlines, population by zip code, and the locations of federally controlled lands, such as national forests and Native American reservations. Data regarding uranium and radon were obtained after contacting multiple geological experts in South Dakota for information. A file containing the location of all known uranium deposits in the state [29] was modified from a mineral resource data system (MRDS) list produced by the US Geological Survey (USGS), which originally contained data points for many minerals [30]. In the modified file, all points that did not contain uranium were removed. Also, many new data points were added after research was conducted on old maps and other reports. A map of all the locations of known uranium deposits was generated. Data obtained from previous voluntary surveys of indoor radon levels [26] were used to generate a map of average indoor radon concentrations by county. Finally, maps of uranium concentrations in soil [31] and in stream water [32] were generated. It should be borne in mind that the purpose of the data accumulation and display was for qualitative exploratory analysis of the potential for elevated indoor radon, and not for rigorous science involving correlation between indoor radon and geology. The blending of information from different sources obtained using disparate methods was not considered to be inappropriate because of the goals of this work. While the impacts of building construction are very relevant and the regional prevalence of different home types could have been mapped, this was not done for this particular study because of a lack of overall information.

RESULTS

The type of land and population are critical considerations when planning radon surveys, because of the need to identify appropriate governmental jurisdiction, regions of impact upon the largest groups of people, and locations of concern from the viewpoint of environmental justice. A map of South Dakota's population by postal zip code appears as Fig. 1, while Fig. 2 shows the locations of federally controlled lands in South Dakota.

As seen in Fig. 3, the locations of uranium deposits appear to be in the northwest and southwest corners of the state. Radon levels could potentially be the highest in those regions. No uranium deposits are found in the central or eastern portion of the state, so lower indoor radon concentrations could be anticipated there. Although the data for South Dakota overall are sparse, the highest uranium concentrations in soil, Fig. 4, are in the northwest corner of South Dakota, at 460 ppm, compared with average global uranium concentrations the order of 2 ppm. The more extensive dataset containing uranium concentrations in stream water, Fig. 5, reveals highest levels in the northwest and southwest corners of the state. The maximum uranium concentration found in South Dakota streams is 250 ppm. Although many streams might not be used as drinking water sources, this is substantially higher than the US average and is an indication of elevated environmental uranium. While the relationship between surface water uranium or radium concentrations and indoor radon has not been

established, elevated surface water concentrations should correlate with increased soil levels. In South Dakota, because of unmitigated uranium strip mining activities, which may dramatically change naturally occurring radionuclide distributions, stream water information is not considered completely irrelevant. All information should be looked at when searching for elevated indoor radon, particularly if there are gaps in data about parameters considered most important. The central portion of the state contains very few soil data points and no stream data points, which makes identifying possible high-radon areas very difficult. Collectively, the data from all three geological datasets relating to uranium concentrations suggest that the highest indoor radon levels could be found in the northwest and southwest corners of South Dakota.

Although the stream samples are quite dense on the west side of the state, there are no samples obtained within the Native American reservations. Although the uranium concentrations in streams surrounding the reservations are not the highest in the state, they are still cause for concern, particularly because of the potential for increased exposure and atypical water usage. Ideally, samples should be obtained within the reservations in order to identify any potential problems and correct them. Soil sample data throughout the state are similarly relatively sparse. For instance, in the southwest corner, although there are multiple uranium deposits, only two soil samples were obtained. A more thorough survey of the amount of uranium in soil would be even more helpful.

Actual measurements of indoor radon are undoubtedly superior information to geological data for predicting public health risk. Unfortunately, the available data [26] from short-term charcoal canister screening tests, mapped in Fig. 6, provide no information about indoor radon levels for western South Dakota. It is interesting to note, however, that for the counties in the state for which radon levels were available, all but Todd County have radon levels well above 48 Bq m^{-3} , which is similar to the average found in homes across the USA. Yankton County had the highest average indoor radon levels of those recorded for South Dakota at 197 Bq m^{-3} . These numbers alone likely justify further testing.

If radon survey averages consistently exceed some value selected by public health officials, then comprehensive surveys should be conducted and appropriate mitigation approaches designed. As shown in previous work, a populated region with higher than average indoor radon levels that also has elevated environmental uranium may contain a dwelling with an extremely elevated indoor radon concentration meritorious of immediate mitigation [1]. Such information provides an excellent opportunity to motivate further efforts toward public health benefit.

The population throughout the high-risk areas varies significantly, but conducting research throughout the entire region is important because of the potential for very high indoor radon gas concentrations in a few homes and the imperative for environmental justice. Although statistically significant data is of concern for research, the primary objective of radon screening is one of protection of individuals. Although only a small number of people live in the northwest corner of South Dakota, because of the potential for incredibly high and dangerous radon levels [1], further testing is readily justified. The number of residents located near the uranium deposits in the southwest corner, known as the Black Hills, is considerably higher and also merits attention. The highest population is located in or around Rapid City, where many people may potentially be exposed

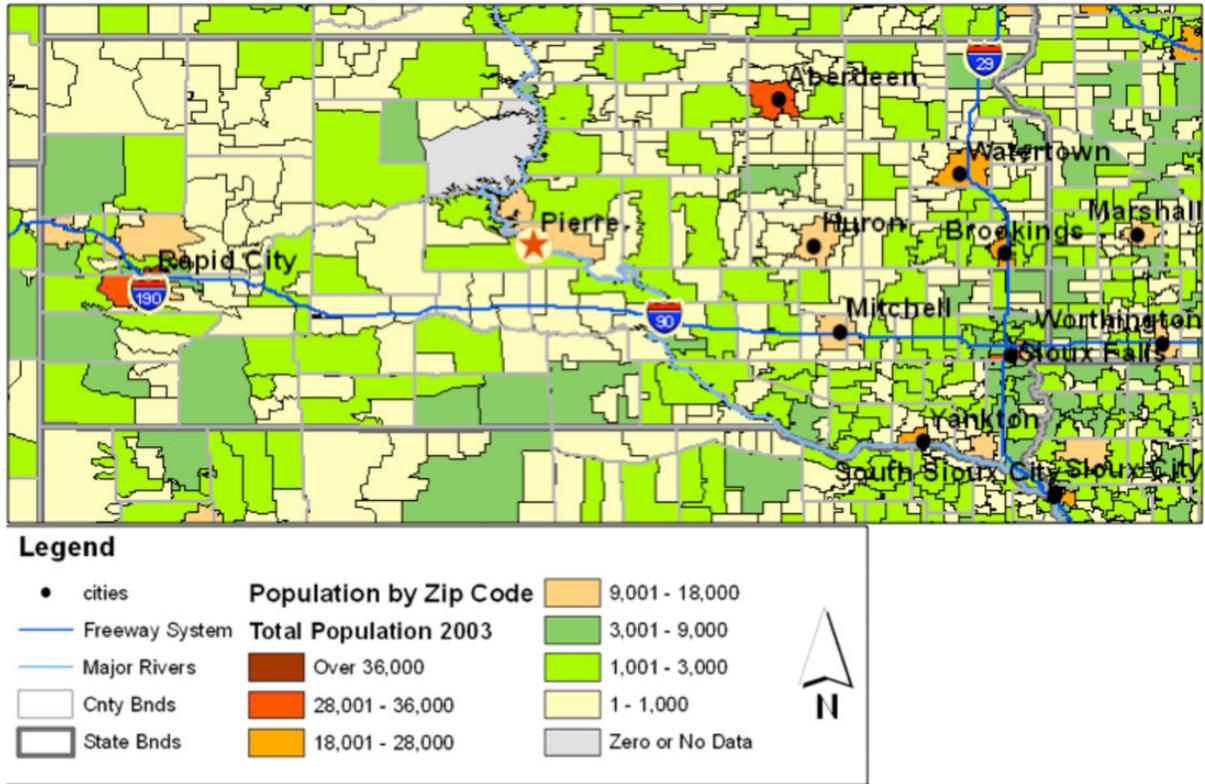


Fig. 1. Map of South Dakota population by zip code.

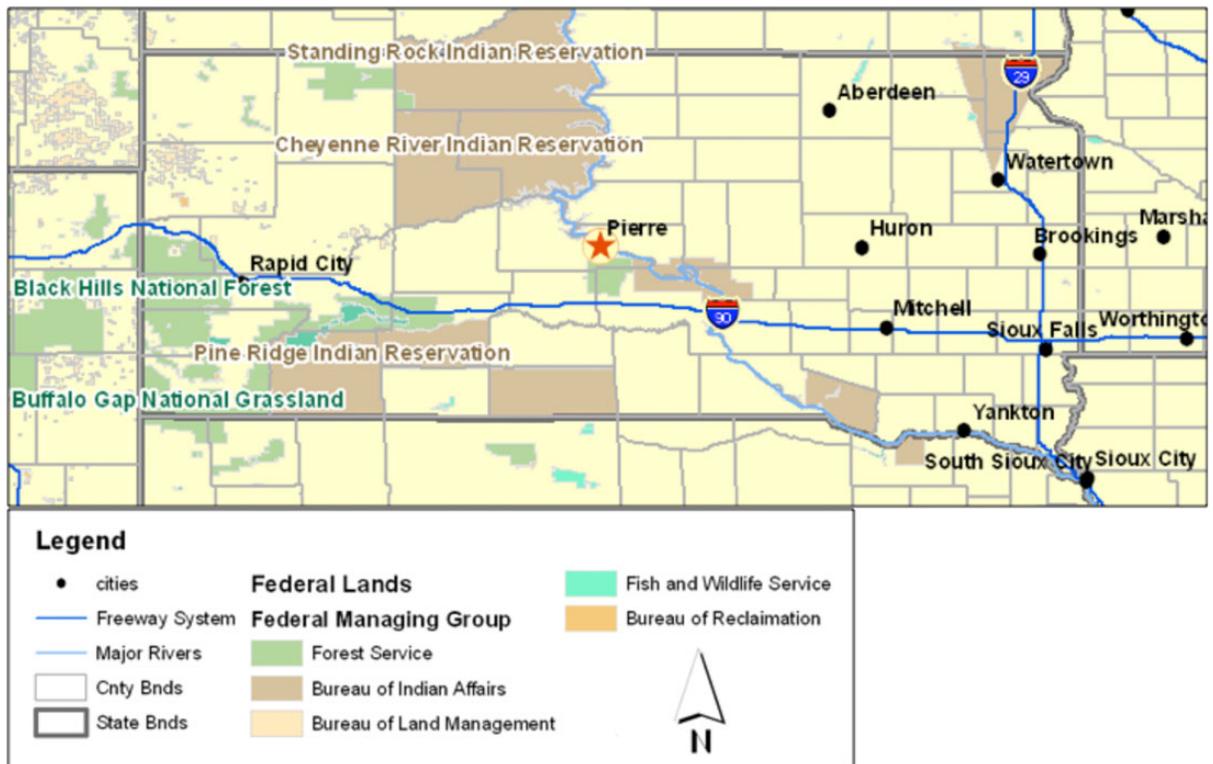


Fig. 2. Map of South Dakota federal lands.

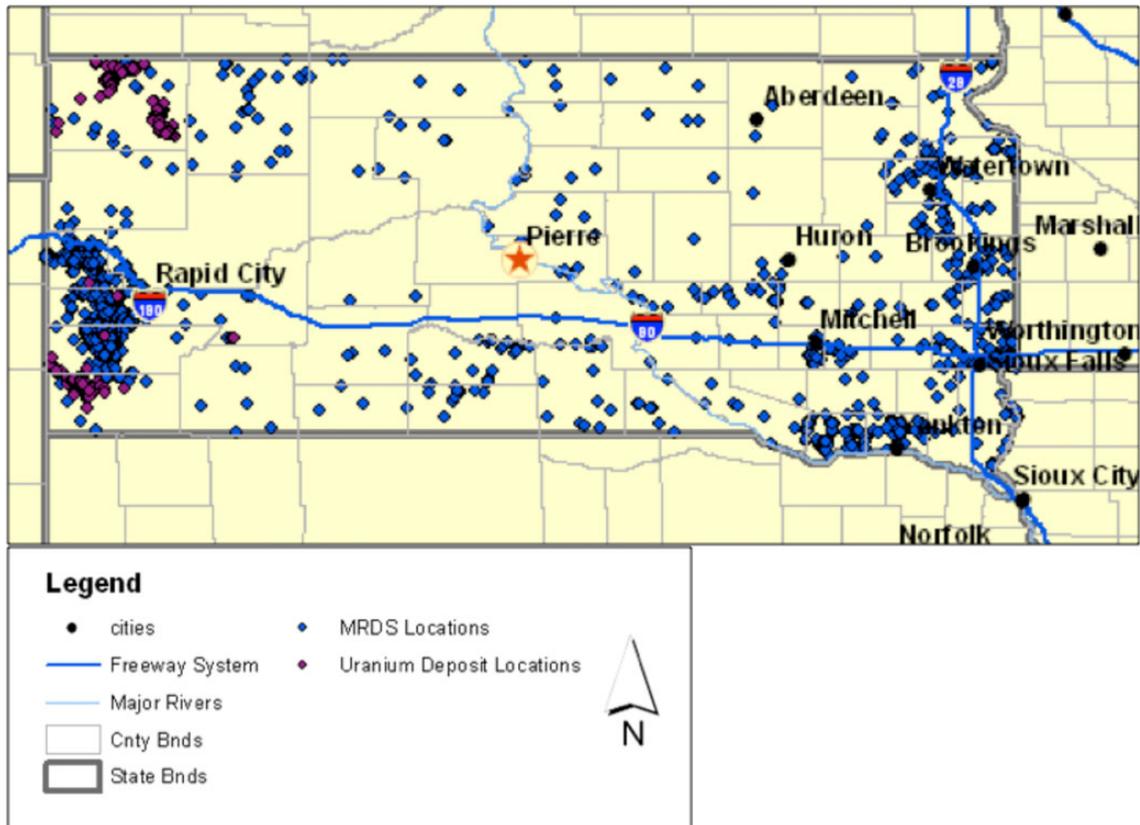


Fig. 3. Map of uranium deposits and MRDS sample locations in South Dakota.

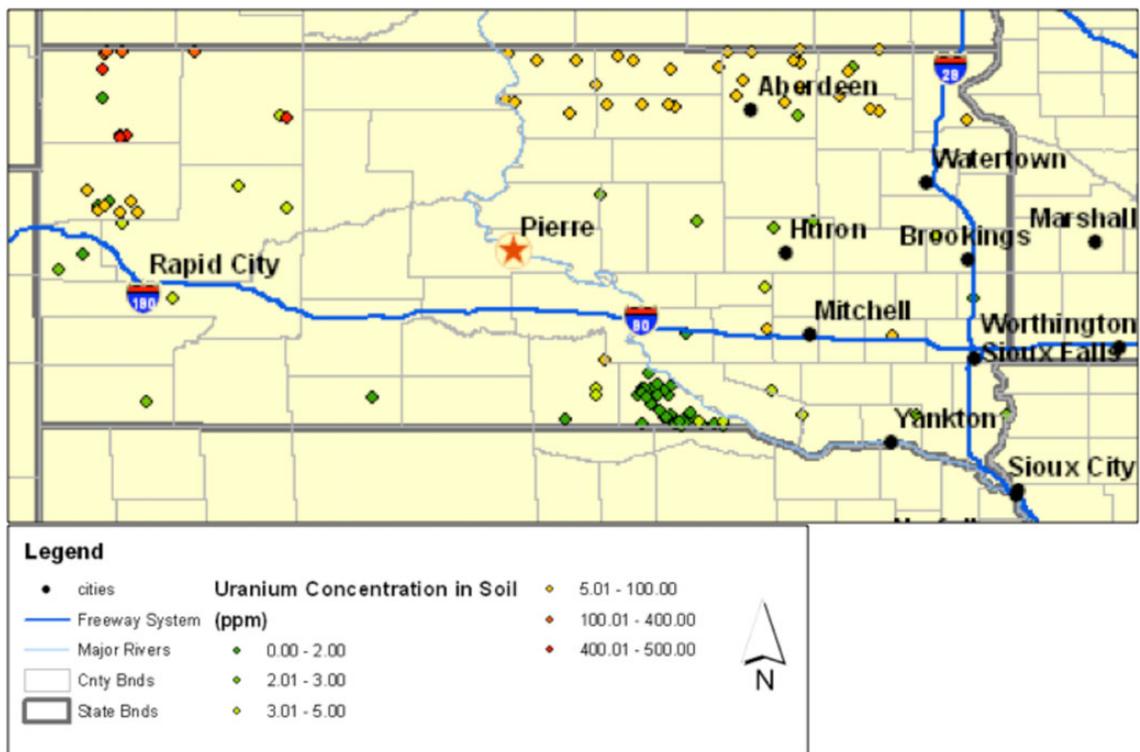


Figure 4. Map of uranium concentration in soil in South Dakota.



Fig. 5. Map of uranium concentration in stream water in South Dakota.

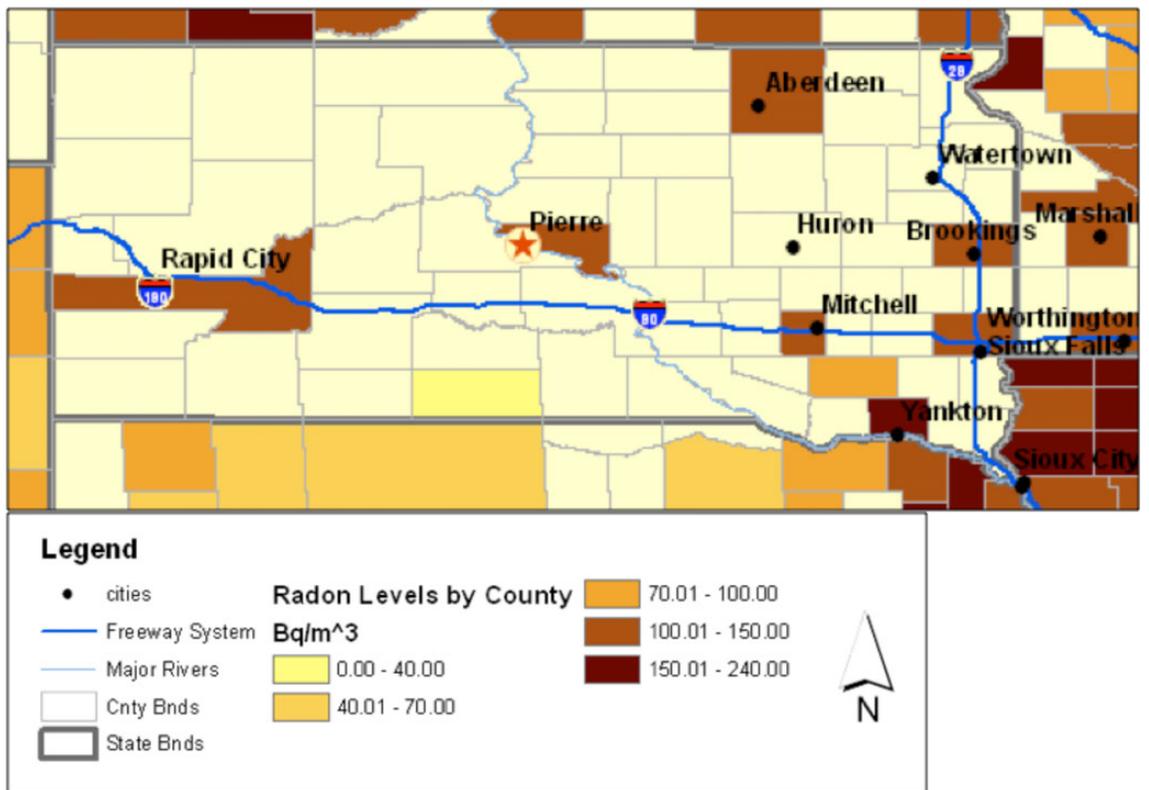


Figure 6. Map of average indoor radon concentration by county in South Dakota.

to high levels of radon gas. Indoor radon levels need to be tested in order to identify any potential problems and take steps to correct them. Were more data available, it might be possible to compute a figure of merit to assist in the design of both a radon screening and intensive testing program that combines population density with knowledge about local geology and prior radon tests. Such a plan could be modified as additional data were obtained.

DISCUSSION

By gathering together many sources of data, it becomes possible to determine the regions that are most likely to have high indoor radon levels. Unfortunately, the data points indicating uranium levels in soil and water are relatively sparse across most of South Dakota. Still, knowing the location of uranium deposits, it would appear that the highest radon levels might be found in the northwest and southwest corners of the state. So far, very little data have been collected in these regions and the potential for research is high, both outside and within the Native American reservations. Until more tests are conducted, however, it is impossible to know exact radon levels. GIS software tools are very useful for targeting areas for more intense study.

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