RADON AND LUNG CANCER IN NEBRASKA

ENVIRONMENTAL PUBLIC HEALTH TRACKING

ASTHO FELLOWSHIP REPORT

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INTRODUCTION

The State of Nebraska Department of Health and Human Services (NDHHS) Division of Public Health devotes time and energy to the source and quality of data that is collected in the Division. Our Director, Dr. Joann Schaefer has as one of her priorities for public health: "Become a trusted source of state health data." As part of our efforts towards this goal, the Environmental Health Unit of DHHS is anxious to learn more of the existing requirements of the Environmental Public Health Tracking Network while visiting those knowledgeable in the program. To that end, DHHS applied for, and was awarded funds in January 2012.

The initial proposal was to conduct an ecological analysis of the relationship of residential radon measurements and the incidence of lung cancer in Nebraska. While ecological studies are often considered inferior to cohort and case-control studies, their advantages are that they can be carried out easily, quickly and inexpensively using data that are generally already available. In this case, the project will match data from the Nebraska Radon database and the Nebraska Cancer Registry and analyze by county and other geographical identifiers. The expectation is that this first analysis would help build a template for further analyses of radon level and lung cancer as well as develop the template for further studies into other environmental topics. In addition, the results of this project will be presented to the Department as an example of the value of environmental health data linkage projects and the potential of the Environmental Public Health Tracking Network (EPHTN).

In addition to the ecological analysis, DHHS committed to sending staff to the Spring 2012 CDC EPHT Workshop, as well as to the Missouri Department of Health and Human Services for a two to three-day site visit.

REPORT ON TRACKING ACTIVITIES

Visit host state

Two DHHS Public Health Support staff members visited the Missouri EPHT program on March 19 and 20, 2012 hosted by the Missouri program director, Roger Gibson, MPH and 6 or 7 staff members. The first day was devoted to presenting the Missouri program operations and lessons learned, and topics discussed included how to set up the programs and the approach that Missouri took to establish the EPHT program. The second day involved discussion around participation in and interaction with EPHT groups, and a question and answer period. The trip was a success, and offered valuable insights, including:

- Build the program with devoted staff, and do not spread money too thin between too many programs, as it is likely to fail that way
- Work with IT (Information Technology) from day one, especially GIS staff
- Have a good data steward relationship

Attend Spring 2012 CDC EPHT Workshop

The Spring 2012 CDC EPHT workshop was held April 30th in Denver, CO. Two DHHS Public Health Support staff members attended the workshop, which was a business workshop for EPHT teams, academic partners and CDC subcontractors and staff. The meeting provides a platform for people from different states to exchange their experiences and information about tracking. In addition to opening and closing sessions, staff participated in air quality, CVD, climate change, environmental health, occupational health, and GIS team report sessions. The sessions offered valuable insights, including:

- To put data to good use (i.e. display online), the methods to link different datasets and display in the sense of geographic distribution (e.g., geo-coding and maps), further research tools are needed.
- The training session on Methods and Models for Multi-Level Spatial Analysis offered a lot of detail on the influence of spatial autocorrelation in a regression model. Participants were able to successfully run the example code on their own laptops, getting valuable experience.
- Data collection, integration and linkage are the first step for bio monitoring; tracking and interpretation needs more work in the future.
- The participant's between- session discussion offered information about other states' work on radon reduction.
- The reporting quality of each subgroup varies greatly
- Portal is the biggest thing at this point
- CDC programs do not always work together
- There are many different approaches to setting up EPHT program, all seemed successful. Shared EPHT resources for other programs seems work, for example using portal to report other program data
- Massachusetts and Wisconsin are drivers of content. Missouri is one of the drivers in IT/portal stuff.

SMALL PROJECT

Abstract
Radon is an odorless, colorless, and tasteless gas that can increase the risk of lung cancer, which is often the leading cause of cancer mortality in Nebraska. The causal relationship between radon exposure and lung cancer has been well-established across the United States and the rest of the world, however Nebraska lacks state-specific information. The purpose of this study is to conduct an ecological analysis of the relationship of residential radon measurements and the incidence of lung cancer in Nebraska; generating maps to visually display the results of the data cleaning process and results. From this population-level analysis, twenty-two counties have been shown to have both average radon levels above 4 pCi/L and a lung cancer incidence rate higher than state incidence rate. In addition, six counties have an average radon level more than twice the action level (≥ 8 pCi/L) and a lung cancer incidence rate more than 10% higher than the state average (≥ 69.41).

Specific Aims
Lung cancer has a significant impact on Nebraskans, in both incidence and mortality. While it was only the third most frequently diagnosed cancer among Nebraska residents in 2009, it was the year’s leading cause of cancer mortality, accounting for more than 25% of the state’s cancer deaths. During the past five years (2005-2009), lung cancer has averaged about 1,200 diagnoses and 900 deaths in Nebraska per year. Although lung cancer is more likely to strike men than women, there has been a 30% drop in the rate of lung cancer deaths among Nebraska men since 1990, but no decline at all among women. The large number of lung cancer deaths is due to the

small number of cases that are detected at an early stage: as a result, the five-year survival rate for people who diagnosed with lung cancer is less than 20% (NDHHS, 2009).

While the leading cause of lung cancer is undisputedly tobacco use; radon exposure has been clearly shown to increase risk as well (Lubin, et al 1995; Field, 1999; NCI, 2004; Krewski, et al 2006; WHO, 2009). For many years now, the Environmental Protection Agency (EPA) has spearheaded efforts nationwide to encourage research on radon issues as well as to educate people of the risk of radon exposure. The primary public health message developed from EPA has been encouragement for people to test their home; and if the radon level exceeds the "action level" of 4.0 pCi/L, then to have the home mitigated. Nebraska has worked in conjunction with the national program by managing a statewide radon program for approximately 22 years. This state level program has conducted education and outreach on radon issues, as well as to regulate the industry; a byproduct of which is a database containing information about all the radon testing conducted in the state. The Nebraska Radon Program has created maps in the past to show summary information on radon levels across the state, most commonly using the Radon Zone model developed by EPA. This model includes three zones, each of which show the predicted average indoor radon screening level related to the action level. Zone 1 counties are red, with an average screening level above 4.0 pCi/L; Zone 2 counties are orange, with an average screening level between 2 and 4 pCi/L; and Zone 3 counties are yellow, with an average screening level lower than 2 pCi/L (EPA, 2009).

The main aim of this project is to conduct an ecological analysis of the relationship between the lung cancer and radon data sets. Since an ecological analysis is by nature associative, it was determined that the best way to present the results of this data linkage project would be with a set of maps. More robust statistical analysis would not be appropriate in this type of study, since the intent is not to make strong causal inferences. Also, focusing our product to maps will prevent any assumptions regarding an individual correlation based on an observation at the population level. Finally, this is a somewhat unique project in that we are associating a data set containing patient information with a data set containing housing information.

Additional aims of the project are to assess and improve the quality of environmental data, to build a template for further analyses of radon level and lung cancer incidence data, and to develop the template for further studies into other environmental topics. In addition, the results of this project will be presented to the Department as an example of the value of environmental health data linkage projects and the potential of the Environmental Health Tracking Network.

Benefits/Significance

As mentioned previously, it is a priority of the Division of Public Health's Director that the Division "Become a trusted source of state health data." Therefore, efforts that enhance our ability to collect, integrate, link, track and interpret data are supported by upper management. In addition, the Nebraska Radon Program will benefit from the end product of this project, in that it can utilize the maps as part of the regular outreach and awareness activities it conducts. Finally, not just the Radon Program, but other programs throughout the Environmental Health Unit will benefit from the process of conducting the data analysis and the developed template for future studies.

The EPHTN is in a position to benefit from this project as well. While radon is not one of the current program areas that are being tracked by EPHTN partners, it is undergoing the review process to determine whether it should be added as such. Missouri's EPHTN program is heading the small committee looking into this issue, and while they have extensive experience with the EPHTN, the Missouri Radon Program is not regulatory and so does not collect extensive amounts of radon testing or mitigation data. Therefore, this project stands to give EPHTN and its partners a sample of the type of work that could be done with the radon data collected should this issue be added as a tracked program area.

Research Design/Methods/Key Personnel

Neither data set was statistically analyzed; however in order to compare the data it was necessary to ensure that each data set was treated similarly. Therefore, some manipulation of each data set was conducted prior to making maps. Radon data used in the project was pulled from the Nebraska Radon Program's Radon Database. The intent of the database is to be the official record of radon testing throughout the state. Therefore, the data is in a raw state that needs to be cleaned in order to remove unwanted and potentially invalid measurements prior to analysis. This project allowed staff to develop a systematic data cleaning and de-duplication methodology that provided more a more robust radon data set.

The data cleaning procedure removed radon measurements such as duplicate tests, multiple tests at the same address, known invalid tests, known spikes and blanks (tests either underexposed or overexposed for quality and assurance purposes), and any records missing vital information. Specifically, all radon tests below 0.2 pCi/L were removed to eliminate potential blank tests, and duplicate tests in the data set were averaged and collapsed into one test. If multiple tests were linked to one address, only the highest radon test was retained in order to account for seasonal variability (i.e. the tendency for radon levels to be higher in the winter months as compared to summer months). The final product after this cleaning was a set of data that represented one radon test per house that has tested between 2005 and 2009.

This data set was then aggregated by county throughout the state, and summarized to produce the average radon level per county and other data indicators. Any county with less than five radon tests conducted was marked to be suppressed. This is due to both a too-small number of tests to obtain an average from, as well as the desire to maintain consistency with how the lung cancer data was treated.

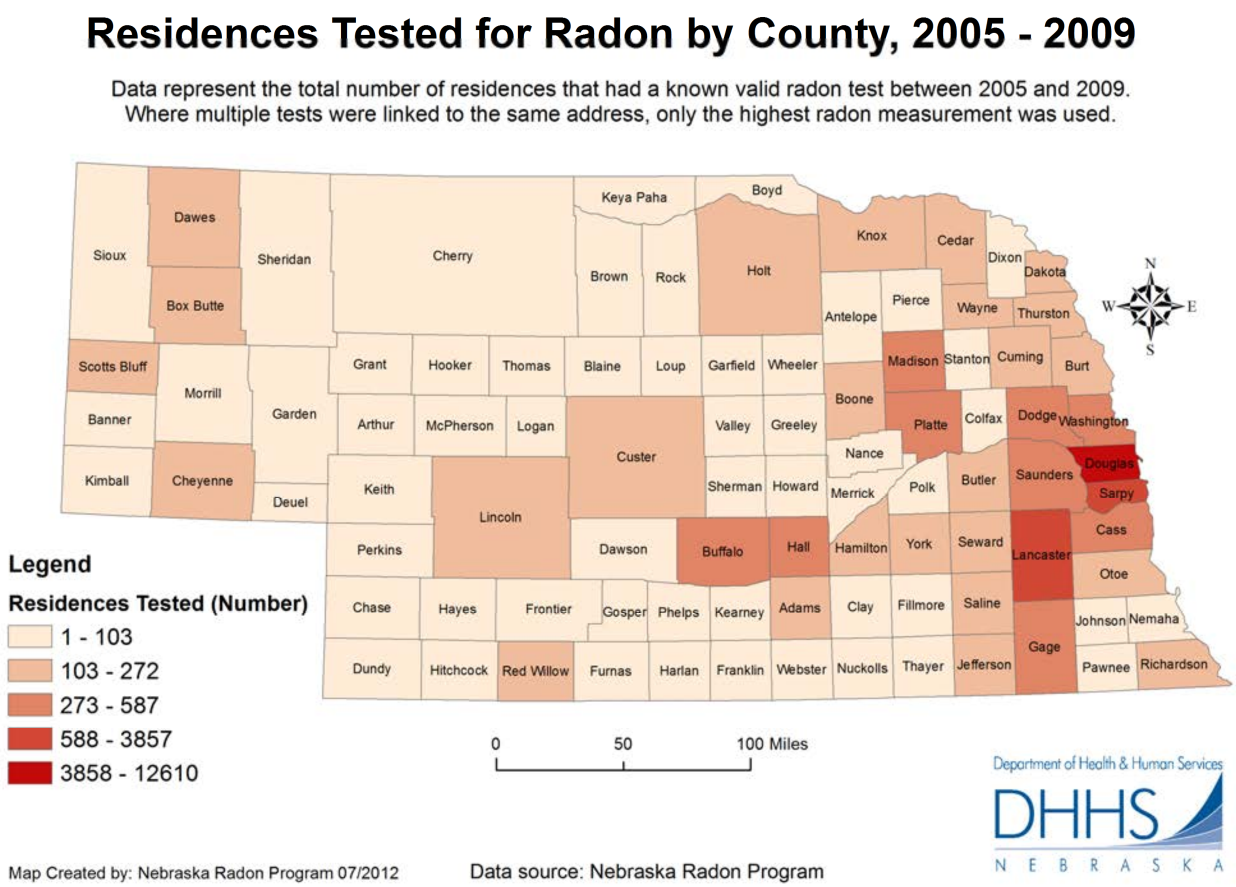
The lung cancer data set used in the project was obtained from the Nebraska Cancer Registry (NCR), which was compiled for the annual report, "Cancer Incidence and Mortality in Nebraska: 2009. The NCR gathers cancer data on Nebraska residents diagnosed and treated for malignant and in situ tumors. Information gathered from each case includes the patient's confidential information, primary site of the cancer, histological code, etc. The registry collects this information from every hospital in the state, excluding facilities operated by the US Department of Veterans Affairs. The registry also includes information about Nebraska residents who are diagnosed with and/or treated for cancer out of state, as well as cases diagnosed and/or treated at pathology laboratories, radiation therapy sites, outpatient surgery facilities, physicians' offices, and cases identified from death certificates. In this report, we only used the aggregated numbers of lung cancer from 2005 to 2009.

The incidence rates used in this report have all been age-adjusted using the US population in 2000 as the standard. Statewide and national rates are age-adjusted using 19 age groups (<1, 1-4, 5-9,10-14, 15-19, 20-24, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64, 65-69, 70-74, 75-79, 80-84, 85+ years), while county and regional rates are age-adjusted using 11 age groups (<1, 1-4, 5-14, 15-24, 25-34, 35-44, 45-54, 55-64, 65-74, 75-84, 85+ years). In order to compare rates between populations that have different age distributions and compare rates within a single population over time, we use age-adjustment incident rates in this report. However, incidence rate is not shown if based on five or fewer events to protect the confidentiality and the rates are per 100,000 population and are age-adjusted to the 2000 US population.

In order to visualize the data, lung cancer and radon data were used to create a series of maps using ArcMap 10, including the number of residences tested for radon by county; the percent of residences with radon levels above 4 pCi/L; average radon level by county, and a final map comparing lung cancer incidence and average radon level by county.

Key personnel for this project include staff from Public Health Support: Ming Qu, Administrator; Yushiuan Chen, Health Data Coordinator; and Ge Lin, GIS Coordinator. Also staff from the Environmental Health Unit: Mary Sue Semerena, Administrator; Sara Morgan, Indoor Air Quality Program Manager; and Derry Stover, Environmental Health Analyst.

Results



<u>Figure 1</u>

Between 2005 and 2009, a radon test was conducted in 30,828 residences throughout Nebraska. Figure 1 shows the number of residences tested by county. Out of these radon tests, 17,879 (58%) were higher than the action level of 4.0 pCi/L. Statewide, the average radon level among these tests was 6.3 pCi/L.

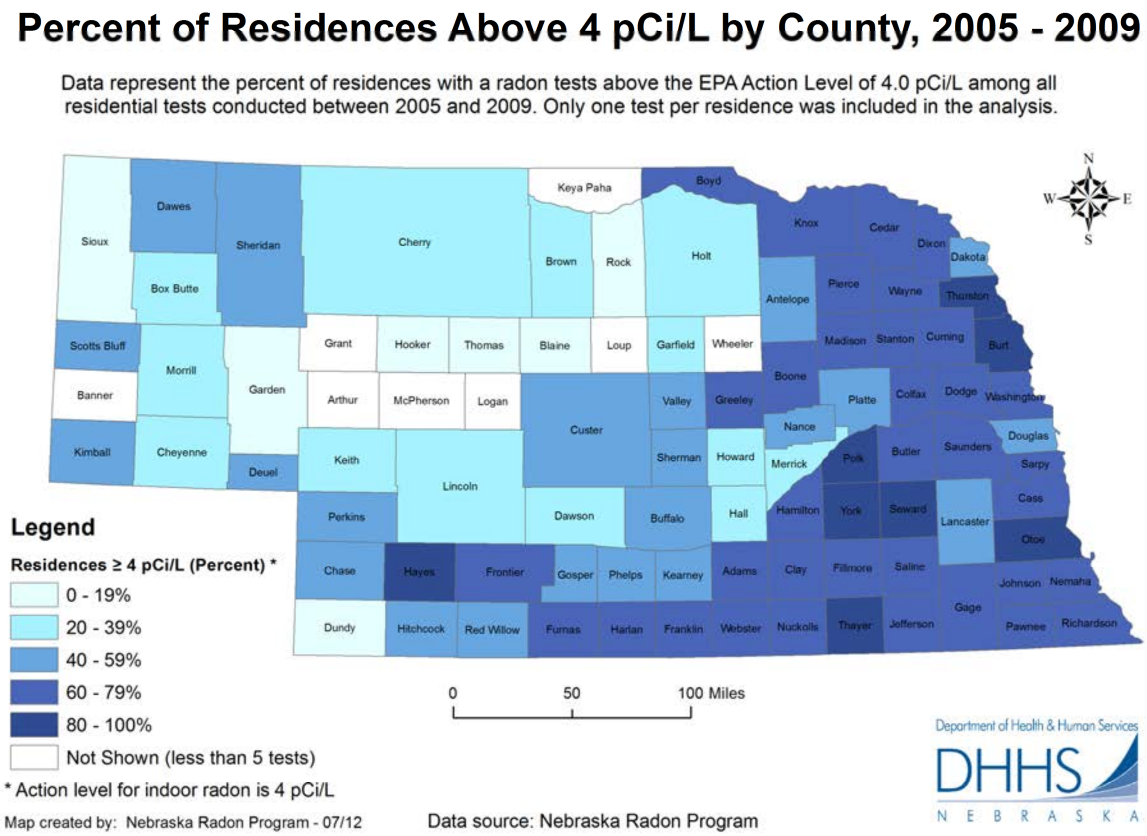


Figure 2

One approach to assess the prevalence of radon risk in Nebraska is to determine the percentage of residences that tested above the 4 pCi/L action level. Figure 2 shows the proportion of elevated tests among all tests per residence. This allows for a statewide comparison of risk without the potential of extreme radon levels influencing the map, as is the case with mapping average radon levels.

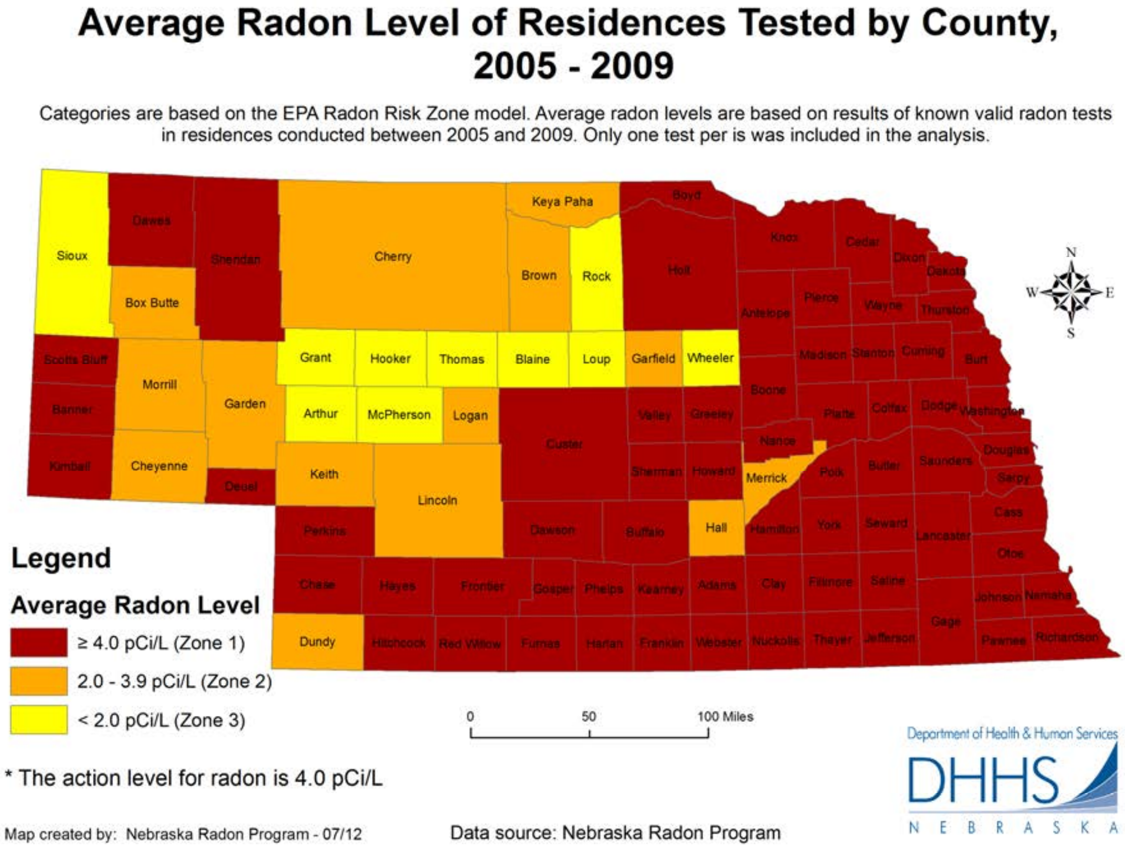


Figure 3

The map in Figure 3 shows average radon levels of residences tested between 2005 and 2009. County averages where organized into three categories that match the EPA's Radon Risk Zone map. Out of the 93 counties in Nebraska, the map shows that the average radon level is above the action level in 69 counties.

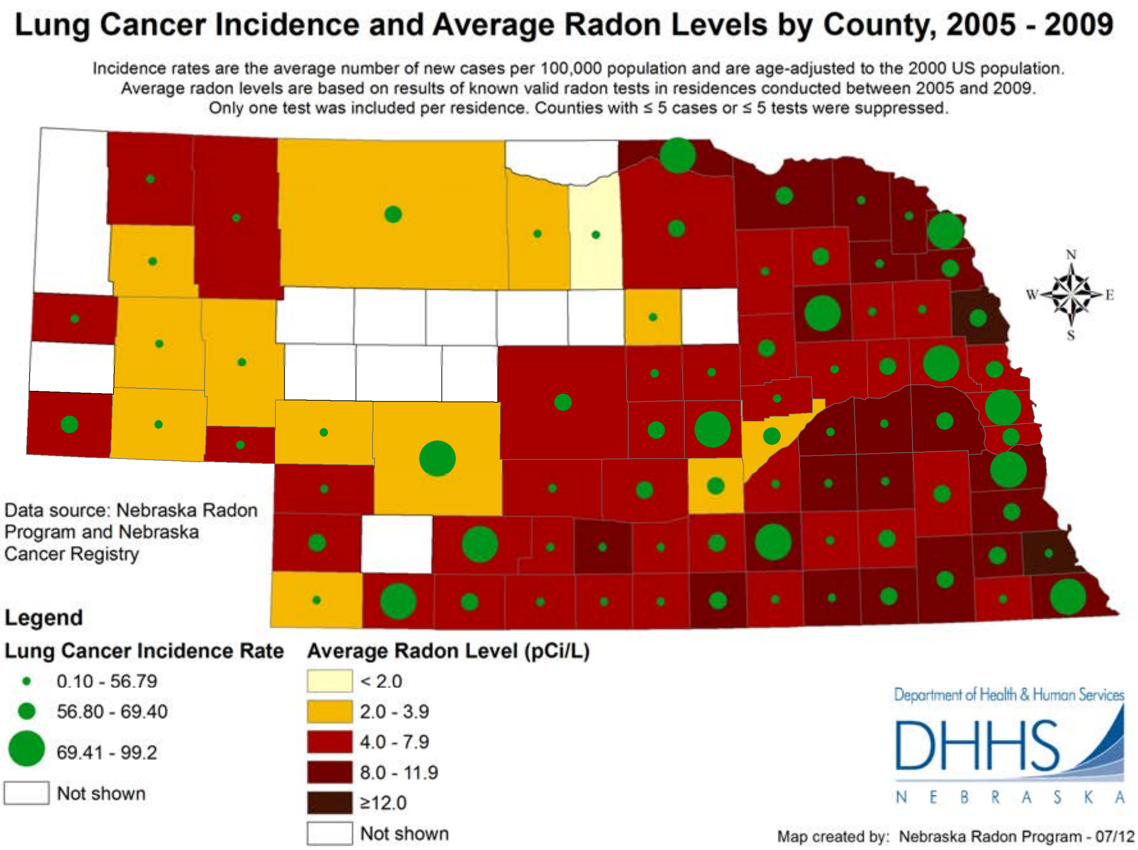


Figure 4

The map in Figure 4 uses the same county average radon level data with expanded colored categories to highlight areas of Nebraska with excessive radon risk. Furthermore, lung cancer incidence data for 2005 to 2009 are layered on top of the radon data. Lung cancer data is displayed as three categories based on incidence rates lower than 10% of the state average in the low group and incidence rates greater than 10% in the high group. The map shows that six counties have an average radon level more than twice the action level (≥ 8 pCi/L) and a lung cancer incidence rate more than 10% higher than the state average (≥ 69.41).

Counties in Nebraska with Average Radon Levels ≥ 4.0 pCi/L and Lung Cancer Incidence Rates ≥ the Statewide Incidence Rate

Region	Lung Cancer Cases	Lung Cancer Incidence Rate	Residences Tested for Radon	Average Radon Level (pCi/L)
Statewide	5,974	63.1	30,828	6.3
County				
Adams	127	66.1	245	7.3
Boone	27	65.2	111	5.9
Boyd	14	70.4	69	8.4
Burt	37	63.8	197	12.2
Cass	108	76.9	476	9.7
Clay	43	92.2	86	8.3
Colfax	35	64.7	92	7.7
Custer	56	67	116	5.4
Dakota	75	87.5	114	8.1
Dodge	169	71	429	6.7
Douglas	1665	74.2	12610	5.2
Frontier	14	87.1	31	5.4
Gage	101	64.2	334	9.3
Hitchcock	25	99.2	79	5.2
Holt	53	68.1	175	4.2
Howard	35	79.7	56	4.0
Madison	149	76.1	535	8.9
Red Willow	50	67.2	158	5.2
Richardson	46	71.2	156	9.5
Saline	55	67.7	273	7.9
Sarpy	364	67.8	3858	6.5
Saunders	83	67.2	364	9.5

Table 1

There were 5,974 lung (and bronchus) cancer cases and 4,513 deaths in Nebraska between 2005 and 2009. The state incidence rate for this period was 63.1. The lung cancer mortality rate during this time was 47.3, which is much higher than most types of cancer. In 2009, lung cancer was the leading cause of cancer mortality in Nebraska (NDHHS, 2009). Twenty-two counties, as shown in Table 1, have both average radon levels above 4 pCi/L and have a lung cancer incidence rate higher than state incidence rate.

Discussion

Even though lung cancer and radon measurement data were not compared via statistical analysis, ensuring the quality of both data sets is important when creating data linkages. Performing the cleaning and de-duplication procedures with the radon data allows the Department to better assess the feasibility of using the data for future and more complex analyses. The accompanying maps made with the refined data set enable us to better understand radon data in Nebraska and identify priority areas for enhanced public health outcomes.

The map in Figure 1 shows radon testing rates significantly differ across Nebraska. While radon testing numbers are much higher in the populous counties of Eastern Nebraska, there are also several counties with less than 100 tested residences in this data set. This geographic inconsistency in radon testing can introduce bias in the data set; which is further discussed in the Limitations section.

Currently, the Radon Database includes several addresses that are linked to multiple radon measurements. In prior years, these measurements were included data analysis and mapping. Since the inclusion of these tests can potentially skew the data, the data cleaning procedure was developed to identify and eliminate these unwanted tests for the final data set. This allows a comparison to be made based on the percentage of residences that tested high (above 4 pCi/L), as shown in Figure 2. Despite low sample sizes in some counties, this type of analysis will help the Department with any future efforts to estimate the number of houses in Nebraska with an elevated radon level.

EPA recommends that radon levels higher 4 pCi/L radon be lowered, and those living in residences with radon levels between 2 and 4 pCi/L should consider lowering the radon level. A radon level below 2 pCi/L would be considered low risk. Therefore, the purpose of the map shown in Figure 3 is to display county averages that match these three Radon Risk Zones. County risk zones do not drastically change when compared to previous radon maps made with un-cleaned data, and many counties in Eastern Nebraska average radon levels above 4.0 pCi/L. Since the majority of the population lives in eastern part of the state, this map shows that most Nebraskans live in Risk Zone 1 counties.

While the radon risk zone map is best suited for outreach to the public, the low number of categories does not facilitate a detailed comparison of geographic differences. The map in Figure 4 uses the county average radon level data but with expanded colored categories to highlight areas of Nebraska with excessive radon risk. When lung cancer incidence data for 2005 to 2009 are layered on top of the radon data in this map, an assessment of the two data sets can be made. This assessment can help identify future needs and priority areas for DHHS. For instance, average radon levels in many Northeast and Southeast counties are as much as twice the action level of 4 pCi/L. These “radon hotspots” may be areas of Nebraska where residents are exposed to very high concentrations to radon gas. For future analysis, identifying these hotspots with more robust data can assist in focusing communication efforts to the highest risk areas of the State.

By using these data, as well as other data sets like smoking prevalence, DHHS can better identify areas of the State with a disproportionate risk of lung cancer. Comparing the data and map helps in identifying 22 counties with average radon levels above 4 pCi/L *and* a lung cancer incidence rate higher than state incidence rate. Furthermore, six counties have an average radon level more than twice the action level (≥ 8 pCi/L) and a lung cancer incidence rate more than 10% higher than the state average (≥ 69.41).

Limitations

Arguably, the largest limitation of this study is the inability to account for smoking behavior in individuals. Tobacco use is the leading cause of lung cancer, and will account for the majority of lung cancer cases in Nebraska. While the Nebraska Cancer Registry contains valuable information about patients, smoking history was retired from the current required information (National Program of Cancer Registries). This makes it a challenge to connect cancer information with smoking behaviors in the individual patient.

Limitations inherent in the radon data set exist; including the low numbers of tests conducted in certain rural counties and the sampling bias which is present in many databases of this type. The sampling bias is due to the fact that much of the data in the radon data set is volunteer-based in origin, i.e. conducted by people who take the initiative to obtain and conduct a radon test; as opposed to a designed sampling study that would follow a geographically-weighted or population-weighted study design. Volunteer-based sampling can tend to over sample high radon areas, thus skewing the average for the county higher than it might be with a more representative sample (Burke and Murphy, 2011).

The nature of ecological studies poses additional limitations. Observations at the population level do not correlate to an individual. Thus, even though there are counties with both high average radon levels and high rates of lung cancer; it does not mean that the lung cancer is due to radon exposure. However, this type of study frees us from other limitations common to radon analysis: the mobility of the population (i.e. people live in multiple houses through their lifetimes, so their radon exposure varies) and the long latency period of lung cancer (i.e. the disease typically presents in middle-aged or senior individuals, representing a lifetime of exposure). This study type also allows us to be comfortable with the differences in the two data sets we have compared, particularly in the range of years looked at.

Planned Activities

Moving forward, DHHS has planned activities related to this particular data project, specifically to make the data sets even more robust by adding additional years and cleaning/de-duplicating more of the radon data set. This would improve data quality and evaluation, and allow for better linkages between these two data sets. In addition, without the capability to connect smoking history with the information in the Nebraska Cancer Registry, an alternate route to addressing the smoking confounder is the Behavioral Risk Factor Surveillance Survey (BRFSS), which includes questions about smoking behaviors. A future step would be determine needs associated with this data set and the possibility of incorporating it into the project design.

A long term tracking goal would be to include more information about lung cancer patients, such as their level and length of radon exposure and smoking behavior. This would of course require an institutional change statewide, however would greatly benefit future projects of this type.

DHHS will continue to collect Environmental Health data including radon, drinking water, lead, and asbestos information. Should funding become available to further enhance the infrastructure within DHHS to expand tracking activities; DHHS will certainly apply. As mentioned above, additional work on this project will continue, and new projects could be considered as resources allow.

Conclusion

This study intended to use existing data from the Nebraska Radon Program Radon Database and the Nebraska Cancer Registry study the relationship between radon exposure and health outcome. After each data set was cleaned and summarized, maps were produced showing a variety of outcomes, including Residences Tested for Radon by County; Percent of Residences above 4 pCi/L by County; Average Radon Level of Residences by County, and the overlay of Lung Cancer Incidence and Average Radon Level by County. From these maps, we were able to show that twenty-two counties have both average radon levels above 4 pCi/L and a lung cancer incidence rate higher than state incidence rate.

Limitations in the study prohibit strong conclusions regarding the relationship of these two data sets. These include the inability to control for smoking behavior, the sampling bias in the radon data set, and the inherent limits of an ecological analysis. However, this project allowed DHHS staff to explore the benefits of data tracking and analysis, as well as to realize the needs of this type of study.

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