Letter Health Consultation

Review of Ambient Air Monitoring Data

SUMMARY OF RODA AIR EXPOSURES
RODA, VIRGINIA

MAY 20, 2010

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Atlanta, Georgia 30333

Health Consultation: A Note of Explanation

An ATSDR health consultation is a verbal or written response from ATSDR to a specific request for information about health risks related to a specific site, a chemical release, or the presence of hazardous material. In order to prevent or mitigate exposures, a consultation may lead to specific actions, such as restricting use of or replacing water supplies; intensifying environmental sampling; restricting site access; or removing the contaminated material.

In addition, consultations may recommend additional public health actions, such as conducting health surveillance activities to evaluate exposure or trends in adverse health outcomes; conducting biological indicators of exposure studies to assess exposure; and providing health education for health care providers and community members. This concludes the health consultation process for this site, unless additional information is obtained by ATSDR which, in the Agency's opinion, indicates a need to revise or append the conclusions previously issued.

DEPARTMENT OF HEALTH & HUMAN SERVICES
Agency for Toxic Substances and Disease Registry
Region 3
1650 Arch Street, 3HS00
Philadelphia, PA 19103

Public Health Service

TO:	Dr. Tina Forrester, Director, ATSDR Division of Regional Operations (DRO)
FROM:	Lora Werner, ATSDR Region 3
SUBJECT:	Addendum to March 2010 Letter Health Consultation, Review of Ambient Air Monitoring Data, Summary of Roda Air Exposures
DATE:	April 26, 2010

The purpose of this memorandum is to document additional information relevant for the "Letter Health Consultation Review of Ambient Air Monitoring Data, Summary of Roda Air Exposures, Roda, VA" document published by ATSDR in March 2010.

The Virginia Department of Quality (VADEQ) raised data quality concerns about the air monitoring data collected by North Carolina State University. Specifically, VADEQ contended that the North Carolina State University's filters contained particles above the 10 micron threshold. We reported this information in our Letter Health Consultation (LHC) document. However, North Carolina State University undertook additional analytical work to address this concern about the integrity of their filter media and presented these findings to the Virginia State Air Pollution Control Board in November 2009. This information was provided to ATSDR Region 3 during the development of our LHC, but it was not specifically discussed in the original document. With this memorandum, I would like to acknowledge this pertinent information. I will distribute this memorandum to the interested site stakeholders who received original copies of our report.

On November 20, 2009, Dr. Aneja presented additional information to the Virginia State Air Pollution Control Board regarding the procedures, equipment and conclusions from the study conducted in 2008. Dr. Aneja presented the following points to support the validity of the 2008 study:

- The study utilized standard U.S. EPA measurements protocols which revealed the presence of PM_{10} up to three times the NAAQS standard;
- The EPA PM_{10} standard references the aerodynamic diameter of the particulate matter, not the diameter of the particle once it has been captured by the filter; and,
- No scientific study has ever established that microscopy of particles in a filter can be used to determine the aerodynamic diameter of those particles.

To further support the 2008 study, Dr. Aneja showed that by using scanning electron microscopy, or SEM (as opposed to the optical microscopy used by VADEQ), the particles measured in the 2008 study were in fact less than PM_{10}, pointing out that particles grow by the process of collision, coalescence and/or agglomeration. Dr. Aneja provided a number of SEM slides of the 2008 filters which supported his conclusion that the particle sizes were less than 10 microns ($<PM_{10}$).

This additional information from North Carolina State University does not change the conclusions and recommendations of our March 2010 report. Rather, this additional information provides further support for our evaluation to the extent that the information supports the validity of the maximum particulate matter monitoring results obtained in the 2008 sampling event.

Table of Contents

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

Agency for Toxic Substances
and Disease Registry
Region 3
1650 Arch Street, 3HS00
Philadelphia, PA 19103

David K. Paylor
Director
Virginia Department of Environmental Quality
629 East Main Street
Richmond, VA 23219

Dear Mr. Paylor:

This letter Health Consultation serves as the written Agency for Toxic Substances and Disease Registry (ATSDR) response to your May 11, 2009 letter. In that letter, the Virginia Department of Environmental Quality (VADEQ) asked ATSDR to evaluate reported levels of PM10 air pollution in the Roda, Virginia area in the context of public health questions raised about these sampling results. As we stated in our September 21, 2009 acknowledgement letter to you, ATSDR accepted your request and reviewed the information you submitted to us, including:

1. Aneja, V. 2009. Characterization of Particulate Matter (PM10) in Roda, Virginia. North Carolina State University.
2. Turner, C. 2009. Report on Monitoring Study in Roda, Virginia. Virginia Department of Environmental Quality. August 26.
3. Skelly and Loy. 2009. Ambient Dust Characterization for Roda Road. Va State Route 685, Wise County, Virginia. Prepared for Cumberland Resources Corporation. August.

ATSDR Region 3 staff members have had detailed verbal and electronic communications with VADEQ Southwest Regional Office staff members regarding this concern over the past several months. As your staff recognize, community exposures to particulate matter are complex to evaluate. The particulate matter air quality picture in the Roda area is complicated by the contributions of coal dust, road dust, and diesel truck emissions.

ATSDR concludes that exposure to particulate matter at the highest levels reported in 2008-2009 were likely to be of health concern, especially for sensitive individuals. This conclusion assumes an important proportion of the measured PM10 particulate consisted of PM2.5. A limitation of the data sets available for ATSDR's review is that no PM2.5 information was collected in the sampling events. ATSDR recognizes that the North Carolina State University information does not include quality assurance/quality control processes, and that VADEQ questions the validity of the data and operating procedures used in this study.

Individuals that may be more susceptible or sensitive to the effects of all PM exposures include infants, older adults, asthmatics, individuals with chronic obstructive pulmonary disease (COPD) or cardiovascular disease, diabetics, and individuals with certain genetic polymorphisms. Given the subsequent measures taken to control dust along the road and the reduction in mining activities and associated truck traffic in the community, we do not know if particulate levels presently remain a public health concern for Roda residents.

Based on ATSDR's screening of the VADEQ sampling results for metals, ATSDR concludes that the Roda community's exposure to metals in the air is not likely to be of public health concern. All of the metals results in the VADEQ sampling event were below health-based comparison values, with the exception of cancer risk evaluation guidelines for chromium and arsenic. The chromium and arsenic results represent slight increased lifetime additional cancer risks. These levels are comparable to "background" levels for these metals in U.S. air.

ATSDR appreciates that VADEQ and the Virginia Department of Mines, Minerals, and Energy signed an interagency Memorandum of Agreement (MOA) in December 2009 to facilitate efficient and effective administration of applicable State and Federal environmental laws, regulations and policies for the control of fugitive dust on and immediately adjacent to active coal mining sites in the Commonwealth of Virginia.

ATSDR recommends that federal, state, and local agencies in the area should continue to take any available measures (including effective implementation of the above mentioned MOA) to reduce particulate matter and dust affecting the residential areas along Roda Road, and in other areas with similar conditions in the state. Effective implementation of this MOA should help in addressing issues in communities with similar air quality concerns from mining/trucking activities. If the State Air Pollution Control Board finds that the MOA is not effective in addressing these air quality concerns at Roda or other similar sites, then ATSDR recommends that VADEQ conduct additional assessment efforts to further evaluate this exposure concern, such as receptor-specific and ambient monitoring for both PM2.5 and PM10 exposures, and consider other requirements as needed. VADEQ should consult with the appropriate agencies should the further need for this kind of additional monitoring arise. Lastly, residents in the most impacted areas should consider personal health-protective steps to limit their particulate matter and dust exposures, as described in more detail in the Health Consultation document.

We hope this letter provides useful information to VADEQ as you continue to work on this difficult problem. If you would like to discuss the information in this letter further, please contact me at 215-814-3141 or via email at lkw9@cdc.gov.

Sincerely,

Lora Siegmann Werner, MPH
Senior Regional Representative
Division of Regional Operations
Agency for Toxic Substances and Disease Registry (ATSDR), Region 3

Cc: Dr. Tina Forrester, ATSDR Division of Regional Operations
Dr. Paul Garbe and Dr. Fuyuen Yip, National Center For Environmental Health
Dallas Sizemore and Crystal Bazyk, VADEQ Southwest Regional Office
Dr. Sue Cantrell, VADOH/Lenowisco Health District Director
Dr. Dwight Flammia, VADOH

Summary of ATSDR Public Health Evaluation of Roda, VA Air Exposures

Introduction and Background

ATSDR's primary objective is to ensure that the residents of Roda, VA and state and local officials serving this community have the best information possible to safeguard public health. Residents living adjacent to Roda Road are concerned about health effects from particulate matter exposures in the community. Air quality in Roda is affected by coal mining operations and associated diesel truck traffic on Roda Road. Residents sought the assistance of the Southern Appalachian Mountain Stewards and the Sierra Club to evaluate the air quality in Roda. These organizations contracted with North Carolina State University to conduct an air sampling program in Roda in 2008. Based on the findings from this 2008 study, the State Air Pollution Control Board directed the Virginia Department of Environmental Quality (VADEQ) to gather additional monitoring data and develop a regional response plan. In May 2009, VADEQ wrote to ATSDR requesting assistance to obtain a better understanding of the potential health risks associated with particulate matter exposures in order to ensure the health and safety of the residents of Roda and the other Virginia communities. Further, VADEQ conducted a follow-up air monitoring program in Roda in 2009. ATSDR evaluated both the 2008 North Carolina State University and 2009 VADEQ sampling data for Roda.

ATSDR's Public Health Consultation Process

ATSDR's public health consultation process involves evaluating available environmental data, community concerns, and health outcome data (if available) for a site. The information from this health consultation activity is then used to decide what other activities are needed, such as recommendations to protect public health or health education. ATSDR identified "completed exposure pathways" for this evaluation. Exposure pathways are different ways that contaminants move in the environment and the different ways that people can come into contact with chemicals, such as breathing them in (inhalation). ATSDR identified one completed exposure pathway for the Roda, VA site: inhalation of particulates in the air by community members. This pathway was complete in the past, and is expected to be a completed pathway for the present and future.

We screened the available environmental sampling data for this site against the appropriate ATSDR health and environmental guidelines (acute, intermediate or chronic exposure durations). These health-based screening values are called comparison values or CVs. Comparison values are conservative estimates of contaminant levels at which no health effects would be expected. Although concentrations at or below a CV may be considered safe, concentrations above a CV will not necessarily be harmful.

Conclusion

ATSDR concludes that Roda residents exposed to particulate concentrations at the highest levels reported in 2008-2009 were likely to be of health concern, especially for sensitive individuals. This conclusion assumes an important proportion of the measured PM10 particulate consisted of PM2.5. Individuals that may be more susceptible or sensitive to the effects of all PM exposures include infants, older adults, asthmatics, individuals with chronic obstructive pulmonary disease (COPD) or cardiovascular disease, diabetics, and individuals with certain genetic polymorphisms. Given the subsequent measures taken to control dust along the road, the reduction in mining activities and associated truck traffic in the community, and the limitations of the sampling information, we do not know if particulate levels presently remain a public health concern for Roda residents.

Based on the VADEQ sampling results for metals, ATSDR concludes that the Roda community's exposure to metals in the air is not likely to be of public health concern. All of the metals results in the VADEQ sampling event were below health-based comparison values, with the exception of cancer risk evaluation guidelines for chromium and arsenic. The chromium and arsenic results represent slight increased lifetime additional cancer risks. Although this is does not establish health risk, these levels are comparable to "background" levels for these metals in U.S. air.

Basis for conclusion

The primary basis for ATSDR's conclusion is the peak levels of particulate matter measured by North Carolina State University and VADEQ during air monitoring events in the community in 2008 and 2009. In the North Carolina State University sampling, the maximum PM10 result was 469.7 $\mu g/m^3$, with PM10 results at this residential location exceeding the NAAQS standard of 150 $\mu g/m^3$ on 10 of 12 days. In the VADEQ sampling, the maximum PM10 result was 160 $\mu g/m^3$, and this result was found at the same residential location as the maximum result in the North Carolina State sampling. Supporting evidence is provided via anecdotal reports from the community regarding observed dust levels outside and inside homes and health complaints consistent with exposures to particulate matter.

All particulate matter is not the same. Depending on the source, size, distribution, duration of exposure, and exposure conditions, particulate matter can irritate healthy people's eyes, nose, throat, and lungs. More serious health problems can occur in sensitive populations. Most healthy adults and children will recover quickly from short-term particulate matter exposures and will not suffer long-term consequences. Certain sensitive populations are more susceptible to particulate matter exposures, and can develop cough, phlegm, wheezing, shortness of breath, bronchitis, increased asthma attacks, and aggravation of lung or heart disease. Exposure to fine particles is of special concern, and can be associated with several serious health effects such as myocardial infarction. Some sensitive people might experience health problems after even short duration exposures (such as several hours or a day) to fine and/or ultrafine particles.

Uncertainty

In general, the 2008-2009 air monitoring information provides a snapshot in time of conditions existing in the recent past that may not be representative of current conditions. Data quality issues and concerns about non-mining related air quality influences during the sampling periods (e.g., roadwork and collection issues in 2008 and potential burning activities in 2009) contribute to the uncertainty in this evaluation. Further, an important specific data gap is the lack of sampling information for smaller particulate matter (i.e., particulate matter less than less than 2.5 micrometers in diameter (PM2.5) and ultrafine particles), and the lack of receptor-specific monitoring locations and/or personal monitoring that could define short-term exposures during high intensity mining/truck traffic periods.

Next Steps

1. Federal, state and local agencies in the area should continue to take any available measures (including effective implementation of the VADMME/VADEQ MOA) to reduce particulate matter and dust emissions affecting the residential areas along Roda Road, and in other areas with similar conditions in the state.

ATSDR understands and appreciates that VADEQ is engaged in longer term efforts with railroad and state authorities to potentially improve Roda Road. VADEQ could enhance these efforts with plans with the mining companies to continue to minimize the residential impact of the truck emissions in the area (e.g., diverting traffic to alternate roads if possible, continuing/enhancing road dust control measures involving water trucks, roadway sweepers and truck washes, instituting clean diesel controls on trucks using the road, etc). Mining activities are coming to a close in the Roda area. However, ATSDR encourages VADEQ to use the experiences gained from this site to proactively implement similar particulate matter exposure reduction activities in other communities with similar air quality concerns from mining/trucking activities.

2. If the State Air Pollution Control Board finds that the MOA is not being effective in addressing the air quality concerns at Roda or other similar sites, ATSDR recommends that VADEQ consider additional environmental assessment efforts. Options VADEQ should consider include:

- Additional environmental sampling of the fine particulate matter fraction (PM2.5 monitoring) in the air of the community. ATSDR recommends that if this sampling is conducted, that it be designed to be receptor-specific (either personal-type monitoring or ambient monitors in yards close to the road) as opposed to NAAQS-based, in order

to fully address the cumulative exposures from mining and diesel exhaust in the community.

- Conducting real-time airborne dust monitoring to determine peak dust concentrations for PM10 and PM2.5.
- Further laboratory analysis of samples collected in VADEQ's prior sampling event to generate empirical data to determine what percentage of the Roda particulate matter is coal dust.
- Documenting with the mining company the number of trucks using Roda Road per day/week/month/year, and estimating changes in diesel emissions and subsequent community exposures based on truck volume.

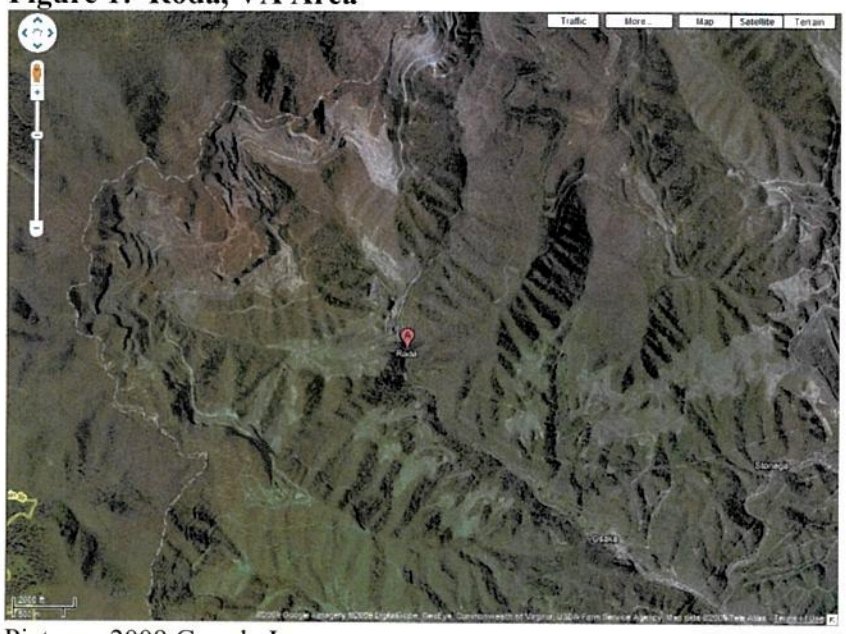
3. Residents in the most impacted homes should consider personal health-protective steps to limit their particulate matter exposures, and discuss personal health concerns with a health care professional. Examples of personal health-protective steps include:

- If particle levels are high outside, keep windows and doors closed. If needed for comfort, use air conditioners or heating systems on recycle/recirculation mode, if available. Inspect and change filters often in home systems.
- When the air quality improves (e.g., on the weekends when truck traffic is reduced), open up and air out the home.
- Reduce indoor sources of particles, including: propane/wood/coal burning stoves and furnaces, natural gas stoves and ovens, and gas logs. Activities such as cooking, burning candles, and tobacco smoking greatly increase the particle levels in a home. Even vacuuming can stir up and greatly increase particle levels in the air.
- Residential trash burning is a source of harmful air emissions. Residents are strongly encouraged to haul trash to approved facilities, or at a minimum to limit this activity in close proximity to homes and people.
- Consider using a vacuum cleaner with a "high efficiency particulate arresting" or HEPA filter, if available.
- Some air cleaners can be effective at reducing indoor particulate levels, but they must properly be matched to the size of the space to be cleaned. Keep these devices clean and the filters changed frequently.
- Wipe floors and hard surfaces with a damp mop or cloth that will retain the dust.
- Sensitive individuals with heart or lung disease, the elderly, and children should consider the following additional measures
    - On particularly dusty days, limit time outdoors.
    - Avoid physical exertion, indoors or outdoors, when particulate matter levels are high.
    - If you have symptoms of heart or lung disease, including shortness of breath, chest tightness, chest pain, palpitations or unusual fatigue, contact your health care provider.
    - If you have heart or lung diseases, make sure you have adequate medication on hand. If you have asthma, be sure to follow your asthma management plan.

I. Background and Introduction

Roda is an unincorporated community located in the coalfields and mountains of Wise County, VA (Figure 1). The population of Roda, along with the neighboring unincorporated community of Osaka, consists of approximately 90 homes built within 10-20 feet from the edge of Roda Road (Route 685). Roda Road is a narrow, public road that branches off of Virginia State Route 78, and terminates after four miles at the entrance to several surface and underground coal mining operations. The mining companies haul coal by truck along Roda Road.

Figure 1: Roda, VA Area



Picture: 2009 Google Imagery.

In 2008, there were nine active surface mining permits with entrances at the end of Roda Road. As of February 2010, there has been a substantial reduction in the permitted operations at the end of Roda Road and there are now only three active permits on the road. Table 1 summarizes the current and expected future status of mining permit activity in the Roda area. After approximately March 1, 2010, it is expected that only a single mine (Maggard Branch Coal LLC, Big Laurel mine) in the Roda community will have an active production operation. (Personal communication, Baszyk C to Werner L 2010).

Table 1. Summary of Mining Permit Activity in Roda, VA Area

Company	*Permit #*	*Status*
A & G Coal Corporation		
	PN 1101914	Active status with mine producing minimal product, per company
	PN 1101916	Completion report; inactive per DMME
	PN 1101917	active status but not producing per DMME
Nally & Hamilton Enterprises		
	PN 1101820	Active status but not producing per DMME
	PN 1701819	in temporary cessation status per DMME
Nine Mile Spur, LLC		
	PN 1101990	Active; this is the Fairbanks mine, and they are taking coal across the mountain and not using Roda Road. This mine will close in ~1 month per the company
Maggard Branch Coal LLC		

Company	*Permit #*	*Status*
	PN 1201828	Guess #3 mine; active status, but closed, per company
	PN 1201890	Big Laurel mine will continue operation per company
	PN 1201945	An active mining operation in OSAKA. This area is below Roda and these trucks do not pass through Roda, per company.
	PN 1402002	Guess #4 mine; active status, but mining should be completed by the end of February per company - truck traffic not using Roda road
Meadow Branch Coal LLC		
	PN 1201972	Active status; this is a ventilation cut-out associated with Big Laurel mine. No trucking activity per company

Source: Personal communication, Baszyk C to Werner L, January 26, 2010.

As a result of the mining operations, heavy trucks travel on Roda Road. Truck traffic varies with the mining operations, but in the past residents reported that there were often at least 10 trucks every hour for up to twenty hours per day passing through the community. These trucks represent the large majority of the traffic on this road, with the remainder consisting of local residents, their families and friends, and school buses. The trucks track coal, mud, and other debris away from the mine sites and onto the road. When this mud dries it turns into dust, which is then released into the air by the passage of other vehicles. In addition, fugitive dust, including coal fines, is released directly from the trucks (North Carolina State University 2008). Further, the diesel trucks themselves emit fine particulate matter pollution from the combustion of their engines. Figure 2 is an image depicting the proximity of the truck traffic to the residences in Roda.

Figure 2: Coal Trucks Traveling Through Roda, VA

Picture: Dr. Viney Aneja. (North Carolina State University 2008)

The residents of Roda have filed complaints with the Virginia Department of Mines, Minerals, and Energy (DMME) regarding their concerns about air quality along Roda Road. Roda residents describe their health concerns as including a variety of respiratory ailments that may be linked to or exacerbated by high dust levels. The residents report that the dust levels they experience effects their quality of life and restricts the amount of time they spend outdoors. Local residents sought the assistance of the Southern Appalachian Mountain Stewards and the Sierra Club. These organizations responded with an air sampling program conducted by North Carolina State University. This sampling program was set up to

measure particulate matter 10 microns or less in size (PM10) outside the homes of two Roda residents in August 2008 (North Carolina State University 2008).

The findings from the North Carolina State University study were presented to the State Air Pollution Control Board on April 24, 2009. Based on the findings from this study, the State Air Pollution Control Board directed the Virginia Department of Environmental Quality (VADEQ)'s Office of Air Quality Monitoring to "gather monitoring data in the Roda area and develop a plan for regional response for other communities where there is a need." To meet this directive, VADEQ designed and implemented the Roda Monitoring Study. The first phase of VADEQ's study was designed to gather data to directly compare to the North Carolina State University's study results, and to evaluate PM10 from locations which meet EPA National Ambient Air Quality Standards (NAAQS) siting criteria, and this phase was completed in August 2009. The second phase was designed to ascertain PM10 levels from locations which meet EPA siting criteria and from micro-level exposures along the truck route along Stonega Road, and involved the installation of two additional PM10 monitors that would gather data through mid September 2009 (VADEQ 2009). In May 2009, VADEQ wrote to ATSDR requesting ATSDR assistance to obtain a better understanding of the potential health risks associated with the PM10 exposures in order to ensure the health and safety of the residents of Roda and the other Virginia communities. This letter was brought to the attention of ATSDR program staff members in August 2009. ATSDR began communicating with VADEQ staff members at that point, and formally acknowledged VADEQ's request for assistance in a letter dated September 2009. ATSDR formally accepted VADEQ's request for public health evaluation in December 2009.

VADEQ and the Virginia Department of Mines, Minerals, and Energy (VADMME) collaborated to sign an interagency Memorandum of Agreement (MOA) in December 2009 to facilitate efficient and effective administration of applicable State and Federal environmental laws, regulations and policies for the control of fugitive dust on and immediately adjacent to active coal mining sites in the Commonwealth of Virginia (VADMME, VADEQ 2009).

II. ATSDR Evaluation Process

ATSDR's public health assessment process involves ATSDR evaluating all relevant environmental data, community concerns, and available health outcome data for a site. The information from this first activity is then used to decide what other activities are needed, such as medical testing, health education, and health promotion. This evaluation for the Roda, VA site focuses on evaluating environmental data from the site area collected in 2008 and 2009.

ATSDR identifies "exposure pathways" at the beginning of the assessment process. Exposure pathways are different ways that contaminants move in the environment and the different ways that people can come into contact with chemicals, such as breathing them in (inhalation) or accidentally drinking or eating them (ingestion). A "completed exposure pathway" exists when information shows that people have come into contact with a contaminant in soil, water, or air. Completed exposure pathways can be either in the past, the present, or could be in the future. ATSDR identified one completed exposure pathway for the Roda, VA site: inhalation of particulates in the air by community members. This pathway was complete in the past, and is also expected to be a completed pathway for the present and future. However, exposures to particulates in the community's air is expected to be less now than it was in the past, based on the reduction in mining activities and associated truck traffic in the town.

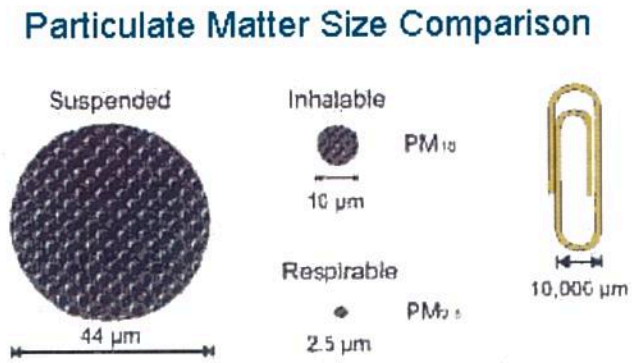
III. Analytical Data Summary and Evaluation

ATSDR's public health review focuses on the completed exposure pathway for this site, inhalation of particulates in the air by Roda, VA community members. Airborne particulate matter consists of many different substances suspended in air in the form of particles (solids or liquid droplets) that vary widely in size.

Overview of Particulate Matter Sizes

The particle mix in most U.S. cities is dominated by fine particles (less than 2.5 micrometers in diameter) generated by combustion sources (such as vehicle exhaust), with smaller amounts of coarse dust (between 2.5 and 10 micrometers in diameter). Particles *smaller* than 10 micrometers in diameter include both fine and coarse dust particles. The smaller particles pose the greatest health concern because they can penetrate deeply into the lungs. Particles *larger* than 10 micrometers in diameter can cause irritation to the eyes, nose and throat in some people, but they are not likely to cause more serious problems since they typically do not get deep into the lungs. Figure 3 provides a graphic description of the different size ranges of particulate matter.

Figure 3.



Picture from Air Quality Management Division, Hamilton County, OH:
http://www.hcdoes.org/airquality/Monitoring/PM.htm

Analytical Data Summary

The following sections summarize ATSDR's review of each of the three reports on air quality in the Roda area.

1. *North Carolina State University Report:*
   - PM10 was sampled at two locations in Roda over the course of about two weeks in early August 2008.
   - The maximum PM10 result was 469.7 µg/m3 at the Campbell Site.
   - PM10 results for the Willis site exceeded the NAAQS standard of 150 µg/m3 on 6 of 12 days.
   - PM10 results for the Campbell site exceeded the EPA National Ambient Air Quality Standard (NAAQS) of 150 µg/m3 on 10 of 12 days.
   - A portable meteorological station equipped with an onboard data logger was employed to measure and record site weather conditions at one of the residential monitoring locations throughout the study period.

As discussed in the summary of the VADEQ report below, the North Carolina State University's filters contained particles above the 10 micron threshold. Therefore, the North Carolina State University sampling information cannot be strictly interpreted as representing only PM10 or smaller sized particles. (As stated earlier, particles larger than 10 micrometers in diameter are not likely to cause more serious health problems since they do not get down into the lungs.)

On one random day of the North Carolina State University sampling event, quartz filters were used to collect particulate samples for metals analyses. These analyses identified the presence of metals, including antimony, arsenic, beryllium, cadmium, chromium, cobalt, lead, manganese, mercury, nickel, and selenium. Not enough information is provided in this report to allow the calculation of the total particulate matter by air volume collected, and some inaccuracies were noted in the provided

information.[1] Therefore, ATSDR did not further evaluate the metals information collected by North Carolina State University. However, ATSDR was able to perform a screening analysis of the metals data collected by VADEQ.

2. *VADEQ Report*:
This report is the result of the State Air Control Board's order to VADEQ to "gather monitoring data in the Roda area and develop a plan for regional response for other communities where there is a need." VADEQ's study was conducted in the summer/fall of 2009 and in two phases. The first phase was to gather data to directly compare to the North Carolina State University's study results, and to evaluate PM10 from locations which meet EPA siting criteria. The second phase was to ascertain PM10 levels from locations which meet EPA siting criteria (40 CFR Part 58) and from micro-level exposures along the truck route along Stonega Road. VADEQ monitored air quality at the Campbell, Willis and Sampson sites from May 28, 2009 through August 17, 2009, and at the Wells (Stonega) and the Gibson (NAAQS compliant) sites until September 16, 2009.

- The maximum PM10 concentration was 160 µg/m3. This maximum concentration was from the Campbell site, where the North Carolina State University's study reported the highest result.
- The mean concentrations (47.7 µg/m3, 69.7 µg/m3, and 22.9 µg/m3) from each of the three locations sited in phase 1 were well below the NAAQS PM10 standard (150 µg/m3), including the Sampson site, which meets EPA siting criteria.
- Both locations which meet EPA siting criteria showed results for PM10 were below the NAAQS standard.
- The North Carolina State University's filters contained particles above the 10 micron threshold and VADEQ's filters demonstrated an effective segregation of the PM10 portion.
- Five to eight PM10 samples from five different locations were analyzed for beryllium, chromium, manganese, nickel, arsenic, cadmium and lead.

The VADEQ study concludes that based on results from the two locations which meet EPA siting criteria, "there is no regional scale PM10 issue in the area of this study." VADEQ's report states that, "overall, the PM10 concentrations at the Campbell monitoring site are generally higher than those found at the Willis site, while still averaging below the numeric standard of 150 µg/m3. The likely explanation for this difference is the proximity of the Campbell site to the coal origination points, the road configuration at the site and the existing road dust that is made airborne by the truck traffic."

ATSDR screened the VADEQ sampling results for metals that were collected from 6/6/09 through 8/5/09 against ATSDR's health based comparison values (CVs). The maximum beryllium result was below the lowest comparison value (CREG [cancer risk evaluation guide] of 0.0004 ug/m3 (micrograms per cubic meter). All total chromium results (range 0.000164-0.000393 ug/m3, average 0.000278 ug/m3) exceeded the CREG of 0.00008 ug/m3 for hexavalent chromium (the most conservative CV [comparison value]), but are well below the EPA reference concentration of 0.100 ug/m3. The maximum manganese result (0.03725 ug/m3) was below both the chronic EMEG (environmental media evaluation guideline) of 0.300 ug/m3 and EPA's reference concentration (RfC) of 0.050 ug/m3. The maximum nickel result 0.00277 ug/m3) was below the chronic EMEG (0.090 ug/m3). The average arsenic results at each sampling location (range 0.00053-0.00089 ug/m3) exceeded the CREG (0.0002 ug/m3). The maximum cadmium result (0.00031 ug/m3) was below the lowest comparison value (CREG of 0.0006 ug/m3). No

[1] Tables 1 and 2 of this report summarize the metals analytical results and comparison values used by North Carolina State University. One comparison value column header "ASTDR [as printed in the report] Standard" provides 8-hour occupational exposure standards. These are not ATSDR numbers. ATSDR does not develop 8 hour exposure standards. We do develop community screening values based on 24 hour exposures. The standard in the table for lead is based on EPA's environmental air standard averaged over a 3-month period. All the other standards are actually OSHA 8-hour permissible work exposure levels, with the wrong units (should be milligrams not micrograms) for antimony, chromium (species not noted), cobalt, manganese, mercury, nickel, and selenium. Therefore, direct comparisons to the calculated 8-hr masses are not possible without correction, except for arsenic, beryllium, and cadmium.

comparison values are available for lead dust, except the NAAQS (National Ambient Air Quality Standard) quarterly value of 0.15 ug/m3. The maximum lead result (.01249 ug/m3) was more than 10 times below the NAAQS value and the overall average (0.00201 ug/m3) was 75 times lower than the NAAQS value.

3. *Cumberland Resources Corporation/Skelly and Loy Report*:
This document (1) reviews the history of Roda and Roda Road, (2) evaluates the North Carolina State University study, (3) summarizes steps taken by Cumberland Resources Corporation (CRC) to manage the dust along Roda and Stonega Road, and (4) reports preliminary results of the "joint VADEQ and CRC Air Sampling Program." Major findings in this report:

- Roda Road was constructed to support coal mining activities. The lack of space along the road limits the options for improving the road to reduce dust issues (i.e. re-entrainment). CRC spends $900,000 per year for water trucks, roadway sweepers and truck washes to manage fugitive dust along Roda and Stonega Roads.
- This report noted the following limitations in the North Carolina State University study: (a) monitor locations did not meet NAAQS siting criteria; (2) the study was of short duration; (c) meteorological data were lacking; (d) the results were confounded by VADOT roadwork which was underway during the sampling period; and (d) the discussion of health effects was overstated (the discussion presumed that the particulate measured was in the form of PM2.5 and not PM10 or TSP).
- Regarding the VADEQ sampling, this report stated that there was evidence that local residents were burning refuse near the Campbell site during the sampling time period, potentially elevating the measured concentrations.
- This report concluded that the joint VADEQ and CRC study's preliminary results suggest that ambient PM10 along the Roda and Stonega Roads do not exceed EPA standards.

Meteorological Information Summary

Site-specific meteorological information provides important descriptive context for air quality investigations occurring in the same location over different time periods. The closest public meteorological station to the site collecting rainfall information is the Kingsport station (about 35 miles SE of Roda in Tennessee). At the Kingsport station, summary rainfall conditions in the summer of 2008 (when North Carolina State University sampled in Roda) were substantially drier as compared to the summer of 2009 (when VADEQ sampled in Roda). Specifically, from 5/28/08 to 8/17/08, the Kingsport station recorded 8.12 inches of rain with an average mean temperature of 73 degrees F, (with 2.99 inches of rain reported for August 2008). In contrast, for the same period in 2009, the Kingsport station recorded 13.34 inches of rain with an average mean temp of 72 degrees F (with 1.52 inches of rain reported for August 2009) (Weather Underground 2010).

Both North Carolina State and VADEQ obtained meteorological information specifically from Roda, VA during their sampling events as well. For the North Carolina State sampling, an onsite meteorological station was operated throughout the duration of the sampling event. However, rainfall information was not collected at this station (Personal communication, Aneja V. to Werner, L. 2010). VADEQ obtained their meteorological information from CRC, which began operating stations at Andover, Exeter, Roda, and Stonega in March 2009. The total rainfall measured at CRC's Roda station from 5/28/09 to 8/17/09 was 15.81 inches (with 3.72 inches of rain reported for August 2009) (CRC Meteorological Data Summary 2010). Based on this information for the summer of 2009, more rainfall fell in Roda (15.81 inches) as compared to Kingsport (13.34 inches) over the same time period.

As noted earlier the Kingsport station is at a considerable distance from the Roda community. The terrain in this region is mountainous and complex. The CRC report (2009) notes that historical data from the National Weather Service refers to the period including the 2008 sampling as being under a drought watch, but that local weather reports indicated several days of rain. Therefore, the weather information

summarized here should only be considered approximate comparisons of the sampling environments in 2008 and 2009.

IV. Public Health Implications

ATSDR recognizes that impacts on air quality from mobile sources such as diesel trucks are regulated differently than from fixed sources such as a mining site, and that from a regulatory point of view, VADEQ has had to focus on the potential particulate (e.g., coal, soil, road dust) aspect of the air quality concern in Roda. However, from a public health (non-regulatory) perspective, ATSDR focused on the cumulative particulate matter exposure to the exposed individuals. In Roda, this cumulative exposure includes the combined particulate matter exposures from coal dust, road dust, and diesel truck emissions.

Particulate Matter Exposures

None of the Roda air monitoring efforts to date distinguished the proportion of fine particulate matter (particulate matter of diameters 2.5 microns or less) in the air of this community.[2] ATSDR would expect that with the contributions from the diesel truck emissions in this community, fine particulate matter exposures would need to be considered in Roda to fully evaluate public health exposures from airborne dust.

NIOSH evaluated data from two mining operations to characterize the fugitive dust emissions from haul trucks at surface mine sites. The study consisted of unpaved and untreated roads for a limestone quarry and a coal preparation plant waste hauling operation with truck speed averages just under 16 mph. The study employed personal air samplers (37-mm cassettes) and MIE-DataRAMs. In this study, 14.5% of the dust measured was <10 μm, 3.5% of dust was <3.5 μm, and 85.5% of the measured dust was not respirable. Dust levels were highest closest to the road, and achieved background levels at a distance of 100 feet from the road. The study found that primarily wind, distance and road treatment conditions notably affected the dust concentrations at locations next to, 50 feet from, and 100 feet away from the unpaved haulage road. Airborne dust measured along the unpaved haul road showed that high concentrations of fugitive dust can be generated with these concentrations rapidly decreasing to nearly background levels within 100 feet of the road. Instantaneous respirable dust measurements illustrated that the trucks generate a real-time dust cloud that has a peak concentration with a time-related decay rate as the dust moves past the sampling locations. The respirable dust concentrations and peak levels were notably diminished as the dust cloud was transported, diluted, and diffused by the wind over the 100 feet distance from the road. Individual truck concentrations and peak levels measured next to the dry road surface test section were quite variable and dependent on wind conditions, particularly wind direction, with respect to reaching the sampling location (NIOSH 2007). In contrast, the particle size distribution from diesel truck engine emissions is strongly weighted towards the finest fractions. The particle size distribution of diesel exhaust can be described as bi-modal. The nuclei mode consists of particles 0.0075 to 0.042 μm in diameter, and the accumulation mode has particles 0.042 to 1.0 μm in diameter. Approximately 98% of the particles emitted from diesel engines are less than 10 microns in diameter, 94% less than 2.5 microns in diameter, and 92% less than 1.0 microns in diameter (NTP 2005).

Mortality as well as cardiovascular and respiratory morbidity has been associated with both short and long term exposure to PM2.5 (EPA 2008). Thresholds for these health effects have not been identified. Given that there is substantial inter-individual variability in PM exposures, and in the response to a given PM exposure, it is unlikely that any standard or guideline value will lead to complete protection for every

[2] Ultrafine particles are defined as those less than 0.100 micrometers (um). Ultrafine particles are the result of combustion or friction processes or natural processes in the air or water. Animal studies have shown that ultrafine particles have a significantly greater pulmonary inflammatory potency than larger submicronic particles of the same chemical composition. These results form the basis for the ultrafine particle hypothesis, and this is an area of ongoing research particulate matter and health effects research. Ultrafine particles are not routinely monitored for in environmental sampling investigations. This hypothesis highlights the concern about the smallest sized particles.

individual against all possible adverse health effects from PM2.5 exposures (WHO 2006). Several significant health studies have investigated potential health effects resulting from long-term exposure to particulate matter. The historical mean PM2.5 concentration was 18 μg/m3 (range 11.0 - 29.6 μg/m3) in the Six-Cities Study and 20 μg/m3 (range 9.0 – 33.5 μg/m3) in the American Cancer Society (ACS) study (Dockery et al. 1993; Pope et al. 1995, 2002; HEI 2000; Jerrett 2005). Thresholds are not apparent in these studies, although the precise periods and patterns of relevant exposure could not be ascertained. In the ACS study, statistical uncertainty in the risk estimates becomes apparent at concentrations of about 13 μg/m3, below which the confidence bounds significantly widen due to the variability in the exposure concentrations. According to the results of the Dockery et al. (1993) study, the risks are similar in the cities with the lowest long-term PM2.5 concentrations (i.e., 11 and 12.5 μg/m3). Increases in risk are apparent in the city with the next-lowest long-term PM2.5 average concentration (i.e., 14.9 μg/m3), indicating that health effects can be expected when annual mean concentrations are in the range of 11-15 μg/m3 (WHO 2006).

Individuals that may be more susceptible or sensitive to the effects of all PM exposures include infants, older adults, asthmatics, individuals with chronic obstructive pulmonary disease (COPD) or cardiovascular disease, diabetics, and individuals with certain genetic polymorphisms (EPA 2008).

- Levels of pollutants that might not affect healthy people might cause breathing difficulties for people with asthma or other chronic lung diseases, especially children. Individuals with emphysema and chronic bronchitis may also experience a worsening of their conditions because of exposure to dust and smoke. Studies have linked particulate matter pollution to increased risk of hospitalizations for respiratory disease, asthma attacks, and respiratory mortality.

- People with heart disease might also experience symptoms such as shortness of breath or chest tightness. Studies have linked particulate pollution to increased risk of hospitalizations for cardiovascular disease, heart attacks, and cardiovascular mortality.

- The elderly are more likely to have pre-existing lung and heart diseases, and therefore are more susceptible to health effects from exposure to particle pollution.

- Children, even those without pre-existing illness or chronic conditions, are susceptible to air pollution because their lungs are still developing, and they are often engaged in vigorous outdoor activities, making them more sensitive to pollution than healthy adults. Studies have shown that in children, particulate pollution is associated with increased episodes of coughing and difficulty breathing, and decreased lung function.

- People who smoke, especially those who have smoked for many years, generally have reduced lung function and may be affected by dust and smoke exposure. Smokers are also less likely to recognize and report symptoms from exposure to irritant chemicals than nonsmokers.

ATSDR recognizes that the NAAQS regulatory framework is robust for addressing area-wide air quality concerns. However, the NAAQS framework is not as well suited to define localized air quality concerns that are being compounded by diesel traffic emissions (in fact, the NAAQS siting criteria are designed to minimize the impact of traffic emissions by siting NAAQS-compliant monitors sufficiently far away from roads). Therefore, even though ATSDR agrees that there may not be ambient PM10 levels exceeding regulatory standards in the Roda area, the possibility remains from the available information that PM2.5 exposures in the homes closest to the impacted roads exceed levels of health concern on an episodic basis.

Metals Exposures

ATSDR was unable to evaluate the North Carolina State University sampling results for metals, but we were able to screen the VADEQ sampling results for metals. In the VADEQ data, only chromium and arsenic exceed their respective cancer risk evaluation guidelines, or CREGs. All other metals (beryllium,

manganese, nickel, cadmium and lead) are below respective CVs. ATSDR evaluated the information for arsenic and chromium further in this subsection.

- Arsenic. All of the measured concentrations of arsenic in the VADEQ sampling event are lower than health-based comparison values for health effects other than cancer, suggesting that exposures to the measured concentration would not be expected to cause non-cancer health effects. ATSDR evaluated the potential for carcinogenic effects because inorganic arsenic is a known human carcinogen.

  The maximum level of arsenic (0.00155 ug/m3) measured in total suspended particulates (TSP) in Roda corresponds to a slight (6.5 in 1,000,000) increase in the estimated risk for developing cancer following a lifetime of exposure. Although this does not establish health risk, the measured arsenic concentrations near Roda are consistent with "background" levels observed in urban and suburban locations throughout the United States. For instance, a recent review of arsenic monitoring data collected between 2003 and 2005 and reported to EPA found that 59% of monitoring locations had arsenic concentrations greater than the 1 in 1,000,000 estimated cancer risk level (McCarthy et al., 2009). Other reviews of ambient monitoring data suggest that the arsenic concentrations measured near Roda are consistent with levels routinely observed in various setting nationwide (ATSDR 2007).

- Chromium. All of the concentrations of total chromium near Roda measured by VADEQ are lower than health-based comparison values for health effects other than cancer, suggesting that exposures to the measured concentration would not be expected to cause such health effects. ATSDR evaluated the potential for carcinogenic effects because hexavalent chromium is a known human carcinogen.

  A complicating factor is the fact that chromium found in ambient air exists in many forms that have differing toxicities. The most common forms found in ambient air are trivalent chromium and hexavalent chromium. Of these two, only hexavalent chromium is a known human carcinogen. However, most commonly-used environmental sampling and analytical methods measure ambient air concentrations of total chromium, without specifying the relative amounts of the hexavalent and trivalent forms. As a first approximation, ATSDR assumed that one-sixth of the total chromium is in the hexavalent form—an assumption frequently used and suggested in an EPA risk assessment publication (EPA 2009). Under this assumption, the estimated increased cancer risk following lifetime exposure to 1/6 of the maximum level of total chromium measured by VADEQ (0.00393 ug/m3) would be 7.9 in 1,000,000, representing a slight increase in the risk for developing cancer. ATSDR further notes that, similar to the information for arsenic, the measured concentrations of total chromium in the VADEQ sampling event are comparable to "background" levels documented in multiple scientific studies (ATSDR 2008).

Conclusions and Recommendations

Conclusion

Based on all of the above information, ATSDR concludes that Roda residents exposed to particulate matter at the highest levels reported in 2008-2009 were likely to be of health concern, especially for sensitive individuals. This conclusion assumes an important proportion of the measured PM10 particulate consisted of PM2.5. Given the subsequent measures taken to control dust along the road and the reduction in mining activities and associated truck traffic in the community, we do not know if particulate levels presently remain a public health concern for Roda residents.

There are significant data gaps that prevent ATSDR from evaluating exposures and predicting the likelihood of actual health effects for the residents along Roda Road. In general, the 2008-2009 air

monitoring information provides a snapshot in time of conditions existing in the recent past that may not be representative of current conditions. Data quality issues and concerns about non-mining related air quality influences during the sampling periods (e.g., roadwork and data collection concerns in 2008 and potential burning activities in 2009) contribute to the uncertainty in this evaluation. Further, an important specific data gap is the lack of sampling information for smaller particulate matter (i.e., particulate matter less than less than 2.5 micrometers in diameter (PM2.5) and ultrafine particles), and the lack of receptor-specific monitoring locations and/or personal monitoring that could define short-term exposures during high intensity mining/truck traffic periods.

Based on ATSDR's screening of the VADEQ sampling results for metals, ATSDR concludes that the Roda community's exposure to metals in the air is not likely to be of public health concern. All of the metals results in the VADEQ sampling event were below health-based comparison values, with the exception of cancer risk evaluation guidelines for chromium and arsenic. The chromium and arsenic results represent slight increased lifetime additional cancer risks; the levels found are comparable to "background" levels for these metals in U.S. air.

Recommendations

1. Federal, state and local agencies in the area should continue to take any available measures (including effective implementation of the VADMME/VADEQ MOA) to reduce particulate matter and dust emissions affecting the residential areas along Roda Road, and in other areas with similar conditions in the state.

ATSDR understands and appreciates that VADEQ is already engaged in longer term efforts with railroad and state authorities to potentially improve Roda Road. VADEQ and VADMME should continue efforts with the mining companies to minimize the residential impact of the truck emissions in affected areas like Roda or similar communities (e.g., diverting traffic to alternate roads if possible, continuing/enhancing road dust control measures involving water trucks, roadway sweepers and truck washes, instituting clean diesel controls on trucks using the road, etc). Mining activities are coming to a close in the Roda area. However, ATSDR encourages VADEQ to use the experiences gained from this site to proactively implement similar particulate matter and dust exposure reduction activities in other communities with similar air quality concerns from mining/trucking activities.

2. If the State Air Pollution Control Board finds that the MOA is not being effective in addressing the air quality concerns at Roda or other similar sites, ATSDR recommends that VADEQ consider additional environmental assessment efforts. Options VADEQ should consider include:

- Additional environmental sampling of the fine particulate matter fraction (PM2.5 monitoring) in the air of the community. ATSDR recommends that if this sampling is conducted, that it be designed to be receptor-specific (e.g., personal-type monitoring and/or ambient monitors in yards close to the road) as opposed to NAAQS-based, in order to fully address the cumulative exposures from mining and diesel exhaust in the community.
- Real time air monitoring of PM2.5 and PM10 to determine peaks near the receptor population.
- Further laboratory analysis of samples collected in VADEQ's prior sampling event in Roda to generate empirical data to determine what percentage of the Roda particulate matter is coal dust.
- Documenting with the mining company the number of trucks using Roda Road or other similar affected haul roads per day/week/month/year, and estimating changes in diesel emissions and subsequent community exposures based on truck volume.

3. Residents in the most impacted homes should consider personal health-protective steps to limit their particulate matter exposures, and discuss personal health concerns with a health care professional. Examples of personal health-protective steps include:

- If particle levels are high outside, keep windows and doors closed. If needed for comfort, use air conditioners or heating systems on recycle/recirculation mode, if available. Inspect and change filters often in home systems.

- When the air quality improves (e.g., on the weekends when truck traffic is reduced), open up and air out the home.
- Reduce indoor sources of particles, including: propane/wood/coal burning stoves and furnaces, natural gas stoves and ovens, and gas logs. Activities such as cooking, burning candles, and tobacco smoking greatly increase the particle levels in a home. Even vacuuming can stir up and greatly increase particle levels in the air.
- Residential trash burning is a source of harmful air emissions. Residents are strongly encouraged to haul trash to approved facilities, or at a minimum to limit this activity in close proximity to homes and people.
- Consider using a vacuum cleaner with a "high efficiency particulate arresting" or HEPA filter, if available.
- Some air cleaners can be effective at reducing indoor particulate levels, but they must properly be matched to the size of the space to be cleaned. Keep these devices clean and the filters changed frequently.
- Wipe floors and hard surfaces with a damp mop or cloth that will retain the dust.
- Sensitive individuals with heart or lung disease, the elderly, and children should consider the following additional measures
    - On particularly dusty days, limit time outdoors.
    - Avoid physical exertion, indoors or outdoors, when particulate matter levels are high.
    - If you have symptoms of heart or lung disease, including shortness of breath, chest tightness, chest pain, palpitations or unusual fatigue, contact your health care provider.
    - If you have heart or lung diseases, make sure you have adequate medication on hand. If you have asthma, be sure to follow your asthma management plan (EPA 2007).

Authors, Technical Advisors, Reviewers

Authors:
Lora Werner, MPH, ATSDR Region 3
Robert Helverson, ATSDR Region 3

Reviewers:
Tina Forrester, PhD, ATSDR DRO
Karl Markiewicz, PhD, ATSDR DRO
Fuyuen Yip, NCEH

The authors gratefully acknowledge the contributions and literature reviews from Dr. David Fowler, ATSDR DHAC in the "Particulate Matter Exposures" and "Metals Exposures" subsections, and the cooperation of the Virginia Department of Environmental Quality and Dr. Aneja, North Carolina State University in this effort.

References

[ATSDR] Agency for Toxic Substances and Disease Registry. 2007. Toxicological Profile for Arsenic. August 2007.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2008. Toxicological Profile for Chromium. September 2008.

Aneja, Viney to Werner, Lora ATSDR Region 3. Personal communication via telephone. January 29, 2010.

Baszyk, Crystal, VADEQ Southwest District Office to Werner, Lora ATSDR Region 3. Personal communication via email. January 26, 2010.

[CRC] Skelly and Loy. 2009. Ambient Dust Characterization for Roda Road. Va State Route 685, Wise County, Virginia. Prepared for Cumberland Resources Corporation. August.

[CRC]. 2010. Meteorological Data Summary Spreadsheets, Andover, Exeter, Roda, and Stonega Stations. May 27, 2009 – September 16, 2009.

Dockery DW, et al. 1993. An association between air pollution and mortality in six U.S. cities. New England Journal of Medicine, 329:1753-1759.

[EPA] US Environmental Protection Agency. 2007. PM 10 Factsheet. Last updated July 24, 2007. http://www.epa.gov/wtc/pm10/pm_fact_sheet.html

[EPA] US Environmental Protection Agency. 2008. Integrated Science Assessment for Particulate Matter. First External Review Draft. ISA: EPA/600/R-08/139. December 2008.

[EPA] US Environmental Protection Agency. 2009. Regional Screening Levels for Chemical Contaminants at Superfund Sites: User's Guide. December 2009. http://www.epa.gov/reg3hscd/risk/human/rb-concentration_table/usersguide.htm

[HEI] Health Effects Institute. 2000. A Reanalysis of the Harvard Six-Cities study and the American Cancer Society study of particulate air pollution and mortality. A special report of the Institute's Particle Epidemiology reanalysis Project. Cambridge, MA.

Jerrett M. 2005. Spatial analysis of air pollution and mortality in Los Angeles. Epidemiology, 16:727-736.

McCarthy MC, O'Brien TE, Charrier JG, and Hafner HR. 2009. Characterization of the Chronic Risk and Hazard of Hazardous Air Pollutants in the United States Using Ambient Monitoring Data. Environmental Health Perspectives, 117(5):790-796.

[NIOSH] Reed WR and Organiscak JA. Haul Road Dust Control: Fugitive dust characteristics from surface mine haul roads and methods of control. 2007. Coal Age; Journal Volume: 112; Journal Issue: 10. http://www.cdc.gov/niosh/mining/pubs/pdfs/hrdcf.pdf

[North Carolina State University] Aneja, V. 2008. Characterization of Particulate Matter (PM10) in Roda, Virginia. North Carolina State University.

[NTP] Report on Carcinogens, Eleventh Edition. U.S. Department of Health and Human Services, Public Health Service, National Toxicology Program. 2005. Diesel Exhaust Particulates. http://ntp.niehs.nih.gov/ntp/roc/eleventh/profiles/s069dies.pdf

Pope CA III, Thun MJ, Namboodiri MM, et al. 1995. Particulate air pollution as a predictor of mortality in a prospective study of U.S. adults. American Journal of Respiratory and Critical Care Medicine, 151:669-674.

Pope CA III, Burnett RT, Goldberg MS, et al. 2002. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. Journal of the American Medical Association, 287:1132-1141.

[VADMME, VADEQ]. Walz, S. and Paylor D. 2009. Memorandum of Agreement between the Department of Mines, Minerals and Energy (DMME), and the Department of Environmental Quality (DEQ). December 9.

[VADEQ] Turner, C. 2009. Report on Monitoring Study in Roda, Virginia. Virginia Department of Environmental Quality (VADEQ). August 26.

[WHO] World Health Organization. 2006. WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide; Global update 2005: Summary of risk assessment. WHO/SDE/PHE/OEH/06.02.

[Weather Underground] Weather Underground. 2010. Historical data summaries for the Kingsport TN meteorological station. http://www.wunderground.com/history/airport/KTRI/