Potential Public Health Impacts of Natural Gas Development and Production in the Marcellus Shale in Western Maryland

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SCHOOL OF
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5 GLOSSARY OF TERMS

ATSDR:	Agency for Toxic Substances and Disease Registry, a part of CDC
AAA:	American Automobile Association
BTU:	British Thermal Units
CH_4:	Methane
CO:	Carbon monoxide
CO_2:	Carbon dioxide
CAL EPA:	California Environmental Protection Agency
CAA:	Clean Air Act
CWA:	Clean Water Act
CDC:	Center for Disease Control and Prevention
CERCLA:	Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS:	Comprehensive Environmental Response, Compensation, and Liability Information System
CDGP:	Comprehensive Gas Development Plan
CNGDP:	Conventional Natural Gas Production
CRA	Cumulative Risk Assessment
dB:	Decibel
dBA:	A-weighted decibel level used for measuring loudness to the human ear
DPM:	Diesel Particulate Matter
DEP:	Department of Environmental Protection
DHMH:	Maryland Department of Mental Health and Hygiene
EPA:	Environmental Protection Agency
EPA IRIS:	Environmental Protection Agency's Integrated Risk Information System
EPCRA:	Emergency Planning and Community Right-to-Know Act
EIA:	Environmental Impact Assessment
FTE:	Full-time employees
GCDH:	Garrett County Department of Health
GCMH:	Garrett County Memorial Hospital
H_2S:	Hydrogen Sulfide
HC:	Hydrocarbons
HH:	Household
HS:	High School

HIA:	Health Impact Assessment
HPSA:	Health Professional Shortage Areas
HVHF:	High Volume Hydraulic Fracturing
IARC:	International Agency for Research on Cancer
LULU:	Locally Unwanted Land Use
LUST:	Leaking Underground Storage Tank
µg/L:	Micrograms per liter
$\mu g/m^3$:	Micrograms per cubic meter
MD:	Maryland
MDE:	Maryland Department of the Environment
MDNR:	Maryland Department of Natural Resources
MIAEH:	Maryland Institute of Applied Environmental Health
MOU:	Memorandum of Understanding
MLMC:	Mountain Laurel Medical Center
MOSH:	Maryland Occupational Safety and Health
MSDS:	Material Data and Safety Sheets
MUA:	Medically Underserved Areas
NATA:	National-Scale Air Toxics Assessment
NIOSH:	National Institute for Occupational Safety and Health
NGDP:	Natural Gas Development And Production
NO_x:	Nitrogen Oxides
NORM:	Naturally Occurring Radioactive Material
NPDES:	National Pollution Elimination Discharge System
NYSDEC:	New York State Department of Environmental Conservation
ODNR:	Ohio Department of Natural Resources
OEHHA:	Office of Environmental Health Hazard Assessment
OSHA:	Occupational Safety and Health Administration
O_3:	Ozone
PA:	Pennsylvania
PM:	Particulate Matter
$PM_{2.5}$:	Particulate Matter with aerodynamic diameter 2.5 microns or less
PM_{10}:	Particulate Matter with aerodynamic diameter 10 microns or less
ppb:	Parts per billion

ppm:	Parts per million
PEL:	Permissible Exposure Limits
PSE:	Physicians Scientists and Engineers for Healthy Energy
pCi/L:	Picocurie, amount of ionizing radiation per liter
PAH:	Polycyclic Aromatic Hydrocarbon
POTW:	Publicly Operated Treatment Work
RCRA:	Resource Conservation and Recovery Act
RESI:	Regional Economic Studies Institute, Towson University
REL:	Respiratory Exposure Limits
SDWA:	Safe Drinking Water Act
SDH:	Social Determinants Of Health
SES:	Socio-Economic Status
STIs:	Sexually-Transmitted Infections
SO_x:	Sulfur Oxides
SP-OMS:	SoundPro Outdoor Measuring System
TRI:	Toxic Release Inventory
TWA:	Time Weighted Average
UNGD:	Unconventional Natural Gas Development
UNGDP:	Unconventional Natural Gas Development and Production
USGS:	United States Geological Survey
UST:	Underground Storage Tank
VOCs:	Volatile Organic Compounds
WMHS:	Western Maryland Health System
WHO:	World Health Organization
WV:	West Virginia

6 EXECUTIVE SUMMARY

On October 18, 2013, the Maryland Department of Health and Mental Hygiene (DHMH) signed a memorandum of understanding (MOU) with the Maryland Institute for Applied Environmental Health (MIAEH), School of Public Health, University of Maryland, College Park to conduct an assessment of the potential public health impacts associated with drilling in the Marcellus Shale in Maryland and to provide a Marcellus Shale Public Health Report. This document is the final report.

The MOU specified that the "project is designed to provide a baseline assessment of current regional population health, an assessment of potential public health impacts, and possible adaptive and public health mitigation strategies in the event that natural gas extraction takes place within Maryland's Marcellus Shale resource." In particular, the project is not designed to make recommendations about whether or when to allow unconventional natural gas development and production (UNGDP) in Maryland. Rather this study is designed to inform decisions by clearly describing the risks and potential public health responses.

This public health study draws upon several methods of a rapid Health Impact Assessment (HIA) including: scoping, assessment of baseline health and potential health impacts of shale gas development, and this final report with recommendations for public health responses. The scoping process sought input from a wide range of stakeholders through public meetings and publication of a draft detailed scoping document. Comments on the scoping document were used to make modifications to the scope and are reflected in this final report. Due to time constraints, we will not publish a revised scoping report. Rather, we describe the revisions to the scope in section 8 of this final report. Although global climate change is a major concern and some stakeholders wanted it included, it remains beyond the scope of this study. Our focus is on public health impacts that would be concentrated in and unique to the Garrett and Allegany County populations living and working near the sites of shale gas development.

The baseline health assessment examined demographics, potential vulnerable populations, a wide range of health indicators, social determinants of health, and healthcare infrastructure in Garrett and Allegany counties. The impact assessment is based on available data from other states with ongoing UNGDP regarding exposure and health outcomes and on epidemiologic and toxicologic data from other contexts that are relevant to potential UNGDP related exposures. Our assessments of potential health impacts are not predictions that these effects will necessarily occur in Maryland, where regulation is likely to be stricter than in some states where UNGDP is already underway. Rather, we provide assessments of the impacts that could occur and that need to be addressed by preventive public health measures if and when drilling is allowed. Thus, the focus of our recommendations is on answering this question: Given the baseline population health, vulnerabilities, and potential impacts of UNGDP, how can Maryland best protect public health if and when UNGDP goes forward?

We presented a draft of this report and its recommendations in a final progress report at a public meeting June 28, 2014. This final report reflects stakeholder input received at and subsequent to that meeting. Several of the recommendations have been significantly revised. **The final recommendations in this report supersede the recommendations contained in the slides posted from the June 28, 2014 meeting.**

6.1 Baseline Health Assessment

The first step in the Health Impact Assessment process is identifying the health trends and issues currently impacting the population. Therefore, to assess the baseline health of Allegany and Garrett County residents, we considered demographics, potential vulnerable populations, a wide range of health indicators, environmental health, social determinants of health, and healthcare infrastructure. Ideally, a baseline assessment would, and stakeholder input urged us to, collect primary, representative, individual health and exposure data. However, conducting a new survey was beyond the time and funding limitations of this study, as is often true of health impact assessments. In this study, most health data was only available at the county-level. Thus analysis at the town or census tract level was not possible. Many of the physical and social determinants of health covered in this baseline assessment were raised as concerns at scoping meetings by stakeholders including residents of Allegany and Garrett Counties, health practitioners, policymakers, environmental non-governmental organizations, and health advocates. While this baseline assessment only focuses on residents of Allegany and Garrett Counties, it may have relevance for individuals in surrounding counties or with other shale deposits in the State of Maryland. A brief summary of the baseline assessment is provided here, a more detailed summary is contained in the body of this report and the full baseline health assessment is available in the Appendix.

6.1.1 Vulnerable Populations

It is important to recognize underlying social, economic, geographic, and individual level vulnerabilities that may increase risk of disease and premature mortality for populations in Garrett and Allegany counties. For example, residential proximity is an important factor in geographic vulnerability; there are many conventional gas wells in Western Garrett County and individuals who live near them could have higher exposure compared to individuals who live farther away. There are many existing conventional gas wells and EPA-regulated facilities and land uses including Superfund sites, brownfields, leaking underground storage tanks (LUSTs), and National Pollution Discharge Elimination System (NPDES) sites in Allegany and Garret Counties. The particular subpopulations living near these facilities may have environmental exposure burden disparities and cumulative impacts that increase exposure and health risks. Additionally, almost 40% of the population (children under age 18 and adults over 65) may be considered more vulnerable to certain exposures including chemical and physical agents and social stressors. Other factors including genetics, pre-existing disease, exposure to psychosocial stress, socioeconomic status, educational attainment, pregnancy, and behaviors such as alcohol consumption, smoking history, nutrition, and lifestyle can also influence vulnerability to disease. Occupational exposures and lack of access to health care infrastructure may also contribute to risk of disease. One group that is particularly at risk is surface owners who do not have mineral rights; they are subject to stress associated with the lack of control as well as any negative impacts associated with UNGDP activities. Unfortunately, we do not have accurate data on mineral rights ownership.

6.1.2 Physical Determinants of Health

To assess the baseline physical health of the Allegany and Garrett counties and compare to the surrounding region (counties in Pennsylvania and West Virginia) and the State of Maryland, the

HIA team obtained and analyzed environmental health data, health status data, chronic disease data, cancer incidence and cancer mortality data, other mortality data, and information on birth outcomes including low birth weight and premature births and infant mortality. Currently, daily $PM_{2.5}$ levels average around 13 $\mu g/m^3$ for Allegany and Garrett Counties, which is slightly higher than daily average for the state of Maryland. We observe that TRI releases are significantly higher in Allegany County compared to Garrett County, but there has been a decrease in total TRI releases in the state from 2000 to 2010. From the NATA dataset, we found that the estimated lifetime cancer and respiratory risks from air toxics were higher for individuals in Allegany County compared to Garrett County. For both, we observe that overall risk has decreased in the state of Maryland which could be due to reduction in air pollution levels or changes in the risk calculation. The rate of poor physical health days and preventable hospital stays was higher in Allegany County compared to Garrett, the region, and the state of Maryland. The percent of adults with hypertension, diabetes, obese, or smokers was higher in Allegany County compared to Garrett County and the overall trend in the state of Maryland for 2006-2012. Only for hypertension, was the percentage noticeably higher in Allegany County compared to the region. We obtained cancer incidence data from NCI for 2006-2010 and found that Allegany had a higher cancer incidence rate for non-Hodgkin's lymphoma, leukemia, and colorectal cancer compared to both Garrett County and the state of Maryland. While, Garrett only had a bladder cancer rate higher than both Allegany and the state of Maryland. Over the 10-year period between 2000 and 2010, the cancers with the highest mortality rates in Allegany and Garrett counties were colorectal, breast, and prostate cancers. Deaths from these cancers were higher in these counties compared to the region and State of Maryland overall. Furthermore, compared to the leading causes of death from cancer nationwide, these counties' rates of colorectal cancer deaths were higher. Over the ten-year period from 2000 and 2010, rates of chronic respiratory disease mortality, cardiovascular disease mortality, cerebrovascular disease mortality, and septicemia mortality were higher in Allegany County compared to the rates of Garrett, Maryland, and the region. From the 2006-201 time period, percentage of babies born with low birth weight (LBW) in Allegany (9.1%) was higher than % low birth weight for Garrett (7.5%), MD (9%), region (8%), and the United States (8.2%); while, infant mortality rates of 8.4 deaths/1000 births (Allegany) and 10.8 deaths/1000 births (Garrett) were higher than the rates for the MD (7.2 deaths/1000 births), and US (6.9 births/1000 deaths).

6.1.3 Social Determinants of Health

To evaluate the baseline social determinants of health in Allegany and Garrett counties, we obtained available information regarding sexually transmitted infections (STI), crime, injuries, mental health, and substance abuse. In 2011, STI rates including HIV remain low in both counties when compared to the State of Maryland. In Garrett County, crime rates across all categories remain steady and lower than the Maryland State averages, fluctuating slightly over the 10-year period between 2000 and 2010. In Allegany County, there was a slow but steady increase in most crime categories in this same period. This increase runs counter to statewide trends, which demonstrate major decreases in crime rates across all categories in the last decade. Total mortality rates from unintentional injury, motor vehicle traffic accidents, and intentional self-harm (suicide) are much higher in Allegany and Garrett counties than the average for the State of Maryland. Data gathered from County Health Rankings, the Health Indicators Warehouse, and the Behavioral Risk Factor Surveillance System (BRFSS) indicate that poor mental health, insufficient social and emotional support, and alcohol abuse appear to be the top indicators of the burden of mental health and substance abuse in Allegany and Garrett counties.

To assess the healthcare infrastructure of Allegany and Garrett counties, we obtained information from the US Health Resources and Services Administration (HRSA) regarding rates and ratios of primary care physicians, dentists, and mental health providers to the population. These rates are, on average, much lower for both counties than the statewide averages, especially for mental health providers, indicating a critical shortage of providers in both Allegany and Garrett counties. In addition, Allegany County is a designated Health Professional Shortage Area (HPSA) for primary care for low-income populations, mental health care for Medical Assistance populations, and dental care for Medical Assistance populations. Allegany County has a critical need for specialty providers including vascular surgery, urology, as well as dentists willing to provide care for adults with no insurance or Medical Assistance. Garrett County is a designated HPSA for primary and mental health care, and dental care for Medical Assistance populations. All of Garrett County is considered a Medically Underserved Area (MUA), while substantial portions of Allegany County (Orleans, Lonaconing, Oldtown, and Cumberland) also qualify as MUAs. Finally, the percentage of uninsured residents in Allegany County was similar to the statewide average of 12%, while the percentage was slightly higher (14%) for Garrett County.

The body of this report contains a summary of the baseline health assessment and the Appendix contains a more detailed baseline health profile and assessment for Allegany and Garrett counties.

6.2 Impact Assessment

6.2.1 Hazard Evaluation Methods and Summary

To evaluate the potential public health impact of UNGDP process in Allegany and Garrett Counties, we conducted an extensive review of the literature. We identified the hazards that most concern community members through a detailed scoping process. We also conducted a site visit to a community with active UNGDP in Doddridge County, WV to directly observe the impacts, both positive and negative. During that visit, we gained firsthand knowledge about the hidden sufferings experienced by residents as well as benefits experienced by the local businesses. We also met by teleconference with the American Petroleum Institute to obtain their views and reviewed comments and literature that they submitted as part of their stakeholder input to the public health study.

Based on the scoping process and existing literature, we categorized the UNGDP associated hazards into eight broad categories: i) Air quality, ii) Water-related (water quality, soil quality and naturally occurring radioactive materials), iii) Noise, iv) Earthquakes, v) Social determinant of health (e.g., sexually transmitted infections (STIs), traffic, crime), vi) Healthcare infrastructure, vii) Occupational health, and viii) Cumulative exposure/risk. We then ranked each of these hazards using seven criteria. The scores were summed across the evaluation criteria to obtain an overall score for the hazards. Based on this overall score, we classified each hazard as:

- H: High likelihood that UNGDP related changes will have negative impact on public health
- M: Moderately high likelihood that UNGDP related changes will have negative impact on public health.
- L: Low likelihood that UNGDP related changes will have negative impact on public health.

After much internal discussion on the study team, we agreed on “Moderate” as our middle hazard classification in time for the final progress report presentation – but were never truly comfortable with it. However, following the June 28 meeting, we found that our original classification term “Moderate” was frequently misunderstood and resulted in repeated requests for clarification. Apparently some see “moderate” as similar to “moderation is good” and we were asked if we meant it was not significant. An alternative classification that might be clearer would be “not significant”, “moderately significant”, and “highly significant” likelihood of negative impact. But, that seemed unwieldy. High and low are clear and succinct. To retain their brevity and to be clear that our middle category does not consist of hazards that should be dismissed, we have chosen “Moderately High” as the middle category for this final report.

A summary of the hazard classification for each of the eight broad categories of UNGDP associated hazards is shown in Table 6-1. Three categories were classified as having high likelihood, three were classified as having moderately high, and one as having low likelihood of negative impacts on public health. The following sections 6.2.2 through 6.2.9 give summary explanations of these classifications for each category of hazards. The detailed hazard evaluation is contained in section 10 Impact Assessment.

Table 6-1: Hazard Evaluation Summary

Topic	Likelihood of Negative Public Health Impact
Air Quality	High
Healthcare Infrastructure	High
Occupational Health	High
Social Determinants of Health	High
Cumulative Exposures/Risks	Moderately High
Flowback and Production Water-Related	Moderately High
Noise	Moderately High
Earthquakes	Low

High = high likelihood of negative health impacts, Moderately High = moderately high likelihood of negative health impacts, Low = low likelihood of negative health impacts

6.2.2 Air Quality

Epidemiological studies over the past 50 years have documented the relationships between exposure to selected air pollutants and various adverse health outcomes. Recent data suggests these air pollutants are associated with UNGDP - some are produced as a part of the process (site preparation, production), while others are present in the natural gas. At present, linking exposure to air pollution associated with UNGDP - a new phenomenon- with adverse health outcome is challenging because: 1) discrepancy in temporal scale between onset of exposure (dating only few years back) and manifestation of outcomes that are known to have a notable lag time, particularly for chronic diseases, 2) epidemiological studies designed to investigate such association are often 3-5 years in duration with additional 1-2 years for data to be published in a peer-reviewed journals. Despite these challenges, findings have started to emerge in peer-reviewed journals linking exposure to air pollution associated with UNGDP increased risk of sub-chronic health effects, adverse birth outcomes including congenital heart defects and neural tube defects, as well as higher prevalence of symptoms such as throat & nasal irritation, sinus problems, eye burning, severe headaches, persistent cough, skin rashes, and frequent nose bleeds among respondents living within 1500 feet of UNGDP facilities compared to those who lived >1500 feet [1–3]. Major determinants of these relationships include the concentration of the pollutants in the environment, frequency and duration of exposures encountered by individuals as well as potency of these pollutants. At present, there is a dearth of information that allows public health professionals to critically evaluate these aspects. While no information is available on the concentration profile of air pollutants as a function of distance from the well pads and compression stations, increasing body of literature on traffic related air pollution show that the concentrations of traffic related air pollutants reach to background level beyond 500-1000m (1640-3280 feet) distance from the roads.

Based on our evaluations of the limited but emerging epidemiological evidence from UNGDP impacted areas and air quality measurements as well as epidemiological evidence from other fields, we conclude that there is a **High Likelihood** UNGDP related changes in air quality will have a negative impact on public health in Garrett and Allegany Counties. The extent of the impact will be based on population vulnerability, proximity to the sites, and the success of public health prevention strategies implemented by the State and local communities and control measures taken by the industry to minimize exposures.

6.2.3 Flowback and Production Water-Related

The scientific literature has documented many plausible pathways by which natural and anthropogenic contamination may become available for human exposure as a result of unconventional natural gas development. The evidence base to date suggests that gases, chemical compounds, and to a lesser extent naturally occurring radioactive materials (NORM), are mobilized during the drilling and wastewater recovery phases of the fracturing process and may result in contamination of ground waters used for drinking water. Concerns also exist regarding the surface impoundment of wastewater in ponds or pits, in regards to both accumulation of radiological material and the concurrent potential for spills or leaks due to overfilling or ruptures in impoundment liners. While challenges (some peer-reviewed) exist to assertions that fracturing activities are impacting drinking water sources, there appears to be scientific consensus that high-quality baseline and periodic monitoring data are largely absent in states that currently permit fracturing. This lack of data complicates assessment of the potential impacts of fracturing activities and may preclude determination of best practices or other interventions aimed at minimizing exposures. Despite these gaps, there is consistency in the literature that wells within shorter distances (typically <1 km) of drill sites are likely to be impaired, potentially by fracturing activities. The most commonly documented contamination in these wells is methane gas.

Since horizontal drilling with hydraulic fracturing has not yet occurred in the state, Maryland has an opportunity to conduct a thorough baseline characterization of ground water conditions prior to allowing UNGDP. That way, if the state were to proceed with permitting the practice, it would have comparison data to revisit its decision in the future. Questions remain, however, whether feasible technologies exist to reverse groundwater impacts that may later be determined to have arisen as a result of fracturing activities.

Studies of health effects of drinking water exposures to fracturing contaminants do not yet exist, though many anecdotal reports would suggest that high-quality, rigorous studies should be conducted to better understand the health consequences of exposure. Evidence exists to show recovered wastewater can be contaminated with NORM and heavy metals. The composition of the NORM appears to depend on the geologic composition of bedrock in which drilling is occurring. It is common for radium isotopes to be used as indices of radiological contamination, but emerging thought would suggest that radium alone might be an inadequate surrogate for monitoring radiological activity. “Beneficial” reuses of fracking brines, especially those that involve land application of brines or wastewater, are inadvisable as a result of concerns related to potential human exposures to radionuclides and heavy metals.

After carefully reviewing the limited evidence from UNGDP impacted areas and current scientific understanding form non-UNGDP related fields, we conclude that there is a **Moderately High Likelihood** that UNGDP’s impact on water quality, soil quality and naturally occurring radioactive materials will have a negative impact on public health in Garrett and Allegany Counties. The overall score for Flowback and Production Water related concerns are primarily driven by concerns related to water quality and the large fraction of population relying on well water..

6.2.4 Noise

Environmental noise associated with UNGDP was identified as a top concern among residents of Western Maryland. The literature on UNGDP noise is very limited, however a few studies have shown that at 1,000 to 2,000 feet from a well pad noise levels can be expected to range from 44 dBA to 76 dBA, depending on the phase. Due to a lack of information regarding compressor stations, we conducted a small pilot study in Doddridge County, WV to understand the noise levels associated with living near a compressor station. We found at 1,000-2,000 feet from the compressor station noise levels were 55.78 dBA over a 24-hour period, 52.75 dBA during daytime hours and 51.75 dBA during nighttime hours. While there are not any epidemiologic studies on UNGDP noise, we know from other industries that long-term exposure to environmental noise has been associated with a myriad of health outcomes, including stress and annoyance, sleep disturbances, hypertension, and cardiovascular disease. Noise levels can be reduced by distance, enforcement of regulatory standards, and use of sound reduction technologies.

Based on prior evidence regarding negative impact of noise exposures and noise monitoring results from UNGDP sites that included our own monitoring results from WV, we conclude that there is a **Moderately High Likelihood** that UNGDP related changes in noise exposure will have negative impacts on public health in Garrett and Allegany Counties.

6.2.5 Earthquakes

Recent studies suggest that an increasing frequency of earthquakes, particularly in the Central and Eastern US may be associated with UNGDP, primarily linked with deep well injection of wastewater. The actual process of hydraulic fracturing used for initiation of new wells produces thousands of micro earthquakes (most too small to feel). The potential public health effects of earthquakes related to deep well injection is a concern. However, the potential public health effects associated with micro earthquakes resulting from hydraulic fracturing appears to be negligible, based on current literature. There is considerable evidence that suggest earthquakes can persist years after the start/stop of well activities. At present, it remain unclear if the underground stress produced by horizontal drilling and hydraulic fracturing can cumulate over space (high well density) and time to produce much more significant earthquakes in the future years/decades, that could have a much more significant impact on public health.

Provided that Maryland does not allow deep well injection of wastewater, we conclude that there is a **Low Likelihood** that UNGDP related earthquakes will have a negative impact on public health in Garrett and Allegany Counties.

6.2.6 Social Determinants of Health

Many of the rural communities that will be potentially impacted by unconventional natural gas development (UNGD) operations are not fully equipped to handle the influx of industrial traffic. Evidence from UNGDP impacted area suggest that increased truck traffic associated with UNGDP related activities exposes residents to greater risk of motor vehicle crashes involving injury, or even death. These communities also experience increases in violent crime, sexually transmitted diseases, mental health problems and substance abuse. Crime statistics, disease rates, and police accounts all suggest the introduction of UNGD operations to a community places the local residents' safety as well as the safety of the workers at risk. Most of the research conducted on these issues suggest there are solutions available to these problems [4–7].

Based on data from UNGDP impacted communities as well as previous knowledge related to boom town, we conclude that there is a **High Likelihood** UNGDP related activities will have a negative impact on the social determinants of health.

6.2.7 Occupational Health

The promise of UNGDP operations brings the promise of jobs. Yet the men and women who work these jobs are at greater risk of harmful occupational exposures than many other industries in Maryland. Of particular concern are exposures to crystalline silica, hydrogen sulfide, and diesel particulate matter, as well as fatalities from truck accidents, which accounted for 49% of oil and gas extraction fatalities in 2012. Recently reported unusually high level of UNGDP workers' exposure to crystalline silica, which is known to cause silicosis and lung cancer, is of particular concern [30]. Evidence shows that numerous social hazards, such as mental distress, suicide, stress, and substance abuse, have been associated with working on a UNGDP operation due to the transient nature of the work. These social hazards also put a strain on communities, as evidenced by increased incidence in violent crime arrests, drug violations, and sexually transmitted infections. Based on these, we conclude that there is a **High Likelihood** of adverse outcomes among UNGDP workers in Garrett and Allegany Counties.

6.2.8 Healthcare Infrastructure

Our assessment of the impact to healthcare infrastructure in Allegany and Garrett counties is based upon RESI's estimate of an average of 1327-2825 migrant workers during the first 10 years of drilling and 151-189 migrant workers on average during the 10-year period after drilling.

Impacts to the healthcare infrastructure are expected to be *high* due to a substantial increase in the migrant workforce and population and the associated potential increase in health care utilization in Allegany and Garrett counties. Research indicates that healthcare infrastructure impacts will be observed when the influx of workers is the highest, during the initial years of the project in the development phase, and that this impact will be uneven during the lifecycle of the project. If UNGDP workers are insured, local primary care and public health services will be supported. However, it is unclear whether an increase in the insured population and UNGDP revenues will lead to healthcare infrastructure development in Allegany and Garrett counties. If UNGDP workers are uninsured, they would stress an already under-resourced healthcare infrastructure. In addition, utilization rates for primary and public health care systems, especially in the areas of emergency, urgent care, and trauma care, is likely to rise as a result of an increase in the UNGDP workforce regardless of their insurance status. Because Allegany and Garrett counties' healthcare infrastructure needs are substantial (e.g. HPSA and MUA areas) and a high number of their populations are vulnerable and because of the large number of expected long-term migrant workers relative to population size, we predict that UNGDP would have a **high likelihood** of negatively impacting healthcare infrastructure.

6.2.9 Cumulative Exposures/Risk

Exposure does not happen in vacuum. Community members impacted by UNGDP will be exposed to multiple chemical hazards (VOCs, PM, PAHs), physical hazards (noise, radiation), and a host of psychosocial stressors including those related to public safety, potential loss of property values, disruption of existing social fabric, crime, among others. In addition, such developments also disproportionately impact underserved communities such as those with low SES, and without a strong political voice. The question of combined effect of these cumulative exposures, as well as the interactions between chemical and non-chemical stressors needs to be considered. While there is strong agreement in scientific community that the traditional single chemical centric risk assessment methods are inadequate in dealing with such issues, the emerging field of cumulative risk assessment is still in its infancy. Epidemiological and clinical evidence from other disciplines document: 1) interactions between chemical hazards, 2) interaction between chemical and physical hazards, and that 3) psychological stress increases susceptibility to respiratory infections that are known to be major drivers of asthma morbidity. Furthermore, significant evidence suggests that disadvantaged communities are disproportionately exposed and are more vulnerable to the effect of these hazards. Based on this, it is reasonable to assume that the combined effect of UNGDP related hazards described in this report may be higher than the simple sum, and that the impact will be more pronounced in disadvantaged communities and will be disproportionately felt by vulnerable subpopulations such as property owners without mineral rights, elderly, children, and individuals with preexisting diseases. Therefore, we conclude that there is a **Moderately High Likelihood** that the UNGDP related activities will have a net negative impact in the cumulative exposure/risk.

6.3 Recommendations

6.3.1 Comprehensive Gas Development Plans (CGDP)

Potential public health impacts and prevention and mitigation strategies should be included in the CGDP so that the required and routine public hearings on the plan can include an informed discussion of health as well as environmental impacts.

R1. Require assessment of air quality and other potential health impacts and propose strategies to protect the community and workers from exposure to hazardous air pollutants.

R2. Require assessment of whether application of standard setback distances will be adequate to protect public health, including consideration of prevailing winds and topography.

R3. Require disclosure of planned well stimulation methods and classes and amounts of chemicals to be used.

R4. Require a quality assurance plan.

R5. Require an air, water, and soil-monitoring plan.

R6. Require assessment of impact on and a monitoring plan for potential fugitive emissions from existing and historic gas wells within the horizontal extent of the fractured area.

R7. Require that all UNGDP materials and wastes be stored in closed tanks; open pits shall only be used for storage of fresh water.

6.3.2 Disclosure of Well Stimulation Materials

Recommendations concerning disclosure were revised and moved to a separate section based on feedback received at and following the public progress report on June 28, 2014. The final recommendations are now in line with the proposed legislation H.B. 1030 [8]. Three phases of disclosure are included – a preliminary more general disclosure with the CGDP, a specific detailed disclosure with the well permit application, and a specific detailed disclosure after well stimulation is finished.

R8. Require preliminary disclosure at time of CGDP submission (see CGDP recommendations), detailed disclosure at time of well permit application, and detailed reporting of actual materials used within 30 days of finishing well stimulation activities. Require notification of MDE, local emergency responders and public notice of significant variances from materials and concentrations proposed in the permit within 24-hours of occurrence.

R9. Require detailed disclosures to include CAS numbers, volume and concentration of every chemical or distinct material including proppants, their physical form,

and identification of engineered nanomaterials – including drilling muds and hydraulic fracturing and other fluids – used in well stimulation. Do not allow claims of trade secrets for identities and concentrations of specific chemicals or nanomaterials used in well stimulation.

R10. Require detailed disclosures to include base fluid volume and sources including percentages that are recycled fracturing fluid, production water, and fresh water.

R11. Require simultaneous submission to state regulators and FracFocus.

R12. Collaborate with California to develop a State controlled and archived Internet Web site consistent with the provisions of California SB 4.

R13. Implement the provisions of H.B. 1030 for timely access to disclosed information by medical professionals, emergency responders, poison control centers, local officials, scientists, and the public.

6.3.3 Air Quality

Based on our evaluations of the limited but emerging epidemiological evidence from UNGDP impacted areas and air quality measurements as well as epidemiological evidence from other fields, we conclude that there is a **High Likelihood** UNGDP related changes in air quality will have a negative impact on public health in Garrett and Allegany Counties. Should Maryland move forward with UNGDP, the following recommendations should be implemented to prevent or minimize potential negative impacts on public health.

R14. Require a minimal setback distance of 2000 feet from well pads and from compressor stations not using electric motors.

R15. Require electrically powered motors wherever possible; do not permit use of unprocessed natural gas to power equipment. This recommendation is designed to reduce VOCs and PAHs emissions from drilling equipment and compressors.

R16. Require all trucks transporting dirt, drilling cuttings to be covered.

R17. Require storage tanks for all materials other than fresh water and other UNGDP equipment to meet EPA emission standards to minimize VOC emissions.

R18. Establish a panel consisting of community residents and industry personnel to actively address complaints regarding odor.

R19. Conduct Air Quality Monitoring

- **a. Initiate air monitoring to evaluate impact of all phases of UNGDP on local air quality (baseline, development and production).**
- **b. Conduct source apportionment that allows UNGDP signal to be separated from the local and regional sources.**
- **c. Conduct air monitoring with active input from community members in planning, execution, and evaluation of results.**

d. **Conduct air monitoring in a manner to capture both acute and chronic exposures, particularly short-term peak exposures.**

e. **Clearly communicate to community members expectations about what is achievable through air monitoring.**

6.3.4 Flowback and Production Water-Related

Based on our evaluations of the limited data available from UNGDP impacted areas, we conclude that there is a **Moderately High Likelihood** that UNGDP's impact on water quality, soil quality and naturally occurring radioactive materials will have a negative impact on public health in Garrett and Allegany Counties. The overall score for Flowback and Production Water related concerns are primarily driven by concerns related to water quality. Should Maryland move forward with UNGDP, the following recommendation should be implemented to prevent or minimize potential negative impacts on public health.

6.3.4.1 Water & Soil Quality

R20. Prohibit well pads within watersheds of drinking water reservoirs and protect public and private drinking water wells with appropriate setbacks.

R21. Implement UMCES-AL/MDE water monitoring plan. Require monitoring of water quality during initial gas production and at regular intervals thereafter.

R22. Implement the UMCES-AL recommendations for management and recycling of flowback and production fluids.

R23. Require identification and monitoring of "signature" chemicals in fracturing fluids to allow for future identification of ground water infiltration/contamination.

R24. Conduct soil monitoring in areas potentially impacted by UNGD upset conditions.

R25. Prohibit flowback and production wastewater or brine use to suppress road dust, de-ice roads, or other land/surface applications.

6.3.4.2 NORM

R26. Conduct research to identify the appropriate suite of priority radionuclides for assessment of radiological activity.

In the meantime, metrics such as total alpha activity, or total gamma activity should be used to assess radiological contamination and support decision-making.

6.3.5 Noise

Based on our monitoring results from Doddridge County, WV as well as other noise monitoring reports, we conclude that there is a **Moderately High Likelihood** that UNGDP related changes in noise exposure will have negative impacts on public health in Garrett and Allegany Counties. Should Maryland move forward with UNGDP, the following recommendation should be implemented to prevent or minimize potential negative impacts on public health.

R27. Implement noise reduction strategies recommended by UMCES-AL in the MD Best Management Practices, including requiring electric motors wherever power supplies are available and construction of artificial sound barriers.

R28. Require a setback of 2,000 feet for natural gas compressor stations using diesel engines, 1000 feet for stations using electric motors and sound barriers.

R29. Establish a system to actively address noise complaints.

6.3.6 Earthquakes

Based on our review of literature, there is clear evidence that deep well injection of wastewater is related to earthquakes that are greater than magnitude 3. However, earthquakes related to hydraulic fracturing itself are very small (less than magnitude 3). Provided that Maryland does not allow deep well injection of wastewater, there is a **Low Likelihood** UNGDP related earthquakes will have a negative impact on public health in Garrett and Allegany Counties. Should Maryland move forward with UNGDP, following recommendation should be taken into consideration to minimize potential negative impact on public health.

R30. Collect baseline data on seismic activities using methods that can record earthquakes smaller than magnitude 3.

R31. Restrict issuing UIC Class II permits for disposal of UNGDP fluids until licensing requirements adequately addresses earthquake risk.

R32. Implement use of sensitive seismic monitoring technology to better detect small earthquake activity that could presage larger seismic events as well as using a "traffic-light system" that sets thresholds for seismic activity notification.

6.3.7 Social Determinants of Health

Based on our review of social determinants of health, we conclude that there is a **High Likelihood** UNGDP related activities will have a negative impact on the social determinants of health. Should Maryland move forward with UNGDP, the following recommendation should be implemented to prevent or minimize potential negative impacts on public health.

6.3.7.1 Traffic Safety

R33. Increase state and local highway patrols to closely monitor truck traffic subject to the Oilfield Exemption from highway safety rules.

R34. Empower local communities to control truck speed and traffic patterns.

R35. Route truck traffic to maintain separation between UNGDP activities and the public (such as, avoid trucking during school bus transport).

R36. Consider use of pipelines to move UNGDP fluids between sites.

6.3.7.2 Empower communities

R37. Enact a Surface Owners Protection Act as recommended in the MDE Part I report.

R38. Engage local communities in monitoring and ensuring that setback distances are properly implemented.

R39. Create maps using buffer zones (setback distance) to identify specific areas were fracking should be restricted (homes, churches, schools, hospitals, daycare centers, parks, recreational water bodies) and make these available for community members.

6.3.8 Healthcare Infrastructure

Based on our evaluations of the current healthcare infrastructure in Garret and Allegany Counties as well as expected number of migrant workers that will come to these areas, we conclude that there is a **High Likelihood** UNGDP related activities will have a negative impact on public healthcare infrastructure in Garrett and Allegany Counties. Should Maryland move forward with UNGDP, the following recommendations should be implemented to prevent or minimize potential negative impact on public health.

R40. Closely monitor whether prospective UNGDP companies provide adequate health insurance coverage for all employees.

R41. Organize a local health care forum with key stakeholders to assess health care services and anticipated needs related to UNGDP.

R42. Inform and train emergency and medical personnel on specific medical needs of UNGDP workforce.

R43. Review and monitor county-level tax revenues and assess improvements necessary to meet increased services need.

R44. Establish a committee of state and local stakeholders (including UNGDP officials and local providers and residents) for early identification of impacts to healthcare infrastructure.

R45. Initiate monitoring of UNGDP healthcare-related costs.

6.3.9 Cumulative Exposure/Risk

The combination of chemical, physical, and psychosocial stressors can lead to effects that are cumulative involving potentially additive or multiplicative interactions among the exposures. Observed health impacts, if any, will result from these cumulative impacts. We anticipate the cumulative risk from the physical, chemical and psychosocial stressors will be greater than the simple sum of individual risks. We further anticipate that the impact will be disproportionately felt by vulnerable subgroups such as children, elderly, individuals with existing diseases, poor residents, and individuals without mineral rights. We conclude that there is a **Moderately High Likelihood** that the UNGDP related activities will have a net negative impact in the cumulative exposure/risk.

Most of the recommendations in this report are targeted at primary prevention (i.e. to prevent the occurrence of adverse health effects). However, a monitoring method is needed to verify the effectiveness of primary prevention activities and to improve them as necessary. Furthermore, secondary and tertiary prevention should not be neglected. Thus, disease surveillance and targeted longitudinal epidemiologic studies are needed for both evaluation of primary prevention effectiveness and as a means of providing continuing improvement of regulations. Surveillance and epidemiologic studies will need to incorporate appropriate exposure assessment programs, and to be most useful, need to be started immediately so as to provide comparable baseline data should Maryland decide to move forward with UNGDP.

R46. Initiate a birth outcomes surveillance system

R47. Initiate a longitudinal epidemiologic study of dermal, mucosal, and respiratory irritation

R48. Develop a funding mechanism for public health studies

6.3.10 Occupational Health

Based on our evaluations of the limited but emerging studies of UNGDP workers' exposures to respirable crystalline silica (frack sand) and what is known from epidemiologic and toxicologic studies of crystalline silica (silicosis, lung cancer), we conclude that there is a **High Likelihood** of adverse outcomes among UNGDP workers in Garrett and Allegany Counties. Should Maryland move forward with UNGDP, the following recommendations are made to prevent most and minimize residual potential negative impacts on occupational health.

R49. Require implementation of NIOSH and OSHA recommended controls for silica exposure in UNGDP operations.

R50. Provide MOSH with resources to regularly inspect UNGDP workplaces and monitor worker exposures.

R51. Establish community outreach programs to help transient workers feel more welcome in the community as a means of reducing rates of depression, suicide, and drug use.

R52. Require employers to provide employee assistance programs including counseling and substance abuse treatment.

7 INTRODUCTION

On June 6, 2011, Governor Martin O'Malley issued Executive Order 01.01.2011.11, establishing the Marcellus Shale Safe Drilling Initiative (Initiative). The Initiative's purpose is to assist state policymakers and regulators in determining whether and how gas production from the Marcellus Shale and other shale formations in Maryland can be accomplished without unacceptable risks to public health, safety, the environment, and natural resources. On October 18, 2013, the Maryland Department of Health and Mental Hygiene (DHMH) signed a MOU with the Maryland Institute of Applied Environmental Health (MIAEH) at the University of Maryland, College Park to evaluate the potential public health impacts associated with drilling in the Marcellus Shale in Maryland. The study, as outlined in the MOU, will include:

- **Detailed Scoping**, including timetable for remaining deliverables, methods, and public input to determine study objectives.
- **Baseline Assessment** of current regional population health, including demographics, causes of morbidity and mortality, local health priorities, vulnerable populations, local healthcare and social service infrastructure.
- **Impact Assessment** of the potential exposures, including hazards and known health impacts both directly and indirectly associated with hydraulic fracturing, assessment of current exposures and data gaps prior to onset of hydraulic fracturing.
- **Final Report,** which will include the study findings, monitoring and assessment recommendations, and public health response and mitigation strategies.

7.1 Health Impact Assessment Process and the Public Health Study

Health Impact Assessment (HIA) is a tool that is designed to support decision and policymaking. HIA combines array of data sources, analytic methods and input from stakeholders including community members to determine if a proposed policy, plan, program, and/or decision has the potential to impact the health of the community, and how these effects are distributed within population subgroups that differ by geography, SES, and demographic characteristics [9]. This information is then fed back to the policymakers to help them make an informed decision on the pending policy, plan, program and/or decision.

HIA is not a quantitative risk assessment, rather it provides information that is qualitative in nature that can be used to assess whether and how community wellbeing may be impacted, both directly and indirectly. It consists of 6 steps:

1. Screening: Initial step to determine the need for HIA.
2. Scoping: With community input, identify the most important hazard and health impact to focus on.
3. Assessment: Analyze the baseline characteristics of the population and provide anticipated potential effects.
4. Recommendations: Based on the assessment, develop recommendations for minimizing health effects, and approaches for monitoring.
5. Reporting: Prepare a report for the decision makers, disseminate the findings and recommendations to all the stakeholders including community members.
6. Monitoring and Evaluation of the HIA Process: Evaluate if the HIA process helped the decision making process.

This public health study, which draws upon several elements of the HIA, including scoping, baseline assessment, impact assessment as well as reporting, was conducted to inform the Marcellus Shale Safe Drilling Initiative Advisory Commission, State legislators and the Governor about potential health impacts associated with UNGDP related activities so they make an informed decision that takes into account the health and well-being of Marylanders. Should Maryland decided to move forward with UNGDP, this report provides set of recommendations that will minimize negative impact on public health. This public health study does not address economic benefits associated with UNGDP as these issues are addressed in a separate Economic Report prepared for the commission by RESI [10]. As outlined in the National Academy of Science Report, quantitative risk assessment is beyond the scope of HIA. As such, this study did not conduct a formal quantitative risk assessment [9].

7.2 Natural Gas Development & Production

7.2.1 Conventional vs. Unconventional Natural Gas

While increasing domestic production of natural gas provides economic growth and jobs, there is concern that new extraction technologies could negatively impact public health, safety, the environment, and natural resources. There are several key differences between conventional natural gas development and production (CNGDP) and unconventional natural gas development and production (UNGDP). CNGDP requires vertical drilling and hydraulic fracturing, while UNGDP uses new horizontal drilling techniques along with hydraulic fracturing. There are also other, less common alternative well stimulation technologies sometimes combined with horizontal drilling, including acid well stimulation. This report is focused on horizontal drilling and hydraulic fracturing. The direction and length of the lateral section of the well can range from 4,000 to 5,000 feet [11]. The additional horizontal drilling leads to more cuttings – a mixture of coarse chips and finer particles of rock that are produced as the well is drilled – that have to be removed. The use of horizontal drilling requires a larger well pad to accommodate increased on-site storage of equipment and fluid [11]. CNGDP requires up to three acres per well pad, while UNGDP requires up to six acres [11]. UNGDP also requires significantly more time, water, and fluid – CNGDP lasts approximately one month and uses up to 80,000 gallons of water, while UNGDP lasts approximately three months and uses up to four million gallons of water [11]. The water is mixed with a mixture of chemicals and natural or manufactured sand grains used to hold open the fractures created during hydraulic fracturing called proppants [11]. This mixture often referred to as "fracking fluid", is forced into the gas-bearing rock under intense pressure to fracture the rock proximate to the wall. These fractures form pathways so that the natural gas can be released and captured.

7.2.2 The Marcellus Shale

The Marcellus Shale gas formation is abundant in natural gas resources. It is one of the largest shale regions in the United States; covering over 95,000 square miles and 4,000-8,000 miles feet depth [12]. This 400-year-old rock contains more than 410 trillion cubic feet of natural gas and is found beneath the surface of Pennsylvania, Ohio, West Virginia, New York and Western Maryland [12]. The Marcellus Shale contains both dry and wet gas. Maryland's area of Marcellus Shale is composed of mostly dry gas, which is composed almost entirely of methane, while wet gas contains not only methane, but also natural gas liquids (NGLs) including ethane, butane and propane. There is greater demand for wet gas due its versatility as a fuel and use as a feedstock for plastics and other petrochemical production [11]. The revenue generated from these NGLs sales counterbalance the low price of natural gas, leaving dry gas drilling less popular and profitable. Thus, it seems likely that the demand for natural gas from Maryland's portion of the Marcellus Shale will not be sufficient to attract significant investment until and unless the price of natural gas increases significantly. [13]

7.2.3 Terminology

As discussed by Shonkoff and colleagues, there is some confusion regarding terminology [14]. We will be using the term UNGDP to refer to the entire process, from well pad construction to pipeline development. High-volume hydraulic fracturing (HVHF) refers to the well completion stage, when a mixture of water, chemicals, and proppant are injected into the well at high pressure. Unconventional natural gas development (UNGD) includes well pad preparation, vertical and horizontal drilling, and well completion. Well completion includes completion transition, hydraulic fracturing, and flowback. Unconventional natural gas production (UNGP) includes pipeline development and operation of compressor stations. Detailed activities involved in this process are depicted in Figure 7-1. [15]

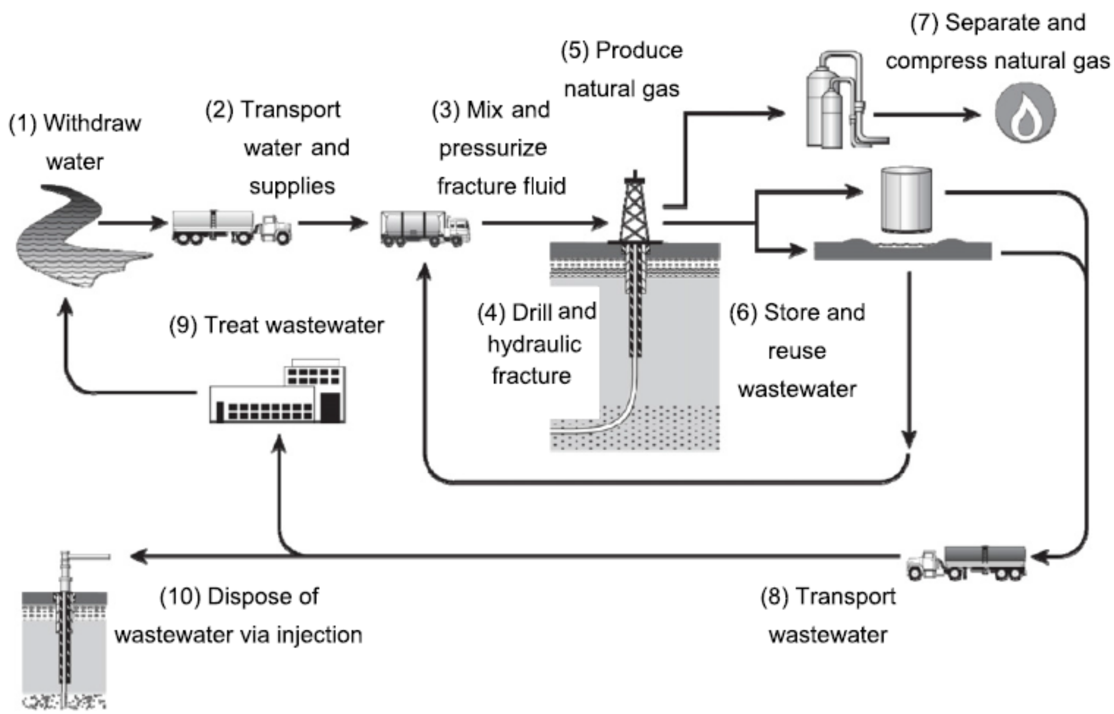

Figure 7-1: Major Activities Associated with UNGDP Process [15]

7.2.4 Unconventional Natural Gas Development (UNGD)

Once an applicant is granted the right to extract natural gas, a preliminary Comprehensive Gas Development Plan (CGDP) has to be prepared including all exploration and production activities. According to Maryland's Best Management Practice, a CGDP is designed to address the larger, landscape-level issues and cumulative effects, which offers significant benefits to both the industry and the public [16]. A CGDP will be mandatory in Maryland, once the adopted best management plan is implemented in regulations, and will serve as a prerequisite to an application for a well permit. The CGDP must contain locations for well pads, roads, pipelines, and other ancillary equipment, which precedes an individual well permit of more detail and explanation of each activity, step and process. Engineering, design, and environmental plans must meet or exceed the standards set by the departments in order for a company to develop the CGDP in a process that allows for public participation. A completed CGDP, approved by the State is effective for ten years and enable provisions for individual wells to be made.

The development phase of a well requires pad preparation, drilling, and well completion. UNGD in the Marcellus Shale uses high volume, slickwater, horizontal hydraulic fracturing. A vertical well is drilled along with a horizontal or lateral extension. These horizontal, gas-bearing layers require a higher volume of water to fracture the shale. In order to increase the speed of fluid inside the well, a combination of chemicals, also known as slickwater, are added to the water to adjust viscosity or thickness [11]. Marcellus wells are drilled and cased in multiple stages. Before the process begins, there must be an established well pad, large enough to support all equipment needed for drilling. In the interest of horizontal drilling, a special drill bit is used to turn the drill at a predetermined depth, known as the kickoff point. This point is reached after 1000 feet of drilling in order to fully turn a well horizontal. Multiple barriers of steel casing and cement are installed to protect the hole from collapsing as well as the escape of drilling fluids and gas from the side of the well. As the hole is drilled deeper and cemented in place, guiding shoes on the ends of the casing assist in the lengthening of casing down the well safely until it reaches the annulus, or space between the casing and the drilled well. A wiper plug forces cement out of the well bore, cleans the inside of casing walls and separates the cement from additional drilling muds, or lubrication for easier and faster drilling [11].

There are several layers of casing –conductor pipe, surface, intermediate, and production –that are designed to protect against environmental contamination. A conductor pipe has the largest diameter and prevents the top of the well from collapsing and exchange of fluids like water and gas. This provides a path for drilling muds. Conductor pipe casing also has blowout preventers, which regulate erratic pressure changes that can be found while drilling. The next three levels of casing are surface, intermediate and production casing. Surface casing, similar to the conductor pipe prevents contamination of groundwater water by drilling muds and also preventing sediment from caving into the well [11]. Intermediate casing regulates potential problems like abnormal pressure from shallow gas pockets. Production casing is the thinnest in diameter and runs through the length of the well to isolate the zone containing natural gas from subsurface formations [17]. Once the casing is in place, perforation guns positioned in the lateral part of the well create punctured holes for natural gas to flow into the well. The guns' small projectile shots are steel piercing bullets that punch through the steel casing and cement-filled annulus. The fracking process last three to five days, while allowing up to ten fractures per well and between six to ten drillable wells per well pad. After the well has been completed, the gas company performs a series of "shut-ins" or pressure tests on the well. These tests take another three days, in order to assess the proper functioning of the drilling and casing. A device referred to as the "Christmas Tree" is placed on top of the well surface to allow gas to be pumped into production pipelines, seal gas in the well in an emergency and monitor production [11]. After the surface facilities are installed, the well is placed on production for 20 to 30 years, during which time the well may be refractured several times in an effort to increase production.

Figure 7-2: UNG Compressor Station

Following completion, various procedures are conducted to measure the effectiveness of the hydraulic fracturing process. A combination of micro-seismic mapping and measurements are taken to identify temperature, production and video imaging logging [11]. Such techniques are costly, however, the information collected is used to evaluate fractures near the wellbore. Since horizontal hydraulic fracturing requires large quantities of water, it also needs chemicals, ranging from benign to toxic. The various chemicals mixed with water create a fracturing fluid, of which a portion returns to the surface. The flowback water at the surface contains fracturing fluids as well as various amounts of heavy metals, salts, and naturally occurring radioactive material found in the gas-bearing unit [11]. This fluid is a concern for the Marcellus Shale due to the handling, treating and disposal of the contaminated water. Current options for disposal include deep fluid injection wells or onsite water treatment and recycling. Deep fluid injection consists of injecting contaminated water into a deep, impermeable formation, where it is stored permanently; recycling water restores and prolongs its use for future hydraulic fracturing jobs [11].

7.2.5 Unconventional Natural Gas Production (UNGP)

During the production phase, [18]natural gas travels from the well, where liquids and gases are separated, through a network of pipes and field compressor stations that serve as a gathering system. A processing facility is frequently required to remove impurities such as hydrogen sulfide, helium, carbon dioxide, hydrocarbons, and water vapor that were not removed at the well head. Once these impurities are removed, the gas is pumped into large high pressure interstate pipelines.

8 SCOPING UPDATE

Our Draft Scoping Report (http://www.marcellushealth.org/detailed-scoping-report.html) was released for public comment on December 23, 2013. We received 46 comments from concerned residents, environmental advocacy organizations, and the industry and 2 reviews from external experts recruited by DHMH to provide input. After carefully considering all of the input, we made changes to our project's timeline and to the baseline health and health impact assessments.

We altered the timeline for the study as follows: First, we incorporated the baseline health assessment, impact assessment, and recommendations into a single final report, rather than issuing a separate baseline health assessment earlier in the process. This provided additional time to develop the baseline health assessment. Second, we presented a progress report with a summary of our findings and recommendations at a community meeting in Western Maryland on June 28, 2014. Third, this final report will be released July 2014 to allow for a public comment period. All comments on this report will go directly to the Marcellus Shale Safe Drilling Advisory Commission for consideration, along with comments from external reviewers arranged by DHMH. This report will not be revised.

We revised the terminology of the report to be more inclusive of the entire development and production process. Thus, we now refer to unconventional natural gas development and production (UNGDP) as described in section 7.2.3. We also recognize that well stimulation can involve other technologies besides hydraulic fracturing and make recommendations accordingly.

We also developed a regional group of counties including the surrounding counties in Pennsylvania and West Virginia to provide relevant comparisons for data for Garrett and Allegany counties. We also added several indicators to our baseline health assessment. These include:

Violent and non-violent crime
Public water service areas
Sources of public water
Water quality of public and private water
Suicide rates
Drug and alcohol addiction
Smoking
Overall mental health status

The impact assessment plan was expanded to include:

Use of brine or flowback on roads
Impact of compressor stations, excluding Cove Point LNG plant associated
Soil contamination
Radon and naturally occurring radioactive materials
Proppants with airborne qualities,

Specific literature recommended by commenters was reviewed. A complete list of literature can be found at www.marcellushealth.org/resources.

Through our scoping process, community members clearly identified climate change as one of the issues of concern to them. Fugitive emission of methane, which can occur throughout the production and distribution process, can significantly contribute to climate change and climate change is considerable threat to public health. However, a different study team would be required to assess the climate tradeoffs inherent in using shale gas as a transition fuel. This report is focused on health impacts that are primarily restricted to the local area where UNGDP takes place.

9 BASELINE HEALTH ASSESSMENT

9.1 Introduction

A robust understanding of the health trends and issues currently affecting a community is an important step in the HIA process. This public health study provides the baseline community health information needed to fully evaluate potential impacts to human health from UNGDP. Baseline health of a community can be estimated by examining a wide range of health indicators including vulnerable populations, chronic and non-chronic disease, major causes of morbidity and mortality, environmental health, social determinants of health, and healthcare infrastructure. Factors such as age, genetics, behavior, educational attainment, family income, poverty status, access to quality healthcare, proximity to hazards, and environmental exposures can influence individual health status. The Marcellus Shale Commission requested the baseline health assessment of Garrett and Allegany Counties prior to UNGDP activity in the region.

In order to assess the baseline health of Allegany and Garrett County residents, we considered demographics, potential vulnerable populations, a wide range of health indicators, environmental health, social determinants of health, and healthcare infrastructure. We used county level and census tract level statistics for the baseline health assessment. When possible, data for Allegany and Garrett counties was compared to the health data of the region (Allegany and Garrett Counties in Maryland; Bedford, Fayette, and Somerset Counties in Pennsylvania, and Grant, Hampshire, Mineral, Preston, and Tucker Counties in West Virginia), and the State of Maryland for an overall baseline health profile.

The full baseline health assessment profile for Allegany and Garrett counties is available in the Appendix.

9.2 Overview of Allegany and Garrett Counties

Allegany County with a population of 75,087 individuals is located in the northwestern part of Maryland and is 424.16 square miles. Positioned in the Ridge-and-Valley Country of the Appalachian Mountains, it is bordered to the north by the Mason-Dixon Line along with Pennsylvania. To the south, it is surrounded by the Potomac River and West Virginia. To the west is the Allegheny Front, and to the east is Frostburg, MD.

Garrett County is the western-most county in Maryland, and it's bordered to the north by the Mason-Dixon Line with Pennsylvania, to the south by the Potomac River and West Virginia. Garrett County with a population of 30,097 individuals is 647.10 square miles of incorporated and unincorporated jurisdictions. Garrett County has over 76,000 acres of parks, lakes, and publicly accessible forestland. Nicknamed Maryland's "Mountaintop Playground," the county has the state's highest elevation at 3,360 feet, as well as its largest inland body of water (Deep Creek Lake). Garrett County is home to the state's only sub-arctic wetlands and is the only county in the state to produce natural gas. There are approximately 153 churches, 87 schools, and 3 hospitals in both counties.

9.3 Demographics

As of 2012, 50.4% of the population in Garrett County were female and 49.6% were male; 27.1% of the population were under the age of 18, while 17.7% of adults were 65 years and older; 97.2% of the population identified themselves White, 1% as African-American, 0.8 % as Hispanic and 1% as other; 3.7% of the population were unemployed and 13% of the residents were living below the federal poverty line. The median income for Garrett County residents is approximately $45,354, which is higher than the regional average of $39,026 but much lower than the Maryland state average of $68,559. In Allegany County, 48% of county residents were female, and 52% were male. In addition, 18% of the population were under the age of 18, while 18.1% were 65 years and older. For those who reported their race, 88.3% identified themselves as white, 7.6% as African-American, 1.5% as Hispanic and 2.6% as other. Approximately 16.1% of Allegany residents live at or below poverty. The median income in Allegany County is $39,087, which like Garrett County, is slightly higher than the regional average but much lower compared to the Maryland state average. When comparing Allegany and Garrett Counties, Garrett County had the highest number of residents with less than a high school education (15%).

9.4 Vulnerable Populations

It is important to recognize underlying social, economic, geographic, and individual level vulnerabilities that may increase risk of disease and premature mortality for populations in Garrett and Allegany counties. Vulnerability is commonly defined as how individuals or groups of individuals or organisms respond to and recover from stressors inadequately or not as well as the average [19, 20]. Factors that contribute to vulnerability include characteristics at the individual and/or community levels that moderate the effect of environmental hazards on community health and well-being, and can be demographic, biological, social, and behavioral. Demographic factors of interest when assessing vulnerability include race, ethnicity, age, and sex [7]. Biologic factors include genetic make-up and pre-existing medical conditions; pre-existing conditions have been associated with reduced response to stressors. Other individual level vulnerability factors such as low socio-economic status, low educational attainment, and psychosocial stress have also been associated with negative health outcomes. Health behaviors play a role in increasing or decreasing an individual's vulnerability. In this study, we are limited to assessing vulnerability using sociodemographic data and county-level health data. We were unable to obtain individual health data including family history of disease for populations in both counties.

9.5 Health Indicators

9.5.1 Environmental Health

A large proportion of Marylanders currently rely on unregulated private wells as sources of drinking water. An estimated 1 million Maryland residents draw drinking water from private wells [21]. Elevated levels of nitrates and other chemicals have been noted in Maryland's groundwater [22, 23]. In Garrett County, private wells are concentrated most heavily around McHenry, Grantsville and Oakland. Over 14,200 well location records are currently available for the county. Approximately, 8,250 or 58% of well records occur in grid cells that contain Marcellus Shale gas leases. Annual average $PM_{2.5}$ concentrations were ~13 µg/m^3 in both Allegany and Garrett counties. These mean levels were higher than the mean concentrations for the state of Maryland as a whole. Scientific literature has shown relationships between PM exposure (e.g., coarse or fine particles, acute or chronic) and increased respiratory and cardiovascular health end points including increased mortality, hospital admissions, and emergency department visits.

9.5.2 Physical Health Indicators

The health profile of the residents of this region was compiled by using data collected on overall life expectancy, poor physical days, preventable hospital stays, chronic diseases, major causes of morbidity and mortality, and birth outcomes. Data for Allegany and Garrett counties was compared to the health data of the region (Allegany and Garrett Counties in Maryland; Bedford, Fayette, and Somerset Counties in Pennsylvania, and Grant, Hampshire, Mineral, Preston, and Tucker Counties in West Virginia), and the State of Maryland for an overall health profile.

9.5.2.1 Life Expectancy

Data on life expectancy was obtained from the CDC's Community Health Status Indicators website. Garrett County has the highest average life expectancy (78.2), compared to Allegany County (77.4), the state of Maryland (67.8), and the region (76.7).

9.5.2.2 Poor physical health days

Data on poor physical health days was obtained from the Behavioral Risk Factor Surveillance System (BRFSS) for the years of 2006-2012. Allegany County residents had a higher number of poor physical days (4.8) than those in Garrett County (3.7). Both counties had higher numbers than those for the State of Maryland (3.1).

9.5.2.3 Preventable hospital stays

We obtained data from the University of Wisconsin County Health Indicators Project for 2011. The Ambulatory Care Sensitive Conditions (ACSC) rate for preventable hospital stays in Allegany (88.0) and Garrett (67.6) counties was higher than the overall state rate (60.2). The ACSC rate for Allegany was higher than the rate for the both the region (85.6) and Garrett County.

9.5.2.4 Chronic Diseases

9.5.2.4.1 Adult Hypertension

We obtained data on adults with high blood pressure for 2006-2012 from the Behavioral Risk Factor Surveillance System **(**BRFSS**).** Both Allegany and Garrett counties had higher percentages of adults with high blood pressure (37% and 31% respectively) when compared to the State of Maryland (30%). Compared to the region (34.3%), Allegany County has a higher percentage of adults with high blood pressure while Garrett County's percentage was lower.

9.5.2.4.2 Adult Obesity and Diabetes

Adult obesity and diabetes data were obtained for years 2006-2012 from BRFSS. The percentages of obese adults in Allegany and Garrett counties were 21% and 30%, respectively, while, the percentages with diabetes in Allegany and Garrett counties were 12% and 11%, respectively. These trends mirror each other since obesity has been linked to the development of Type 2 diabetes [24]. While both counties have lower percentages of obese adults and either equal or lower percentages of diabetic adults compared to the region (12%), they are both higher compared to the state of the Maryland (9.7%).

9.5.2.4.3 Adult Smoking

We obtained adult smoking data for the years 2006-2012 from BRFSS. In both Allegany (23%) and Garrett (19.5%) counties, the percent of adults who smoke was much higher than the percent of adults who do the same across the state (15.4%). However, only the smoking rate for Allegany was higher than the smoking rate for the region (22.7%).

9.5.3 Major Causes of Morbidity and Mortality

9.5.3.1 Cancer

We obtained cancer incidence data from the National Cancer Institute's (NCI) State Cancer Profile site (2006-2010) and cancer mortality data from CDC Wonder (2000-2010) on non-Hodgkin's lymphoma, multiple myeloma, leukemia, malignant melanoma of skin, malignant neoplasm of breast, malignant neoplasm of prostate, malignant neoplasm of bladder, and malignant neoplasms of colon, rectum and anus. Prostate cancer, breast cancer, and colorectal cancer were the cancers with the highest incidence rates. The top three cancers in Allegany and Garrett counties that result in the highest rates of deaths were colorectal, breast, and prostate cancers. Death rates from these cancers were higher in these counties compared to the region and the state of Maryland. Overall, the total cancer death rate in Allegany County (196.1 per 100,000) were higher than that of Garrett County (174.9 per 100,000), the region (191.1 per 100,000), and the State of Maryland (194 per 100,000).

9.5.3.2 Other Mortality Data

9.5.3.2.1 Chronic respiratory disease deaths

We obtained data on chronic respiratory deaths from CDC Wonder. The death rates in Allegany (54.5 per 100,000) and Garrett counties (51.4 per 100,000) due to chronic respiratory disease were higher than those for the region (47.8 per 100,000) and the state (37.1 per 100,000).

9.5.3.2.2 Flu deaths

We obtained data on influenza and pneumonia mortality from CDC Wonder. The death rates attributed to flu in Allegany County (17.2 per 100,000) was higher than those for Garrett County (14.5 per 100,000), yet both were lower than the death rate from flu for the state (20.1 per 100,000).

9.5.3.2.3 Cardiovascular disease deaths

We obtained heart disease mortality data using CDC Wonder. Cardiovascular disease mortality rates for Allegany (275.6 per 100,000) and Garrett counties (253.9 per 100,000) were much higher than the rates for the region (249.5 per 100,000) and the state (216.5 per 100,000).

9.5.3.2.4 Cerebrovascular disease deaths

We obtained data on cerebrovascular disease mortality from CDC Wonder. The rate of stroke-related mortality for Allegany County (59 per 100,000) was higher than the mortality rates for Garrett (49.6 per 100,000), the region (53 per 100,000), and the state (46.7 per 100,000).

9.5.3.2.5 Septicemia deaths

Data on Sepsis (septicemia) mortality was obtained through CDC Wonder. Septicemia is an illness that affects all parts of the body that can happen in response to an infection and can quickly become life-threatening. People with weakened immune systems, infants and children, elderly citizens, and people with chronic diseases are at risk from this condition. We found that the septicemia mortality rate for Allegany County was 20.8 per 100,000. This rate is twice as high as the rate of Garrett County (10 per 100,000) and also higher than the rates of the region (12.9 per 100,000) and the state (18.8 per 100,000).

9.5.3.2.6 All-Cause mortality

All-Cause mortality rates for Allegany (853 per 100,000) and Garrett (808 per 100,000) were higher than the rate for Maryland (768 per 100,000).

9.5.3.3 Birth Outcomes

9.5.3.3.1 Low birth weight and premature births

We obtained data on percent low birth weight (< 2800 grams) and infant mortality for Allegany, Garrett, the region, the state of Maryland, and the US from the Health Indicators Warehouse and National Vital Statistics System (2006-2012). Percentage of babies born with low birth weight (LBW) in Allegany (9.1%) was higher than % low birth weight for Garrett (7.5%), MD (9.0%), region (8%), and the United States (8.2%). The percentages of premature births for Allegany County (13%) were higher than the rates for Garrett (12%), the region (11.6%), the State of Maryland (12.9%), and the United States (12.2%).

9.5.3.3.2 Infant mortality

We obtained data on infant mortality for Allegany and Garrett counties, the region, the state of Maryland, and the US from the Health Indicators Warehouse and National Vital Statistics System. Infant mortality rates of 8.4 deaths/1000 births (Allegany) and 10.8 deaths/1000 births (Garrett) were higher than the rates for MD (7.2 deaths/1000 births), and the US (6.9 deaths/1000 births).

9.6 Social Determinants of Health

To evaluate the baseline social determinants of health in Allegany and Garrett counties, we obtained available information regarding sexually transmitted infections (STI), crime, injuries, mental health, and substance abuse from a variety of sources, as summarized in the Appendix.

Data regarding STIs was obtained from the Health Indicators Warehouse for years 2010 (HIV) and 2011 (gonorrhea) and from the 2011 County Health Rankings (chlamydia). STI rates, specifically chlamydia, gonorrhea, and HIV, in this area are much lower compared to the rest of the state.

Information regarding violent and property crime was obtained from the Maryland Governor's Office on Crime Control and Prevention Crime Statistics Report for 2000, 2005, and 2010. Data regarding homicides was obtained from County Health Rankings and the National Center for Health Statistics for 2010. In Garrett County, crime rates across all categories remain steady and lower than the Maryland State averages, fluctuating slightly over the 10-year period between 2000 and 2010. In Allegany County, there is a slow but steady increase in most crime categories in this same period. This increase is in contrast to statewide trends, which demonstrate major decreases in crime rates across all categories in the last decade, from 2000 to 2010. Homicide rates, as reported in the County Rankings Data shows that rates in both counties are quite low, much lower than the Maryland State average of 9.3 homicides per 100,000.

Data for deaths resulting from unintentional injuries were obtained from Health Indicators Warehouse, National Vital Statistics System for the years 2006-2010. Both Allegany and Garrett counties have much higher total mortality rates from unintentional injury than the Maryland State average and both are slightly higher than the national average. Mortality from motor vehicle traffic deaths was also higher for both counties than the State of Maryland average. Information on alcohol impaired driving deaths was obtained from the 2014 County Health Rankings Information and the Fatality Analysis Reporting System. The percentage of driving deaths that were a result of alcohol impairment is lower for Allegany County (29%) and higher for Garrett County (41%) than the State of Maryland average (33%).

Data on suicide including intentional self-harm by discharge of firearms and intentional self-harm by other and unspecified means and their sequelae were obtained from CDC Wonder Mortality from 2000-2010. The total mortality rate from intentional self-harm (suicide) for Allegany and Garrett counties were significantly higher than the State average.

Data on mental health specific to residents of Allegany and Garrett counties were obtained through the County Health Rankings Database and the Health Indicators Warehouse from 2006-2012. Mental health was measured by the number of reported mentally unhealthy days per month among adults over age 18. In the period 2006-2012, adults in Allegany and Garrett counties reported slightly higher mentally unhealthy days per month than the Maryland state average. A related measure on the perceived availability of social-emotional support was obtained through the Behavioral Risk Factor Surveillance System for 2006-2012. Adults in Allegany County had lower rates of perceived social and emotional support (18.7%) while adults in Garrett County had slightly higher rates 20.0% than those for Maryland as a whole (19.8%).

Substance abuse data were extracted from the Health Indicators Warehouse, with measures for adult binge drinking and excessive drinking, collected from the period 2006-2012. The Behavioral Risk Factor Surveillance System was used for self-reported data on binge drinking[1] and excessive drinking[2]. Both counties report slightly higher rates when compared to Maryland State averages (14.4% binge drinking and 15.7% for excessive drinking), wide margins of error could account for these differences. Information on other types of substance abuse were more difficult to obtain.

9.7 Healthcare Infrastructure

To assess the healthcare infrastructure of Allegany and Garrett counties, the team obtained information regarding rates and ratios of primary care physicians, dentists, and mental health

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1 Sample respondents age 18+ who drank 5 or more drinks for men, 4 or more drinks for women, at one or more occasions in the past 30 days [286].

2 Sample respondents age 18+ who drank more than two drinks per day on average (for men) or more than one drink per day on average (for women) or who drank 5 or more drinks during a single occasion (for men) or 4 or more drinks (for women) during a single occasion [286].

providers to the population from the 2014 County Health Indicators and the Health Resources and Services Administration (HRSA) Area Resource Files. Rates and ratios of these service providers are, on average, much lower than the statewide averages, especially for mental health providers, indicating a critical shortage of providers in both Allegany and Garrett counties.

According to HRSA, Allegany County is a designated Health Professional Shortage Areas (HPSA) for primary care for low-income populations, mental health care for Medical Assistance populations, and dental care for Medical Assistance populations. Allegany County has a critical need for specialty providers including vascular surgery, urology, as well as dentists willing to provide care for adults with no insurance or Medical Assistance. Garrett County is a designated HPSA for primary and mental health care, and dental care for Medical Assistance populations. Furthermore, all of Garrett County is considered a Medically Underserved Area (MUA), while substantial portions of Allegany County (Orleans, Lonaconing, Oldtown, and Cumberland) also qualify as MUA.

The team also obtained information on insurance status of individuals living in Garrett and Allegany counties from the County Health Rankings Database. As of 2011, 11.9% of the total population of Allegany County and 14% of Garrett County were uninsured; these are similar to and higher than statewide averages (12%).

10 IMPACT ASSESSMENT

10.1 Overview of Key Determinants of Human Exposures to UNGDP Related Hazards

This section provides a brief overview on key determinants of human exposures to UNGDP related hazards, which is integral to understanding the relationship between exposures and adverse health outcomes.

The fate and transport of hazards emitted from a source depend upon several factors including chemical and physical properties of the hazard as well as meteorological conditions, local topography, and source characteristics. Depending upon these factors, hazards released from the UNGDP process may end up in several media (air, dust, water, food and/or soil). For example, hazards that are volatile or very small in size may end up in air, while those that are non-volatile and/or larger in particle size end up in the soil. The presence of these hazards in the environment also depends upon their half-life as well as the extent to which the hazard under consideration interacts with other hazards.

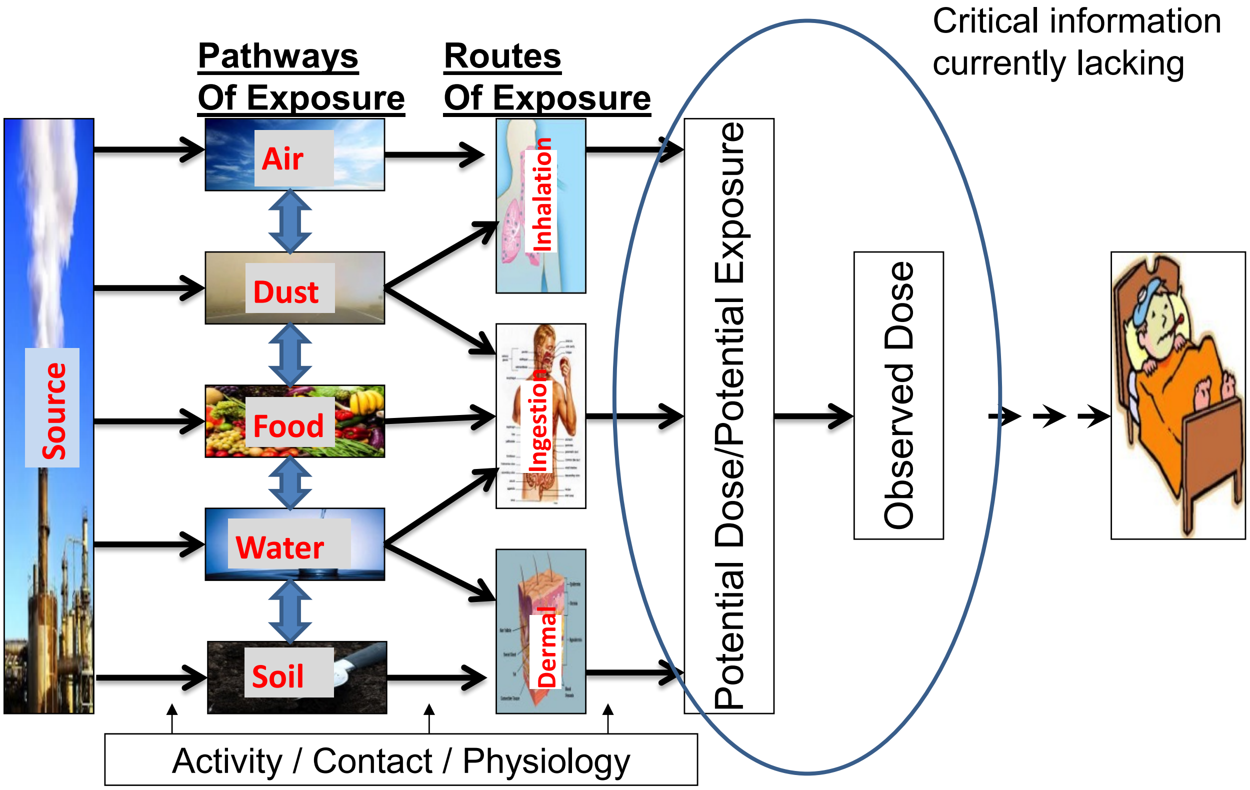

Figure 10-1: Source to Effect Continuum for a Typical Environmental Hazard

Residents from impacted communities will be exposed to hazards through inhalation if the hazard is present in the air or in dust. If the hazard is present in dust, food or water, individuals will be exposed through ingestion. While less common among adults, ingestion of contaminated dust can be a major driver of exposure among young children as they explore their world through hand to mouth activities. Individuals may get exposed to hazards present in the soil or water through dermal routes. Dermal exposure can be substantial if the hazard under consideration is lipophilic (having an affinity for fat or oil). Exposure can be further enhanced if the integrity of the skin surface that comes into contact with the hazard is compromised.

When contact is established between a hazard and external body surface, there is a potential for human exposure. The magnitude of this potential exposure/dose depends upon:

1. Concentration of the hazard in the environment,
2. Frequency of exposure to the hazard,
3. Duration of exposure to the hazard.

Concentration of the hazard in the environment is directly related to the source activity, meteorological conditions, topography, atmospheric chemistry, and the half-life of the hazard in the environment. Frequency of exposure is related to the contact rate between the hazard and the external body surface, and depends upon the exposure pathways. For example, if the hazard is present in the air, then exposure is continuous, but if the hazard is in the water and the only route of exposure is dermal, then frequency of exposure may be once a day or every other day depending upon how often the individual showers/takes a bath. Duration of exposure reflects the length of contact between the hazard and the external body surface. For example, if the hazard under consideration is related to well development, then the duration of exposure may last a few months while the wells are being drilled. But if the hazard is related to compressor stations (production phase), then the duration of exposure can be decades, as the compressor stations are in service for a long period of time. Duration of exposure may also differ by population subgroups. For instance, workers from out of town may be exposed to the air pollutants for 8 hr/day during the workday, while community residents may be exposed 24hr/day if they work and reside in the area.

There are additional factors that may modify an individual's exposure. These include individual level activities, lifestyles and physiological factors. For instance, an individual who leads a very active life may breathe a higher volume of air compared to someone who leads a sedentary lifestyle, and in doing so, may be exposed to a higher level of hazards present in the air. Likewise, overall dermal uptake of a hazard may be considerably higher among individuals whose skin integrity is compromised due to old age, open wounds or dry skin. In addition, the potential to detoxify hazards varies across individuals based on their genetic makeup.

Information regarding potential dose and/or observed dose is desirable while evaluating the impact of UNGDP on public health. Currently such individual level measures of exposure are lacking Figure 10-1. Available information is restricted to selected media within exposure pathways (air, dust and water).

10.1.1 Overview of Exposure Assessment Methods for UNGDP Related Hazards

There may be considerable variability in the concentration of UNGDP related hazards in different microenvironments within one location. Similarly, there likely is variability in the concentration of hazards related to UNGDP processes across different geographic locations. Finally, this variability is not constant (i.e., they change from day to day). Since individuals spend their time moving from one microenvironment to another, it is important to capture the spatial and temporal variability in concentrations while conducting exposure measurements for epidemiological studies. There are several approaches available for quantifying an individual's true exposure, with varying accuracy.

Table 10-1: Ranking of Exposure Assessment Methods

Type of Exposure Data		Approximation of True Exposure
Individual level measurements		
	Biomarker	Best
	Personal Air Samples	↓
	Dermal Samples	
Area Level Samples		
	Indoor air/dust samples from residence	
	Indoor air/dust samples from workplace	
	Air samples from neighborhood/central site monitors	
Exposure Surrogates		
	Sources of water (municipal vs private well)	
	Distance between residence and the source	
	Residence or employment in the neighborhood impacted by fracking	
	Residence or employment in the county impacted by the fracking	Worst

Table 10-1 provides a summary of exposure assessment methods that can be used for quantifying residents' exposures to UNGDP related hazards. These methods are ranked in decreasing order based on their ability to approximate an individual's true exposure. For example, biomarker (biological samples) is ranked highest because it provides a good estimate of individuals' "total exposure" that may be coming from inhalation, ingestion or dermal routes of exposure. Personal air samples, on the other hand, capture inhalation exposures only, and thus may miss exposures taking place through the dermal and ingestion route of exposure. In addition, a biomarker indicates that the toxicant has already gotten into the human body (internal dose) while personal air samples indicate potential exposure/potential dose. Area level samples are less desirable than individual level measurements as they do not account for the variability that exists between individuals (between person variability). Likewise, surrogates (e.g. distance of home from well pad) are less desirable than area level samples, as they are simple proxies of exposure, and as such do not provide any quantitative information on the individual hazard themselves.

The cost associated with implementing these exposure assessment methods also varies, with the individual level measurements being the most expensive to the exposure surrogates being the least expensive. Individual level measurements entail contacting each participant, collecting samples (biological, personal air, dermal), and performing detailed laboratory analysis of those samples. Thus, it requires large field study teams, sampling equipment as well as extensive laboratory testing; each component requiring numerous resources. Surrogates on the other hand, do not require contacting individual participants or laboratory analysis. In terms of feasibility, implementing biomarker-based exposure assessment methods in a large epidemiological study is less feasible because of the cost and time requirements. Exposure surrogates, including questionnaire based methods on the other hand can be implemented in large studies. Both cost and feasibility need to be taken into consideration while deciding which sampling approach to use for exposure assessment.

10.1.2 Linking Exposure to Hazards with Adverse Health Outcomes

The linkage between hazards, exposures, and adverse health outcomes is established using epidemiological studies. The causality of these associations is evaluated using a set of criteria, often referred to as Hill's Criteria for Causality. They include:

- Strength of Association: Stronger the association, less likely it is due to an extraneous variable.
- Temporality: Exposure precedes the disease on a temporal scale.
- Consistency: Multiple, independently conducted studies report the same findings.
- Dose-response relationship: As the exposure increases, disease risk increases as well.
- Theoretical Plausibility: Current understanding provides theoretical basis for the observed association.
- Specificity in the cause: Ideally, the effect has one primary cause.
- Experimental Evidence: Experimental studies support the findings.
- Removal of exposure alleviates the risk.

However, it is important to note that this type of information is currently not available in the context of UNGDP for several reasons:

- Recent exposures - UNGDP is a relatively new process; so, the residents of the impacted communities have been exposed for a relatively short period of time.
- Issue of lag time - some of the chronic health outcomes take a long time to manifest after the onset of exposure (long lag time). For certain chronic diseases such as cancer, prior evidence suggests that the lag time can be substantial, often several decades. Since the UNGDP-related exposures are relatively recent, this issue of lag time needs to be considered in epidemiological studies.
- Duration of Epidemiological Studies - Epidemiological studies used for studying the link between potential exposure to a hazard and adverse health outcome often take 3-5 years to complete. In addition, the peer-review process that investigators rely on to disseminate their findings may take an additional 1-2 years. Thus, even if epidemiological studies were

initiated at the onset of UNGDP (which is unlikely), the findings from these studies may not be available in the peer-reviewed literature. Results from epidemiological studies related to UNGDP are just appearing in the peer-reviewed literature.

These factors are of particular relevance to UNGDP and should be taken into consideration while evaluating the impact of UNGDP on human health. Simply put, the absence of investigation or peer-reviewed data does not imply the absence of harm.

10.2 Methods

10.2.1 Overview of Data Collection

10.2.1.1 Literature Search

A literature search was performed using ISI Web of Knowledge (www.isiknowledge.com) and PubMed (http://www.ncbi.nlm.nih.gov/pubmed) between October 2013 and May 2014. Additional publications were identified based on communication with experts, references cited within the published articles, and the 'citation track' feature available from the ISI Web of Knowledge. Search terms included 'fracking' OR 'hydraulic fracturing' OR 'natural gas' OR 'unconventional natural gas' OR 'Marcellus shale' AND 'air quality' OR 'air pollution' OR 'water quality' OR 'water pollution' OR 'radiation' OR 'health effects' OR 'adverse health outcomes' OR 'public health'.

Additional searches were conducted using Physicians Scientists and Engineers for Healthy Energy (PSE) Citation Database on Shale Gas and Tight Oil Development (http://www.psehealthyenergy.org/site/view/1180). We also used Google and Google Scholar to search for government reports, and reports from non-governmental organizations. Finally, we considered additional reports and articles submitted to us from the community, industry groups, and environmental advocacy organizations.

All articles were screened for titles and abstracts. Articles that were not related to UNGDP were eliminated from the list. Articles that were not related to human health, such as those related to drilling technology, exploration, and development were excluded as well. Reports and white papers from governmental agencies (local/state/federal), academic institutions, non-profit groups, industry, and activists were considered, provided they were related to the environment and/or human health.

10.2.1.2 Monitoring Data

Baseline and post-UNGDP monitoring data on air and water quality were gleaned from peer-reviewed literature and reports from state, local, and non-governmental organizations. Whenever available, raw data were used to come to a conclusion instead of relying on the authors' interpretation of the data. Criteria air pollution data for Maryland was obtained from U.S. EPA.

10.2.2 Identification of Hazards of Concern to Western Maryland Communities

As described in detail in the Scoping Report, we used a detailed scoping process to identify UNGDP-related hazards that were of most concern to the community members in Western

Maryland. Additional hazards were identified based on the literature review. We grouped these UNGDP-related hazards and stressors into 8 broad categories as shown below:

1) Air quality
2) Flowback and Production Water Related
   a) Water quality
   b) Soil quality
   c) Naturally Occurring Radioactive Materials (NORM)
3) Noise
4) Earthquakes
5) Social determinants of health
   a) Sexually transmitted infections
   b) Traffic
   c) Crime
6) Healthcare infrastructure
7) Occupational health
8) Cumulative exposure/risk

We combined water quality, soil quality and NORM under the Flowback and Production Water related concerns because they are all related to the wastewater. Similarly we combined sexually transmitted infections, traffic and crime into Social Determinants of Health. The traffic-related issues discussed within the framework of public safety pertains to traffic accidents, not air quality. The fugitive emission of methane throughout the production and distribution process and the issue of climate change was brought up during the scoping process. Community members were particularly concerned about the contribution of shale gas development to the impending threat of climate change on their community. However this report is focused on health impacts of UNGDP that are restricted to the area where gas production occurs. We did not consider secondary effects that may manifest due to climate change.

10.2.3 Ranking of Hazards

Based on our review of the literature, we scored each hazard using a set of seven criteria that was adapted from Witter and colleagues, who previously used them in the Battlement Mesa Health Impact Assessment [7]. The modified metrics included in our evaluation are: 1) vulnerable populations, 2) geographic extent, 3) duration of exposure, 4) frequency of exposure, 5) likelihood of health effects, 6) magnitude of health effects, 7) effectiveness of the setback, and 8) public health impact. The detailed description of these ranking criteria are provided in Table 10-2.

Table 10-2: Description of the evaluation criteria used for hazard ranking

Evaluation Criteria	Result	Score	Description
Presence of vulnerable	No	1	Affects all populations equally

populations	Yes	2	Disproportionately affects vulnerable population
Duration of exposure	Short	1	Lasts less than 1 month
	Medium	2	Lasts at least one month but less than one year
	Long	3	Lasts one year or more
Frequency of exposure	Infrequent	1	Occurs sporadically or rarely
	Frequent	2	Occurs constantly, recurrently, and/or numerously
Likelihood of health effects	Unlikely	0	Prior evidence suggests exposure is not related to adverse health outcomes
	Unknown	1	Evidence inconclusive/insufficient data
	Possible	2	Prior evidence suggests exposures may be associated with adverse health outcomes
	Likely	3	Prior evidence suggests similar exposures to be associated with adverse health outcomes
Magnitude/severity of health effects	None	0	No adverse health effects
	Unknown	1	Evidence inconclusive/insufficient data
	Low	1	Causes health effects that can be quickly and easily managed, do not require medical treatment

	Medium	2	Causes health effects that necessitate treatment of medical management and are reversible
	High	3	Causes health effects that are chronic, irreversible or fatal
Geographic extent	Localized	1	Effects occur in close proximity to UNG-Development and/or Production
	Community-wide	2	Effects occur across most of the community
Effectiveness of setback	Positive	1	Setback is anticipated to minimize health effects
	Negative	2	Setback is not anticipated to minimize health effects
Public health impact	No-low impact	Green	Hazard received a score of 6-9
	Moderately-high impact	Yellow	Hazard received a score of 10-14
	High impact	High	Hazard received a score of 15-17

We summed the score for each hazard across the seven evaluation criteria to obtain an overall score. These overall scores were then used to rank each hazard into three broad categories using color-coded scheme (Table 10-2). They include:

H: High likelihood that UNGDP related changes will have negative impact on public health

M: Moderately high likelihood that UNGDP related changes will have negative impact on public health.

L: Low likelihood that UNGDP related changes will have negative impact on public health.

This approach enabled us to rank each of the eight hazards, identified with community input, using a consistent approach. We set the bar for "High impact" to include only the three highest possible scores (15,16 & 17) so as to clearly distinguish those hazards that should be of the greatest concern.

10.2.4 Identifying Chemicals of Concern

The fluid composition used to hydraulically fracture a well is a mixture of 99.2% water and 0.79% additives consisting of acids, corrosion inhibitors, friction reducers, clay control, crosslinkers, scale inhibitors, breakers, iron control, and biocides [25]. These chemicals are an important part of the process and play an important role in natural gas extraction. Table 10-3 outlines why the additives are used and the consequences of not using them. The industry has argued that these necessary additives account for a minute fraction of the fracking fluid, therefore their impact will be negligible. While the statement regarding a small fraction is true, it needs to be discussed in the right context:

1. USGS estimates suggest that 3 to 7 million gallons of water are used per well. Furthermore, 5 to 12 wells are located in a single well pad. Taking these two figures under consideration, even if only 0.8% of the total volumes are additives, this amounts to 340,000 gallons (range 120,000-672,000 gallons) of chemicals used per well pad, a single point source (1.29 million liters, range 0.45 -2.5 million liters). So the argument that more than 99% of fluids used are water, while correct, is misleading because it does not tell the whole story.
2. The "less than 1% is chemical" argument also overlooks basic principles of toxicity. While discussing UNGDP related additives and chemicals, their toxicity also needs to be taken into consideration. If a chemical is highly toxic, even exposures to small amounts can be detrimental to human health.

   These misleading statements, combined with opacity surrounding the nature of individual chemicals present in the fracking fluid serves to drive public mistrust of the overall fracking process.

Table 10-3. Chemicals Commonly Used in Shale Fracturing and Consequence of Not Using the Chemicals, Source: [26]

Chemical	**Use**	**Consequence of not using chemical**
Acid	Removes near well damage	Higher treating pressure, slightly more engine emissions
Biocides	Controls bacterial growth	Increased risk of souring and increased erosion
Corrosion inhibitor	Prevent corrosion in the pipe	Increased risk of pipe corrosion from acid
Friction reducer	Decreases pumping friction	Increased surface pressure and engine emissions
Gelling agents	Improves proppant placement	Increased water use and decreased gas recovery
Oxygen scavenger	Prevents corrosion of well tubulars by oxygen	Increased corrosion and compromised well integrity

The U.S. House of Representatives Committee on Energy and Commerce published a report in April 2011 outlining a comprehensive list of the chemicals used by 14 oil and gas companies during hydraulic fracturing between 2005-2009 [27]. A total of 2,500 products containing 750 chemicals were reported. We cross referenced these chemicals with four databases to identify their carcinogenic potential and specific organ toxicity. These databases included International Agency for Research on Cancer (IARC), the US Environmental Protection Agency's (EPA) Integrated Risk Information System (IRIS), Cal EPA's Office of Environmental Health Hazard Assessment (OEHHA) Toxicity Criteria database, and the Agency for Toxic Substances and Disease Registry (ATSDR) Toxic Substances portal. We grouped the chemicals according to carcinogenicity and target organ system. The four categories for carcinogenicity:

- Known human carcinogen
- Probable carcinogen
- Possible carcinogen
- Not a likely to be carcinogen.

Each of these categories includes classifications from all four databases. Carcinogen includes IARC Group 1, EPA IRIS Group A, chemicals classified as carcinogens by CalEPA, and chemicals classified as "known to be a human carcinogen" by ATSDR. Probable carcinogen includes IARC Group 2A, EPA IRIS Group B1 and B2, and chemicals classified as "reasonably anticipated to be a human carcinogen" by ATSDR. CalEPA does not have a carcinogenicity classification other than carcinogen. Possible carcinogens include IARC Group 2B and EPA IRIS Group C. Neither CalEPA nor ATSDR have a classification for possible carcinogens. Not a likely carcinogen includes IARC Group 3 and EPA IRIS Group E. We identified 11 target organ systems: nervous, endocrine, circulatory, lymphatic (immune), digestive, respiratory, urinary, reproductive system, skeletal, integumentary (skin), and muscular systems. As shown in Figure 10-2, six chemicals used in UNGDP were identified by IARC as known human carcinogens, an additional two were identified as probable human carcinogens and eight were identified as possible carcinogens.

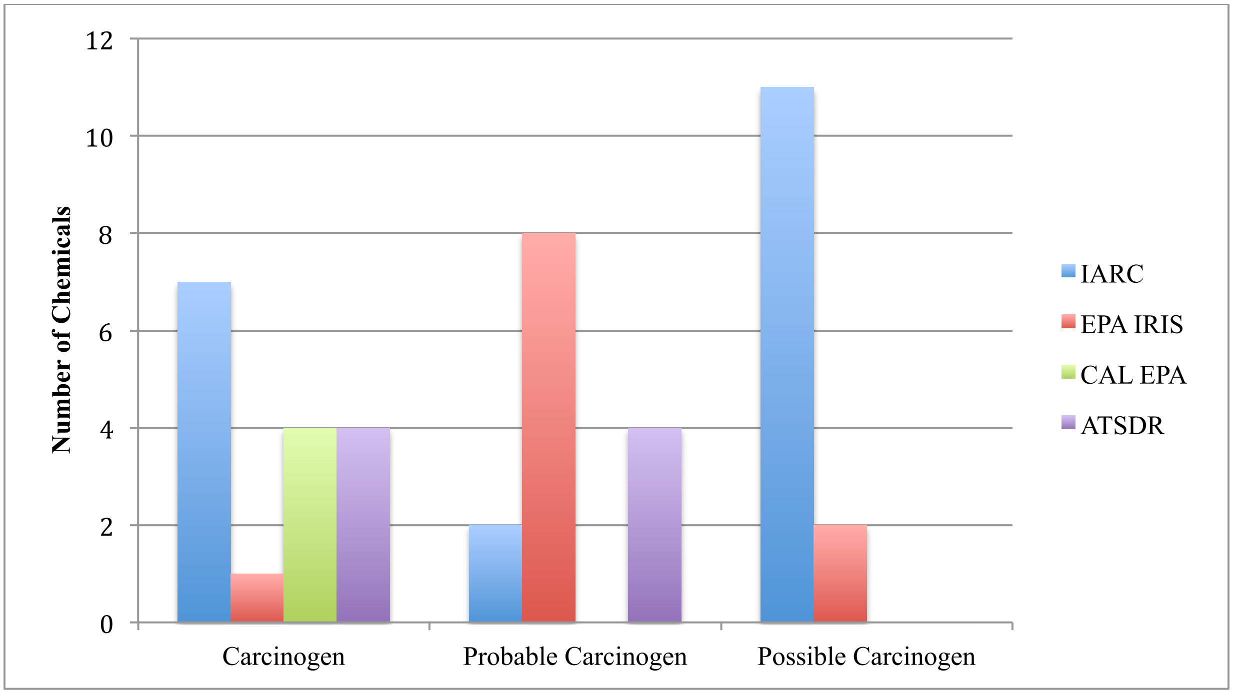

Figure 10-2: Carcinogenicity Classification for Chemicals used During UNGDP

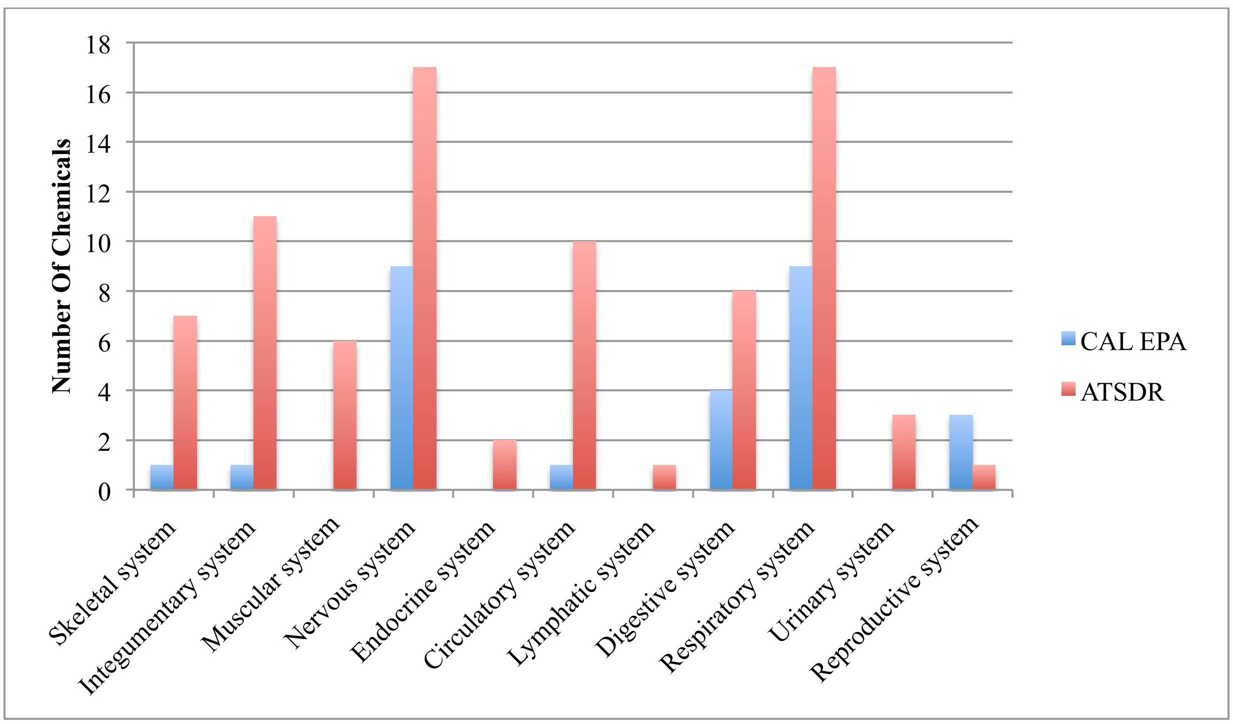

Figure 10-3: Target organ systems for chemicals used during UNGDP, from Cal EPA's OEHHA Toxicity Criteria database and ATSDR's Toxic Substance Portal

10.3 Community Impacts

The major stressors we identified and evaluated were determined through our charge from DHMH, the scoping process, and our review of the literature. The eight stressors that were addressed were: air quality, flowback and production water-related concerns (water quality, soil quality, and naturally-occurring radiological materials), noise, earthquakes, social determinants of health, healthcare infrastructure, occupational health, and cumulative exposures/risk. In this section, we evaluate each stressor and assess if UNGDP related changes in the stressor are likely to negatively impact public health (High Likelihood, Moderately High Likelihood, and Low Likelihood).

10.3.1 Air Quality

10.3.1.1 Air Pollutants Associated with UNGDP Activities

Details regarding broad categories of air pollutants associated with different stages of the UNGDP process are described in the Ambient Air Monitoring report prepared by Leidos Incorporated for MDE [28]. Table 10-4 shows a list of selected pollutants associated with different UNGDP activities. The information in Table 10-4 was taken from the Leidos report with slight modifications, particularly related to traffic. In addition, it should be noted that Table 10-4 does not provide separate descriptions for two important pollutants (ozone and polycyclic aromatic hydrocarbons (PAHs)).

Table 10-4: Summary of selected air pollutants associated with the UNGDP process, as described in Leidos report [28], with slight modification.

Extraction Activity	Source of Emissions	Combustion products (CO, Nox and SO2)	Non-methane hydrocarbons	Methane, Organic HAPs, H2S	Particulate Matter
Site Development and Drilling Preparation	Traffic	X	X	X	X
	Site preparation engines	X			X
	Dusts suspension				X
Drilling	Diesel engines	X	X	X	X
	Gas escape from wellbore		X	X	
	Storage of drilling fluids, muds and cuttings		X	X	
Fracturing and Completion	Large pumps	X	X	X	X
	Proppant handling				X
	Flowback and flaring	X	X	X	X
	Flowback liquids		X	X	
	Traffic	X	X	X	X
Well Production and Compressor Stations	Leakage from valves, seals, and gaskets		X	X	
	Venting and flaring	X	X	X	X
	Compressor engine exhaust	X	X		X
	Pneumatic pumps and devices		X	X	
Well Recompletions	Same as fracking and completions	X	X	X	X

In reviewing 353 chemicals associated with the UNGDP process, one study estimated that up to 75% of the chemicals have a potential to adversely affect eyes, skin and other sensory organs as well as respiratory and gastrointestinal systems; an additional 40-50% have the potential to affect nervous, immune and cardiovascular systems; 37% have the potential to affect the endocrine system; and 25% may have carcinogenic potential [29].

Currently, MDE is collecting baseline air quality data for criteria air pollutants as well as selected VOCs at the Piney Run Reservoir. Additional monitoring data is available for Garrett County from the EPA Air Quality Data Mart. In general, monitoring data from 2013 suggest that air quality in Garrett County is better than Maryland as a whole, with noted exceptions for SO_2 concentrations (Figure 10-4).

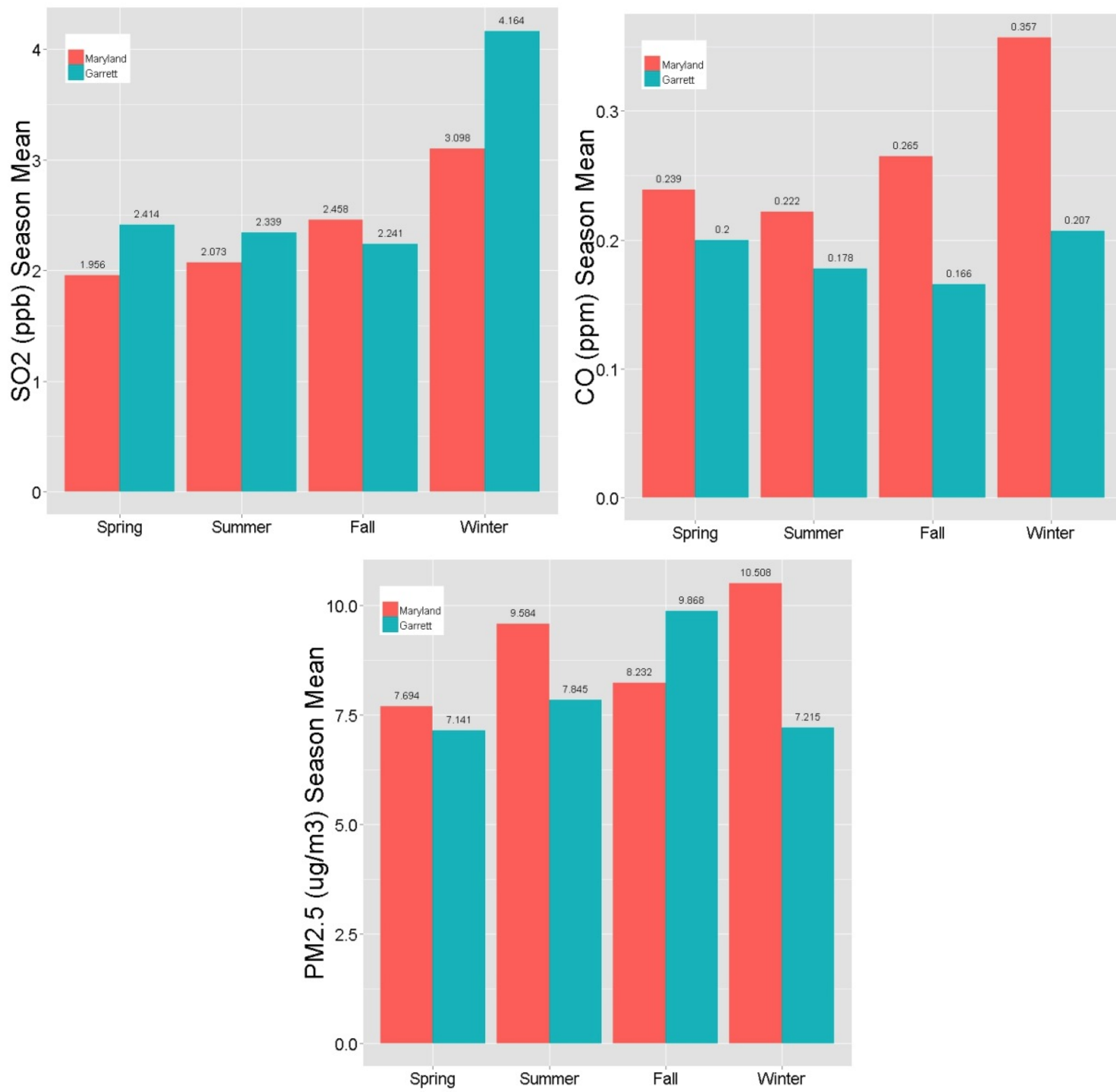

Figure 10-4: Seasonal comparisons of air quality for Garrett County and the State of Maryland for selected criteria air pollutants, 2013

10.3.1.2 Overview of Studies Related to Air Pollution

Studies Based on Individual Level of Measurements: As stated earlier, exposure data collected on individual respondents are ideal as they provide a good approximation of an individual's true exposure. Currently such data are not available for residents impacted by UNGDP. A study conducted by investigators from the National Institute for Occupational Safety and Health (NIOSH) measured workers exposures to respirable crystalline silica (frac sand) at 11 sites across five states [30]. The authors collected 111 samples from the breathing zone of workers that showed unusually high levels of exposure to respirable crystalline silica among workers. In multiple instances, these exposures were > 10 times higher than the occupational health standards such as OSHA's permissible exposure limit or NIOSH's recommended exposure limit. This is of significant concern to public health because:

a) Crystalline silica is known to cause silicosis
b) Crystalline silica is a known human carcinogen
c) The respirators used by workers to protect themselves are not recommended at such high exposure levels (i.e., they do not provide adequate protection)
d) People living, working, or attending school near and downwind of a well pad would be at high risk of exposure. Because respirable crystalline silica particles are very small and remain airborne indefinitely in outdoor air, they can travel from well pads to nearby communities where they may disproportionately affect vulnerable populations such as children, the elderly, asthmatics and individuals living with chronic obstructive pulmonary diseases (COPDs).

Studies Based on Area Level Measurements: Most of the studies on air quality available to date have relied on ambient monitoring near UNGDP facilities. One study collected 163 background air samples at locations >0.5 miles from well pads and compared them to area samples collected within <0.5 miles of well pads during the well completion phase [1]. Results showed that concentrations of VOCs were significantly higher within 0.5 miles from the well pad (median benzene 2.6 $\mu g/m^3$, range 0.9-69 $\mu g/m^3$) compared to >0.5 miles from well pads (median benzene 0.9 $\mu g/m^3$, range 0.1-14 $\mu g/m^3$). The corresponding values for hexane were 7.7 $\mu g/m^3$ (range 1.7-255 $\mu g/m^3$ and 4.0 $\mu g/m^3$ (range 0.23-62 $\mu g/m^3$) and). Based on a twelve month field study, Colborn et al. 2014 reported the highest levels of non-methane hydrocarbons NMHC concentrations during the initial drilling phase. The methane concentrations reported were particularly high ranging from 1600 to 5500 ppb (mean 2473 ppb), while methylene chloride ranged from 2.7 to 1730 ppb (mean 206 ppb). The authors reported that the levels of PAHs detected in this particular study were higher than the ones that produced lower developmental and IQ scores in children in a separate study [31].

Results from extensive air monitoring performed near UNGDP sites in Fort Worth, Texas showed elevated levels of methane, ethane, propane and butane. In some cases, the methane concentrations exceeded 5000 ppb. However, benzene concentrations were reported to be consistently below 0.7 ppb. Some of the high UNGDP activity sites had average benzene concentrations less than 0.2 ppb. This is an interesting observation for a high activity UNGDP site located in Fort Worth Texas; given that background benzene concentrations at urban locations routinely exceed 0.2 ppb level. A separate report on air quality monitoring by the Pennsylvania Department of Environmental Protection conducted in Southwest and Northeast PA showed VOC concentrations significantly lower than the ones reported by McCawley in a West Virginia study [32–34]. For example, the benzene levels in the PA study ranged from 0.29 to 1.7 $\mu g/m^3$ across monitoring stations [32, 33]. It is important to note that the measurements made using Open Path Fourier Transform Infrared (OP-FTIR) consistently showed concentrations that were an order of magnitude higher than the ones obtained using canister samplers. However, the validity of OP-FTIR measurements is questionable as they are likely influenced by other factors including humidity levels. So a direct comparison of FTIR and canister results is not recommended.

More relevant air pollution data for MD comes from a recent University of West Virginia study that collected various air quality and noise data associated with UNGDP processes in WV. The air quality measurements were taken at location 625 feet away from the well pads. Results suggest that the concentrations of selected VOCs were considerably higher than the ones reported for Colorado, including benzene (mean 32.2 μg/m^3 median 9.35 μg/m^3, 95th percentile 160 μg/m^3), hexane (mean 10.4 μg/m^3, median 8.1 μg/m^3, 95th percentile 22 μg/m^3), acetone (mean 99.3 μg/m^3 median 90 μg/m^3, 95th percentile 210 μg/m^3). The overall distribution of concentrations for selected VOCs is presented in Figure 10-5. The concentrations of these VOCs in the West Virginia study varied considerably across different well pads. An example of this variability is provided in Figure 10-6. The WV study also collected air samples from control sites (Morgantown, WV) using an identical method. Although the sample size at the control site was limited (3), none of the control samples had detectable levels of VOCs.

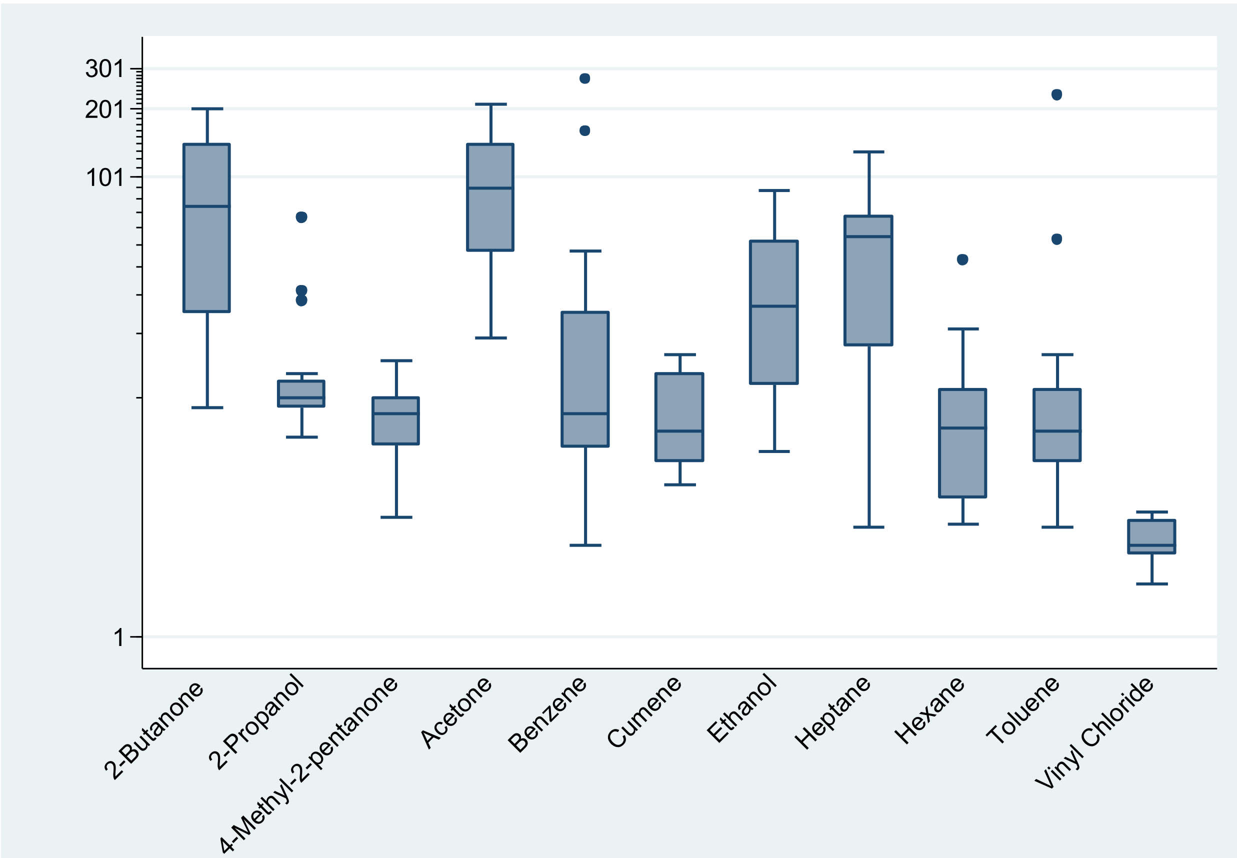

Figure 10-5: Ambient concentrations for selected VOCs near well pads in WV. Data taken from University of WV study by McCawley et al. [34]

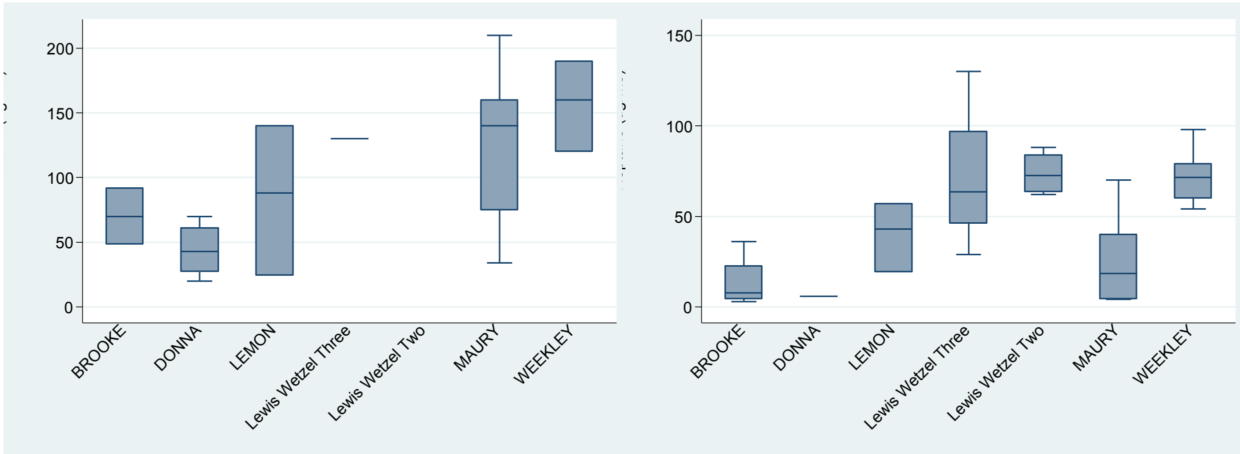

Figure 10-6: Variability in ambient concentrations of Acetone and Heptane across different well pads in WV. Data taken from University of WV study by McCawley et al. [34]

10.3.1.3 Estimated Emissions for Pollutants from UNGDP Activities

10.3.1.3.1 Drilling Scenarios

The Regional Economic Studies Institute (RESI) has developed Drilling Scenarios for Western Maryland, as reported in the Impact Analysis of the Marcellus Shale Safe Drilling Initiative [10]. According to this scenario, the estimated UNG-Development phase will last for 10 years (2017-2026) with peak development from 2018-2021 (RESI Drilling Scenarios). A well can produce for 25-30 years, therefore, we estimate UNG-Production to end 30 years after the last well is drilled in 2026 (2017-2056). Table 10-5 provides the number of new and existing wells in Western MD under 25% and 75% extraction scenarios.

Table 10-5: RESI scenarios by development year

	Scenario 1: 25%				**Scenario 2: 75%**			
Year	**Number of New Wells Drilled**	**Number of New Well Pads**	**Total Number of Wells**	**Total Number of Well Pads**	**Number of New Wells Drilled**	**Number of New Well Pads**	**Total Number of Wells**	**Total Number of Well Pads**
2017	8	4	8	4	36	12	36	12
2018	16	4	24	8	72	12	108	24
2019	29	3	53	11	63	9	171	33
2020	22	3	75	14	54	9	225	42
2021	18	3	93	17	63	9	288	51
2022	15	2	108	19	42	6	330	57
2023	12	2	120	21	36	6	366	63
2024	12	2	132	23	36	6	402	69
2025	12	2	144	25	36	6	438	75

2026	6	0	150	25	12	0	450	75

10.3.1.3.2 Emission Estimates

The City of Fort Worth natural gas air quality study [35] estimated that the total yearly emissions of organic compound from 375 well pads, 8 compressor stations, 1 gas processing plant, a saltwater treatment facility, a drilling operation, a fracking operation and a completion operation would sum up to be 20,818 tons per year. The report suggested that the majority of these yearly emissions are attributable to well pads, accounting for 75% of the total emissions.

In a recent study, Roy and colleagues [36] provided process-level emission estimates along with uncertainty for each sources in UNGDP related activities. The authors assumed that there will be significant decreases in the emissions from each source by 2020, compared to 2009, because of stricter emission controls. These process-level estimates from Roy and colleagues are provided in Table 10-6 for NO_x, $PM_{2.5}$ and VOCs. We used these process-level emission estimates and the well development scenarios derived by RESI for Allegany and Garrett Counties to derive total yearly emissions for NO_x, $PM_{2.5}$ and VOCs using the following assumptions:

- The source emissions for compressor stations in Table 10-6 are based on the volume of gas processed (billion cubic feet). To derive the estimated production volumes, we used predicted number of wells and the estimated Marcellus Shale well production curve from the RESI Report Figure 10-7.
- We further assumed that 85% of the estimated ultimate recovery (EUR) will be extracted by the end of year three as described in the Impact Analysis of the Marcellus Shale Safe Drilling Initiative [10].
- We took the 2009 process level to calculate overall emissions. This was done because the likelihood of implementing stricter emission control policies (as described in Roy et al. 2014) in the next 6 years (2020) remains unclear.
- The total yearly emissions were derived by summing up all process-level emissions for a given year.

Table 10-6: Process level emission estimates for selected pollutants based on 2009 and 2020 emission levels, [36]

Sources		NOx				PM2.5				VOCs			
		2009		2020		2009		2020		2009		2020	
Drill rigs (tons/well drilled)		4.4	(0.8–11.5)	2.9	(0.5–8.1)	0.3	(0.03–1)	0.1	(0.01–0.4)	0.5	(0.1–1.8)	0.1	(0.02–0.5)
Frac (tons/well drilled)		2.2	(0.7–4.3)	1.8	(0.6–3.4)	0.16	(0.03–0.4)	0.1	(0.01–0.3)	0.25	(0.07–0.7)	0.14	(0.03–0.5)
Trucks (tons/well drilled)		6.9	(1.4–20)	1.5	(0.2–4.5)	0.07	($4x10^{-4}$ -0.3)	0.02	($2x10^{-4}$ -0.09)	0.4	(0.02–2.2)	0.2	(0.01–1.2)
Flowback													
	Dry well	n/a		n/a		n/a		n/a		3.8	($2x10^{-3}$-29)	1.01	($5x10^{-4}$-8.3)
	Wet well	n/a		n/a		n/a		n/a		21	(0.09-145)	5.5	(0.02-37.5)
Pneumatics (tons/producing well)													
	Dry gas	n/a		n/a		n/a		n/a		0.5	(0.08-0.8)	0.1	(0.02-0.2)
	Wet gas	n/a		n/a		n/a		n/a		3.3	(2.4-4.4)	0.8	(0.5-1.0)
Compressor Stations (tons/BCF)		3.3	(1.0-5.2)	1.5	(0.3-3.0)	0.3	($4x10^{-4}$ - 0.1)	0.3	($4x10^{-4}$-0.1)	1	(0.3-3.0)	0.4	(0.06-1.0)

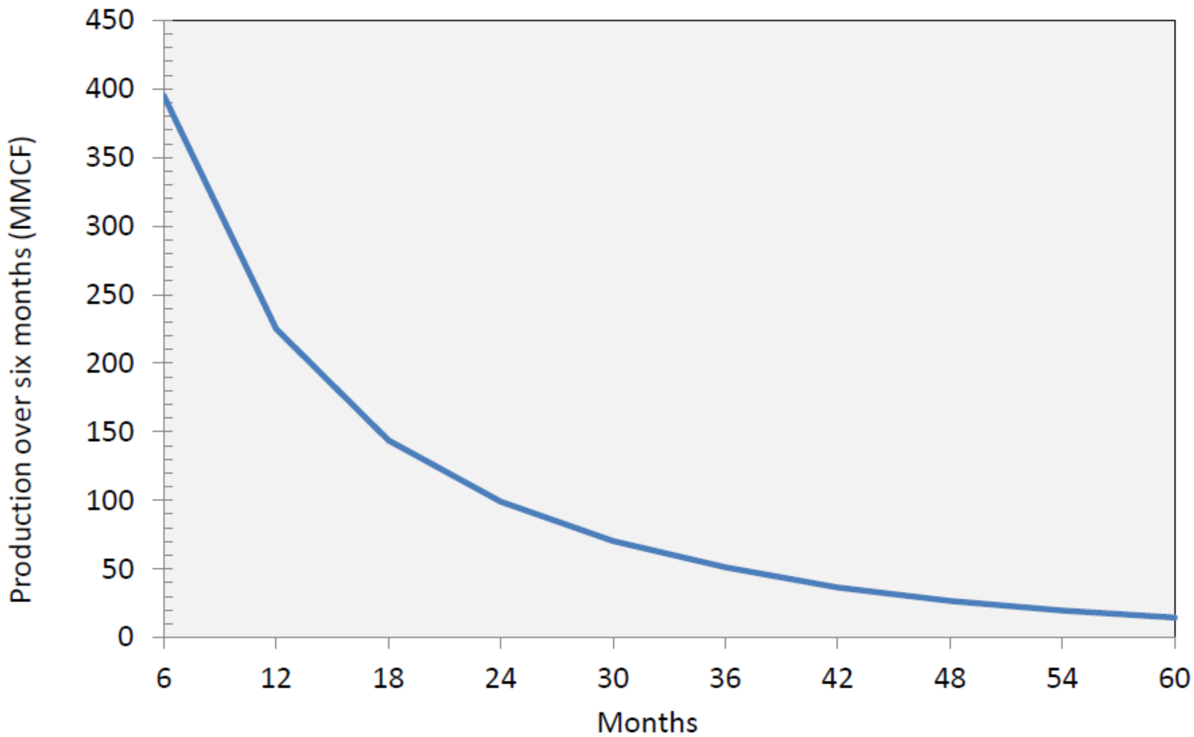

Figure 10-7: Estimated Marcellus Shale well production curve (million cubic foot) for Maryland during the first five years. Source: Regional Economic Studies Institute 2014. [10]

Based on these assumptions, we calculated yearly emissions (Figure 10-8, Figure 10-9, & Figure 10-10) associated with UNGDP-related activities in Garrett and Allegany Counties for both 25% and 75% extraction scenarios described in detail in the Impact Analysis of the Marcellus Shale Safe Drilling Initiative. Results based on the 25% extraction scenario suggest that during peak production years, approximately 22 tons of $PM_{2.5}$ will be emitted per year (range 1.76-51.62 tons/year). In addition, 468 tons of NO_x per year (range 107-1159 tons/year) and 517 tons of VOCs per year (range 80-2867 tons/year) will be produced during the peak years (Figure 10-9 and Figure 10-10). When we considered the 75% extraction scenario, yearly emissions for $PM_{2.5}$ were estimated to be 52 tons/year (range 3.8-113.3 tons/year). The corresponding estimates for NO_x and VOCs were 1,151 tons/year (range 263-2,860 tons/year) and 1,462 tons/year (range 390-6,708 tons/year), respectively (Figure 10-9 and Figure 10-10).

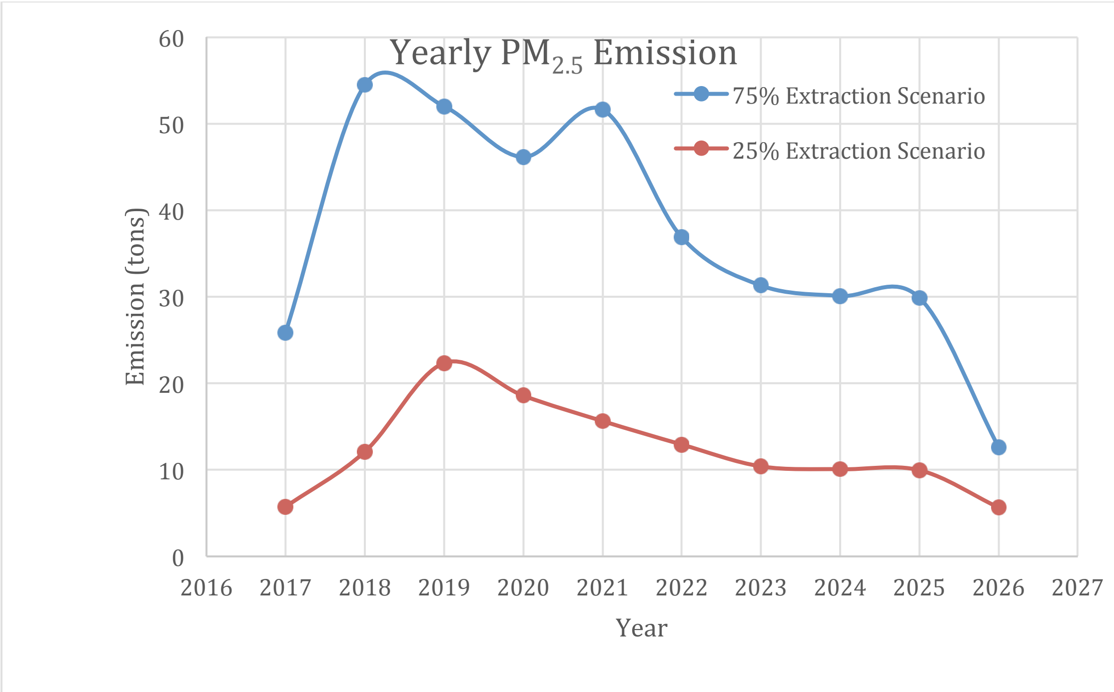

Figure 10-8: Estimated yearly emissions for $PM_{2.5}$ in Western Maryland under 25% and 75% extraction scenarios

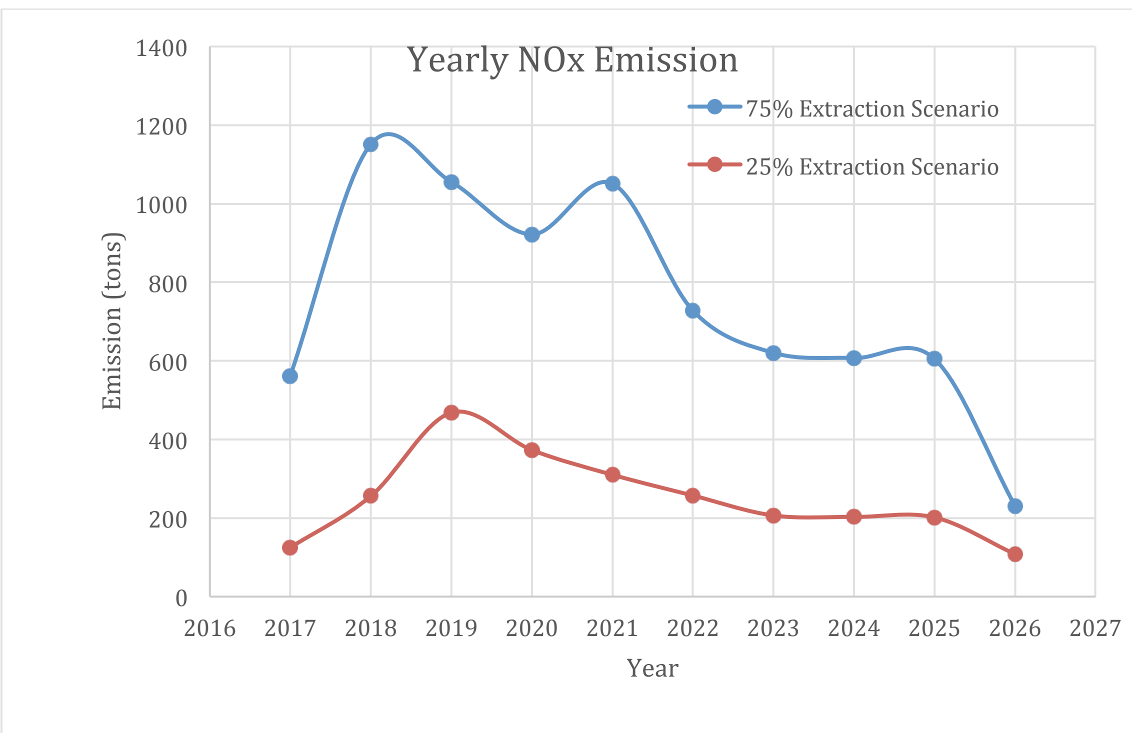

Figure 10-9: Estimated yearly emissions for NO_x in Western Maryland under 25% and 75% extraction scenarios

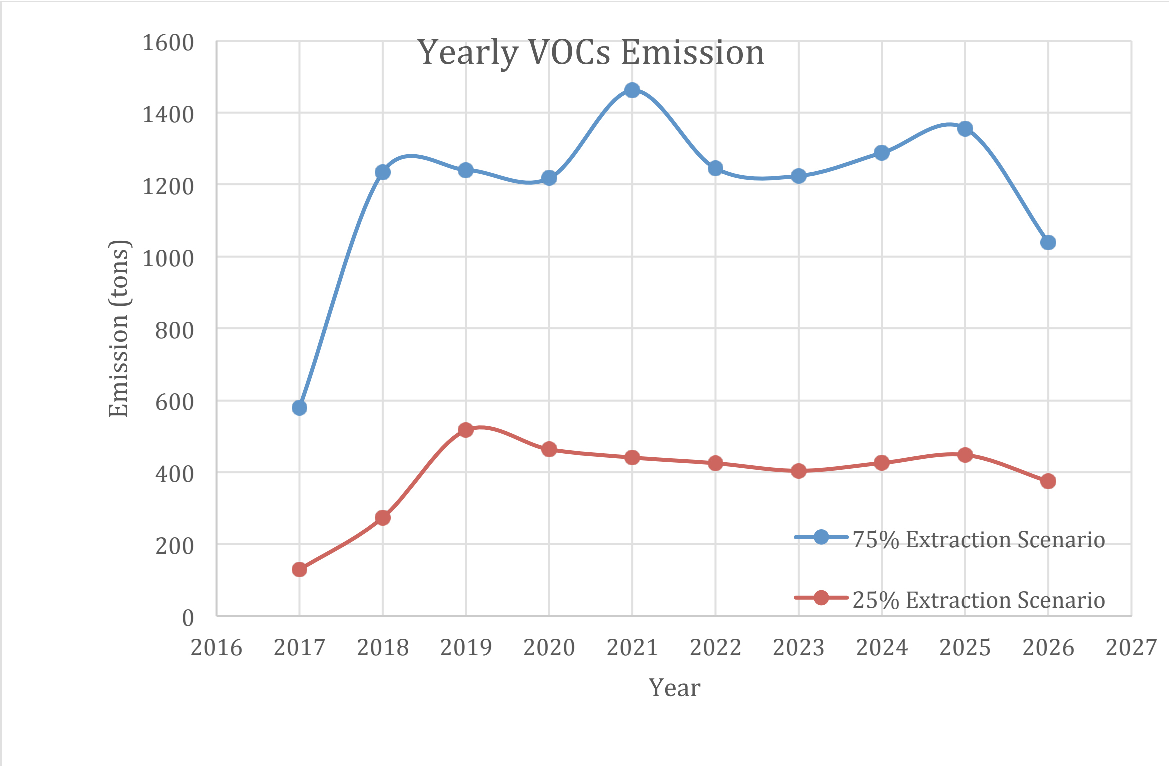

Figure 10-10: Estimated yearly emissions for VOCs in Western Maryland under 25% and 75% extraction scenarios

10.3.1.4 Studies on UNGDP Related Exposures and Adverse Health Outcomes

McKenzie and colleagues evaluated the health risks associated with UNGDP air emissions. [1]. They estimated the chronic and sub chronic non-cancer hazard indices, and the cancer risks for residents living within a ½ mile radius of UNGDP facilities and compared them with that of residents living greater than ½ mile away. The results suggest that residents who lived closer to the wells were at greater risk of adverse health outcomes related to UNGDP-related air emissions compared to those who lived more than ½ mile away. The subchronic hazard quotient (HQ) of 5 observed for residents <1/2 mile away from wells was considerably higher than the subchronic HQ of 0.2 observed for those living >1/2 mile away.

In a separate study, [2] investigated the relationship between maternal residence near UNGDP wells and risk of adverse birth outcomes in rural Colorado. The authors calculated maternal exposure during pregnancy using inverse distance weighted well count data within a specified radius. This inverse distance weighting approach assigned higher weights to wells that are closer to the mother's residence compared to those that were located further away. The index was then divided into tertiles (low, medium and high). Mothers at the highest tertile of exposure were more likely to give birth to children with congenital heart defects (CHDs) compared to mothers at the lowest tertile of exposure (Odds Ratios (OR) 1.3, 95% Confidence Interval (CI): 1.2-1.5). The authors observed similar associations for neural tube defects (NTDs) as well (OR 2.0, CI: 1.0-3.9). In a similar study, Hill [37] investigated maternal residency in areas heavily impacted by UNGDP and risk of adverse birth outcome including low birth weight (LBW) and preterm birth (PTB). The study included 22,000 live births in Colorado and 2,500 live births in

Pennsylvania. In Colorado, mothers who lived within 1 km of well were more likely to have LBW babies as well were at increased risk of delivering prematurely (PTB) compared to mothers who lived 2-5 km of well. Similarly in PA, the prevalence of LBW and PTB increased in 2.5 km radius of the well after the well development [37].

A survey of PA residents living in counties impacted by UNGDP [3] found an increased prevalence of symptoms such as throat & nasal irritation, sinus problems, eye burning, severe headaches, persistent cough, skin rashes, and frequent nose bleeds among respondents living within 1500 feet of UNGDP facilities compared to those who lived >1500 feet away. Some noted limitations of the study include a small sample size (108 respondents) and non-random samples. Furthermore, the analysis was not adjusted for potential confounders. But the study did have some highly exposed individuals, and a large exposure gradient (distance to the facility ranging from 350 feet to 5 miles). Findings of this particular study related to headaches, throat/nose irritation, severe headaches, skin rashes and nose bleeds are consistent with the common symptoms reported to us by residents of West Virginia during our site visit (November 16, 2013). The findings of Steinzor et al. [3] serve as an important hypothesis generating step that needs to be further confirmed with detailed epidemiologic investigations that take into account potential confounders.

In a separate study funded by The American Natural Gas Alliance, Fryzek and colleagues [38] investigated the association between childhood cancer incidence in Pennsylvania and UNGDP by linking childhood cancer data from 1990 through 2009 with 29,000 wells drilled during the same time period. The authors reported no association between UNGDP and childhood cancer. This particular study suffers from two serious flaws in study design: 1) the first UNGDP well was dug in PA in 2006 with production starting in 2008, so the vast majority of cancer cases in the study predated the exposure of interest; and 2) the study overlooked the issue of lag time that is known to exist for chronic outcomes such as cancer. Thus, the design of this study was such that it could not possibly have found an effect. This study highlights the need for high quality epidemiological investigations with robust exposure assessments that enable investigators to carefully match the temporal scale of exposure and outcome of interest.

10.3.1.5 External Evidence for the Health Effects of Air Pollution

10.3.1.5.1 *Air Pollution and Cardiovascular Disease Deaths*

Previous research has shown an association between exposure to air pollution and cardiovascular disease morbidity and mortality. Morris and colleagues [39] found a positive association between ambient carbon monoxide levels and hospital admissions for congestive heart failure. Venners and colleagues [40] found that risk of cardiovascular mortality was associated with an increase in peak SO_2 levels. Dockery et al (2001) reported that particulate matter was associated with increased heart rate, decreased heart rate variability, and cardiac arrhythmias. In addition, exposure to black carbon is associated with cardiovascular disease including emergency department visits and hospitalizations [41]. Research conducted by Adar and Kaufman [42] reviewed several studies that examined the impact of traffic related pollution on cardiovascular disease, and despite the variations in techniques used to assess this relationship, there was consistent evidence that confirmed the association between cardiovascular disease and traffic exposure. In addition, another study by Hoffman and colleagues [43] found that, long-term exposure to heavily trafficked residential areas was associated with coronary heart disease. Moreover, there was a 1.95 fold increase in cardiopulmonary mortality in residents that lived close (≤ 150 m) to major roadways which means that traffic exposure should be considered as a risk factor for cardiovascular disease in addition to more traditional factors [43]. Gan and colleagues [44] found that individuals living near a roadway were 29% more likely to die from heart disease. Jerrett and colleagues [45] spatially examined the relationship between air pollution and mortality in Los Angeles and found that $PM_{2.5}$ was more associated with ischemic heart disease mortality than with cardiopulmonary or all-cause mortality. Additional air pollution from UNGDP activities in Western Maryland could lead to an increase in heart disease morbidity and mortality in areas and expand health disparities in areas with Marcellus shale deposits.

10.3.1.5.2 *Air Pollution and Cerebrovascular Disease Deaths*

Previous research has shown that exposure to particulate air pollution may similarly increase the risk of stroke. We suspect that $PM_{2.5}$ levels will increase in Garrett and Allegany counties due to UNGDP activities including emissions from diesel truck traffic, gas flaring, compressor stations and other sources of air pollution. Studies of small-area variation have found a positive association between stroke mortality rates and living in areas of high-ambient pollution. Residents who live near UNGDP facilities particularly those who have previously had a stroke, who are elderly, have diabetes, have heart disease, smoke, are overweight, or are in poor health may have higher risk of strokes compared to residents with similar conditions who live farther way from activities. Wellenius and colleagues [46] found that an increase in PM_{10}, CO, NO_2, and SO_2 was associated with an increase risk for stroke admissions. Hong and colleagues [47] found exposure to $PM_{2.5}$ and PM_{10} was associated with an increased risk of ischemic stroke attack. In addition, Wellenius and colleagues [46] found that exposure to $PM_{2.5}$ levels considered safe by the U.S. EPA increased the risk of stroke onset within hours of exposure. While, Kettunen and colleagues [48] found that levels of $PM_{2.5}$, ultrafine particles, and CO were associated with increased risk of stroke mortality, but only in the warmer season. Additionally, Franklin, Zeka, and Schwartz [49] found a 1.03% increase in stroke related mortality with a 10 $\mu g/m^3$ increase in the previous day's $PM_{2.5}$ level. Time series studies using hospital discharge data reveal a statistically significant positive association between daily measures of PM_{10} and cerebrovascular hospitalizations, but the results have been inconsistent [50]. Overall, local health departments and clinics should monitor for increase in stroke morbidity and mortality in areas with UNGDP activities due to a decrease in local air quality because of $PM_{2.5}$ and PM_{10}.

10.3.1.5.3 *Air Pollution and All-cause Mortality*

This rate could increase due to exposure to air pollution from UNGDP activities in the counties that could lead to more heart disease and respiratory problems. Previous studies have shown an association between air pollution and all-cause mortality. Franklin, Zeka, and Schwartz [49] observed a 1.21% increase in all-cause mortality with a 10 $\mu g/m^3$ increase in fine particulate matter from the previous day. Ostro and colleagues [51] studied the relationship between fine particulate matter and all-cause mortality in California and found that a 10 $\mu g/m^3$ change in the 2-day $PM_{2.5}$ concentrations corresponded to a .6% increase in all-cause mortality.

10.3.1.5.4 *Air Pollution and Low Birth Weight*

Studies have shown exposure to high levels of particulate matter is associated with premature births [52] and others have shown that UNGDP operations increase local particulate matter concentrations [6, 7]. Brauer and colleagues [53] found that residing within 50 m of highways was associated with an 11% increase in low birthweight. Other combustion-related pollution such as carbon monoxide has been associated with a significantly increased risk for low birth weight among women living near heavily trafficked areas [54]. One study conducted in Los Angeles, found that women who lived within 1 mile from high levels of particulate matter from air emissions had at least a 27% increased risk for preterm delivery [55]. Black carbon a constituent of fine particulate matter that comes from diesel exhaust has been shown to also contribute to low birth weight among infants [56]. Therefore, it is likely that the number of premature births and low birth weight babies will increase in this area.

10.3.1.5.5 *Air Pollution and Infant Mortality*

Previous research has shown a relationship between exposure to air pollution including traffic-related pollution and infant mortality. Woodruff and colleagues [57] found an odds ratio of 1.07 for overall postneonatal mortality and 2.13 for respiratory-related postneonatal mortality. While, Woodruff and colleagues [58] found an odds ratio of 1.16 for a 10 $\mu g/m^3$ increase in PM_{10} for respiratory causes of neonatal mortality and 1.20 odds ratio for a 10 ppb increase in ozone and death from SIDS. Exposure to air pollution related to UNGDP activities and increases in social stressors could have an impact on maternal stress and infant mortality rates.

10.3.1.6 Assessment

Based on our evaluations of the limited but emerging epidemiological evidence from UNGDP impacted areas and air quality measurements as well as epidemiological evidence from other fields (external evidence), we conclude that there is a **High Likelihood** that UNGDP related changes in air quality will have a negative impact on public health in Garrett and Allegany Counties. Table 10-7 describes the scoring system we used to arrive at this conclusion.

Table 10-7: Air Quality Evaluation

Evaluation Criteria	**Score**
Vulnerable populations	2
Duration of exposure	3
Frequency of exposure	2
Likelihood of health effects	3
Magnitude/severity of health effects	3
Geographic extent	1
Effectiveness of Setback	1
Overall Score	15
Hazard Rank	H

The rationale used for scoring:

1. Vulnerable population received a score of 2 as exposure to air pollution is not equal for all members of a population. Concentrations of air pollution will decrease as the distance from the UNGDP facility increases. Therefore individuals living closer to the UNGDP

facilities will experience higher exposures. These individuals may be property owners who do not have mineral rights.

2. Duration of exposure received a score of 3. While the exposure to air pollution resulting from site development may decrease once the site preparation is completed, exposures related to production, such as those associated with compressor stations will continue to persist for years/decades.
3. Frequency of exposure received a score of 2 as exposure to air pollution occurs continuously, 24 hrs/day, 7 days/week.
4. Likelihood of health effects was assigned a score of 3 because emerging epidemiological evidence shows that exposure to UNGDP related changes in air quality may be associated with adverse birth outcomes including NTD and CHD. There is also strong epidemiologic evidence from studies outside of UNGDP settings that show exposures to air pollutants associated with UNGDP related activities, including crystalline silica, VOCs, and PM have negative effects on human health.
5. Magnitude/severity of health effects was assigned a score of 3 because exposure to air pollutants that are present in UNGDP processes are known to cause human health effects that can be irreversible, chronic, and at times fatal.
6. Geographic extent received a score of 1 because as outlined in the first bullet, the impact will be more pronounced in the immediate vicinity of the UNGDP facilities.
7. Effectiveness of setback was assigned a score of 1 because evidence from traffic-related air pollution studies indicated that the concentrations of traffic-related pollutants drop to the background level beyond 500-700m (1640-2296 feet). Likewise, a study from Colorado reported air pollution levels significantly higher within 0.5 miles (2640 feet) of UNGDP facilities compared to >0.5 miles. Based on this, we concluded that an adequate setback from the corner of a UNGDP facility to the corner of a residential property (2000 feet) can minimize exposure.

10.3.2 Flowback and Production Water-Related

This section details concerns related to human contact with natural and anthropogenic compounds made available for exposure through activities related to UNGDP. Specifically, it will focus on exposure to chemical and radiological hazards present in water and soil impacted by hydraulic fracturing activities.

This section will rely primarily on evidence from the peer-reviewed scientific literature. To a lesser extent, information from the grey literature, including governmental and independent consulting firm reports, will be included.

10.3.2.1 Water-related exposure pathways resulting from hydraulic fracturing

Humans can be exposed to fracking-related chemicals through a number of environmental pathways. These exposure pathways can be grouped by water source.

1. **Ground water.** Some ground water aquifers are used by people for drinking, cooking, bathing, and other household purposes. In the state of Maryland, more than one third of residents rely on ground water for their water supply [21]. Over 1.1 million Maryland

residents rely on individual, domestic wells, accounting for 31% of ground water usage in the state [21]. Ground waters that are developed for private wells may be vulnerable to both naturally-occurring and anthropogenic contamination resulting from fracking activities.

Private wells, as compared to community water systems, are uniquely vulnerable, in that they are not protected by the Safe Drinking Water Act and are thus unregulated by the EPA [59]. In addition, hydraulic fracturing activities are also exempted from consideration under SDWA [60].

2. **Production water and "flowback".** Large volumes of water are used in the process of UNGDP; according to the USGS, stimulation of the shale formation to prompt gas recovery can require between 3 and 7 million gallons of water per well [61, 62]. While UNGDP has been shown to generate less wastewater per unit of natural gas recovered than conventional drilling, the dramatic increase in drilling over the past decade has resulted in an overall increase in the amount of wastewater produced. Lutz et al. have estimated that since 2004, the generation of wastewater has increased by 570%, an amount that exceeds the wastewater disposal infrastructure capacity [63]. Production water refers to water that comes to the surface with the gas that originates from the subsurface, whereas "flowback" water refers to the water injected into the well during the fracking process [64].

   To recover natural gas from production wells, the injected water must first be removed and brought to the surface. Much of the injected water and fluids may be unrecovered – recent estimates place the loss rate of injected water at 47 – 91 % [65]. Additionally, an analysis of Marcellus Shale well logs reveals that the low permeability shale retains little free water, and thus fracturing fluids may be absorbed into the shale [65].

Once water is removed from production wells, numerous methods are employed to manage the water; many of these can create opportunities for human exposures.

1. **Storage of production waters**. After recovery, flowback water is often temporarily stored at the surface at impoundment ponds or pits prior to reuse or disposal. Concerns exist that surface leaks and spills are possible at impoundment ponds [60]
2. **Treatment of production waters.** While less common today, production waters from fracking operations in Pennsylvania were often sent to commercial or municipal wastewater treatment plants (WWTPs). After treatment at these plants, treated production waters were typically discharged into surface waters like rivers and streams. In 2011, the Pennsylvania Department of Environmental Protection (PADEP) requested that production waters from fracking operations no longer be sent to commercial and municipal WWTPs. Some production waters from wells in Pennsylvania and other states have been sent to industrial wastewater treatment plants [66]. In addition, a number of alternative strategies have been pursued for disposal of fracking production water.
3. **Water Reuse.** Recycling/reuse of fracking water has become more common since 2011 [67], though it requires a pre-treatment before reuse, and some well operators are not willing to pay the cost related to separation and filtration [68]. Prior to 2011, it has been estimated that only 13% of wastewater was recycled [63]. It was estimated that 70% of production water was reused in the state of Pennsylvania [66].

4. **Deep Injection Wells.** To a limited extent in Pennsylvania, and a greater extent in Ohio and Texas, deep injection wells (Class II) are being used as a method for disposal of fracking wastewater at depths considered to be below aquifers that would be used as sources of drinking water.
5. **Road and Land Application.** Production water has also been periodically used as a road de-icer (due to its high salinity) and as a dust suppressant for road maintenance. In some instances, production water and sludge have been used as an agricultural land amendment [67].
6. **Transport of Production Water.** Transport of production water for treatment, re-use, or other purposes, creates the opportunity for spillage or leakage, which may lead to unwanted exposures [69].

10.3.2.2 Origins of Chemical and Radiological Hazards in Water Sources

Existing research suggests that contamination of shallow aquifers used for drinking water may occur through a variety of mechanisms, though there is a lack of high quality baseline data to challenge the certainty of such processes [64]. Ground water resources appear to be at increased risk of contaminant infiltration (by naturally occurring chemical hazards and radiological materials that may exist in the subsurface) as a result of fracturing activities [66]. Poorly constructed or faulty well casings may allow for chemicals present in production waters to leak from production wells into the surrounding geology, a scenario that can introduce contamination into shallow aquifers used for drinking water. Furthermore, chemicals associated with fracturing use may be abandoned or improperly sealed in oil and gas wells [65].

Rozell and Reaven [68] present a conceptual model of pathways by which ground waters and production waters can become contaminated (Figure 10-11).

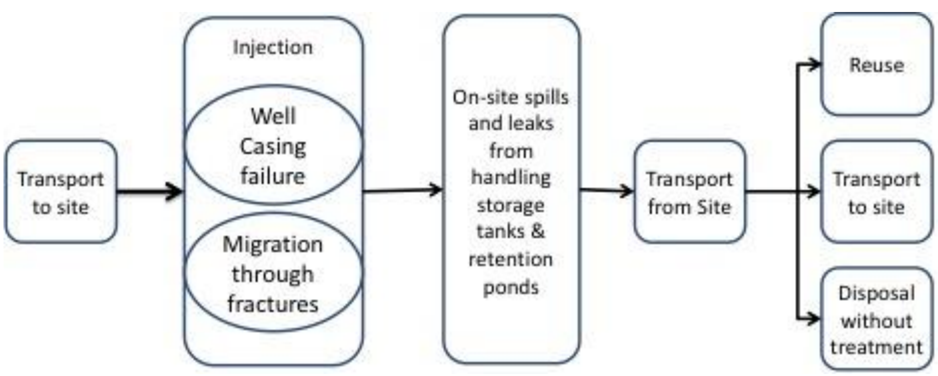

Figure 10-11. Conceptual model of water contamination pathways, from Rozell and Reaven 2012

The process of fracking requires the use of liquid mixtures of numerous chemicals to prop open subsurface fractures to allow the movement of natural gas through drilled wells for recovery at the surface. The composition of these mixtures is typically considered to be a trade secret, and thus in many cases it is not disclosed to the public [70]. Chemicals comprise between 0.5 – 2 % of fracking fluids; while they may constitute a small fraction of the total fluids used, the very large volume of fluid used (3-7 million gallons per well) combined with 5-12 wells per well pad means the overall volume of chemicals used at a single location can be substantial [71]. A list of chemicals suspected to be used in fracking has been compiled and made available to the public [72]. The fluid solutions used to prop open fractures likely varies considerably by drilling company, and poses challenges in terms of characterization of water quality and hazard assessment. Based on this composition, recommendations have been made that candidate chemicals for monitoring the impact of fracking flowback on water quality should include sodium hydroxide, 4,4-dimethyloxazolidine, and hydrochloric acid [60, 73].

In addition to the chemical constituents of flowback, production water also brings large quantities of brine. The characteristics of recovered brines from produced waters have been described, and treatment and disposal of these brines has been seen as a burden to well operators. The concentrations of metals in recovered fluids increase over time once recovery of flowback water from the well begins, and the concentrations of inorganic elements such as barium, strontium and radioactive radium appear to increase with salinity [60, 64]. Brines are typically rich in chloride and sodium bicarbonate, among other constituents. At elevated concentrations, constituents of these brines have been demonstrated to have adverse effects on ecological receptors [69].

10.3.2.3 Gases/Chemicals

Multiple mechanisms can allow for the migration of gases (including methane, ethane and propane) into shallow aquifers used for drinking water, raising the risk of gas accumulation to concentrations that pose a risk of explosion [60]. This gas may originate from the target formation and may migrate from the well annulus and through the cement sheath into the surrounding geology. Alternatively, the fracking process may create pathways for stray gas (that originates outside of the borehole, but has been released as a result of the fracturing) to migrate into groundwater resources [65]. Leaky casings, abandoned oil and gas wells, and existing or even newly-formed faults resulting from fracturing activities can serve as potential opportunities for migration of gases [60, 66, 74]. Bacteriogenic gases may play a role in contamination [74], but studies on ground waters within a kilometer of shale gas production sites have shown relatively enriched thermogenic carbon isotope fingerprints. Other investigations have found that wells where stray gas was evident had gas composition profiles of production gases consistent with Marcellus and Upper Devonian formations [60].

A USGS-led investigation of isotopic signatures of gases in groundwater in northern Tioga County in Pennsylvania noted complicating factors (arising from multiple potential gas sources) in pinpointing the precise origins of the identified hydrocarbons [75]. However, the authors noted that ground waters had evidence of both thermogenic and biogenic methane, and wells had evidence of thermogenic methane [75]. The isotopic signatures of gases detected in ground waters and wells suggest the same source as gases found in storage field observation wells [75].

Pathways for stray gases into shallow aquifers may also facilitate the flow of fluids from the fracturing site to the surface and shallow aquifers [74]. Other researchers (including those funded by the energy industry) have contested this claim, asserting that pre-existing hydraulic gradients and factors related to bedrock permeability limit the upward flow of fracking fluid and brines that may result from fracking [76]. Contamination of groundwater sources with fracking fluids has not been studied extensively; the existing literature is summarized in a following section.

After hydraulic fracturing has been performed, the fraction of wastewater that has been recovered from the well may be temporarily stored in surface impoundments. Some criteria have been established in certain states for this practice; for example, in Pennsylvania, the impoundments must have a plastic liner 30 mm in thickness with seams sealed to prevent leaks [67]. Despite these criteria, concerns remain over ruptures in liner materials and overflows of impoundments with fracturing water.

The Gradient consulting firm (whose client list includes members of the energy industry) evaluated concerns related to the potential for constituents of flowback to impair processes at publicly-owned treatment works, and concluded that flowback chemical constituents were unlikely to impact Publicly-Owned Treatment Works (POTWs) [77].

Limited investigation has examined the impact of industrial wastewater treatment on the contaminant profile of treated flowback water. Warner and colleagues [66] studied effluent from the Josephine Brine Treatment facility in Pennsylvania, and reported that the treatment process resulted in elevated concentrations of chloride and bromide relative to background levels [66]. Whereas concentrations of barium and radium in treated flowback were significantly reduced compared to that of untreated flowback [66].

Concerns have been raised that improper treatment, resulting in either enrichment with (or improper removal of) halides could result in the formation of trihalomethanes, some of which are recognized carcinogens [60]. A study of effluent from a commercial wastewater treatment plant (CWT) that accepted flowback water showed decreased diversity of disinfection byproducts, while the actual concentration of two disinfection byproducts, dibromochloronitromethane and chloroform, at the CWT were far higher than those in the effluent of typical POTWs [78]. The authors also reported finding elevated concentrations of bromide and chloride, which are precursors to disinfection byproducts in the CWT that accepted flowback water [78].

10.3.2.4 Radiological materials

Wastewater from UNGDP operations has been shown to carry residual levels of radionuclides, often referred to as naturally occurring radioactive materials (NORM). The presence of NORM, and the nature of NORM, is highly dependent on the shale formation in which fracturing is occurring [64]. According to scientists from the USGS, the Marcellus Shale is recognized to have elevated uranium content, whose daughter product Ra^{226} can be present in shale brine at levels exceeding 10,000 pCi/L [67]. Prominent NORM found in production water from the Marcellus Shale includes radioactive radium (often Ra^{226} and Ra^{228}) with activities ranging from 185 to 592 Bq/L [66]. When radium is present under circumstances of high salinity and reducing conditions, it can be dissolved in and mobilized by water [67].

Examinations of effluent from a Pennsylvania facility treating flowback demonstrated significant reductions in radium and barium content, lowering activity of residual radium to less than 2 Bq/L, the industrial discharge limit [66]. Despite these reductions, the authors described accumulation of radium in point-of-discharge stream sediments to levels approximately 200 times higher than what was observed in background and upstream samples at levels in excess of standards for radioactive waste disposal [66].

The chemical composition of flowback brine derived from fracking wells in the Marcellus Shale region was recently examined for similarity with brines from oilfields and other processes. Among other findings, the authors reported that flowback brines from fracking wells had concentrations of $Ra^{226,}$ Ra^{228}, and Ba at levels that far exceed radiologically-based drinking water standards [79]. The authors cautioned that flowback water must be managed carefully, to avoid human exposures to relatively high levels of these radionuclides [79]. The study team also reported that levels of other constituents of the brine, including total dissolved solids, chlorine, bromine, sodium, calcium, and strontium, were elevated above typical seawater concentrations by factors of 5 – 10 [79].

A study of soils and sediment samples near roads where brines from conventional oil and gas wells were spread as a de-icing agent found increases in Ra^{226} [80]. As compared to background roads (where brines were not used), sediments recovered near roads (where brines from conventional oil and gas wells were used for de-icing) were found to contain elevated concentrations of elemental contaminants such as Ra^{226} [80]. Ra^{226} was 20% above background. No significant increases in Ra^{226} were observed in effluent from POTWs that received recovered water from fracking wells [80].

While much of the research surrounding radiological hazards focuses on the activity of Ra^{226}, a recent examination of pit sludge from fracking operations characterized the frequency and activity of a wide array of radionuclides beyond Ra^{226} and Ra^{228} including beryllium, potassium, scandium, cobalt, cesium, thallium, $lead^{210}$, $lead^{214}$, $bismuth^{212}$, $bismuth^{214}$, thorium, uranium, Sr^{89} and Sr^{90}[81]. While the results did not exceeded regulatory guidelines for any one particular radionuclides, the total beta activity in one sludge sample (1329 pCi/g) exceeded regulatory guidelines by more than 8 times (eg Texas Administrative Code, Title 16, Part 1, Chapter4, Subchapter F, Rule §4.614) which lead authors to question the adequacy of solely using radium as an indicator of NORM contamination and as a basis for a complete risk assessment [81].

In summary, concerns have been raised regarding the potential for human exposure to radionuclides present in NORM from unconventional gas recovery. The majority of attention has been focused around radioactive radium (and to a lesser extent radon, which is largely assumed to be released at well heads [59]) as an indicator for NORM, though other radionuclides may also be present and pose cumulative risks. Despite this, regulatory oversight aimed at exposure mitigation appears to be minimal, and the likelihood of human exposures and disease resulting from potential exposures are largely uncharacterized [67]. Studies of exposures to radiological material from fracking are underway at PADEP and EPA, though the results of those studies have yet to be released.

10.3.2.5 Evidence of well water contamination

There have been a limited number of studies examining the potential impacts of fracking on groundwater wells used for drinking. Studies have examined contamination with gases, brine, various chemical contaminants (including those thought to be constituents in fracking fluids), and radiological hazards. To date, studies reporting the infiltration of gases, chemicals and other process wastes into groundwater sources have been mixed [64].

Osborn and colleagues [82] examined drinking water wells in New York and northeastern Pennsylvania and found that methane concentrations in drinking water wells located in active drilling areas (within 1 km of unconventional gas wells) were higher than those in areas >1 km away, with concentrations 17 times higher on average. The authors reported that the ratios of methane to higher chain hydrocarbons like ethane, propane and butane suggest a thermogenic origin in active drilling areas and primarily biogenic methane in areas where drilling was not occurring. An investigation of the geochemical and isotopic features of the water recovered from shallow wells did not suggest mixing with brine or fracturing fluids from drilling, and the authors concluded that there was no evidence of contamination with these compounds [82].

A separate investigation examined relationships between geographic proximity to natural gas wells and methane and ethane concentrations for 141 drinking water wells in the Appalachian Plateaus of Pennsylvania [83]. Significant spatial relationships were observed, where drinking water wells less than 1 km from gas wells had average methane concentrations six times higher than those further away. Geographic distance from gas wells was also found to be significant for both methane and ethane concentrations. The isotopic signatures of gases examined in the study were consistent with a hypothesis of thermogenic origin and were unlikely to be of biogenic origin. The authors concluded that living within 1 km of gas wells likely predicts exposures to drinking water contamination with stray gases [83].

Fontenot and colleagues [84] reported an investigation of 100 drinking water wells in the Barnett Shale Formation, including 91 wells in areas of active extraction, 4 wells from areas of non-active extraction, and 5 reference sites. Comparisons were made between concentrations of selected contaminants in water from the active area wells compared to those at inactive, reference, and historic sites (measured between 1989 and 1999). The authors found significantly elevated concentrations of arsenic, selenium, strontium and barium at active area wells compared to historic sites. Arsenic and barium levels were also found to be significantly higher in measured non-active and reference area wells. Despite this high background level, the maximum detected arsenic and barium concentrations in the active area were nearly 18 and 3 times higher than those in the inactive/reference area, respectively. The authors also reported proximity to the nearest gas well as an important factor in predicting the contaminant concentrations. Methanol and ethanol concentrations were also examined in active and inactive/reference areas. While the compounds were found in wells from both areas, methanol concentrations were highest in the active area. The authors were not able to speak definitively to the sources of the contamination, citing the need for sampling data collected, before, during and after extraction activities to pinpoint with certainty drilling as the source of contamination. However, they suggest that this scenario is plausible, and that private wells closer to natural gas extraction may be at increased risk of contamination as compared to those further away. [84]

A study of 1,701 water wells conducted in Northeastern Pennsylvania examined historic and “background” surveys of methane content and other water quality measures in groundwater to characterize potential sources of methane in drinking water wells [85]. The study, which included an author who had an affiliation with the oil and gas industry, concluded that methane contamination of water is related primarily to topography and groundwater geochemistry, and that activities related to shale gas recovery have not contributed to gas impacts on drinking water sources. The authors also assert that fracturing activities have not created or accentuated fractures that could allow gas migration [85].

Investigators in Colorado reported results of a study examining 176 groundwater wells in the Wattenberg field in northern Colorado where the occurrence of drilling and fracturing is increasing in frequency [86]. The authors found that three quarters of sampled wells contained measurable concentrations of methane, and that the majority of methane detected in sampled wells was of biogenic origin (only two sampled wells had thermogenic methane). They concluded that while fracturing is a possible pathway for thermogenic gas migration into groundwater, the majority of methane present in their study was from microbial sources [86].

Overall, new UNGDP activities could lead to exposure and health risks for populations on well water due to potential contamination of ground water and well water from fracking fluids, recharge, or spills including radionuclides, heavy metals, methane, and benzene among other contaminants.

10.3.2.6 Evidence of Soil Contamination

Soil can be contaminated with drilling fluids, flowback, produced waters, and other wastes. As outlined above, these fluids and wastes may contain numerous contaminants including radionuclides. Soil contamination is likely to occur through: 1) unintentional spills and leaks of waste or chemicals used during UNGDP, 2) the spread of waste onto fields, and 3) the use of wastewater or brine on roads.

Limited evidence in the literature suggests that land application of wastewater and flowback is a practice that could lead to "severe vegetation damage and mortality" [87–89]. Land application of waste is a common waste disposal method in several states [87, 88]. In a land application study in West Virginia's Fernow Experimental Forest, Adams and colleagues observed visible changes to ground vegetation, including browning and wilting leaves, leaf scorch, curling, and drop following land application of drill pit fluids (Adams et al. 2011). The fluids met the regulatory requirements for land application chemicals: chlorides below 12,500 mg $^{L-1}$ and pH between 6 and 10. A few days after land application, nearly all the ground vegetation died. After 7-10 days, "overstory trees began showing similar damage" (Adams et al. 2011). Two-years after the application, 56% of the trees in the area were dead. Damage was attributed to direct contact with the fluids, as well as root uptake from the soil. When they evaluated the soil chemistry, they found statistically significant differences in Ca, Mg, Al, Mn, Zn, and the C/N ratio between the test and control sites [88, 89].

Aminto and Olson [73] used a four-compartment model (including soil, water, air, and biota) to evaluate 12 hazardous components (sodium hydroxide, ethylene glycol, 4,4-dimethyl oxazolidine, 3,4,4-trimethyl oxazolodine, 2-amino-2-methyl-1-propanol, formamide, glutaraldehyde, benzalkonium chloride, ethanol, hydrochloric acid, methanol, and propargyl alcohol) used in hydraulic fracturing fluid. They found that sodium hydroxide, hydrochloric acid, and 4,4-dimethyl oxazolidine were the highest mass concentrations found in the soil compartment [73]. Sang and colleagues (2014) found in controlled laboratory experiments, that flowback fluid has the potential to activate colloid mobilization. Mobilization is dependent on certain chemical constituents, several of which are found in hydraulic fracturing fluid, such as inorganic salts and organic compounds, such as surfactants [87].

Overall, there is little information on the impact of UNGDP activities on soil quality. As discussed above, there are three exposure pathways that could contribute to contamination of soil and groundwater. Accidental spills and leaks due to storage of flowback and production waters can be minimized. According to the Maryland Best Management Practices, the State would require use of enclosed tanks, constructed of metal with liners instead of impoundment ponds. In addition, a barrier that can hold the total volume of the largest storage container or tank located in the enclosed area would surround the tanks [16]. These practices may minimize the potential for contamination.

10.3.2.7 Characterization of water-related human health burden

Despite evidence suggesting that human exposures to contaminants originating from fracking are likely, to date, there is a dearth of studies that have examined relationships between exposed persons and health outcomes [64]. While these studies are critical for decision-making efforts that aim to consider public health concerns, it is critical to recognize that the absence of investigation does not constitute an absence of risk or harm. We were unable to locate any studies of fracking-impaired waters on human health outcomes; this is consistent with the lack of identification of studies noted in a recent review [64].

A study of 39 unique ground water samples collected in Garfield County, Colorado (a region with highly concentrated drilling activity) examined the propensity for flowback water to elicit endocrine activity on estrogen and androgen receptors. As compared to samples collected from a reference region, ground water samples from drilling areas were far more likely to exhibit endocrine activity; 89%, 41%, 12% and 46% exhibited estrogenic, antiestrogenic, androgenic and antiandrogenic activity, respectively. The authors concluded that natural gas drilling operations may contribute to elevated level of endocrine disrupting compounds in ground and surface water [90]. While this study did not characterize likely exposures or associated human health burdens, the findings point toward future directions for epidemiologic investigations.

While there are not any epidemiological studies that have evaluated associations between soil quality and health, Bamberger and Oswald [91] published a study documenting 24 cases of livestock, domesticated animals, and humans that have been adversely impacted by exposure to contaminated water and soil. In case study three, a cattle pasture had been contaminated by wastewater due to a tear in an impoundment pond, and soil tests detected high levels of chloride, sulfate, sodium, and strontium. As a result of the contamination, the cattle experienced reproductive issues, including spontaneous abortion and stillbirth [91].

10.3.2.8 Limitations of existing database – Critical data gaps

1. Baseline water quality data are largely unavailable for states that already allow unconventional natural gas production. This lack of data precludes high quality characterization of the impacts of fracturing activities on drinking water sources, and thus complicates efforts to conduct epidemiologic investigations of potential associations between fracking-related contamination and human health outcomes.
2. The majority of studies examining NORM in fracking brines or recovered waters are typically limited to examination of radioactive radium, and do not include other radionuclides that may co-occur and create additional radiation exposures.
3. Given the proprietary nature of unconventional natural gas development, data are largely unavailable regarding the composition of fluids used for fracturing.
4. We were unable to locate a comprehensive database of best practices aimed at minimizing leakages, storage problems, and other failures that could lead to human exposures; this, too, may be related to the proprietary nature of fracturing.
5. The utility of radium isotopes as indices of contamination with NORM is unclear, but emerging data suggest that other radionuclides may also contribute significantly to cumulative radiological activity.

10.3.2.9 Assessment

Based on our evaluations of the limited data available from UNGDP impacted areas, we conclude that there is a **Moderately High Likelihood** that UNGDP's impact on water quality, soil quality and naturally occurring radioactive materials will have a negative impact on public health in Garrett and Allegany Counties. The overall score for the Flowback and Production

Water Related hazard category is primarily driven by concerns related to water quality. Table 10-7 provides an overview of the scoring for each evaluation criteria.

Table 10-8: Flowback and Production Water Related Evaluation

Evaluation Criteria	**Score**
Vulnerable populations	2
Duration of exposure	3
Frequency of exposure	2
Likelihood of health effects	1
Magnitude/severity of health effects	1
Geographic extent	2
Effectiveness of Setback	2
Overall Score	13
Hazard Rank	M

1. Vulnerable population received a score of 2 as exposure to contaminated water disproportionately affects residents near the UNGDP facilities, particularly those who rely on well water.
2. Duration of exposure received a score of 3 because exposure will persist for longer than 1 year.
3. Frequency of exposure received a score of 2 as exposure to contaminated water is frequent.
4. Likelihood of health effects was assigned a score of 1 because despite evidence of exposure, evidence regarding adverse health outcomes could not be determined because of insufficient data.
5. Magnitude/severity of health effects was assigned score of 1 because despite evidence of exposure, evidence regarding adverse health outcomes could not be determined because of insufficient data.
6. Geographic extent received score of 2 because exposure can be widespread if the drinking water aquifer is contaminated.
7. Effectiveness of setback was assigned score of 2 because setback will not mitigate exposure.

10.3.3 Noise

Environmental noise associated with UNGDP was identified as a top concern by residents in Allegany and Garrett Counties during the Scoping process. Increased noise levels are expected during all phases of development and production. Setback regulations (Table 10-9) and adherence to the state or local noise standards (Table 10-10) are two methods being proposed to minimize noise during development and production [16]. Local governments will be responsible for enforcing the noise standards; however, if the counties do not have the capacity for monitoring and enforcement, the permittee may be required to hire an independent contractor to conduct periodic noise monitoring and to respond to noise complaints [16]. The current noise standards adopted by MDE are outlined in Table 10-10. The residential noise standards for both day and night are relatively high considering the literature on health effects associated with noise exposure and may not adequately protect public health.

Table 10-9. Proposed Setbacks specific to Occupied Dwellings, Source: Maryland Best Management Practices [16]

Distance	**From**	**To**
1,000	Borehole	Any occupied dwelling
1,000	Compressor stations	Any occupied dwelling

Table 10-10. Maryland's Maximum Allowable Noise Levels for Receiving Land Categories

Day/Night[3]	**Industrial**	**Commercial**	**Residential**
Day	75	67	65
Night	75	62	55

10.3.3.1 Hazards associated with noise

Major sources of environmental noise are transportation, including vehicular traffic, aircrafts, and railroads, as well as industrial operations. Urban areas typically have higher noise levels compared to rural areas. Most of the increased noise in urban areas is due to traffic-related noise. Noise is considered a major stressor because of its ability to lead to a number of adverse health effects.

Most of the literature on noise and health effects has focused on transportation (traffic, airplanes, and trains) sources. Adverse health effects from noise are dependent on the duration of exposure and the intensity of the noise. Long-term exposure to A-weighted decibels ranging from 35-75 have been associated with a myriad of health effects, from disruption of sleep and school performance to hypertension [92]. Children, elderly, chronically ill, and hearing impaired individuals have been found to be more susceptible to environmental noise [93]. While increased noise levels are associated with both the UNG-Development and the UNG-Production phase, exposures associated with the UNG-Development phase are temporary as the development activity ceases to exist once the wells are constructed. The noise associated with the production phase, on the other hand, is permanent. Only a few studies have evaluated noise associated with UNGDP activities.

[3] Daytime hours are 7 a.m. to 10 p.m. and Nighttime hours are 10 p.m. to 7 a.m., COMAR 26.02.03.01

Figure 10-12: Well Pad, West Virginia (photo: Brigid Kenney)

10.3.3.2 Noise Associated with UNG-Development

McCawley [34] monitored and recorded the average A-weighted decibel levels (dBA) in West Virginia at 9 sites located around 5 well pads at different stages of natural gas development, including site preparation, vertical drilling, horizontal drilling, hydraulic fracturing, and flowback. He found the average noise levels across the sites were lower than 70 dBA, but the levels were frequently over 55 dBA [34]. The Colorado School of Public Health conducted a HIA to assess the potential health impacts associated with natural gas drilling in Battlement Mesa. They determined that significant sources of noise would be heavy truck traffic, construction equipment, diesel engines used throughout drilling and hydraulic fracturing, and drill rig brakes [7]. Based on these sources and the estimated baseline noise levels in the community, they determined that noise associated with natural gas extraction would produce negative health effects [7]. New York evaluated the noise impact associated with UNGDP in their draft supplemental Environmental Impact Assessment (EIA) using a model to estimate the noise levels at varying distances associated with each stage of well pad construction and drilling. Noise levels were estimated based on data obtained from the industry for the construction equipment. They found that noise levels at a distance of 250-2,000 feet would range from 52-75 dBA during well pad construction, 44-68 dBA during drilling, and 72-90 dBA during high-volume hydraulic fracturing [94]. Noise associated with construction, drilling, and hydraulic fracturing would last approximately 60 days per well pad.

Table 10-11. Noise Associated with UNGD

Phase/Activity	Distance (feet)	Average dBA	Source
Well Development			
Access road construction	50-500	69-89	NYSDEC, 2011
Access road construction	1,000-2,000	57-63	NYSDEC, 2011
Truck traffic, construction	625	56-73	McCawley M, 2013
Truck traffic[4]	< 500	65-85	Witter et al, 2010
Site preparation	625	58-69	McCawley M, 2013
Well pad preparation	50-500	64-84	NYSDEC, 2011
Well pad preparation	1,000-2,000	52-58	NYSDEC, 2011
Drilling			
Vertical drilling	625	54	McCawley M, 2013
Rotary air well drilling	50-500	58-79	NYSDEC, 2011
Rotary air well drilling	1,000-2,000	45-52	NYSDEC, 2011
Horizontal drilling	50-500	56-76	NYSDEC, 2011
Horizontal drilling	1,000-2,000	44-50	NYSDEC, 2011
Well Completion			
Hydraulic fracturing	625	47-60	McCawley M, 2013
Hydraulic fracturing[5]	50-500	82-102	NYSDEC, 2011
Hydraulic fracturing	1,000-2,000	70-76	NYSDEC, 2011
Hydraulic fracturing & flowback	625	55-61	McCawley M, 2013

[4] This is an estimate based on anticipated noise associated with diesel truck traffic and residential proximity to truck routes[9].

[5] Average dBA for pumper truckers with a sound pressure level of 110 and 115.

10.3.3.3 Noise associated with UNGP

Current literature on noise impacts associated with UNGDP focuses on well construction and hydraulic fracturing. There have not been any studies to evaluate noise levels associated with production, including noise originating from compressor stations. Natural gas compressor stations are a more permanent source of noise in the community. To better understand noise exposure levels associated with compressor stations, we conducted a pilot study to monitor and evaluate residential exposure to noise associated with natural gas compressor stations in West Virginia.

Methods

All noise monitoring was conducted around compressor stations in Doddridge County, West Virginia between April 11-17, 2014, using 3M Quest SoundPro noise monitors (3M Personal Safety Division, St. Paul, MN). All monitors were set to collect slow, A-weighted decibel levels (dBA) L_{eq}, L_{min}, L_{max}, L_{peak}, L_5, and L_{95} and C-weighted decibel levels L_{eq}, L_{min}, L_{max}, L_{peak} in 1-minute intervals.

Short-term Measurements: Short-term measurements (20 min) were collected at increasing distance from compressor stations in Doddridge County, WV. The monitors were placed in a safe outdoor location using a tripod. The exact geographical coordinate of the monitor location was recorded.

Medium-term (24 hr) Measurements: 24-hour noise measurements were collected inside and outside homes that were near compressor stations in Doddridge County, WV. A total of three homes were located less than 1,000 feet from the compressor stations, three homes were located between 1,000 and 2,000 feet, and two homes were located between 2,000 and 2,500 feet. An additional 3 homes were recruited as control homes, located beyond 3,500 feet from the compressor stations. Noise monitors (Quest SoundPro SE/DL Series**)** were placed inside and outside each home for 24 hours. Indoor monitors were typically placed in a bedroom and outdoor monitors were placed in the yard facing the natural gas compressor stations (NGCS). Outdoor monitors were encased in an environmental protection kit (3M SoundPro Outdoor Measuring System (SP-OMS)). Outdoor measurements for two homes located 2,000 to 2,500 feet were not for a full 24-hours, due to battery failure. Following the method used by Murphy and King (2014), we evaluated the difference between the C-weighted dB and the A-weighted dB to determine the presence of low-frequency noise. A difference greater than 15 dB indicates the potential for low frequency noise and would require further spectral analysis. Monitors were factory calibrated prior to use and then were pre-calibrated using a Quest QC-10/QC-20 Calibrator onsite prior to each measurement. Following each measurement, the monitor was post-calibrated and the data were downloaded using Quest Suite Professional. The average sound equivalent was calculated using logarithmic averages and was stratified by distance from compressor station, time of day (daytime 7:00 am-10:00 pm and nighttime 10:00 pm-7:00 am), and location (indoor and outdoor).

Results

Noise levels associated with compressor stations were dependent on the distance from the compressor station, location (indoor vs. outdoor), and time of day. Overall the average L_{eq} for the combined compressor stations was 60.20 dBA (range 35.3 to 94.8 dBA), and the average short-term L_{eq} for the combined compressor stations was 61.43 (range 45.3 to 76.1 dBA) (Table

10-12). Average outdoor noise levels were 58.33 (35.3 to 85.0 dBA) compared to 61.27 (35.3 to 95.8 dBA) indoors. Both the short-term and 24-hour measurements decreased with distance from the compressor stations, 63.15 dBA at less than 1,000 feet to 54.09 dBA at 2,000 to 2,500 feet for 24-hour measurements and 63.34 dBA at less than 1,000 feet to 54.10 at 2,000-2,500 feet for short-term measurements (Table 10-12). Noise levels were generally higher during daytime hours compared to nighttime hours, 61.44 dBA and 56.38 dBA, respectively. Noise levels were higher indoors compared to outdoors for homes located within 2,500 feet of a compressor station, 61.27 and 58.33, respectively (Table 10-12). The contribution of outdoor noise to indoor noise varies depending on the type of home and whether the windows are opened or closed. A 17 dB reduction in noise levels would be expected in a cold-climate home with windows open and a 27 dB reduction with windows closed [95]. We observed a 3-7 dB difference in indoor versus outdoor noise levels, much lower than would be expected. There is little indication of low-frequency noise at varying distances from natural gas compressor stations. We observed a difference greater than 15dB at sites located less than 500 feet from the compressor stations.

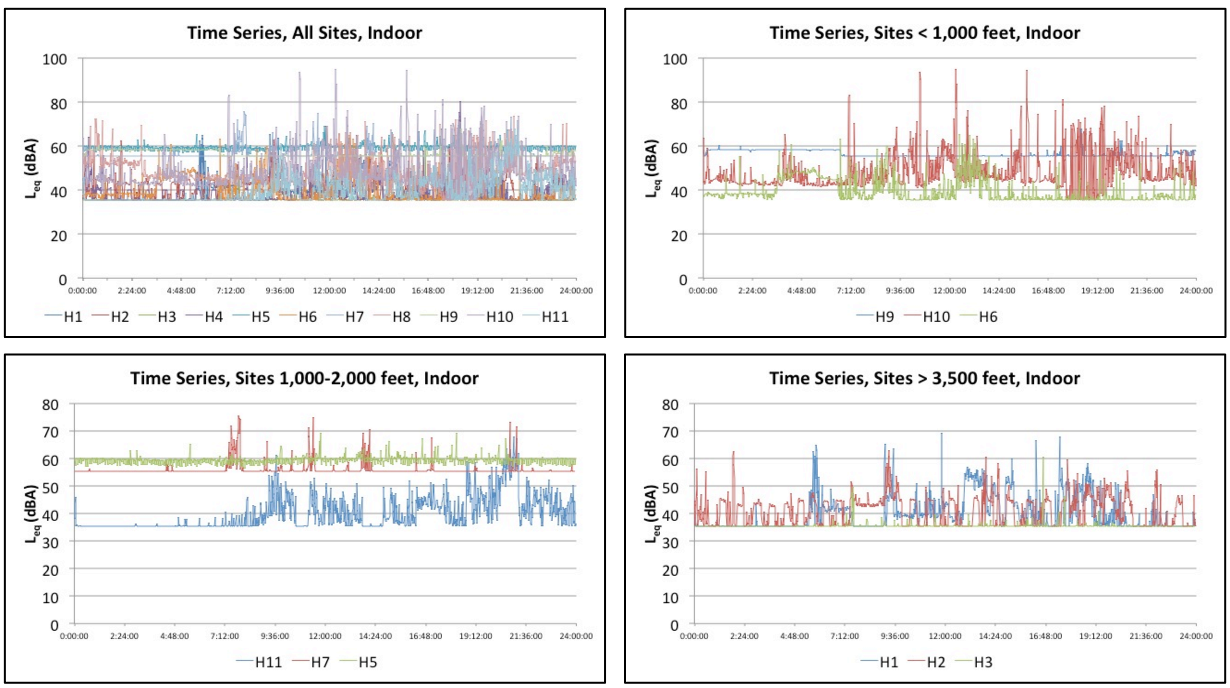

Figure 10-13: Time Series, Indoor L_{eq} by Distance from Compressor Station

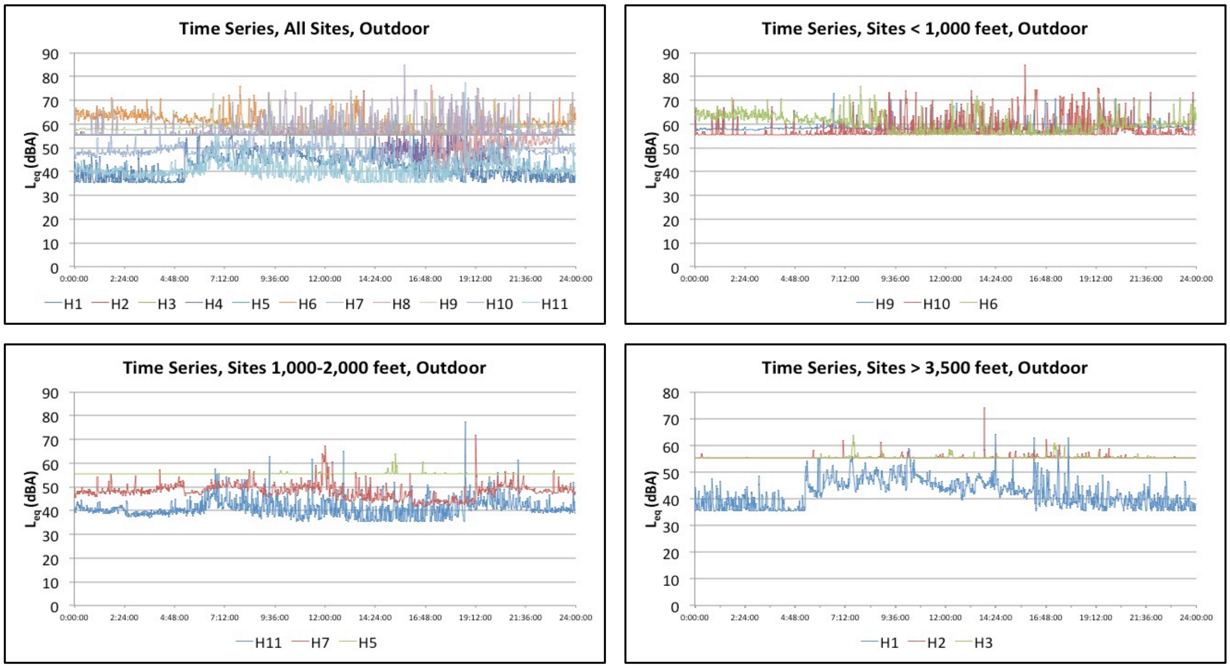

Figure 10-14: Time Series, Outdoor Leq by Distance from Compressor Station

The control homes in West Virginia were set in a semi-rural/rural community, located more than 3,500 feet from a compressor station. It is anticipated that current noise levels in Western Maryland are comparable to the noise levels at the control homes located more than 3,500 feet from a compressor station. Overall, the average L_{eq} at the control homes was 51.40 dBA, with 45.02 dBA indoor and 54.03 dBA outdoors (Table 10-12). Noise levels at homes within 2,500 feet of the compressor station were on average 8.7 dBA higher, with a 16.25 dBA difference indoor and a 4.3 dBA difference outdoor than the levels observed at the control homes.

Table 10-12. Summary Statistics, Stratified by Distance, Location, and Time

Distance (feet)	**Location**	**Time of Day**	**N_1**	**Mean L_{eq} (dBA)**	**Range L_{eq} (dBA)**
All distances	All locations	All times	21205	60.20	35.3-94.8
	Indoor	All times	11520	61.27	35.3-94.8
	Outdoor	All times	9388	58.33	35.3-85
	Short	All times	297	61.43	45.3-76.1
	All locations	Daytime	13575	61.44	35.3-94.8
	All locations	Nighttime	7630	56.39	35.3-73.3
<1000	All locations	All times	8818	63.15	35.3-94.8
	Short	All times	178	63.34	50-76.1
	Indoor	All times	4320	64.59	35.3-94.8
		Daytime	2700	66.49	35.3-94.8

Distance (feet)	Location	Time of Day	N[1]	Mean L_{eq} (dBA)	Range L_{eq} (dBA)
		Nighttime	1620	53.85	35.3-70.1
	Outdoor	All times	4320	60.97	55.3-85
		Daytime	2700	61.25	55.3-85
		Nighttime	1620	60.46	55.3-73.3
1000-2000	All locations	All times	8963	55.48	35.3-77.6
	Short	All times	53	55.40	46.2-67.8
	Indoor	All times	4320	57.28	35.3-75.7
		Daytime	2700	57.86	35.3-75.7
		Nighttime	1620	56.12	35.3-65.3
	Outdoor	All times	4320	52.36	35.3-77.6
		Daytime	2700	52.75	35.3-77.6
		Nighttime	1620	51.62	36.9-57.9
2000-2500	All locations	All times	3694	54.09	35.3-80.3
	Short	All times	66	52.10	45.3-57.1
	Indoor	All times	2880	53.75	35.3-80.3
		Daytime	1800	54.31	35.3-80.3
		Nighttime	1080	52.61	35.3-72.6
	Outdoor	All times	748	55.33	35.3-76.5
		Daytime	678	55.32	35.3-76.5
		Nighttime	70	55.41	50.9-69.6
>3500	All locations	All times	8704	51.50	35.3-74.1
	Indoor	All times	4384	45.02	35.3-69.3
		Daytime	2764	45.95	35.3-69.3
		Nighttime	1620	42.72	35.3-65.1
	Outdoor	All times	4320	54.03	35.3-74.1
		Daytime	2700	54.23	35.3-74.1
		Nighttime	1620	53.66	35.3-58.4

[1] N refers to the number of 1-minute intervals

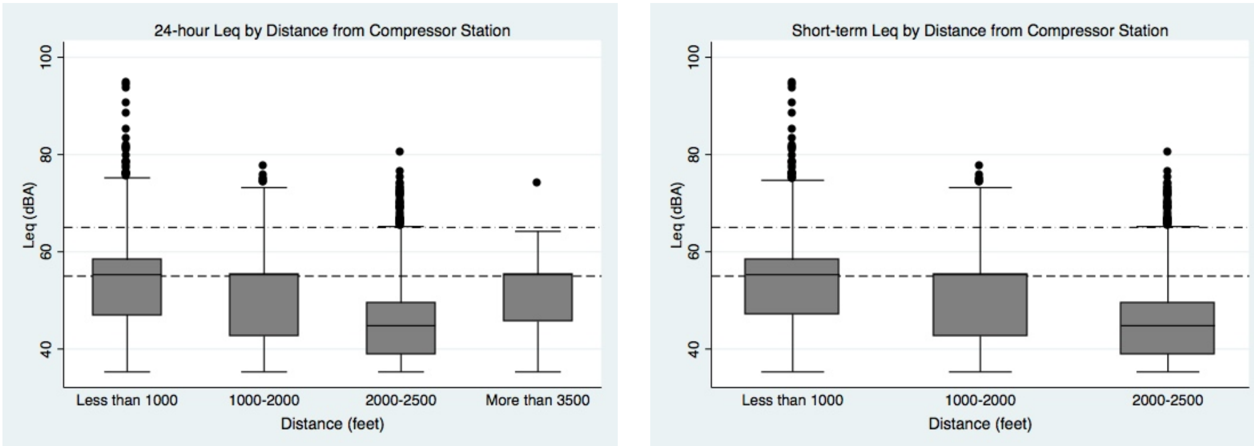

Figure 10-15: Boxplots, Leq by Distance from Compressor Station

10.3.3.4 UNGDP Noise Evaluation

Both daytime and nighttime noise levels associated with natural gas compressor stations routinely exceed the Maryland's maximum allowable noise level of 65 dBA for residential areas, the nighttime noise level is just above the maximum allowable noise level of 55 dBA, as depicted in Figure 10-14. The exceedance was less common at control homes located >3500 feet from the compressor stations. This shows that residents living more than 3,500 feet away from natural gas activity are not expected to experience high levels of noise. This finding should be taken into consideration while deciding on setback distances. Furthermore, the findings presented here are from compressor stations and are not related to development activities. As such, they represent chronic noise exposure that community members will have to encounter for years/decades, not transient exposures that go away after the completion of a well.

There have not been any epidemiologic studies to evaluate health outcomes associated with UNGDP noise; however, numerous studies have evaluated the health impact of long-term exposure to environmental noise from other industries. The most common health effects associated with environmental noise are annoyance, stress, sleeping disturbances, headaches, hypertension, and cardiovascular problems [96–100]. Nighttime noise levels as low as 35 dBA have been found to cause sleep disruption [92]. Children, elderly, and hearing impaired individuals are more susceptible to environmental noise [93].

In addition to noise-related health outcomes, there may be synergistic effects between noise and air pollution associated with UNGDP. Several studies have evaluated the relationship between air quality and noise on health [101–104].

10.3.3.5 Assessment

Based on our monitoring results from Doddridge County, WV as well as other noise monitoring reports, we conclude that there is a **Moderately High Likelihood** that UNGDP related changes in noise exposure will have negative impacts on public health in Garrett and Allegany Counties. Table 10-12 provides an overview of scoring for each evaluation criteria we used to arrive at this conclusion.

Table 10-13: Noise Evaluation

Evaluation Criteria	**Score**
Vulnerable populations	2
Duration of exposure	3
Frequency of exposure	2
Likelihood of health effects	2
Magnitude/severity of health effects	1
Geographic extent	1
Effectiveness of Setback	1
Overall Score	12
Hazard Rank	M

1. Vulnerable population received a score of 2 as exposure to noise disproportionately affects residents near the UNGDP facilities. Property owners without mineral rights are disproportionally burdened as they do not have a voice, and may not be able to sale their property even if they want to move away.
2. Duration of exposure received a score of 3 because exposure to noise will persist for longer than 1 year (fracturing of well, compressor stations).
3. Frequency of exposure received a score of 2 as exposure to noise is frequent.
4. Likelihood of health effects was assigned a score of 2 because noise exposure is known to elicit hearing loss, and increase stress levels.
5. Magnitude/severity of health effects was assigned a score of 1 because the adverse health effects are reversible.
6. Geographic extent received a score of 1 because noise exposure is localized.
7. Effectiveness of setback was assigned a score of 1 because adequate setbacks will mitigate noise exposures.

10.3.4 Earthquakes

In four years, from 2010-2013, roughly 450 earthquakes, with magnitudes of 3.0 or larger, occurred across the central and eastern United States at an average rate of 100 per year. That is a five-fold increase in earthquake occurrence recorded over a 30 –year period from 1970 to 2000 [105]. Limited research has pointed to anthropogenic activities such as UNGDP as a potential reason for the increase, while others have pointed that these small events are nothing to be concerned about [105–109]. To date, none of the earthquakes recorded in Maryland, including the August 2011 event, have been linked to NGDP. Yet earthquake events in the Marcellus Shale area have been attributed to fracking activities [110].

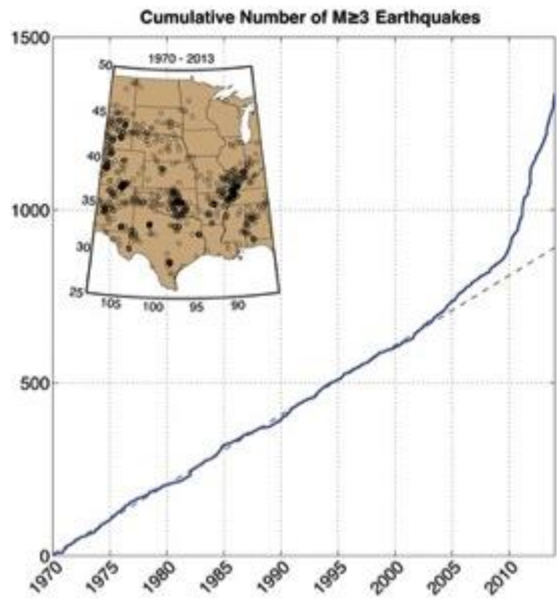

Figure 10-16. Cumulative counts of earthquakes with a magnitude ≥ 3.0 in the central and eastern United States, 1970-2013, [105]

In Figure 10-16, the dashed line corresponds to the long-term rate of 20.2 earthquakes per year, with an increase in the rate of earthquake events starting around 2009.

Earthquakes associated with overall NGDP process can broadly be grouped into 2 categories: those associated with well development/production and those that are associated with the disposal of wastewater through injection.

10.3.4.1 Earthquakes associated with development/production

During the developmental process, micro-earthquakes, ones with a magnitude of 2 or lower, are produced during the hydraulic fracturing (or “fracking”) stage [106]. So far, none of the thousands that have been recorded by seismographic networks in the Marcellus Shale area have been large enough to pose a serious risk [106]. Yet, a modeling simulation conducted to assess the potential for fault reactivation and large seismic events associated with shale-gas hydraulic fracturing operations showed when hydraulic fracturing is conducted in areas with existing faults, it may lead to micro-seismic events [109]. The magnitude of these particular micro-seismic events is somewhat larger than that associated with micro-seismic events originating from regular hydraulic fracturing because of the availability of larger surface area that can rupture [109].

10.3.4.2 Earthquakes associated with injection of wastewater

Disposal of wastewater from NGDP activities is done by injecting the water deep underground, hundreds to thousands of meters below the water table and drinking water aquifers. This is done so as not to contaminate drinking water [105]. However, according to the US Geological Service (USGS), “wastewater injection increases the underground pore pressure, which may, in effect, lubricate nearby faults thereby weakening them. If the pore pressure increases enough, the weakened fault will slip, releasing stored tectonic stress in the form of an earthquake. Even faults that have not moved in millions of years can be made to slip and cause an earthquake if conditions underground are appropriate” [105]. This situation is what is believed to have caused a series of more than 100 earthquakes in Youngstown, Ohio during the fall and winter of 2011 to 2012, the largest of which, recorded in December 2011, had a magnitude of 3.9 [110]. All the events were recorded by the Division of Geological Survey of the Ohio Department of Natural Resources (ODNR) and analyzed with velocity models (1D Earth models) for precise epicenter locations. Each quake was also assessed to determine the effect of vertical velocity heterogeneities on focal depth, which is the depth at which the earthquake's rupture began. The study looked in-depth into the December 2011 quake, and the associated Northstar 1 injection well, since this quake was the largest [105]. The first earthquake experienced by Youngstown occurred 13 days after the well became active and ended when ODNR shut the well down. More importantly, from the modeling, it was shown that the earthquakes' rupture centers were in an ancient fault near the Northstar 1 well, suggesting wastewater injections caused the existing, dormant faults to slip, a theory that is also supported by the USGS [105].

Furthermore, the USGS report suggests that at some NGDP sites, increases in seismicity coincides with the injection of wastewater in deep disposal wells [105]. Others have found a relationship between the magnitude of an earthquake and the total volume of fluid injected into the ground, with 1 million cubic meters of fluid linked to quakes of magnitude 5 or less [111]. In these instances, rate of injection seemed to influence the frequency of quakes [111]. Another study examined the source of three earthquake events near a NGDP site in November of 2011 and indicated that even small- to moderately-sized injection-induced events could release additional tectonic stress and induce an even larger earthquake event [107]. The earthquakes, of magnitudes 5.0, 5.7, and 5.0, sequentially, were felt in 17 states, with the epicentral region the Wilzetta North field. Production of oil from the Wilzetta Northfield occurred primarily in the 1950s and 1960s, with NGDP production continuing into the present. The active wastewater fluid injection wells were located within the Wilzetta North field or just over a kilometer outside it, and use of these injection wells began after 1993 and continues to occur. The group measured the aftershocks of each earthquake event to identify the faults that ruptured in the sequence. Their results show that the tip of the initial rupture plane was within 200 m of active injection wells and within 1 km of the surface. Additionally 30% of early aftershocks occur within the sedimentary section [107]. Using Coulomb stress calculations, they concluded the first event (magnitude of 5.0) was induced by increased fluid pressure from the injection wells. Additionally, the aftershocks of this first event deepen away from the well, suggesting stress was transferred and added to the increased magnitude experienced in the second event (magnitude of 5.7). This study suggests that decades-long timeframes between the beginning of fluid injections and the induction of earthquakes are possible. Furthermore, the sequential rupture of three faults suggests that "stress changes from the initial rupture triggered the successive earthquakes, including one larger than the first" [107].

However, Rutqvist and colleagues suggests that these small earthquake events are not something to be highly concerned about [109]. They conducted numerical simulation studies to evaluate the "potential for injection-induced fault reactivation and notable seismic events associated with shale-gas hydraulic fracturing operations" [109]. Specifically, they focused on the Marcellus Shale, which has an approximate depth of 1500 m (~4,500 feet). Their repeated, modeled injection-events and fault slips resulted in a total rupture length of 50 m, with an offset displacement of less than 0.01 m [109]. They concluded that any fractures to the earth caused by waste injection would occur at great depths below the ground, too low to activate faults or impact drinking water supplies [109]. Yet, this study only used mathematical models to assess the impact of massive physical events that have been previously shown in Oklahoma and Ohio to be of significant concern [109].

Most of the deep injection wells used for disposal of wastewater are classified as Underground Injection Control (UIC) program Class II wells. License and Operational requirements for the UIC Class II wells are regulated under the Safe Drinking Water Act or designated State Authority. Therefore the licensing and operational requirements only address the issues related to potable aquifers to ensure that they are not contaminated for drinking water purposes. These wells are required to report average injection pressure, flow rate and cumulative volume. It does not take into consideration the diffusion of pore pressure into the basement faults, seismic monitoring as well as injection pressure that may cause the critically stressed faults to fail [106]. The national and Maryland inventory of injection wells is provided in Table 10-14.

Table 10-14: National Inventory by Classes of Injection Well [112]

Classes of Well	Uses	Inventory	MD Inventory
Class I	Inject hazardous wastes, industrial non-hazardous liquids, or municipal wastewater beneath the lowermost USDW	680 wells	0
Class II	Inject brines and other fluids associated with oil and gas production, and hydrocarbons for storage.	172, 068 wells	0
Class III	Inject fluids associated with solution mining of minerals beneath the lowermost USDW.	22,131 wells	0
Class IV	Inject hazardous or radioactive wastes into or above USDWs. These wells are banned unless authorized under a federal or state ground water remediation project.	33 sites	0
Class V	All injection wells not included in Classes I-IV. In general, Class V wells inject non-hazardous fluids into or above USDWs and are typically shallow, on-site disposal systems. However, there are some deep Class V wells that inject below USDWs.	400,000 to 650,000 wells. Note: an inventory range is presented because a complete inventory is not available.	13701
Class VI	Inject Carbon Dioxide (CO2) for long term storage, also known as Geologic Sequestration of CO2	6-10 commercial wells expected to come online by 2016. (Interagency Task Force on Carbon Capture and Storage)	Unknown

10.3.4.3 Assessment

Based on our review of literature, there is clear evidence that deep well injection of wastewater is related to earthquakes that are greater than magnitude 3. However, earthquakes related to hydraulic fracturing itself are very small (less than magnitude 3). Provided that Maryland does not allow deep well injection of wastewater, there is a **Low Likelihood** that UNGDP related earthquakes will have a negative impact on public health in Garrett and Allegany Counties. Table 10-15 provides the scoring for the evaluation criteria that we used to arrive at this conclusion.

Table 10-15: Earthquake Evaluation

Evaluation Criteria	**Score**
Vulnerable populations	1
Duration of exposure	1
Frequency of exposure	1
Likelihood of health effects	0
Magnitude/severity of health effects	0
Geographic extent	2
Effectiveness of Setback	2
Overall Score	7
Hazard Rank	L

1. Vulnerable population received a score of 1 as it does not affect populations disproportionately.
2. Duration of exposure received a score of 1 because exposure to an earthquake is short.
3. Frequency of exposure received a score of 1 as exposure to earthquakes is infrequent.
4. Likelihood of health effects was assigned a score of 0 because the low level of earthquakes associated with UNGDP are not likely to have a direct impact on public health. This assumes MDE will not issue permit for deep well injection of waste.
5. Magnitude/severity of health effects was assigned a score of 0.
6. Geographic extent received a score of 2 because earthquakes are not confined to the immediate vicinity of UNGDP facilities.
7. Effectiveness of setback was assigned a score of 2 because adequate setbacks will not mitigate exposure.

10.3.5 Social Determinants of Health

As UNGDP operations continue to grow, the need to address impacts on social determinants of health intensifies. Multiple studies [5–7, 64] have identified the main issues of concern within communities including increased rates of industrial traffic, violent crimes, mental health problems, substance abuse, sexually transmitted infections and the resulting impact on the local police force as well as local healthcare facilities.

10.3.5.1 Traffic Impacts Other Than Air Pollution

Figure 10-17: UNGDP-related Traffic, West Virginia

As UNGDP operations continue to grow, impacted communities will experience significantly higher levels of traffic. Of particular concern is the increased level of truck traffic. It is estimated that, on average, a multistage well can require upwards of 1000 truck round trips to deliver equipment (e.g., bulldozers, graders, pipe), chemicals, sand, and water needed for well development and fracturing) [5, 6, 64]. Additionally, the wastewater from UNGD operations may be trucked offsite for disposal [7], which would result in even greater numbers of large trucks on local roads. In Bradford County, PA, an area rich in UNGDP operations, truck counts were approximately 40% higher than a comparable 5-year average prior to UNGDP [5, 113]. Local traffic would also increase since an average of 120 to 150 workers per day [7] would commute into the community to work on site.

Increased traffic raises issues of air pollution, discussed in section 10.3.1 above. Increased truck traffic in local and residential areas raises other issues such as increased frequency of collisions, need for road maintenance. According to Adgate, "data from the Pennsylvania Department of Transportation's Crash Reporting System indicates a significant increase in the number of total accidents and accidents involving heavy trucks between 1997 and 2011 in counties with a relatively large degree of shale gas development compared to counties with no development" [5, 114]. Even though nationally, the number of automobile accidents has been on the decline since 2005 [115, 116], heavy-truck crashes rose 7.2% in rural Pennsylvania counties heavily impacted by UNGDP [115]. In fact, Pennsylvania counties with the highest density of UNGDP operations had the largest increase in large-truck crashes after UNGDP activity began in 2005 [115]. This trend is seen in UNGDP sites across the country. The Texas Department of Transportation noted a 40% increase in reported fatal motor vehicle accidents from 2008 to 2011 in 20 counties with UNGDP operations [4, 5].

All these accidents have not come without a price. The Bureau of Labor Statistics reported that the fatality rate for oil and gas workers is more than 8 times higher than that of other occupations [5, 117]. Beyond the obvious human cost, there is the economic burden that local communities are carrying for these incidents. In Pennsylvania, a large-truck accident can cost a local community over $200,000 related to deaths, injuries and property damage [115]. An explanation for the increased numbers of accidents experienced by UNGDP truckers is the oil field exemption from highway safety rules. These exemptions allow truckers in the oil and gas industry to work longer hours than drivers in other industries [113, 118], placing them at greater risk for crashes and fatalities. Additionally, much of the truck traffic, and therefore risk of accidents, is concentrated over the first 50 days following well development [7], suggesting that either truckers are rushing to meet deadlines and/or truckers new to the area are unprepared for the mountainous terrain that is typical of shale areas, and have more accidents based upon these factors.

Accidents may also be attributed to deteriorating road conditions surrounding UNGDP sites. Since each UNGDP well site requires thousands of truck trips to deliver UNGDP fluid and materials and to haul away UNGDP wastewater, the local and rural roadways will be strained to keep up with the wear and tear [115, 119]. Together, truck-driving exemptions, poor road quality, unfamiliarity with the area, and pressure to complete a run in a timely manner all contribute to increase risk to UNGDP driver safety.

Because most of these rural communities have few roads that allow access to the UNGDP site, most of the industrial traffic would use the same roads that children use for walking or bicycling to school and bus stops [113], placing them at greater risk of emission exposures as well as placing them in harm's way. Indirectly, increases in traffic may cause some members of the community to decrease their time spent doing outdoor-fitness activities (walking, cycling, running, etc.) [113, 120, 121], thereby lowering their overall physical well-being.

Increased traffic on the roads leads to congestion, congestion that makes it harder for first responders to do their jobs. The increase in traffic accidents has resulted in a significant increase in 911 calls and emergency dispatches [115, 122]. In fact, in Bradford County, PA, the increased traffic has delayed the response times of emergency vehicles [115], placing those who requested them in great danger.

10.3.5.2 Crime

Increase in crimes rates is a major concern for communities with UNGDP operations. A study conducted by Haggerty and colleagues [5] focused on counties within the six major oil- and gas-producing states in the U.S. West. The group conducted statistical analyses to determine whether or not the level of influence of oil and gas extraction on income had been associated with increases or decreases in county well-being [5]. They determined that the average number of violent and property crimes per 1,000 people increases with increased length of specialization in oil and gas and increases at a faster rate for counties whose UNGDP income was higher [5]. Additionally, the longer a county has been specialized in oil and gas, the higher the county's crime rate [5].

While, Haggerty and colleagues [5] focused primarily on violent crime, Food and Water Watch, a non-governmental organization and consumer rights group, conducted an impact assessment on UNGDP operations in Pennsylvania looking at crimes associated with alcohol abuse. According to their impact assessment, counties with the highest density of UNGDP wells (at least 15 wells per square mile) had a greater increase in disorderly conduct, drunk driving, and public intoxication arrests than counties with no wells, after 2005 when UNGDP began. In the most heavily impacted counties in Pennsylvania, average annual number of disorderly conduct arrests rose 17.1 % from 1,336 prior to commercial UNGDP (2000 to 2005) to an average of 1,564 per year after UNGDP. This was three times higher than the average number of disorderly conduct arrests in counties in Pennsylvania with fewer UNGDP operations. Additionally, in these same, heavily impacted counties, the average annual number of public intoxication arrests rose 11.9%, along with steep increases in drunk driving, traffic violations and bar fights [113].

10.3.5.3 Illness, Mental Health, and Substance Abuse

Communities with UNGD operations are also experiencing increasing rates of physical and mental illness. The development of UNGD operations in Pennsylvania has been linked to a rise in sexually transmitted infections [113, 114]. In heavily fracked, rural counties in Pennsylvania, the average annual number of gonorrhea and chlamydia cases increased by 32.4% while the average annual number of the same cases in non-fracking counties only increased 20.1 percent from the previous year. Comparing the two, the most heavily impacted rural Pennsylvania counties had a 61% greater increase in STI rates than counties without UNGDP [113]. This phenomenon is not unique to the Marcellus Shale area. In UNGD regions in North Dakota, doctors are treating more chlamydia cases. Furthermore, this region reported increased sexual and domestic assault rates and local women feeling increasingly unsafe [113, 115]. Overall, in communities with UNGD operations, a trend has emerged with increases in arrests for both crime and substance abuse and STIs corresponding to periods of increased natural gas development [4, 7, 64, 116, 117].

The following table compares the changes in the percentages of these issues across a state (Pennsylvania) verses one rural community (Battlement Mesa, Colorado) [7, 113]. The change is over the time from baseline assessment of the area for UNGD operations to the peak of operations. Generally, there is an upward trend in all areas for both statewide UNGD operations and the operations at the community level. The decrease in substance abuse arrests seen in Battlement Mesa could be due to collection time of the data. Following the peak production, UNGD operations taper off, are not as intensive, and require fewer workers. Additionally, the data for Pennsylvania are statewide, so while some peak UNGD operations are winding down in one area, in another the peak could just be beginning.

Table 10-16. Percent Change in STIs, Disorderly Conduct Arrests, and Substance Abuse Arrests

	Percent Change	
	Pennsylvania (heavily fracked)	**Battlement Mesa, Colorado**
STIs	+ 32.4%	+ 216.7%
Disorderly Conduct Arrests	+ 17.1%	+ 31.8%
Substance Abuse Arrests	+ 11.9%	- 33.4%

Along with increasing rates of STIs, communities with UNGD operations have reported increases in substance abuse. Studies have shown that alcohol and other illicit drug use is highest among the workers in the natural gas development and production industry [7, 118, 119, 123]. Substance abuse has long been associated with mental health issues, and here with UNGD operations, the situation is no different. Witter and colleagues reported that the “transient nature” of the migrant worker along with a high intensity and stressful job make for the perfect combination for psychosocial stressors [7]. The workers are away from social controls and comforts of their home community, the difficult employment fosters the desire for release (through drugs, alcohol, fights, sex, etc.), and high salaries in a predominantly male workforce put the workers at risk for engaging in risky behavior that negatively impact their mental and physical health as well as the health of those who live in the community [7, 124].

Residents of UNGD communities have also experienced mental health problems related to the operations. Ferrar and colleagues [125] noted that individuals who believed their physical health had been affected tended to report higher stress levels due to loss of trust and perceived lack of transparency in the UNGD industry and local government. Seventy-nine percent of subjects reported being denied or receiving false information, while 58% reported that their concerns/complaints were ignored. Interestingly, residents reported more psychosocial stressors than physical stressors, suggesting that resident's mental well-being was impacted more so than their physical well-being [64]. An increase in alcohol consumption as a coping mechanism has been shown in previous research in areas with UNGDP activities and could occur in the two Maryland counties of concern [126].

10.3.5.4 Impact on Residents, Police, and Healthcare System

Some community members in Garfield County, Colorado reported that the development of such an intensive industry in a relatively non-industrial area has negatively affected their sense of community livability and social cohesion. Additionally, land values near UNGD operations are declining, further affecting the psychosocial health of the community [4]. If residents cannot sell their land and homes, they may feel trapped and helpless in their situation. Furthermore, studies have shown that prolonged exposure to stress increases the levels of stress hormones in the body and places the individual under the stress at greater risk for health and cardiovascular disease [4, 120–122].

The impact of UNGDP operations on public safety extends beyond the direct threat of residents' and workers' physical well-being. The safety of all living in a community with UNGD operations could be indirectly impacted by the industry. First, local and state police departments may be ill-equipped to handle the additional increases in crime. Local forces have a limited number of officers they can spare and in some cases, the state police act as local law enforcement when the community is highly rural. When these small-staffed and already stretched departments see large increases in crime, it keeps them preoccupied and unable to handle all the situations. For instance, the Pennsylvania State Police have linked an increase in arrests and crimes involving natural gas workers with community members not receiving help when they need it the most [113, 127].

The boom of UNGD operations can also overwhelm the local healthcare system that is described in the Healthcare Infrastructure section. Rural hospitals are not designed to handle large influxes of triage patients, like those seen in occupational accidents, traffic accidents, or the result of fights. Furthermore, with an increase in population of transient workers, hospitals and clinics are experiencing increases in the incidence of patients exhibiting STIs, mental illness, and substance abuse, issues that small, rural healthcare systems do not have the resources to handle adequately [113, 128]. For instance, when confronted about their lack of treatment for STIs, workers often cite lack of access to healthcare facilities due to geographic isolation or lack of facilities with available walk-in testing along with clinic hours overlapping with their own working hours as a rationale for not seeking treatment [7, 124, 128].

10.3.5.5 Assessment

Based on our review of social determinants of health (section 10.3.5), we conclude that there is a **High Likelihood** that UNGDP related activities will have a negative impact on the social determinants of health. Table 10-16 provides the scoring for the evaluation criteria that we used to arrive at this conclusion.

Table 10-17: Social Determinants of Health Evaluation

Evaluation Criteria	**Score**
Vulnerable populations	2
Duration of exposure	3
Frequency of exposure	2
Likelihood of health effects	3
Magnitude/severity of health effects	2
Geographic extent	2
Effectiveness of Setback	2
Overall Score	15
Hazard Rank	H

1. Vulnerable population received a score of 2 as exposure to public safety issues disproportionately affects residents near UNGDP facilities. Issues of sexually transmitted infections, crime and traffic safety all disproportionately affect community members in the high UNGDP activity areas.
2. Duration of exposure received a score of 3 because exposure to public safety related issues will last for more than 1 year.
3. Frequency of exposure received a score of 2 as exposure is frequent.
4. Likelihood of adverse effect was assigned a score of 3 because evidence from Colorado and Pennsylvania show public safety to be negatively impacted in UNGDP impacted communities.
5. Magnitude/severity of health effects was assigned a score of 2 because the adverse health effects (STD) require medical treatments.
6. Geographic extent received a score of 2 because the entire community is at risk.
7. Effectiveness of setback was assigned a score of 2 because adequate setbacks will not mitigate issues related to public safety.

10.3.6 Healthcare Infrastructure

A community's healthcare infrastructure consists of both healthcare facilities (i.e., private and public healthcare services, hospitals, and emergency transport services) and trained healthcare professionals. In rural communities, disparities in infrastructure or professional capacity to address community health needs may exist due to shortages of primary care physicians and non-physician providers, and specialists; high rates of uninsured, elderly, or poor patients who often require additional health care; and limited public resources allocated to health care [129]. Introduction of new industries, including those in the extractive sector, can have mixed impacts on a community's health care infrastructure, particularly those in rural, resource-poor settings. Revenue flows from the extraction of natural resources, when distributed in an effective and equitable manner, can fund public services such as healthcare infrastructure; the potential increase in workers with health insurance can also have a positive impact on local health care industry [130]. At the same time, increases in population, particularly among those engaged in high-risk occupations may intensify local health care utilization [131, 132]; without adequate strengthening and expansion of existing healthcare infrastructure, these population changes could overextend an already fragile system. Citizens living in Allegany and Garrett counties, during our scoping phase, conveyed their concerns about the negative impact of UNGDP on their already limited healthcare infrastructure. Because UNGDP could modify the usage rates of the healthcare infrastructure in Allegany and Garrett counties, a review of potential health impacts is needed.

10.3.6.1 Current healthcare infrastructure conditions

In Allegany County, Western Maryland Health System (WMHS) provides a continuum of care ranging from primary care to nursing home services. Services offered by WMHS include acute and chronic care, community health and wellness, clinical prevention, care coordination, home care, community health workers, and provider recruitment. WMHS is the only licensed hospice care facility in Allegany County. WMHS is also a Level III trauma center, the only trauma center in Western Maryland. The closest Level I trauma center for both Allegany and Garrett Counties is in Morgantown, WV at West Virginia University Hospital. WMHS operates a regional medical center in Cumberland (a 275-bed hospital), along with two diagnostic centers, a nursing and rehabilitation center in Frostburg, a community health and wellness center, two urgent care centers (one in Short Gap, WV and the other in Frostburg, MD), and three primary care centers (2 in Frostburg and 1 in LaVale, MD). There are approximately 187 physicians affiliated with WMHS. The primary care facilities are open Monday from 8:00 a.m. - 4:30 p.m. and Tuesday - Friday 7:30 a.m. until 6:00 p.m.

In addition to WMHS, other facilities include an inpatient psychiatric hospital, a federally qualified community health center, and nine nursing homes/assisted living facilities in Allegany County. The Thomas B. Finan Center is a state owned and operated inpatient psychiatric facility located in Cumberland, MD with 80 beds. It provides services to those 18 years of age and older and includes inmates with criminal histories, non-criminals who have been involuntarily committed, and voluntary patients. Tri-State Community Health Center is a federally qualified community health center with OB/GYN and primary care services. Tri-State operates five community health center sites located in Allegany (Cumberland) and Washington (Hancock) counties in Maryland; Fulton County in Pennsylvania; and Morgan County in West Virginia. There are a total of nine nursing facilities and assisted living facilities throughout the county including: EGLE Nursing and Rehab, Allegany Health Nursing and Rehab, Devlin Manor Health Care Center, Golden Living Center, The Lions Center, Frostburg Village Nursing Care Center, Moran Manor Health Center, Frostburg Nursing and Rehab, and Kensington-Algonquin and Country House.

Public health services are provided by the Allegany County Health Department, which provides screening and prevention programs, family planning, WIC, inpatient and outpatient behavioral health services, mental health care management, dental services, and food and water protection. The Allegany County Health Department is open five days a week from 9:00 a.m. - 5:00 p.m.

Finally, Allegany College of Maryland and Frostburg State University provide training to local health care providers in nursing, psychology, dental hygiene, radiologic technology, respiratory therapy, and other areas and support continuing education for health care professionals. The Western Maryland Area Health Education Center facilitates continuing education and training for health professionals and conducts health workforce development.

In Garrett County, Garrett County Memorial Hospital (GCMH) operates a 55-bed, not-for-profit, acute care hospital facility, including a 10-bed sub-acute rehabilitation unit. GCMH is the only hospital in the region, serving a population of 31,000, including residents of Garrett County and communities in the surrounding West Virginia counties. Services at the Hospital include a 24-hour emergency department; inpatient care; observations services; obstetrics; pediatrics; medical/surgical intensive care unit; operating room: radiology; lab; cardiopulmonary services; as well as community and worksite wellness; safe sitter; and CPR programs and other ancillaries. In a study conducted by GCMH, individuals utilizing GCMH also reported using a second facility for services, with a majority (72%) traveling to Morgantown, WV, or 23% Cumberland, Maryland in Allegany County [133].

Garrett County also has a Federally-Qualified Health Center in Oakland, MD: Mountain Laurel Medical Center (MLMC). MLMC uses a patient centered medical home model for the delivery of primary health care and offers services such as primary health care services, acute and chronic illness care, care coordination, and health education. They are open Monday, Wednesday, Friday: 7:30AM – 5:00PM; Tuesday and Thursday: 7:30AM – 7:00PM and have a 24 hour on-call access.

There are three assisted living facilities in Garrett County: Dennett Road Nursing Home and Oakland Nursing and Rehabilitation Center--each a 100-bed facility and located in Oakland, MD; and Goodwill Mennonite Nursing Home in Grantsville, MD (89-bed facility). In addition, there is one licensed hospice facility in the county (Hospice of Garrett County in Oakland, MD).

Public health services in Garrett County are provided through the Garrett County Department of Health (GCDH) including adult and geriatric services, behavioral health, dental health, environmental health, WIC, person health including health education and outreach, and home health.

Allegany County is a designated HPSA for primary care for low-income populations, mental health care for Medical Assistance populations, and dental care for Medical Assistance populations. Allegany County has a critical need for specialty providers including vascular surgery, urology, as well as dentists willing to provide care for adults with no insurance or Medical Assistance. Garrett County is a designated HPSA for primary and mental health care, and dental care for Medical Assistance populations. All of Garrett County is considered a medically underserved area (MUA), while substantial portions of Allegany County (Orleans, Lonaconing, Oldtown, and Cumberland) also qualify as a MUA.

10.3.6.2 Rates of insurance coverage

Insurance status of individuals living in Garrett and Allegany counties were obtained from the County Health Rankings Database. In 2011, there were an estimated 6,532 uninsured individuals living in Allegany County, approximately 11.9% of total population, including 4% of children. In Garrett County, an estimated 3,473 individuals were uninsured, approximately 14% of the total population. In the State of Maryland, an average of 12% of the total population is uninsured, with most counties having between 8-16% of the total population uninsured.

10.3.6.3 Migrant workforce and health care usage

UNDGP entails multiple labor intensive phases that could extend several years for larger projects. Much of the impact to health care infrastructure is related to the influx of workers during the initial development phase. The RESI final report predicts workforce numbers based on two possible extraction scenarios which were developed based on conservative and feasible extraction rates given gas reserves in Maryland and the production curve of a horizontal well [10]. Under scenario one, 25% of the total shale gas would be extracted, and scenario two, 75% of the total shale gas would be extracted. RESI estimates that under scenario one, drilling activity will increase employment over baseline by approximately 1327 jobs (1056 in Garrett County and 271 in Allegany County) on average from 2017 to 2026, and in the period after drilling, from 2027 to 2036, economic activity will change the baseline employment with an increase of 151 jobs (113 in Garrett County and 38 in Allegany County). Under scenario two, drilling activity will increase employment by approximately 2825 jobs (2093 in Garrett County and 732 in Allegany County) on average from 2017 to 2026, and by 189 jobs (80 in Garrett County and 109 in Allegany County) from 2027 to 2036.

Although these predictions by RESI project the number of jobs that could be created from specific levels of expenditures based on the number of wells, they do not distinguish between jobs to local and out-of-state workers. Literature indicates that shale gas drilling depends heavily on a migrant workforce residing in Texas and Oklahoma and moves with rig operations to new extraction sites; local residents are often faced with part-time, short-term, and low-wage employment prospects found in supportive industries trucking, construction, and retail jobs [134, 135]. Because data on the number of workers estimated to be migrating into Allegany and Garrett counties to work on the Marcellus Shale Gas Development is unknown, we will use the RESI numbers to approximate low and high levels of the migrant workforce: approximately from 1327-2825 migrant workers on average during the first 10 years of drilling, and 151-189 migrant workers on average during the 10-year period after drilling. We also do not have information on whether this migrant workforce will have insurance. Research literature on this is inconclusive. For instance, a HIA done for Battlement Mesa in Garfield County, Colorado by the University of Colorado School of Public Health predicted the impact to health care infrastructure based on information that all migrant workers would have health insurance [7]. A recent impact assessment of fracking in Carroll County, Ohio by Policy Matters Ohio uses case studies from Sublette County, Wyoming, Lycoming County Pennsylvania, and McKenzie County, North Dakota to conclude that most of these jobs do not offer health insurance. As result, there have been negative impacts on local healthcare infrastructures due to uncompensated care for emergency room visits [135].

Oil and gas extraction and production workers experience seven times the fatality rate of general industry; a vast majority are due to motor vehicle incidents, contact with objects and equipment, and fires and explosions [6, 136]. These workers also experience non-fatal injuries and illnesses (injuries due to being struck by objects or being caught in objects, equipment or material) at a higher rate than other industries [137]. Because of the exposure to such safety hazards, UNGDP workers can increase utilization of emergency, urgent, and trauma care services due to higher rates of occupational related incidents and injuries. Insured workers using healthcare services could offer positive support to existing systems as long as their rate of utilization meets available capacity. If utilization rates surpass current healthcare infrastructure capacity, then this could have adverse consequences for the availability, access, and quality of services. Uninsured UNGDP workers, like any other uninsured population, would place stress on healthcare infrastructure because those who are uninsured are unable to pay for medical care when they do seek care and often go into medical debt; an influx of additional uninsured populations into Allegany and Garrett counties may stress these under-resourced health systems [138].

The use of primary and public health care systems, especially in the areas of emergency, urgent care, and trauma care, may rise as a result of an increase in the UNDGP workforce. These services may or may not be supported by employers through the provision of insurance. If these utilization rates are within current capacity, local healthcare infrastructure could potentially benefit economically from revenues introduced by UNDGP industries. However, if any potential revenues are not reinvested back into the maintenance of current health care infrastructure and the development of new infrastructure, an influx of UNDGP workers may exacerbate existing infrastructure pressures.

10.3.6.4 Characterization of healthcare infrastructure impact

There could be negative impacts to local healthcare infrastructure due to the increase in UNGDP workforce and their potential health care utilization rates. Impacts to the healthcare infrastructure are expected to be ***high*** given that we can expect 1327-2825 migrant workers on average during the first 10 years of drilling, and 151-189 migrant workers on average during the 10-year period after drilling moving into counties with a total population of 29,889 (Garrett) and 73,521 (Allegany). If all or most of these workers are insured, local primary care and public health services will be supported and this support could potentially expand services to all community residents. However, the impact of financial support through the increase in the insured population may not be adequate to foster the development of the existing healthcare infrastructure because it is unclear whether revenues from UNGDP will be substantial enough to directly impact health care infrastructure in Allegany and Garrett counties.

Even though there have been popular and social media accounts of the demands placed on rural and remote health services by extractive industry workers and visitors, there is a critical data gap of evidence-based research around UNGDP and the health of the broader community. A handful of studies that have been conducted indicate that extractive industry workers place similar demands on health care infrastructure as local residents, with an increased demand on emergency department services [131, 132, 139]. Given this literature and the vast health care infrastructure needs of Allegany and Garrett counties (i.e., as federally designated HPSA and MUA areas with high levels of uninsured and medically assisted populations), we predict that an increase in health care utilization, regardless of whether workers are insured or uninsured, would strain the existing healthcare infrastructure, likely leading to decreased quality, availability, and access to services. Even a small stressor to the existing healthcare infrastructure would impact the residents of Allegany and Garrett counties, particularly those who utilize services most often and vulnerable populations such as older adults, pregnant women, and young children.

Studies of boomtown-related theory and research have documented the cyclical nature of the natural gas extraction industry [140–142]. This temporal aspect of the process of natural gas extraction leads us to predict that any impact on healthcare infrastructure will be observed during the initial years of the project in the development phase, which is the most labor-intensive. The cyclical nature of change also leads us to anticipate that any impact to health care infrastructure will be uneven throughout the lifecycle of the project. Any impact, positive or negative, on the healthcare infrastructure will be concentrated during the first phase of development, when labor needs are high and larger numbers of workers are expected; impacts will decline in the production and reclamation phases as labor force requirements even out and eventually decline [6]. Large numbers of workers are expected relative to population size for more than a year, and therefore, there is an increased likelihood that this would stress local health care infrastructure, especially those serving emergency, urgent, and trauma care needs. We expect that residents of Allegany and Garrett counties will experience negative impacts as a result of changes to their healthcare infrastructure. The long-term exposure to the effects of the project along with the potential impact to the health of county residents, a high number of who are vulnerable, could be noticeable. The impact of changes to the healthcare infrastructure is predicted to be negative as a result of the UNGDP.

10.3.6.5 Assessment

Based on our evaluations of the current healthcare infrastructure in Garret and Allegany Counties as well as expected number of migrant workers that will come to these areas, we conclude that there is a **High Likelihood** that UNGDP related activities will have a negative impact on public healthcare infrastructure in Garrett and Allegany Counties. Table 10-17 provides an overview of scoring we used for each evaluation criteria to arrive at this conclusion.

Table 10-18: Health Care Infrastructure Evaluation

Evaluation Criteria	**Score**
Vulnerable populations	2
Duration of exposure	3
Frequency of exposure	2
Likelihood of health effects	2
Magnitude/severity of health effects	2
Geographic extent	2
Effectiveness of Setback	2
Overall Score	15
Hazard Rank	H

1. Vulnerable population received a score of 2 as healthcare infrastructure impacts disproportionately those who are more likely to use healthcare services such as the elderly, the disabled, and children.
2. Duration of exposure received a score of 3 because exposure (the influx of UNGDP workers) will last for more than 1 year.
3. Frequency of exposure received a score of 2 as UNGDP worker health care utilization rates over the length of a UNGDP cycle will be constant.
4. Likelihood of adverse effect was assigned a score of 2 because stress on healthcare infrastructure will preclude individuals from receiving timely treatment.
5. Magnitude/severity of health effects was assigned a score of 2 because health infrastructure effects are noticeable but with proper management and resources, can be reversible.
6. Geographic extent received a score of 2 because the entire community is at risk.
7. Effectiveness of setback was assigned a score of 2 because adequate setbacks will not mitigate issues related to healthcare infrastructure.

10.3.7 Cumulative Exposures/Risk

Conventional risk assessment methods were designed to assist regulators and risk managers in addressing threats resulting from a single chemical or source to a hypothetical individual, instead of a population [143, 144]. This approach fails to account for the fact that exposures do not happen in a vacuum, and that individuals are simultaneously exposed to multiple chemical, biological and physical hazards as well as psychosocial stressors.

This shortcoming of traditional risk assessment has given rise to cumulative risk assessment (CRA) or community-based risk assessment approaches [145]. Cumulative risk is the combined risk from aggregate exposures from all relevant routes, to multiple hazards or stressors, including chemical, biological, physical and psychosocial stressors [143, 145, 146]. Under this framework, the CRA is divided into 3 distinct phases: 1) planning and scoping and problem formulation, 2) analysis phase, and 3) risk estimation and characterization. In this approach, the impacted community is the central focus, instead of a specific chemical or the source. CRA is a tool for organizing and analyzing information to examine, characterize and possibly quantify the combined adverse human health effects from multiple stressors [20, 143, 145–148]. The scoping process allows engagement of stakeholders, particularly impacted community members, from the onset. This process helps to identify concerns that are of high priority to the impacted community. As such, it is a useful tool for a community that is being impacted by new threats including UNGDP activities.

CRA is often not quantitative like conventional risk assessment [143, 145, 148]. This is because CRA deals with the combined effects of multiple hazards (chemical, physical, and biological) and psychosocial stressors, and calculating specific risk, including interactions among various mixtures/stressors is methodologically complex [20, 143, 147, 149, 150]. Although there has been some advancement made in terms of aggregate exposure and dealing with hazards that have common mechanisms of toxicity, similar modes of action, or have common target organs, there are no clear approaches to deal with interactions between multiple stressors, particularly non-chemical stressors such as psychosocial stress from loss of property value, loss of community identity, family conflict, poverty, unemployment, lack of access to amenities, unsafe community conditions and working environments, limited access to healthcare resources, discrimination, residential crowding, street crime, traffic congestion and other circumstances, on risk [20, 143].

The issue of cumulative exposure/risk is of paramount interest among communities impacted by UNGDP activities. These communities encounter a multitude of hazards and psychosocial stressors simultaneously during the development phase (i.e., hydraulic fracturing) and production phase (i.e., compressor stations). The cumulative impact from the spatial concentration of environmental hazards, pollution-intensive facilities, and noxious land uses combined with the potential impacts of future UNGDP activities may lead to negative health outcomes and community stress and lower quality of life and community sustainability. For example, individuals who currently live near multiple facilities could see an increase in exposure and respiratory health risks by new UNGDP activities. For example, McKenzie and colleagues [1] estimated the chronic and subchronic non-cancer hazard indices for residents living within ½ mile radius of UNGDP facilities and compared it with residents living greater than ½ mile away in Garfield County, Colorado. The subchronic HQ of 5 was observed for residents <1/2 mile of wells was considerably higher than subchronic HQ of 0.2 observed for those living >1/2 miles away. In addition, pollution sources tend to concentrate in poor and under-resourced communities leading to disparities in burden and exposure and higher risk of poor health outcomes.

Cumulative exposure assessment should also include positive exposures including the economic benefits of UNGDP activities in a host community. The development and production of shale resources in Allegany and Garrett counties could improve the economy and provide jobs for local residents. However, studies on extractive industries have shown loss of jobs and increase in unemployment rates in boom towns during the “bust” phase [151, 152]. Other industries that need clean environments including good air and water quality and healthy ecosystems including agriculture, tourism, fishing, and recreational industries are incompatible with UNGDP [151, 153, 154]. This could potentially lead to a net loss in jobs, and an increase in the unemployment and poverty rates [113] in both Allegany and Garrett counties. This suggest the overall impact of UNGDP on job creation in western MD is more complex than simple estimation of how many workers do the UNGDP industry need to complete the process.

For reasons mentioned above, public health advocates have long stressed the need to incorporate cumulative exposure/risk as the true impact of UNGDP activities simply cannot be quantified by simple measure of criteria air pollutants, VOCs, contaminants in drinking water supplies, or any other hazards for that matter. What these quantitative measures fail to account for, are the slow and hidden sufferings encountered on daily basis by impacted community members that simply cannot be measured. To understand these hidden costs, the study team embarked on a site visit of a community in Doddridge County of WV where UNGDP activities are already underway. During this site visit, study team members were given a tour of the UNGDP sites across the county. Study team members were informed about the hidden sufferings experienced by individual community members that led to chronic stress, poor quality of life, sense of helplessness, and mental health issues including depression and anxiety.

Examples included:

- Chronically stressed property owners who cannot stop the development in his own property because he/she does not have the mineral rights.
- A mother who cannot let her children play outside because of the odor, and the symptoms her children exhibit if they play in the front yard (throat and eye irritation, skin rash). She cannot sell her house and move away because no one wants to buy her property next to a UNGDP facility.
- Community members who feel that the social fabric of their community has been irreversibly destroyed.
- Families who cannot sleep in their own house because of the constant noise from the compressor station next to their property.
- A resident with a pre-existing condition who is convinced the worsening of his/her symptoms coincides with the odor in the air that comes from the nearby UNGDP facility.
- A neighbor whose two small children both suffer from frequent nosebleeds.

It is clear that communities currently impacted by UNGDP activities need a place-based cumulative exposure/risk assessment to capture their cumulative risks from exposures to multiple chemicals, media, pathways and non-chemical stressors (e.g., psychosocial stressors) or the stakeholders' underlying vulnerabilities, as described in the NRC report [155, 156]. Yet, there are no studies to date that have applied the framework of CRA to look at the risk experienced by UNGDP impacted communities.

10.3.7.1 Assessment

We anticipate the cumulative risk from the physical, chemical and psychosocial stressors will be greater than the simple sum of individual risks. We further anticipate that the impact will be disproportionately felt by vulnerable subgroups such as children, elderly, individuals with existing diseases, poor residents, and individuals without mineral rights. We conclude that there is a **Moderately High Likelihood** that the UNGDP related activities will have a net negative impact in the cumulative exposure/risk. Table 10-18 provides overview of scoring we used for each evaluation criteria to arrive at this conclusion.

Table 10-19: Cumulative Exposures/Risk Evaluation

Evaluation Criteria	Score
Vulnerable populations	2
Duration of exposure	3
Frequency of exposure	2
Likelihood of health effects	2
Magnitude/severity of health effects	1
Geographic extent	2
Effectiveness of Setback	2
Overall Score	14

Hazard Rank	M

1. Vulnerable population received a score of 2 as cumulative risk will not be uniformly distributed, and that the most vulnerable subgroups will be disproportionately burdened.
2. Duration of exposure received a score of 3 because cumulative exposure will persist beyond first year.
3. Frequency of exposure received score of 2 as exposure is frequent.
4. Likelihood of adverse effect was assigned score of 2 because previous evidence document the relationship between exposure to individual hazards and risk.
5. Magnitude/severity of health effects was assigned score of 1 because evidence regarding the magnitude/severity of health effect could not be determined because of insufficient data.
6. Geographic extent received score of 2 because the entire community is at risk.
7. Effectiveness of setback was assigned score of 2 because adequate setback will not mitigate issues related to public safety.

10.4 Occupational Impacts

As the demand for natural gas from UNGDP increases, so does the demand for jobs in the industry. This is seen as economic life-saver in areas such as New York, Pennsylvania, and Maryland that have been economically depressed for last decade. According to a report by the Pennsylvania Labor and Industry Department, from October 2009 through March 2010, 48,000 new jobs were created by the UNGDP industry and its related supply chain, a number expected to increase as the industry grows [157]. Yet this fast growth poses concerns for the safety for those who will be filling those job vacancies. This section covers the injuries and fatalities, overall job hazards (physical, chemical, and social) associated with UNGDP, who is primarily affected, and how these occupational injuries impact the local community and health care system.

10.4.1 Injuries and Fatalities

Across the natural resources and mining section, there were 23,280 reported nonfatal injuries with an average of 11 days away from work, while for the mining industry (which includes oil and gas extraction), there were 7,060 reported nonfatal injuries with an average of 28 days away from work [158]. Contact with objects (33.7 per 10,000 full-time employees (FTE)), overexertion in lifting and lowering (8.8 per 10,000 FTE), and fall on the same level (8.3 per 10,000 FTE) are the most common events leading to nonfatal injuries [158]. These injuries are due to sprains, strains, and tears (34.9 per 10,000 FTE) and fractures (12.9 per 10,000 FTE) [158]. Over half of the nonfatal injuries occurred in workers who have been with their employer for at least one year. This correlates with the age of employees at the time of injury – there were 10,060 injuries among workers aged 16-34 and 12,360 injuries among workers 35-64.

In the U.S., fatalities in the oil and gas extraction industries reached a high in 2012, with 138 total fatalities, which accounted for 78% of the fatal work injuries in the mining industry [159]. Fatalities are most likely to occur in operations run by small subcontractors (those with less than 19 employees), whether they are engaged in drilling or well servicing [159]. In 2012, the top three events that led to the fatalities were transportation incidents (49%), contact with objects or equipment (18%), and fires and explosions (15%) [160]. The increased transportation fatalities are due, in part, to a fifty year old Department of Transportation exemption that allows drivers in the oil and gas industry to work longer hours than most truck drivers. [161].

10.4.2 Job Hazards Overall

10.4.2.1 Physical Hazards

The overall job hazards associated with UNGDP can be categorized into physical, chemical, or social hazards. Physical hazards consist of exposure to high noise levels, slips, trips, and falls, temperature extremes, fatigue, naturally occurring radioactive material, electrical and other hazardous energy, working in confined spaces, ergonomic hazards, high pressure lines and equipment, and machine hazards [162]. According to OSHA, exposure to high noise levels is one of the most common health hazards throughout the oil and gas extraction industry, and hearing loss has been characterized by the CDC as the most common work-related illness in the US [162, 163]. Furthermore, excessive noise and/or continuous noise, such as that typically experienced on a drill site, has documented health impacts such as permanent tinnitus or hearing loss [162]. NIOSH sets occupational noise standards at 85 dBA over 8-hours while OSHA's standards are a bit higher at 90 dBA over 8 hours [163, 164]. Yet noise sampling in New York's Marcellus Shale UNGD measured sound levels from an air compressor (generates some of the highest noise on site) at 105 dBA [94]. This loud, continuous noise not falling within the set regulations creates a dangerous work environment.

10.4.2.2 Chemical Hazards

Chemically, hundreds of chemicals used in hydraulic fracturing. According a 2012 Natural Resources Defense Council issue brief, there are at least twenty-nine states in which hydraulic fracturing activities are underway [165]. Only fourteen of the twenty-nine states require some disclosure and accessibility by the public through FracFocus.org. The requirements of disclosure vary from state to state; therefore the information stored in FracFocus is incomplete. Table 10-3 lists the types of chemicals, their use in hydraulic fracturing, and the consequences of not using the chemical.

Figure 10-18: Silica Dust from a Well Pad, West Virginia

A 2010 NIOSH study found the specific chemical agents of most concern in UNGD to be silica, diesel particulate matter (DPM), VOCs, and hydrogen sulfide [30]. The previously mentioned 2010 NIOSH study identified crystalline silica during UNGDP as the most significant health hazard to workers during UNGD, a finding also supported by the American Public Health Association [30, 166]. A report by Esswein and colleagues described work crew exposures to respirable crystalline silica during hydraulic fracturing [30]. According to the report, workers are exposed to large quantities of silica at multiple points during the UNGD process and currently deployed engineering controls are not adequately protecting workers. The report documented 116 air samples at 11 fracking sites in five states (AR, CO, ND, PA and TX) taken to evaluate worker exposure to crystalline silica. The results showed that 47% of the 116 samples collected exceeded the OSHA permissible exposure limit (PEL) and 79% exceeded the NIOSH recommended exposure limit (REL). Furthermore, 31% of samples that exceeded the NIOSH REL value exceed that value by a factor of 10 or more. The report concluded that the use of a half-face air-purifying respirator does not adequately protect workers because the half-face air-purifying respirators have a maximum use concentration of 10 times the occupational health exposure limit.

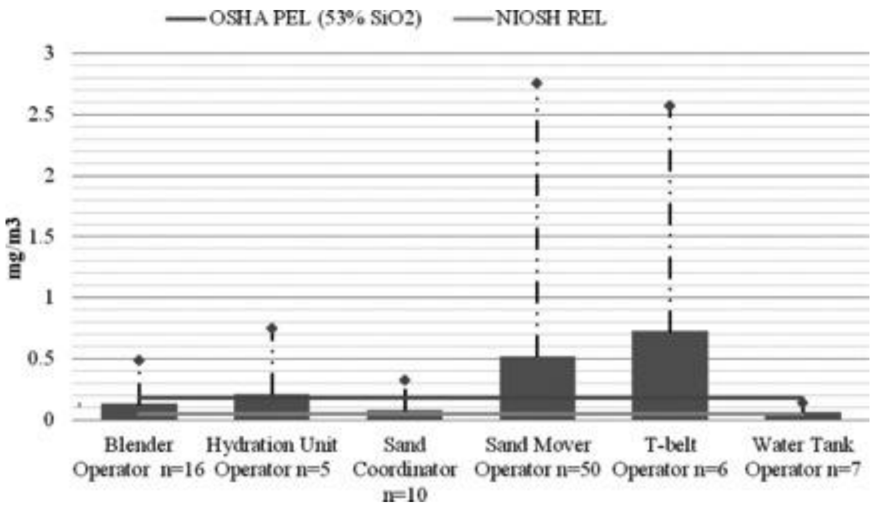

Figure 10-19: Comparisons of arithmetic means of TWAs (mg/m3) for job titles with five or more samples in relation to a calculated OSHA PEL (based on 53% silica) and NIOSH REL for respirable silica. Maximum values for each job title shown by diamonds at the end of dashed lines, Source: [30]

Figure 10-20: Natural Gas Flaring

Given the amount of diesel-based heavy duty vehicles, machineries and generators at the UNGD sites, worker exposure to DPM at these sites is of significant public health concern [136]. Workers exposed to diesel exhaust are at increased risk of adverse health outcomes ranging from irritation of the eyes and nose, headaches and nausea, to respiratory disease and lung cancer [136]. Though diesel exhaust has been classified by International Agency for Cancer Research (IARC) as a known human carcinogen (Group 1), there are currently no federal workplace standard for worker exposure to DPM [167]. The state of California does regulate DPM at workplace with an 8-hour TWA not to exceed 20 mg/m^3 [136]. Limited monitoring data available showed a quarter of the UNGD sites monitored exceeded the 20 mg/m^3 threshold [168].

While research on the impact of hydrogen sulfide at UNGDP sites is lacking, its impact on workers at other natural gas processing plants is raising concern for UNGDP workers. Hydrogen sulfide is a compound that is released through the venting and flaring of natural gas throughout the extraction and refining processes as a safety precaution [169]. This is because hydrogen sulfide is extremely flammable and when mixed with air can be explosive. Additionally, it may travel to sources of ignition and flash back. When ignited, the burning gas produces toxic vapors like sulfur dioxide [170]. Short-term exposure to hydrogen sulfide has been linked to nausea, headache, shortness of breath, sleep disturbance, throat and eye irritation, while long-term exposure causes olfactory nerves paralysis, respiratory inflammation, chronic bronchitis, and chronic tearing of the eyes [169]. As previously stated, data on hydrogen sulfide exposure at UNGDP work sites is limited, but information on its dangers during other natural gas processing and refining show hydrogen sulfide to be a very dangerous chemical if not handled properly. In 2010, a natural gas well salvage and capping business based in Zanesville, Ohio failed to provide "training, along with eye protection, a written respiratory protection program, a written hazard communication program, and material safety data sheets on hydrogen sulfide" that resulted in the death of a worker at a natural gas well site in Londonderry, Ohio [171]. Similarly, workers were injured while vacuuming explosive dust to clean out a natural gas processing unit in a Eustace Gas Processing Plant in Eustace, Texas in 2011 [172]. These incidences show UNGDP workers are at increased risk of adverse health outcome, if more adequate safety measures are not put in place.

10.4.2.3 Social Hazards

Due to the transient nature of employment in the UNGDP sector, workers experience a number of psychosocial issues, including mental distress, suicide, stress, and substance abuse. A project conducted by the UC Davis Center for Reducing Health Disparities on migrant Latina/o agriculture workers and the communities they migrate to focus on the mental burden these workers face. While not employed by the same industry or even of the same ethnic background, UNGDP workers have much in common with Latina/o migrant agriculture workers and their experiences produce similar mental health outcomes. Migrant workers tend to be desperate for obtaining and maintaining employment in order to provide basic necessities for their families [173]. There are stressors that lead to depression, anxiety, and drug and alcohol abuse. The UC Davis project also identified illicit drugs as being sometimes used as a means to cope with or relax after working long hours. Migrant workers experience social stressors such as avoidance at best or discrimination at worst from the communities, and do not bring their families along. As such, they are even more isolated from their support system and more at risk for turning to substances to cope.

This also puts a strain on communities that host UNGDP activities. In Garfield County, Colorado the increase in UNGDP activity coincided with increases in violent crime arrests and drug violations for adults and juveniles alike, along with an increase incidence of STIs [7]. Furthermore, substance abuse information extracted from the Garfield County 's 2006 assessment on community needs indicated depression, anxiety and stress along with tobacco smoking and alcohol abuse appear to be the top indicators of the burden of mental health and substance abuse, respectively.

Furthermore, a disproportionate number of the workers lack health insurance [174]. Rural healthcare facilities are not trauma centers; they are designed to be family clinics. The increases in accidents and other health issues, such as STIs have put a strain on the healthcare system as local hospitals and governments are not compensated for their healthcare services. A hospital in a North Dakotan fracking "boom town" saw its ambulance visits increase four-fold and its debt increase 2,000% to $1.2 million over the past five years [174].

A study conducted by the U.S. Chamber of Commerce's Institute for 21st Century Energy has shown shale oil and gas extraction has accounted for 4,000 ambulatory health care and hospital jobs in North Dakota and more than 2,000 healthcare jobs in Louisiana, with 4,000 more projected by 2035 [175]. Yet the fate of these workers after the UNGDP activity begins to wane is a critical issue that should not be overlooked, this time around. Socially, UNGDP poses a threat to the livelihood of the communities the activities take place in as well as those who work in them.

10.4.3 Assessment

Based on our review of the occupational health hazards associated with UNGDP (section 10.4), we conclude that there is a **High Likelihood** that UNGDP related activities will have a negative impact on occupational health. Table 10-20 provides the scoring for the evaluation criteria that we used to arrive at this conclusion.

Table 10-20: Occupational Health Evaluation

Evaluation Criteria	**Score**
Vulnerable populations	2
Duration of exposure	3
Frequency of exposure	2
Likelihood of health effects	3
Magnitude/severity of health effects	3
Geographic extent	2
Effectiveness of Setback	2
Overall Score	17
Hazard Rank	H

1. Vulnerable population received a score of 2 workers are disproportionately affected.
2. Duration of exposure received a score of 3 because these workers are employed in the UNGDP industries for > 1 year where their exposures continue to persist.
3. Frequency of exposure received score of 2 as workers' exposures are frequent.
4. Likelihood of adverse effect was assigned score of 3 because evidence suggests that these workers are exposed to very high level of hazards, including crystalline silica.

5. Magnitude/severity of health effects was assigned score of 3 because the potential adverse health effects (silicosis, lung cancer) are irreversible.
6. Geographic extent received score of 2 because the workers are from different areas.
7. Effectiveness of setback was assigned score of 2 because adequate setback will not mitigate workers' exposure.

11 REGULATORY LANDSCAPE

Here, we briefly describe the scope and implications of pertinent federal regulations and examine the approach to regulation of UNGDP taken by selected states.

11.1 Federal Regulations

While Congress has the authority to regulate hydraulic fracturing activities under the Commerce Clause (Article I, Section 8, Clause 3 of the U.S. Constitution), legislation of the practices involved in hydraulic fracturing has been primarily put in the hands of the states. Each state is allowed to regulate hydraulic fracturing activities as it sees fit while still maintaining the minimum federal regulations. Yet at the federal level there is little power to regulate hydraulic fracturing through most of the major federal environmental statutes, which include: the Safe Drinking Water Act (SDWA), the Clean Water Act (CWA), the Clean Air Act (CAA), the Resource Conservation and Recovery Act (RCRA), the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and the Emergency Planning and Community Right-To-Know Act (EPCRA) due to the enactment of the 2005 Energy Policy Act. This act was intended to help formulate a new national energy strategy that would address energy production in the United States, focusing on areas such as renewable energy, energy efficiency, climate change technology and domestic extraction of oil and gas. In the process, it created exemptions for natural gas and oil drilling (which hydraulic fracturing falls under), known commonly as Halliburton loopholes [176], which allow hydraulic fracturing activities to bypass the major federal environmental statutes – something that most other large energy industries are not privy to [177].

11.1.1 Water

Our waters are protected by the Safe Drinking Water Act (SDWA) and the Clean Water Act (CWA). The SDWA mandates regulation of underground injection activities in order to protect groundwater resources [59]. Under this statute, groundwater is classified as underground water reserves (e.g., aquifers). Additionally, the SDWA is designed for public municipal drinking water; therefore, the 15% of Americans on private drinking wells and one-third of Maryland residents using private wells are not protected under this Act [21, 178]. Under the 2005 Energy Policy Act, UNGDP is excluded from the SDWA's "underground injection" terminology unless diesel fuels are used during the injection process [179]. Additionally, previous sections of this report have shown groundwater may be affected, altered or contaminated by UNGDP fluids or mobilization of naturally occurring minerals, gases or radiation. Together, this places all of us who drink municipal water at risk for exposure to UNGDP chemicals, and places those using private wells at an even greater risk.

The CWA was enacted to protect and improve water quality in the nation's rivers, streams, creeks, and wetlands [180]. In order to achieve this goal, the CWA requires permits for all discharges of pollutants to those waters. Under the 2005 Energy Policy Act, term "pollutant" does not include water, gas, or other material that is injected into a well to facilitate production of oil or gas, and UNGDP is exempt from the permit requirements [179]. Furthermore, the 2005 Energy Policy Act broadened the discharge permit exemption to include stormwater discharge from oil and gas construction activities. Although in a suit brought against the US Environmental

Protection Agency (EPA) by the National Resource Defense Council (NRDC), the Court decided this broadened exemption was unlawful, the EPA has yet to set forth a better measure to regulate this kind of discharge [181]. Without these protections in place, the natural habitats surrounding UNGDP sites are in danger of being destroyed. This has both direct and indirect consequences for public health. Directly, habitat destruction may result in floods, heat waves, water shortages, landslides, earthquakes; while indirectly, we will see changes in disease risk, reduced crop yields (malnutrition/stunting), and depletion of natural medicines associated with habitat destruction [182].

11.1.2 Air

In 1970, the Clean Air Act (CAA) was passed in an effort to "protect and enhance the quality of the Nation's air resources so as to promote the public health and welfare" [183]. As previously stated, natural gas production produces toxic air pollution, including volatile organic compounds (VOCs) (which react with sunlight to form ground level ozone or smog), methane, hydrochloric acid, and hydrogen sulfide, all contributors to greenhouse gases. Under the CAA, when numerous small sources of air pollution, such as individual oil and gas wells, are under common control and in close proximity they are treated as a "major source" and subject to CAA best technology requirements, and require an emission permit to ensure their emissions are under a set threshold [183]. With the passage of the 2005 Energy Policy Act, most oil and gas production sites are not are treated as a major source and are not required to obtain an emission permit [179]. Many supports of the natural gas industry argue emissions from natural gas power generation are half of that of coal and are comprised more of methane than carbon dioxide, and are therefore not of a great concern in terms of global greenhouse gas emissions. However, according to the EPA, methane is more efficient at trapping radiation than carbon dioxide. "Pound for pound, the comparative impact of methane on climate change is over 20 times greater than carbon dioxide over a 100-year period" [184]. Furthermore, the natural gas/petrol industry was the biggest methane emitter from 1990 to 2012 [185]. The impact of greenhouse gases in terms of climate change on human health ranges from increases in tropical disease incidents such as malaria and cholera to widespread crop failure to mass population displacement [182].

11.1.3 Waste Disposal and the Right to Know

The health and safety of the land and those who occupy it is protected under the Resource Conservation and Recovery Act (RCRA) and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). RCRA enacted by Congress as a "cradle to grave" regulatory framework for managing solid waste, including hazardous waste [186]. Under the 1980 amendments to RCRA known as the Solid Waste Disposal Act Amendments of 1980, Congress temporarily exempted oil and gas exploration and production wastes from regulation under RCRA until the completion of an EPA study to determine whether such wastes should be regulated as hazardous waste under RCRA [187]. EPA finalized this study in 1988, and concluded that regulation of hazardous oil and gas waste under RCRA was unnecessary. This means the hydraulic fracturing fluid, a mixture of water and all the hydraulic fracturing additives (chemicals), used to perform high volume horizontal hydraulic fracturing are not considered hazardous material or hazardous waste and therefore is not regulated in transportation. Therefore labeling, shipping, record keeping, training, etc. are not required for transport. This is contrary to the previously mentioned studies in the report that have identified know toxins and carcinogens in hydraulic fracturing fluid indicating that they should be regulated under RCRA.

Congress enacted CERCLA in 1980, creating a framework for cleanup of toxic materials through creation of the Superfund Program [188]. The oil and gas industry was taxed in order to pay into the Superfund and in exchange was exempted from CERCLA's requirements until 1985. But according to the Environmental Defense Center, the industry continues to be exempt while not paying the tax [189].

These two acts (RCRA and CERCLA) tie directly into the Emergency Planning and Community Right to Know Act (EPCRA). EPCRA was enacted in 1984 in the wake of the chemical explosion and disaster in Bhopal, India, and generally requires companies to disclose information related to locations and quantities of chemicals stored, released, or transferred [190]. This is done for the safety and welfare of those who live and work in an area in which toxic or harmful substances are used, deposited, or transported; they have the right to know what they are being exposed to in their homes and work. Under the 2005 Energy Policy Act, oil and gas exploration and production wastes were exempted from this requirement. EPCRA only applies to hydraulic fracturing when diesel fuels are used [179]. Industry argues revealing chemical compositions of fracture fluid formulations could reveal valuable corporate trade secrets. Additionally, industry is allowed to withhold the specific chemical identity from the reports filed under sections 303, 311, 312 and 313 of EPCRA if the facilities submit a claim with substantiation to EPA. Additionally, the industry argues material safety data sheets (MSDS) are posted on-site at UNGDP sites, as required by law, and MSDSs are freely accessible to the public online [191]. However, simply providing MSDSs is not the same as understanding the exposures risks associated with chemical mixtures, especially if the individual reading the MSDS is not well versed in chemistry or toxicology. Furthermore, UNGDP companies tend to leave out key details when listing compounds on their MSDS. "Frac fluid with additives" is a commonly listed compound on fracking MSDSs, yet nowhere on the sheet does it list what the additives are [191].

11.2 State and Local Regulations

The 2005 Energy Policy Act largely exempted oil and gas development from regulation at the federal level based on an assertion that the oil and gas industry was adequately managed under state regulations. It was assumed that "one size fits all" federal regulations would be inappropriate given the diversity of geology and environments among states. This has resulted in a checkerboard of varying regulations at the state and local levels particularly with regards to setback and disclosure requirements [192, 193]. While most regulation occurs at the state level rather than local level, some local governments have taken an aggressive stance toward UNGDP regulation [194, 195]. In Pennsylvania, the Supreme Court recently struck down limits imposed by the state legislature on local zoning control of oil and gas development [196, 197] providing an increasing role for local government in that state. The district court is now charged with determining if the remainder of Pennsylvania Act-13 is consistent with the state constitution after invalidation of the zoning preemption. In a recent decision in June 2014, the New York State Court of Appeals ruled that towns can use zoning ordinances to ban hydraulic fracturing. This ruling supports efforts of towns across New York including Dryden in Tompkins County and Middlefield in Otsego County who have modified their zoning ordinances to ban the practices on the grounds that it would threaten public health, environment, and the social fabric of local communities [198, 199].

The status of state regulations has been extensively reviewed (Richardson et al. 2013; Konschnik & Boling 2014; McFeeley 2012). However, regulations are rapidly evolving with new laws passed, new regulations proposed or issued, and court decisions rendered on an almost daily basis.[197, 200–202] Hence, any review is rapidly out of date. A comprehensive review of state statutes and regulations across the U.S. is outside the scope of this document.

11.2.1 Setback Requirements

It is clear that states (and some localities) differ widely in setback requirements. A recent report found that setback requirements ranged from 100 to 1000 feet [193]. The City of Dallas, Texas, recently enacted an ordinance requiring 1500 feet setbacks [195]. Maryland should base setback regulations on best available science. If the State decides to allow UNGDP, continual improvement of regulation and enforcement will be necessary as new information becomes available, regardless of whether the state decides to allow development to begin in 2015 or after several more years of study. Thus, recognition of a need for continued evolution of standards and regulations, will be important to acknowledge in the initial regulations [192].

11.2.2 Chemical Disclosure

A second area of important variation among states is the requirement for disclosure of information about chemicals used in UNGDP. Twenty-two states have some requirements for disclosure of hydraulic fracturing chemicals [203]. Of these states, 15 require disclosure to FracFocus.org, including 10 that make the website the “primary or sole location for reporting”. FracFocus has received much criticism for its relatively primitive technology preventing searching and aggregation, onerous terms of use, and its lack of date-time stamping and logging, quality control, verification, and provisions for permanent archiving of data [203–205]. Recommendations for critical improvements were made by a Task Force of the Secretary of Energy Advisory Board [205]. Four states require that records submitted to FracFocus also be submitted directly to the state. California also requires that a the data be made available on a state government website “that allows the public to easily search and aggregate [submitted data] using search functions on that Internet Web site” [206 Sec 3160].

All current state disclosure laws and regulations make some provision for protecting confidential “trade secret” information [203]. Yet, the case for the existence of valid, commercially important trade secret information about the identity of chemicals used in the UNGDP industry was undermined recently by a major oil and gas industry service company’s commitment “to disclose 100% of the chemical ingredients we use in hydraulic fracturing fluids” [207]. Part of the strategy here may be to disclose in an effort to defuse concerns about the chemicals being used.

A letter to the Alaska Oil and Gas Conservation Commission from ten law professors who specialize in intellectual property made the case against trade secret protection in regulation of the UNGDP industry without questioning the legitimacy of the secrets [208]. They argue, "the public’s interest in assuring that hydraulic fracturing is managed in a manner that addresses all significant risks may legitimately outweigh commercial concerns”. Furthermore, “trade secrecy should not impede disclosure of information when the information describes public risks that the trade secret claimant is itself creating." Thus, "even full-blown property rights do not legitimate harming third parties or avoiding duties."

Some states have or are developing administrative procedure to review trade secret claims. The Wyoming Supreme Court recently ruled that, under that state's constitution, failure to disclose chemical constituents of hydraulic fracturing fluids required detailed justification [200]. However, "[a]dministrative agencies are poorly positioned to evaluate and monitor trade secrecy claims and this function is resource intensive"[208]. California does not allow "[t]he identities of the chemical constituents of additives, including CAS identification numbers" to be claimed as trade secrets [206 Sec 3160]. But, the state's new "Well Stimulation" law does require companies to submit extensive information and provide for administrative review of the validity of any submitted claims of confidential trade secrets. Such an effort may be within the reach of resources in a large state such as California – but may not be feasible in Maryland. Thus, alternative approaches [192], or disallowing trade secrets may be necessary to strike the proper balance between public and private interests if this industry is to operate in Maryland.

11.2.3 Other Forms of Well Stimulation

Another area of important variation between states is the extent to which UNGDP regulations address all forms of well stimulation for oil and gas production including potential new and emerging technologies. In his recent review of disclosure laws, McFeeley [203] found that only three states, California, Ohio, and Wyoming require chemical disclosures for all types of well stimulation while most states address only hydraulic fracturing. California titles its act "Well Stimulation" and specifically mentions acid well stimulation as well as hydraulic fracturing [206]. It seems likely that new extraction technologies will continue to evolve. Thus, a forward looking approach, rather than focusing on the technology of the moment, seems warranted.

12 RECOMMENDATIONS

12.1 Comprehensive Gas Development Plans (CGDP)

Potential public health impacts and prevention and mitigation strategies should be included in the CGDP so that the required and routine public hearings on the plan can include an informed discussion of health as well as environmental impacts.

R1. Require assessment of air quality and other potential health impacts and propose strategies to protect the community and workers from exposure to hazardous air pollutants.

Air quality is one of the major potential areas of UNGDP health impacts. It is essential, therefore, that air quality and resulting potential health impacts be addressed at the earliest stage of development – in the Comprehensive Gas Development Plan.

R2. Require assessment of whether application of standard setback distances will be adequate to protect public health, including consideration of prevailing winds and topography.

Each area for proposed development will have unique features not limited to the geology of the site. Differing vulnerabilities of adjacent populations as well as physical features of the landscape may impact the likely effectiveness of setback requirements in preventing health effects from UNGDP. The CGDP, as the first step in development, needs to address this issue.

R3. Require disclosure of planned well stimulation methods and classes and amounts of chemicals to be used.

Although test well results as well as passage of time between submission of a CGDP may result in some changes in the details of planned well stimulation methods, the general approach, methods (hydraulic fracturing, acid stimulation, or other), and types and expected amounts of chemicals expected to be used should be available in advance of the public hearing mandated for consideration of the CGDP. More specific data will be required at later stages as described below. However, because individual well permits are not subject to mandatory public hearings unless MDE is petitioned by individual stakeholders, and because the health impacts and adequacy of prevention measures cannot be assessed at the CGDP stage without knowledge of proposed well stimulation methods, disclosure at the CGDP stage is essential.

R4. Require a quality assurance plan.

Simply having proposed prevention plans in place is not sufficient. A method of ensuring that the planned methods are implemented and monitored is also essential.

R5. Require an air, water, and soil-monitoring plan.

Air, water, and soil monitoring are complex undertakings and adequate monitoring will require significant planning. The CGDP should provide the plan so that it is subject to public review at the mandatory public hearing.

R6. Require assessment of impact on and a monitoring plan for potential fugitive emissions from existing and historic gas wells within the horizontal extent of the fractured area.

Experience in WV suggests that horizontal drilling and hydraulic fracturing can cause long dormant and abandoned wells to begin leaking. The leaks may be associated with a variety of air quality problems, as well as atmospheric methane releases. At the time of the CGDP, the existing wells need to be identified and assessed for potential impact of new development, and a plan for monitoring these potential emission sources put in place.

R7. Require that all UNGDP materials and wastes be stored in closed tanks; open pits shall only be used for storage of fresh water.

This requirement is consistent with the MDE report. The plan for siting of the required tanks and related infrastructure needs to be included in the CGDP.

12.2 Disclosure of Well Stimulation Materials

Recommendations concerning disclosure were revised and moved to a separate section based on feedback received at and following the public progress report on June 28, 2014. The final recommendations are now in line with the proposed legislation H.B. 1030 [8]. Three phases of disclosure are included – a preliminary more general disclosure with the CGDP, a specific detailed disclosure with the well permit application, and a specific detailed disclosure after well stimulation is finished.

R8. Require preliminary disclosure at time of CGDP submission (see CGDP recommendations), detailed disclosure at time of well permit application, and detailed reporting of actual materials used within 30 days of finishing well stimulation activities. Require notification of MDE, local emergency responders and public notice of significant variances from materials and concentrations proposed in the permit within 24-hours of occurrence.

We recommend three phases to the disclosure process. The first phase occurs as a part of the CGDP and is necessarily more general and preliminary. As described in the recommendations for the CGDP (see 12.1 above), this is necessary for informed public discussion of the merits of the plan. The second phase, close in time to the actual well stimulation activity, is the appropriate time for detailed disclosures. The final phase is a record of materials actually used in the well stimulation process. An additional requirement is made for immediate notification of relevant responders and the public if variations from the approved detailed submission occur.

R9. Require detailed disclosures to include CAS numbers, volume and concentration of every chemical or distinct material including proppants, their physical form, and identification of engineered nanomaterials – including drilling muds and hydraulic fracturing and other fluids – used in well stimulation. Do not allow claims of trade secrets for identities and concentrations of specific chemicals or nanomaterials used in well stimulation.

As described in section 11.2.2 above, the legitimacy of claims of trade secrets in the hydraulic fracturing industry is questionable, and even if one grants that some legitimate trade secrets exist, we believe public risk should outweigh commercial concerns especially where the potential risks are created by the trade secret claimant. Were trade secrets to be allowed, administrative due process would be required each time the state declined to release requests made by the public – and initial validity of claims should also be reviewed at the time of submission rather than allow unnecessary delay in access by medical practitioners, emergency responders, or public health researchers. This administrative burden is likely beyond the resources of MDE. What is important for public health is disclosure of the amounts of specific materials injected into the ground, released into the air, or otherwise potentially released into the environment. The exact formulation of products used is not needed – rather it is the final concentrations and amounts in the fluids. Structuring the disclosures in this way may avoid some issues of trade secrets.

R10. Require detailed disclosures to include base fluid volume and sources including percentages that are recycled fracturing fluid, production water, and fresh water.

While recycling of fracturing fluids is highly desirable, this also raises the potential for accumulation of naturally occurring contaminants and reaction products of fracturing chemicals. Thus, knowing the sources of the fluids is important.

R11. Require simultaneous submission to state regulators and FracFocus.

FracFocus is a somewhat useful web portal for information on UNGDP materials and methods. However, as described in section 11.2.2 above, it also has numerous well-known severe limitations that make is unsuitable as the primary or sole repository for disclosed information.

R12. Collaborate with California to develop a State controlled and archived Internet Web site consistent with the provisions of California SB 4.

Under its new Well Stimulation legislation and proposed implementing regulations, California is in the process of developing an accessible and more useable Internet Web site for disclosure of well stimulation material identities. This web site will address many of the limitations in FracFocus. It would be more cost effective for Maryland to partner with California than to try and develop its own web portal.

R13. Implement the provisions of H.B. 1030 for timely access to disclosed information by medical professionals, emergency responders, poison control centers, local officials, scientists, and the public.

The provisions of H.B 1030, considered by the House of Delegates during its 2014 session, particularly its requirement for timely disclosure of information, are supported by this study's analysis.

12.3 Air Quality

Based on our evaluations of the limited but emerging epidemiological evidence from UNGDP impacted areas and air quality measurements as well as epidemiological evidence from other fields, we conclude that there is a **High Likelihood** that UNGDP related changes in air quality will have a negative impact on public health in Garrett and Allegany Counties. Should Maryland move forward with UNGDP, the following recommendations should be implemented to prevent or minimize potential negative impacts on public health.

R14. Require a minimal setback distance of 2000 feet from well pads and from compressor stations not using electric motors.

Evidence from traffic related air pollution studies show that concentration of traffic related pollutants drop down to background level beyond 500-700m (1640-2296 feet). Likewise study from Colorado shows concentration of air pollutant significantly higher within 0.5 miles (2640 feet) of UNGDP facilities compared to >0.5 miles. Based on this, we concluded that adequate setback from periphery of the UNGDP facility to the periphery of residential property can minimize exposure. Based on this data, we recommend minimal setback distance be 2000 feet.

R15. Require electrically powered motors wherever possible; do not permit use of unprocessed natural gas to power equipment. This recommendation is designed to reduce VOCs and PAHs emissions from drilling equipment and compressors.

VOC and PAH emission into the local environment can be eliminated by using electrically powered motors. This is consistent with the recommendation in the UMCES-AL report.[209]

R16. Require all trucks transporting dirt, drilling cuttings to be covered.

Fugitive dust from trucks transporting dirt, drilling cuttings and other waste materials is of concern to the community. Spill from these trucks also contribute to the soil and water contamination issues. To minimize, require all trucks transporting these materials to be covered.

R17. Require storage tanks for all materials other than fresh water and other UNGDP equipment to meet EPA emission standards to minimize VOC emissions.

The EPA issued final standards for emissions from storage tanks and other UNGDP equipment in 2012 with subsequent updates. [210, 211] Maryland should require all facilities, not merely large ones, to meet these standards.

R18. Establish a panel consisting of community residents and industry personnel to actively address complaints regarding odor.

Community residents from Doddridge County in WV complained they often encounter periods of intense odor that is sometimes followed by acute respiratory ailments. These residents feel powerless as there is no one to help them understand the causes of such episodes and ways to minimize them. We recommend establishment of a panel consisting of community and industry representatives that will work to identify the causes of such episodes and minimize/eliminate them.

R19. Conduct Air Quality Monitoring

- **a. Initiate air monitoring to evaluate impact of all phases of UNGDP on local air quality (baseline, development and production).**
- **b. Conduct source apportionment that allows UNGDP signal to be separated from the local and regional sources.**
- **c. Conduct air monitoring with active input from community members in planning, execution, and evaluation of results.**
- **d. Conduct air monitoring in a manner to capture both acute and chronic exposures, particularly short-term peak exposures.**
- **e. Clearly communicate to community members expectations about what is achievable through air monitoring.**

Air monitoring should be conducted to determine the impact of UNGDP on community air quality. This process should incorporate input from community members regarding the location of the monitor, type of pollutants to be monitored, and sampling interval to capture peak concentrations. Community members should be informed regarding the expected outcomes, and results should be disseminated in a timely manner.

12.4 Flowback and Production Water-Related

Based on our evaluations of the limited data available from UNGDP impacted areas, we conclude that there is a **Moderately High Likelihood** that UNGDP's impact on water quality, soil quality and naturally occurring radioactive materials will have a negative impact on public health in Garrett and Allegany Counties. The overall score for the Flowback and Production Water Related hazard category is primarily driven by concerns related to water quality. Should Maryland move forward with UNGDP, the following recommendation should be implemented to prevent or minimize potential negative impacts on public health.

12.4.1 Water & Soil Quality

R20. Prohibit well pads within watersheds of drinking water reservoirs and protect public and private drinking water wells with appropriate setbacks.

The potential for contamination of drinking water is of significant concern to community residents. Risk of public drinking water reservoir contamination should be limited by prohibiting well pads in the reservoir watersheds. Because many rely on public and private wells as their primary source of drinking water, appropriate safeguards for well water are also important. Appropriate setbacks for private and public groundwater wells should be established for each well based on hydrogeologic evaluation as part of the CGDP.

R21. Implement UMCES-AL/MDE water monitoring plan. Require monitoring of water quality during initial gas production and at regular intervals thereafter.

The UMCES-AL and MDE reports provide a reasonable water-monitoring plan. Maryland should incorporate that recommendation and require monitoring at regular intervals.

R22. Implement the UMCES-AL recommendations for management and recycling of flowback and production fluids.

The UMCES-AL report by Eshleman and Elmore [209] provides extensive recommendations for management and recycling of flowback and production fluids. In particular, we endorse their recommendation 3-J. UNGDP in Maryland should not be permitted until an adequate means of disposal of any residual waste, without extensive trucking, is identified.

R23. Require identification and monitoring of "signature" chemicals in fracturing fluids to allow for future identification of ground water infiltration/contamination.

There is a need to identify a panel of "signature" chemicals that are specifically associated with UNGDP. The monitoring campaign described in UMCES-AL and MDE reports should be augmented with these "signature" chemicals or potential "tracer" that can be added in the fracturing fluid to identify water infiltration/contamination.

R24. Conduct soil monitoring in areas potentially impacted by UNGD upset conditions.

Periodic soil monitoring should be conducted to track potential contamination with semi-volatiles, heavy metals, and radionuclides. These sampling plans should be augmented with more intensive campaign if there is evidence of accidental spills (upset conditions).

R25. Prohibit flowback and production wastewater or brine use to suppress road dust, de-ice roads, or other land/surface applications.

Flowback, production water or brine contains many chemical agents, heavy metals, NORMs and other materials used in fracturing fluids. Therefore, their use as road dust suppressor, deicers and/or other land/surface application should be prohibited consistent with the recommendations in the UMCES-AL report.

12.4.2 NORM

R26. Conduct research to identify the appropriate suite of priority radionuclides for assessment of radiological activity.

Studies have relied on radium as a surrogate for overall radioactivity. Emerging evidence suggest that there may be additional radionuclides that may be of concern to human health, and may in fact be present at appreciable concentration. There is a need to characterize a suite of radionuclides that are of concern and use them in the monitoring studies. In the meantime, metrics such as total alpha activity, or total gamma activity should be used to assess radiological contamination and support decision-making.

12.5 Noise

Based on our monitoring results from Doddridge County, WV as well as other noise monitoring reports, we conclude that there is a **Moderately High Likelihood** that UNGDP related changes in noise exposure will have a negative impact on public health in Garrett and Allegany Counties. Should Maryland move forward with UNGDP, the following recommendation should be implemented to prevent or minimize potential negative impacts on public health.

R27. Implement noise reduction strategies recommended by UMCES-AL in the MD Best Management Practices, including requiring electric motors wherever power supplies are available and construction of artificial sound barriers.

Currently technologies do exist to reduce noise levels. In fact such technology is used in urban locations such as Fort Worth, TX (personal communication, API). But because of the cost associated with them, such technologies are not used in places such as Doddridge County, WV. Maryland should require such noise reduction strategies at all locations.

R28. Require a setback of 2,000 feet for natural gas compressor stations using diesel engines, 1000 feet for stations using electric motors and sound barriers.

Based on our data from WV, noise hazard can be minimized through setback distance. Therefore, Maryland should require a setback of 2,000 feet for facilities using diesel engines.

R29. Establish a system to actively address noise complaints.

Panel established with community and industry representatives to monitor the issues related with odor should also be tasked with monitoring the noise complaints and addressing them.

12.6 Earthquakes

Based on our review of literature, there is clear evidence that deep well injection of wastewater is related to earthquakes that are greater than magnitude 3. However, earthquakes related to hydraulic fracturing itself are very small (less than magnitude 3). Provided that Maryland does not allow deep well injection of wastewater, there is a **Low Likelihood** UNGDP related earthquakes will have a negative impact on public health in Garrett and Allegany Counties. Should Maryland move forward with UNGDP, following recommendation should be taken into consideration to minimize potential negative impact on public health.

R30. Collect baseline data on seismic activities using methods that can record earthquakes smaller than magnitude 3.

Earthquakes associated with hydraulic fracturing are of small magnitude. There is a need to collect baseline data on these small earthquakes so changes in trend over time can be established.

R31. Restrict issuing UIC Class II permits for disposal of UNGDP fluids until licensing requirements adequately addresses earthquake risk.

Previous studies have established link between deep well injection of wastewater and increased incidence of earthquakes greater than magnitude 3. Maryland should restrict issuing UIC Class II permits for disposal of UNGDP fluids. Deep well injection of UNGDP fluids in existing wells should also be banned.

R32. Implement use of sensitive seismic monitoring technology to better detect small earthquake activity that could presage larger seismic events as well as using a "traffic-light system" that sets thresholds for seismic activity notification.

An advance warning system should be developed to warn citizens on potential future earthquakes, based on small earthquake activity.

12.7 Social Determinants of Health

Based on our review of social determinants of health (section 10.3.5), we conclude that there is a **High Likelihood** UNGDP related activities will have a negative impact on the social determinants of health. Should Maryland move forward with UNGDP, the following recommendation should be implemented to prevent or minimize potential negative impacts on public health.

12.7.1 Traffic Safety

R33. Increase state and local highway patrols to closely monitor truck traffic subject to the Oilfield Exemption from highway safety rules.

The Oilfield Exemption from highway safety rules allows truck operators to work extended hours without sleep. This creates a dangerous situation with sleep deprived operators driving their vehicles at high speed through rural roads that are not designed to handle such heavy traffic. To minimize this hazard, additional highway patrols should be hired to closely monitor truck traffic.

R34. Empower local communities to control truck speed and traffic patterns.

Local communities should be empowered to determine and enforce routes for truck traffic, as well as installing speed bumps to control speed.

R35. Route truck traffic to maintain separation between UNGDP activities and the public.

Truck traffic should be routed during off peak hours, such as after morning commute, school bus transport and before afternoon rush hours.

R36. Consider use of pipelines to move UNGDP fluids between sites.

When possible, consider using pipelines to move UNGDP fluids between sites as it will minimize the issues related to spill, traffic accidents as well as traffic-related air pollution.

12.7.2 Empower communities

Strong, resilient communities are an important defense against the psychosocial stressors and can make a major contribution to limiting exposure to chemical and physical hazards. Empowered local communities improve community resilience. Processes should be implemented to ensure public participation in decision-making associated with UNGDP activities, particularly actions to reduce or eliminate negative environmental, social, and public health impacts of UNGDP activities.

R37. Enact a Surface Owners Protection Act as recommended in the MDE Part I report.

During scoping process, community members expressed concerns about surface right owners who lack mineral rights for their property. Since mineral rights trumps surface rights, this particular subgroup is considered to be among the most vulnerable. They experience chronic stress that is detrimental to their mental and physical health. Maryland should enact a Surface Owners Protection Act as recommended in the MDE Part I report.

R38. Engage local communities in monitoring and ensuring that setback distances are properly implemented.

We recommend that local communities should be empowered to ensure adequate setback distances are maintained.

R39. Create a mapping tool for community members using buffer zones (setback distance) around homes, churches, schools, hospitals, daycare centers, public parks and recreational water bodies.

A user friendly mapping tool should be created that enables community members to incorporate buffer zones (setbacks) around sensitive human receptor sites and ecological assets including homes, churches, schools, hospitals, daycare centers, parks, recreational water bodies and map specific areas where UNGDP should be restricted.

We recommend that the user friendly mapping tool should be freely available to community members. The team began the development of a public participatory GIS tool for the project. DHMH staff should expand the online mapping tool, host the tool, and make it available for use by residents, health practitioners, advocates, and other stakeholders. This tool will aid communities in implementing recommendation number R38.

12.8 Healthcare Infrastructure

Based on our evaluations of the current healthcare infrastructure in Garrett and Allegany Counties as well as expected number of migrant workers that will come to these areas, we conclude that there is a **High Likelihood** that UNGDP related activities will have a negative impact on public healthcare infrastructure in Garrett and Allegany Counties. Should Maryland move forward with UNGDP, the following recommendations should be implemented to prevent or minimize potential negative impact on public health.

R40. Closely monitor whether prospective UNGDP companies provide adequate health insurance coverage for all employees.

Insured workers using healthcare services could offer positive support to existing systems as long as their rate of utilization is within the scope of available capacity. Uninsured workers, like any other uninsured population, would place stress health care infrastructure due to their inability to pay for services.

R41. Organize a local health care forum with key stakeholders to assess health care services and anticipated needs related to UNGDP.

The use of primary and public health care systems, especially in the areas of emergency, urgent care, and trauma care, may rise as a result of an increase in the UNDGP workforce. It is important to assess current healthcare infrastructure capacity to meet these anticipated needs.

R42. Inform and train emergency and medical personnel on specific medical needs of UNGDP workforce.

UNGDP workers have specific emergency, urgent, and trauma care needs due to higher rates of occupational related incidents and injuries and providers most likely to service UNGDP workers (e.g., emergency personnel and trauma specialists) should be adequately prepared and trained to respond to their needs.

R43. Review and monitor county-level tax revenues and assess improvements necessary to meet increased services need.

Prioritizing health infrastructure at a high level when appropriating local government revenues derived from UNGDP and engaging in long-term planning for healthcare infrastructure development is critical to alleviating existing and anticipated healthcare infrastructure pressures.

R44. Establish a committee of state and local stakeholders (including UNGDP officials and local providers and residents) for early identification of impacts to healthcare infrastructure.

Previous research indicates that healthcare infrastructure impacts will be concentrated during the first phase of UNGDP, when labor needs are high and larger numbers of workers are expected. Initiating ongoing monitoring of healthcare infrastructure utilization rates by collecting information on patients' occupational status is strongly recommended along with close monitoring of healthcare infrastructure access with attention to emergency and trauma care and vulnerable populations.

R45. Initiate monitoring of UNGDP healthcare-related costs.

There is a critical data gap of evidence-based research and monitoring around healthcare-related costs of UNGDP. Economic analysis of medical and healthcare infrastructure costs of increased disease rates and injuries from UNDGP should be initiated.

12.9 Cumulative Exposure/Risk

The combination of chemical, physical, and psychosocial stressors can lead to effects that are cumulative involving potentially additive or multiplicative interactions among the exposures. Observed health impacts, if any, will result from these cumulative impacts. Most of the recommendations in this report are targeted at primary prevention (i.e., to prevent the occurrence of adverse health effects). However, a monitoring method is needed to verify the effectiveness of primary prevention activities and to improve them as necessary. Furthermore, secondary and tertiary prevention should not be neglected. Thus, disease surveillance and targeted longitudinal epidemiologic studies are needed for both evaluation of primary prevention effectiveness and as a means of providing continuing improvement of regulations. Surveillance and epidemiologic studies will need to incorporate appropriate exposure assessment programs, and to be most useful, need to be started immediately so as to provide comparable baseline data in the event that Maryland decides to move forward with UNGDP at some point in the future.

R46. Initiate a birth outcomes surveillance system

Birth outcomes are strongly influenced by exposures occurring during pregnancy, and thus are potentially one of the earliest health effects that might occur as a result of exposures generated by new development. Recent studies (see Section 10.3.1.4) have suggested an association of adverse birth outcomes with UNGDP close to the mother's residence. Therefore, we recommend development of an intensive birth outcomes surveillance system in Garrett and Allegany counties.

R47. Initiate a longitudinal epidemiologic study of dermal, mucosal, and respiratory irritation

Skin rashes and eye, nose, throat, and airway irritation symptoms have been associated with UNGDP (see section 10.3.1.4). Skin, mucosal, and respiratory symptoms such as these can be early indications of exposure and adverse health effects and can occur relatively soon after the start of exposure (days to a few months) compared with other effects, especially cancer, that can have latency periods of years to decades. Therefore, we recommend that the State undertake a longitudinal epidemiologic study of dermal, mucosal, and respiratory irritation in Garrett and Allegany counties.

R48. Develop funding mechanism for public health studies

The surveillance and epidemiologic studies will need to be funded. Some funding may be achieved by collaboration with academic researchers in support of applications for federal funding. However, the State should also develop its own funding through mechanisms such as filing fees for the CGDP, well permits, and severance taxes.

12.10 Occupational Health

Based on our evaluations of the limited but emerging studies of UNGD workers' exposures to respirable crystalline silica (frack sand) and what is known from epidemiologic and toxicological studies of crystalline silica (silicosis, lung cancer), we conclude that there is a **High Likelihood** of adverse outcomes among UNGDP workers in Garrett and Allegany Counties. Should

Maryland move forward with UNGDP, the following recommendations are made to prevent most and minimize residual potential negative impacts on occupational health.

R49. Require implementation of NIOSH and OSHA recommended controls for silica exposure in UNGD operations.

Following the NIOSH study of UNGDP workers, NIOSH and OSHA have provided extensive recommendation to minimize workers' exposure. These recommendations should be implemented.

R50. Provide MOSH with resources to regularly inspect UNGD workplaces and monitor worker exposures.

MOSH should provide resources to implement the NIOSH and OSHA recommended controls for silica exposure as well as workers exposure to other hazards including noise, VOCs, and PAHs.

R51. Establish community outreach programs to help transient workers feel more welcome in the community as a means of reducing rates of depression, suicide, and drug use.

Transient workers suffer from depression, suicide, and drug use to cope with social isolation. We recommend initiating, to the extent possible, outreach programs designed to help workers adapt to their new community environment.

R52. Require employers to provide employee assistance programs including counseling and substance abuse treatment.

In addition to the community, employers should also provide assistance to the employee to cope with the new community environment. It should also include counseling services to deal with depression, suicide, and drug use.

13 LIMITATIONS

As stated in the MOU the "project is designed to provide a baseline assessment of current regional population health, an assessment of potential public health impacts, and possible adaptive and public health mitigation strategies in the event that natural gas extraction takes place within Maryland's Marcellus Shale resource." In particular, the project is not designed to make recommendation about whether or when to allow unconventional natural gas development and production (UNGDP) in Maryland. Rather this study is designed to inform decisions by clearly describing the potential public health impacts and make recommendations for minimizing them, should the decision makers move ahead with UNGDP in Maryland.

Given the short timeframe, the study team made extensive effort to stay within the scope of tasks identified within the MOU. This section identifies limitations of this report, some of which are related to the process itself, while others are related to lack of available data.

- HIA is a relatively new practice. As such, one major limitation is the lack of consistent methods that are universally accepted. As such, comparison between HIA, including ranking of hazards is not straightforward.
- There is a lack of monitoring data available in the literature that has evaluated the impact of UNGDP on air and water quality, based on the measurements taken before UNGDP related activities as well as during the development and production phase. Limited data available to date have focused on spatial contrast (i.e., UNGDP impacted areas vs control sites), as opposed to temporal contrast (data from same site looking at before, during and after UNGDP related activities).
- With the exception of crystalline silica exposure among workers, very little data is available on individual level exposure to both physical and chemical hazards associated with UNGDP related activities.
- The NIOSH study documenting overwhelming level of occupational exposure to respirable crystalline silica draws attention to the potential exposure that may be taking place among nearby residents. Respirable fraction of crystalline silica particles are small enough to travel to nearby communities, where they may disproportionately impact vulnerable populations. So far, the scientific literature has overlooked this potential exposure, and as such we could not evaluate this issue.
- Epidemiological investigations of health outcomes related to UNGDP related activities/hazards is extremely limited, with noted exception of adverse birth outcomes.
- Baseline health assessment did not include health survey for population of concern.
- We conducted noise monitoring in the UNGDP impacted community in WV. This was the only primary data we collected. All other evaluations are based on existing data available through literature review.
- Quantitative health risk assessment and cumulative risk assessment were beyond the data and time resources available to us.

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15 APPENDIX 1: Baseline Health Assessment

15.1 Overview of Allegany and Garrett Counties

15.1.1 Geography

15.1.1.1 Allegany County

Allegany County with a population of 75,087 individuals is located in the northwestern part of Maryland and is 424.16 square miles. Positioned in the Ridge-and-Valley Country of the Appalachian Mountains, it is bordered to the north by the Mason-Dixon Line along with Pennsylvania. To the south, it is surrounded by the Potomac River and West Virginia. To the west is the Allegheny Front, and to the east is Frostburg, MD. The cities, towns & census designated places incorporated municipalities the makeup Allegany County and this include:

Barrelville
Barton*
Bel Air
Bier
Bowling Green
Bowman's Addition
Carlos
Clarysville
Corriganville
Cresaptown
Cumberland*
Danville
Detmold
Eckhart Mines
Ellerslie
Flintstone
Franklin
Frostburg*
Gilmore
Grahamtown
Klondike
La Vale
Little Orleans
Lonaconing*
Luke*
McCoole
Midland*
Midlothian
Moscow
Mount Savage
Nikep
Ocean
Oldtown
Pleasant Grove
Potomac Park
Rawlings
South Cumberland
Spring Gap
Vale Summit
Westernport*
Woodland
Zihlman

Incorporated Places have an asterisk (*)

15.1.1.2 Garrett County

Garrett County with a population of 30,097 individuals is the western-most county in Maryland, and it's bordered to the north by the Mason-Dixon Line with Pennsylvania, to the south by the Potomac River and West Virginia. Garrett County is 647.10 square miles of incorporated and unincorporated jurisdiction divided into several neighborhoods, the names of which are:

Accident*
Bloomington
Crellin
Deer Park*
Finzel
Friendsville*
Gorman
Grantsville*
Hutton
Jennings
Kitzmiller*
Loch Lynn Heights*
Mountain Lake Park*
Oakland
Swanton

Incorporated Places have an asterisk (*)

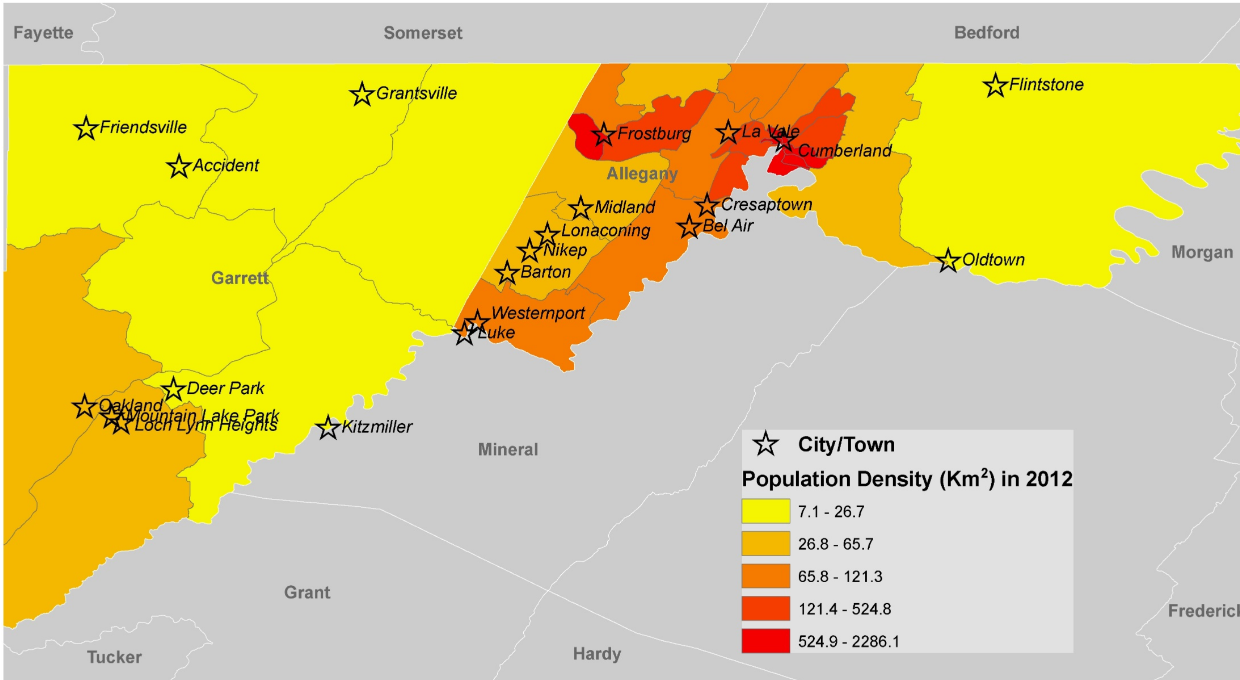


Figure 15-1: Major Cities and Towns in Allegany and Garrett Counties

Figure 15-1 displays the locations of major cities and towns in Allegany and Garrett Counties in relation to population density. We observe that there are almost 15 major cities and towns in Allegany Counties with several having a population density greater 525 people/km^2. The two largest cities (Frostburg and Cumberland) that have high population densities are located in the central and northwestern parts of the county. In contrast, there are only a few major towns in Garrett County with most located in low population density census tracts (< 26.7 persons/km^2).

15.1.2 Schools

Allegany County has fourteen elementary schools, four middle schools, three high schools, one technical education school, and one alternative program in the county [212]. They include:

Elementary School

- Beall Elementary School (451)
- Bel Air Elementary School (215)
- Cash Valley Elementary School (320)
- Cresaptown Elementary School (362)
- Flintstone Elementary School (227)
- Frost Elementary School (233)
- George's Creek Elementary School (316)
- John Humbird Elementary School (291)
- Northeast Elementary School (315)
- Parkside Elementary School (256)
- South Penn Elementary School (497)
- West Side Elementary School (381)

- Westernport Elementary School (277)

Middle School

- Braddock Middle School (573)
- Washington Middle School (695)
- Westmar Middle School (282)
- Mount Savage School (K-8) (401)

High School

- Allegany High School (672)
- Fort Hill High School (754)
- Mountain Ridge High School (840)
- Center for Career & Technical Education (304)
- Eckhart Alternative Program (67)

Garrett County has eight elementary, two middle, and two high schools. They currently include:

Elementary

- Accident Elementary School (235)
- Broad Ford Elementary School (631)
- Crellin Elementary School (109)
- Friendsville Elementary School (132)
- Grantsville Elementary School (227)
- Swan Meadow Elementary School (36)
- Yough Glades Elementary School (329)

Middle

- Northern Middle School (323)
- Southern Middle School (538)

High

- Northern High School (495)
- Southern Garrett High School (695)

15.1.3 Hospitals

Currently in Allegany County, the Western Maryland Health System (WMHS) offers a continuum of care ranging from primary care to nursing home services. Services include acute and chronic care, community health and wellness, clinical prevention, care coordination, home care, community health workers, and provider recruitment. In addition, WMHS is the only licensed hospice care facility in Allegany County and operates a regional medical center consisting of a 275-bed hospital in Cumberland, along with two diagnostic centers, a nursing and rehabilitation center in Frostburg, a community health and wellness center, two urgent care centers, and three primary care centers. WMHS is also a Level III trauma center, the only trauma center in Western Maryland.

In Allegany County, the State of Maryland also owns and operates the Thomas B. Finan Center, an inpatient psychiatric facility with 80 beds, in Cumberland. It provides services to those 18 years of age and older and includes inmates with criminal histories, non-criminals who have been involuntarily committed, and voluntary patients.

In Garrett County, Garrett County Memorial Hospital (GCMH) runs a 55-bed, not-for-profit, acute care hospital facility, including a 10-bed sub-acute rehabilitation unit. GCMH is the only hospital in the region, serving a population of 31,000, including residents of Garrett County and communities in the surrounding West Virginia counties. Services at the Hospital include a 24-hour emergency department; inpatient care; observations services; obstetrics; pediatrics; medical/surgical intensive care unit; operating room: radiology; lab; cardiopulmonary services; as well as community and worksite wellness; safe sitter; and CPR programs and other ancillaries.

15.1.4 Important Landmarks

Garrett County has over 76,000 acres of parks, lakes, and publicly accessible forestland. Nicknamed Maryland's "Mountaintop Playground," the county has the state's highest elevation at 3,360 feet, as well as its largest inland body of water (Deep Creek Lake). Garrett County is home to the state's only sub-arctic wetlands and is the only county in the state to produce natural gas.

According to the National Register of Historic Places listings, Garrett County

has 20 historic landmarks. These include:

The Anderson Chapel
Baltimore and Ohio Railroad Station, Oakland
Bloomington Viaduct
Borderside
Casselman's Bridge, National Road
Creedmore
James Drane House
Fuller-Baker Log House
Garrett County Courthouse
Glamorgan
Hoye Site
Inns on the National Road
Kaese Mill
Mercy Chapel at Mill Run
Meyer Site
Mountain Lake Park Historic District
Oakland Historic District
Pennington Cottage
Stanton's Mill
Tomlinson Inn and the Little Meadows

According to the National Register of Historic Places there are 44 historic landmarks in Allegany County. They include:

16 Altamont Terrace
200-208 Decatur Street
African Methodist Episcopal Church
B'er Chavim Temple
Barton Village Site
Bell Tower Building
Big Bottom Farm
Borden Mines Superintendent's House
Breakneck Road Historic District
Wright Butler House
Canada Hose Company Building
Chapel Hill Historic District
Chesapeake and Ohio Canal National Historical Park
City Hall
Michael Cresap House

Cumberland YMCA
Decatur Heights Historic District
Downtown Cumberland Historic District
First Baptist Church
Folck's Mill
Footer's Dye Works
Frostburg Historic District
Greene Street Historic District
Francis Haley House
Hocking House
Inns on the National Road
Klots Throwing Company Mill
Thomas Koon House
La Vale Tollgate House
Lonaconing Furnace
Lonaconing Historic District
Maryland Railway Station
Mount Savage Historic District
Old National Pike Milestones
Phoenix Mill Farm
Public Safety Building
Rolling Mill Historic District
Shaw Mansion
Shawnee Old Fields Village Site
Town Clock Church
George Truog House
Union Grove Schoolhouse
Washington Street Historic District
Waverly Street Bridge
Western Maryland Railroad Right-of-Way, Milepost 126-Milepost 160
Western

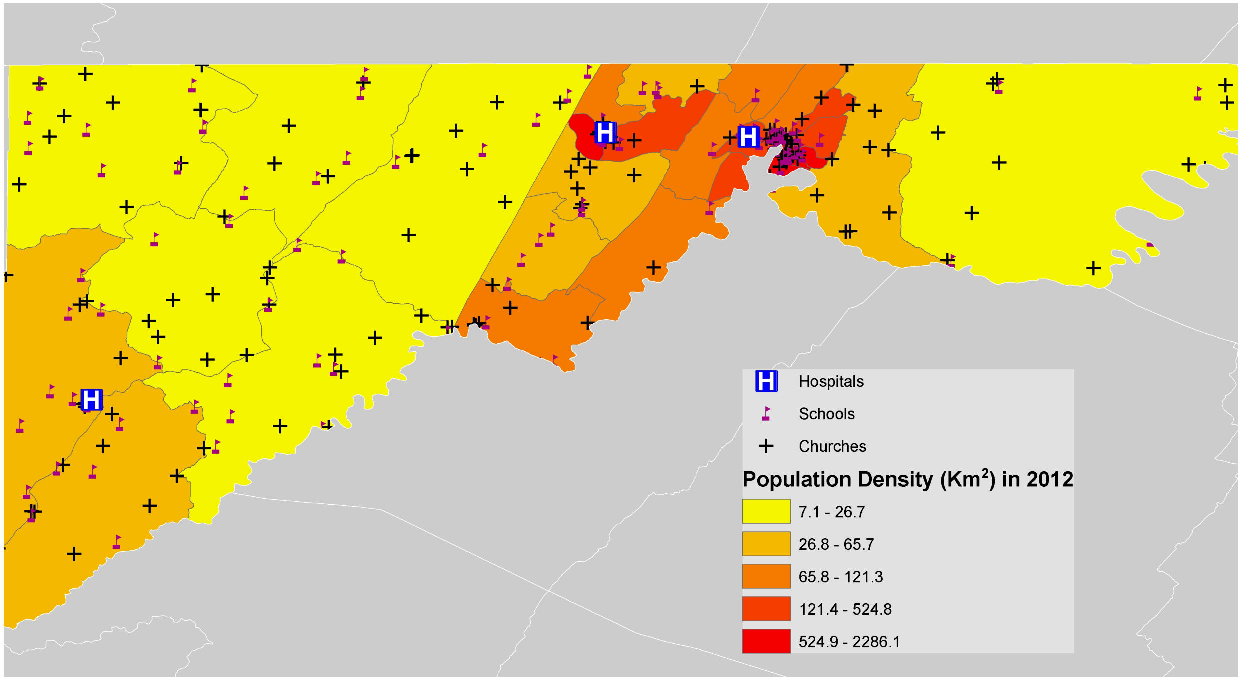


Figure 15-2: Location of Community Assets and Sensitive Human Receptors

Figure 15-2 shows the distribution of community assets and sensitive human receptors including hospitals, schools, churches, and parks in Allegany and Garrett. There are approximately 153 churches and 87 schools in both counties. In Allegany county, the majority of the schools and churches are located in central and western part of the county where there is a higher population density compared to the eastern part of the county. For Garrett County, schools and churches are dispersed somewhat evenly throughout the county, which has very few people as illustrated by the low population density on the map. On the map, we also observe that there are four hospitals in the western part of Allegany County in or near census tracts with high population density. There is only one hospital in Garrett County located in the southwestern part of the county.

Figure 15-2 is important because it illustrates the spatial distribution of sensitive non-residential land uses in the two counties. These land uses are important features of community ecosystems in both counties and act as health promoting elements of the local infrastructure. It is important to note that at these sensitive human receptor locations, there will be vulnerable populations including children, elderly, and individuals with underlying disease who could be at risk from UNGDP activities particularly air pollution near well pads and pollution emitted from diesel truck traffic. In addition, there are small and large parks in both counties that act as ecologic amenities for local populations. These parks act as recreational resources, contribute to local aesthetics, and contribute to health particularly mental health and quality of life for residents. UNGDP activities have the potential to reduce air quality near the parks, have negative ecologic impacts, and reduce the use of the parks for recreational use.

15.2 Demographics

The 2012 U.S. Census was used to obtain the most accurate population counts as well as information on age, gender, and racial composition of Garrett County. The population of Garrett County was defined from the population living in the following zip codes: 21520, 21521, 21522, 21523, 21531, 21532, 21536, 21538, 21539, 21541, 21550, 21561, and 21562.

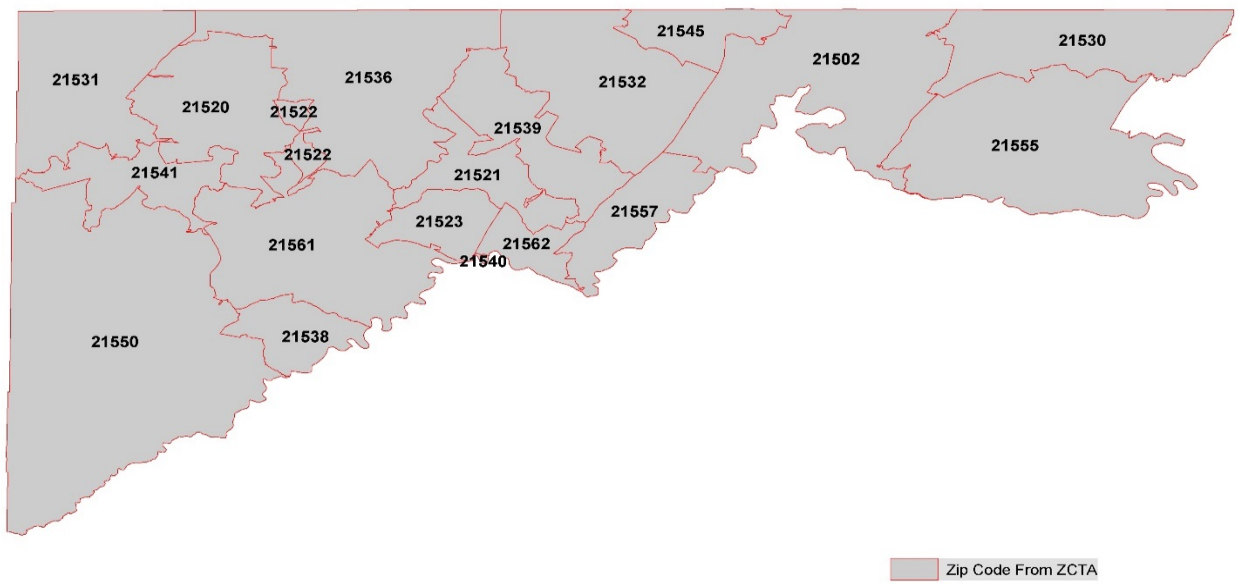


Figure 15-3: Map of Zip Codes in Allegany and Garrett Counties

According to the 2012 U.S. Census, 50.4% of the populations were female and 49.6% were male. 27.1% of the population were under the age of 18, while 17.7% of adults were 65 years and older. Of those reporting race in Garrett County, 97.2% identified themselves White, 1% as African-American, 0.8% as Hispanic and 1% as other. 3.7 percent of the population was unemployed and 13% of the residents were living in poverty. The median income for resident is approximately $45,354, which is higher than the regional average of $39,026.

In Allegany County, the population was defined using the following zip codes: 21502, 21521, 21530, 21532, 21539, 21540, 21545, 21545, 21555, 21557, 21562, 21766, 21501, 21503, 21504, 21505, 21524, 21528, 21529, 21542, 21543, 21556, and 21560. The 2012 U.S. Census was also used to obtain the most accurate population counts as well as information on age, gender, and racial composition of Allegany County. In 2012, the US Census estimated that 48% of county residents were female, and 52% were male. In addition, 18% of the population were under the age of 18, while 18.1% were 65 years and older. For those who reported their race, 88.3% identified themselves as white, 7.6% as African-American, 1.5% as Hispanic and 2.6% as other. In comparison to Garrett County 13%, 16.1% of residents live at or below poverty. The median income in Allegany County is $39,087, compared to the Maryland state average of $68,559.

Table 15-1: Demographics, US Census 2012

Demographic	**Allegany**		**Garrett**		**Maryland**		**Region**	
Category	%	Total	%	Total	%	Total	%	Total

Age < 5	4.6	3,399	5.1	1,537	6.3	365,258	4.9	23,329
Age < 18	18	13,404	21.7	6,530	23.3	1,350,703	20.1	94,998
Age > 65	18.1	13,537	17.7	5,325	12.4	715,726	18.1	85,515
Non-Hispanic White	88.3	65,921	97.2	29,245	54.7	3,163,295	93.9	444,592
Non-Hispanic Black	7.6	5,636	1	288	29	1,675,532	3.4	16,021
Hispanic	1.5	1,089	0.8	227	8.2	472,285	1	4,707
Other	2.6	1,999	1	319	8.2	474,384	1.7	7,985
Less than HS	13.1	6,772	15.1	3,173	11.5	445,826	15.5	52,572
Unemployment	4.9	3,084	3.7	897	5.4	246,720	4.7	18,475
Poverty	16.1	10,740	13	3,797	9.4	532,116	15.6	70,719
Units Built pre-1950	57.9	19,270	27.1	5,107	30.8	731,553	44.7	103,168
Occupied By Owner	85.7	28,537	65.5	12,354	89.9	2,138,806	81.5	188,100
Median HH Income	$39,087		$45,354		$68,995		$39,026	
Per Capita Income	$21,677		$24,904		$32,520		$20,936	

When comparing Allegany and Garrett Counties, Garrett County had the highest number of residents with less than a high school education (15%). In addition 57.9% of Allegany County residents resided in units built before 1950, which is higher than Garrett County (27.1%), the state (30.8%) and the region (44.7%). 85.7 percent of homes were occupied by the owner in Allegany County compared to the region whose average was slightly lower at 81.5%. Garrett had the lowest number of percentage of owners at 65.5%.

15.3 Vulnerable Populations

It is important to recognize underlying social, economic, geographic, and individual level vulnerabilities that may increase risk of disease and premature mortality for populations in Garrett and Allegany counties. Vulnerability has been defined as how individuals or groups of individuals or organisms respond to and recover from stressors inadequately or not as well as the average [19, 20]. Vulnerability factors include characteristics, individual level and/or community level that moderate the effect of environmental hazards on community health and well-being. Individual level vulnerability factors influence the individual's response to stressors. Demographic factors of interest when assessing vulnerability include race, ethnicity, age (e.g., children, elderly), and sex [7]. Some biologic factors include genetic make-up and pre-existing medical conditions [213]. Genetic polymorphisms have been implicated in the etiology of carcinogenesis when exposed to toxic pollutants [214, 215]. Pre-existing conditions and age have also been associated with reduced response to stressors [216].Non-biologic factors such as resilience, a pattern of positive adaptation in the context of significant risk or adversity [217] has been identified as protective against stress [218]. Other individual level vulnerability factors, low socioeconomic status, low educational attainment [219], and psychosocial stress [213] have also been associated with negative health outcomes. Psychosocial stressors act synergistically to raise levels of stress, increase vulnerability, and limit capacity of burdened populations to overcome disease and improve health status [213]. Health behaviors also play a role in increasing or decreasing an individual's vulnerability. For example, individuals who smoke, use alcohol, consume unhealthy foods, or lead sedentary lifestyles have a higher risk of cancer, diabetes, obesity, and lower life expectancy compared to other groups. In this HIA, we are limited to assessing vulnerability using sociodemographic data and some county level health data. We will not have access to individual health data including family history of disease for populations in both counties.

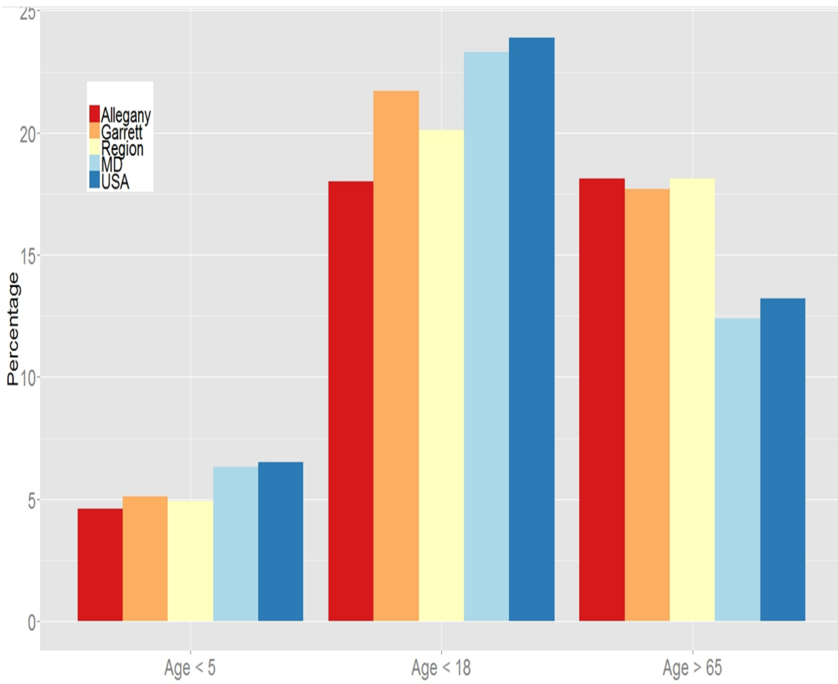


Figure 15-4: Age Distribution for Allegany and Garrett Counties, Maryland, the Region, and the U.S., Source: U.S. Census 2012

15.3.1 Age

In Figure 15-4, we observe a small percentage of children less than age 5 in Garrett and Allegany counties compared to Maryland and the United States. We also observe a `high percentage of children less than age 18 in Garrett County compared to the region and Allegany County. These percentages were somewhat lower than the percentages for Maryland and the United States. For both Allegany and Garrett counties, there is a high percentage of the population (approximately 18%) over the age of 65. Elderly residents may be more vulnerable to exposure to chemicals in air and water due to compromised immune systems and comorbidities. Compared to adults, young children are more susceptible to the potential effects of environmental contaminants because of their higher consumption, metabolic and ventilation rates relative to their body mass [220–223]. Chemical exposures in early childhood could pose long-term health consequences because young children are in a state of rapid growth [220–223]. Exposures in these sensitive developmental windows could lead to poor health outcomes during their non-adult years and chronic health outcomes over their life course. Additionally, young children have unique behavioral and activity patterns that may predispose them to higher exposures. Other factors that make them susceptible to the potential effects of environmental exposures include the fact that: they may explore their world by mouthing objects [222, 223]; they are closer to the ground where they may come into contact with contaminated surfaces; they eat, drink, and breathe more per unit body weight compared to adults; their body systems including nervous, immune, and reproductive systems are still developing; and their detoxification mechanisms may not be fully developed [220, 223–225]. Children can be exposed to a wide range of potentially toxic compounds including metals, PAHs, PCBs, PBDEs, pesticides among other chemicals at their homes, gardens/yards, and school/child cares and these exposures have a longer time to manifest into adverse outcomes [226]. Both elderly populations and children less than age 18 should be viewed as sensitive human receptors in Western Maryland.

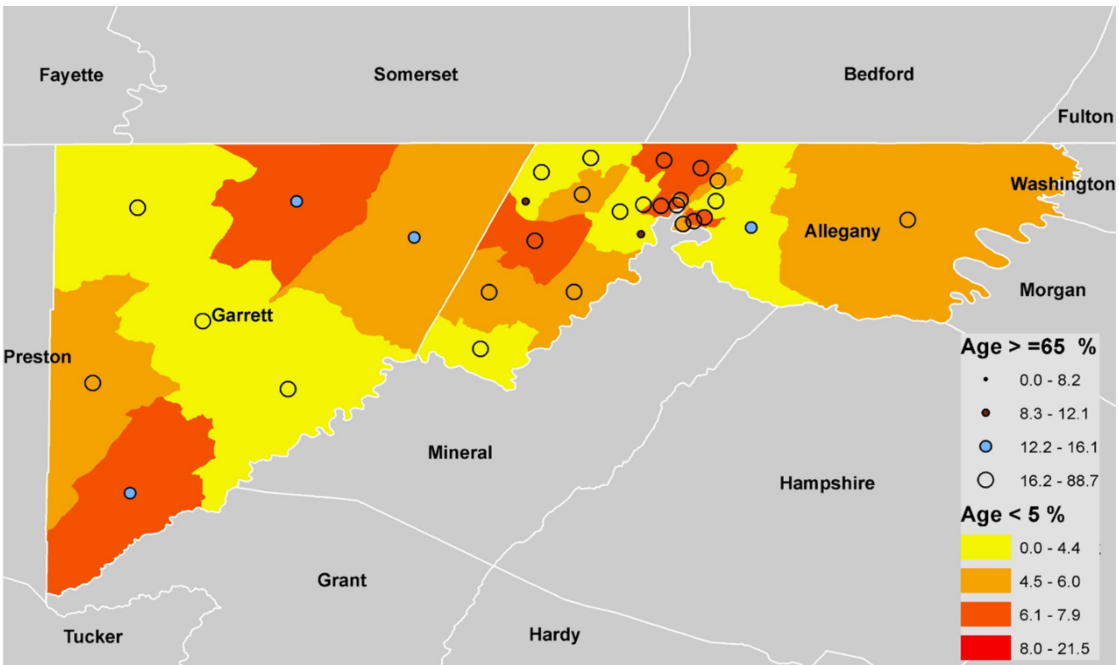


Figure 15-5: Children Less than Age 5 and Adults Greater than 65 in Allegany and Garrett Counties, Source: U.S. Census 2012

In Figure 15-5, we observe that there is a cluster of individuals over the age of 65 who live in central, northwestern, and southwestern parts of Allegany County. We also observe a high percentage of individuals over the age of 65 in the northwestern, central, and southern parts of Garrett County. This population may be more vulnerable and have higher health risks due to their health status, weakened immune systems, and co-morbidities. Additional steps must be taken to ensure that this population has access to appropriate medical care and other resources needed to improve health and quality of life.

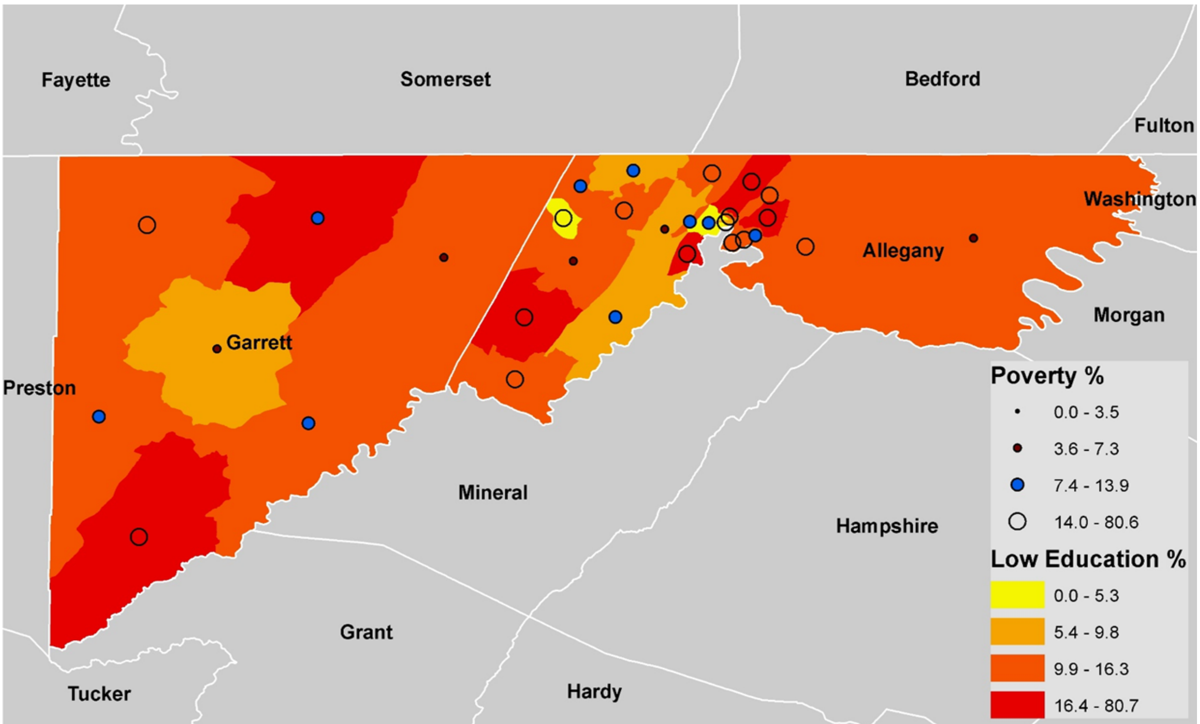


Figure 15-6: Comparison of Percent Poverty and Percent Less than High School Education for Allegany and Garrett Counties, Source: U.S. Census 2012

15.3.2 Socioeconomic Status

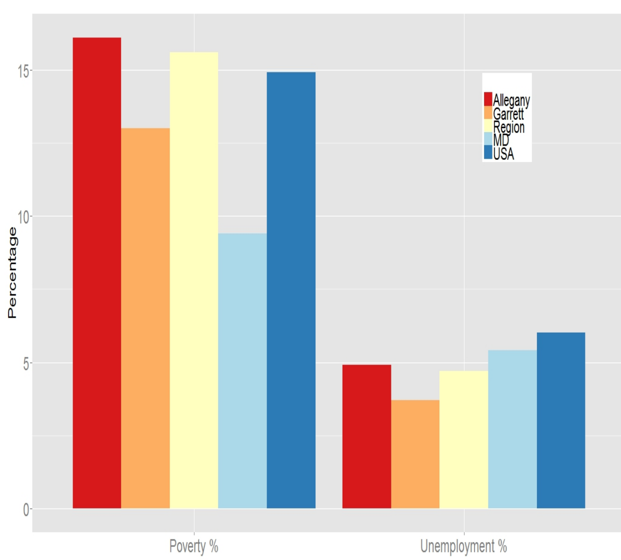


Figure 15-7: Percent Poverty and Unemployment for Allegany and Garrett Counties, Maryland, the Region, and the U.S., Source: U.S. Census 2012

Figure 15-7 shows the spatial relationship between percent poverty and percent low educational attainment (e.g., less than high school education). We observe clusters of high percentages of persons in poverty and with less than HS education in Central and Western Allegany County. We also observe high percentage of individuals without a high school diploma in the north central and south central portions of Garrett County with a large percentage of persons in poverty in the northwestern part and south central portion of the county. Overall, there are a large number of individuals with less than a HS education. The map illustrates the area has an underserved population that lacks economic opportunities. Although both Garrett and Allegany counties had lower unemployment rates compared to the region, the state of Maryland, and the United States, limited educational attainment indicates that the population may only have access to low wage jobs and the population has limited economic mobility since the poverty rates for these counties are high. Over 15% of the population in Allegany County is below the federal poverty level which was higher than the poverty rate for Garrett, the region, Maryland, and the US.

Individuals living below the federal poverty line may have access to fewer resources such as insurance and health care, higher exposure to social stressors, and may not have opportunity to move away from industrial pollution sources. Additional steps must be taken to ensure that this population has access to appropriate medical care and other resources needed to improve health and quality of life [213].

15.4 Environmental Health

The U.S. Environmental Protection Agency (EPA), under the authority of the Emergency Planning and Community Right-to-Know Act (42 USC §11004-11049 [1986]) established the toxic release inventory (TRI) database through section 313 [227–229]. It requires that major industrial facilities that use more than 10,000 pounds or process more than 25,000 pounds of any of the 650 TRI chemicals report their releases and waste management strategies [227]. We extracted 2013 TRI data from an EPA database by using the EPA's TRI Explorer. Superfund data was obtained from the USEPA's Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) public access database, which contains "non-enforcement confidential" information on hazardous waste sites, potentially hazardous waste sites, and remedial activities as well as those noted on the National Priority List. As authorized by the Clean Water Act, the National Pollutant Discharge Elimination System (NPDES) permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States. Industrial, municipal, and other facilities must obtain permits if their discharges go directly to surface waters [230]. The EPA defines a brownfield as "a property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant" [231]. The EPA estimates that more than 450,000 brownfields exist in communities across the US with many in economically depressed rural and urban neighborhoods [231–233]. The EPA defines an Underground Storage Tank (UST) as any underground piping connected to a chemical storage tank with at least 10% of its combined volume underground [234]. Although there are many types of USTs classifiable by their contents, only sites containing hazardous substances are regulated by both the EPA and state agencies such as MDE [234]. Despite the EPA's efforts to manage USTs, 95% of all regulated USTs contain petroleum derivatives. When an UST leaks, it is then known as a Leaking Underground Storage Tank (LUST) [234]. In the event of a leak, air, groundwater, and soil contamination may become potential hazards for residents who live near these sites [234]. We obtained 2013 point location data for TRI facilities, Superfund sites, brownfields, LUSTs, and NPDES permitted facilities from the EPA. We also obtained information on the point location of conventional wells in Garrett County from a 1980 report [235].

We mapped all of the point locations for these facilities and land uses using ArcGIS. In addition, we used ArcGIS to construct overlays of the facility and land use data in relation to population density (persons/km^2) at the census tract level using 2012 American Community Survey five-year estimates (US Census).

Figure 15-8 shows the spatial distribution of conventional gas wells, Superfund sites, brownfields, LUSTs and TRI facilities in Allegany and Garrett counties. The illustration shows the overall burden of the facilities and land uses in both counties. Approximately 210 conventional gas wells were mapped in Garrett County. The wells are unevenly distributed throughout the county. Two large clusters are located in the northwestern quadrant of the county near Friendsville and Accident (see Figure 15-8) in an area with the lowest population density (less than 26.7 persons/km^2). While a heavily concentration of wells is clustered around the south central region of the county near Oakland, Mountain Lake Park, and Loch Lynn Heights. This area is more populated (26.8-65.7 persons/km^2) in comparison to the Accident/Friendship region.

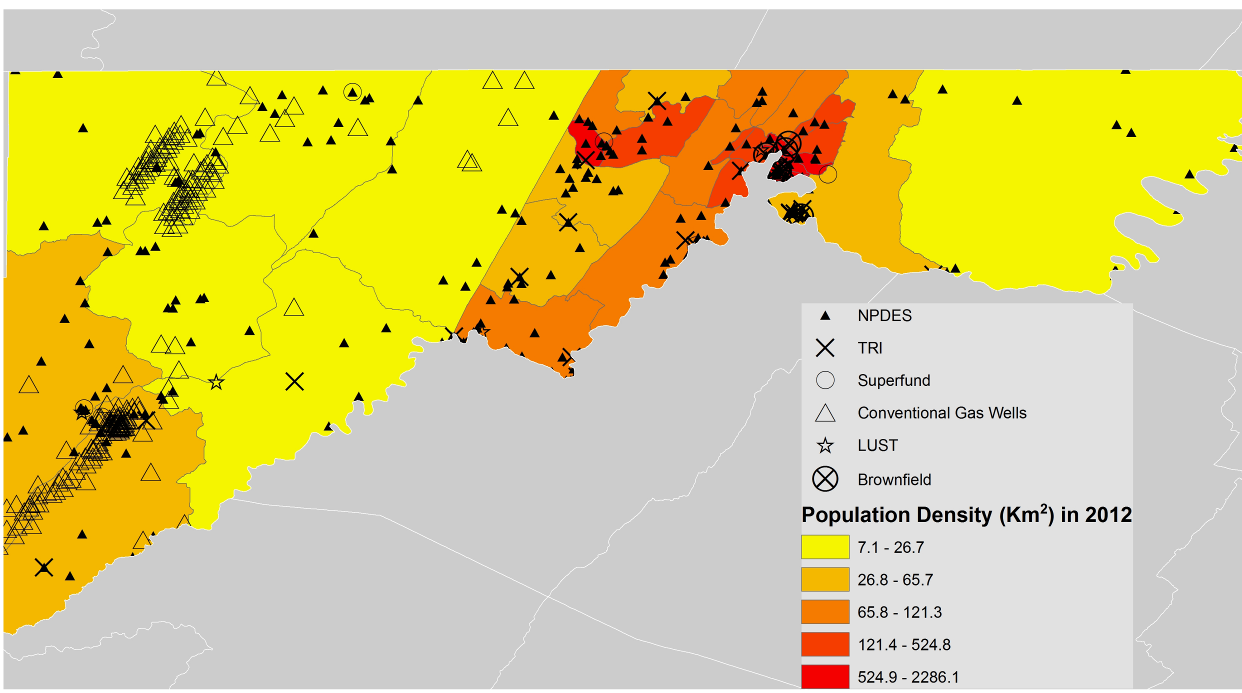


Figure 15-8: Spatial Distribution of Conventional Gas Wells, NPDES-Permitted Facilities, Superfund Sites, Brownfields, LUSTs, and TRI Facilities in Allegany and Garrett Counties

A total of 101 facilities with NPDES permits are located in Allegany County, while 74 are located in Garrett County. In Allegany, NPDES permitted facilities are primarily located in the central, western, and southwestern parts of the county. Major clusters of the NPDES permitted facilities were in Frostburg and Cumberland. Thirteen TRI facilities are located in Allegany County, while three are located in Garrett. Similar to the spatial distribution of the NPDES permitted facilities, the majority of the TRI facilities are dispersed in the central, western, and southwestern portions of Allegany County in or near local cities and towns such as Frostburg, Cumberland, Midland, and Barton. Three Superfund sites are located in Garrett County with two in Oakland in the southwestern part of the county and one in Grantsville in the northern part of the county. Two Superfund sites were found in Allegany with one located in Frostburg and one located in the Cumberland area. Three LUSTs were located in Allegany County, while two LUSTs were located in Garrett County. A total of six brownfields were found in Allegany County with zero located in Garrett County. The majority of the brownfields were located in a high population density census tract in the Cumberland area (central Allegany).

Figure 15-8 illustrates the cumulative burden of various facilities that emit toxic compounds to the air, water, or soil or if there is a breach or leak could have a negative impact on the environment and the health of the public. Previous research has shown that low-income populations, marginalized, and underserved groups such as some of the populations in Allegany and Garrett counties, live in communities that experience a disproportionate risk from the burden of and exposure to environmental hazards including noxious land uses such as landfills, incinerators, brownfields, Publicly Owned Treatment Works (POTWs) (e.g., sewer and water treatment plants), Superfund sites, TRI facilities, energy production facilities, chemical plants, heavily trafficked roadways, LUSTs, and other locally unwanted land uses (LULUs) [213, 236–242]. This disproportionate burden and proximity to one or more pollution sources may lead to an increase in exposure to adverse environmental conditions and contaminants for impacted populations and communities.

15.4.1 Drinking Water

A large proportion of Marylanders currently rely on unregulated private wells as sources of drinking water. An estimated 1.1 million Maryland residents draw drinking water from private wells [21]. Since private wells that serve less than 25 people are not regulated by the federal Safe Drinking Water Act, residents who rely on a private well system for their home drinking water supply have the responsibility of managing the quality of their private well to ensure that it meets drinking water safety standards [59]. As a result of improper well maintenance and testing, a significant proportion of Maryland well owners could be exposed to elevated concentrations of microbiological, chemical and or heavy metal contaminants in their drinking water. Moreover, previous research conducted in our group has provided evidence that groundwater drawn from Maryland aquifers in the Monocacy River basin in Western Maryland are impacted by elevated levels of fecal indicator bacteria, including antibiotic-resistant *Enterococcus* spp [243]. Elevated levels of nitrates and other chemicals have also been noted in Maryland groundwater; however, as mentioned above, comprehensive data regarding the quality of groundwater consumed by private well owners (over 1 million Marylanders) does not exist [22, 23]. Figure 15-9 illustrates that private wells are concentrated most heavily around McHenry, Grantsville and Oakland. Over 14,200 will location records are currently available for Garrett County [244]. Approximately, 8,250 or 58% of well records occur in grid cells that contain Marcellus shale gas leases [244]. Previous studies indicate that private and public wells in close proximity to active gas wells may pose a risk to the health of residents who rely on wells as their primary drinking water source [83, 84].

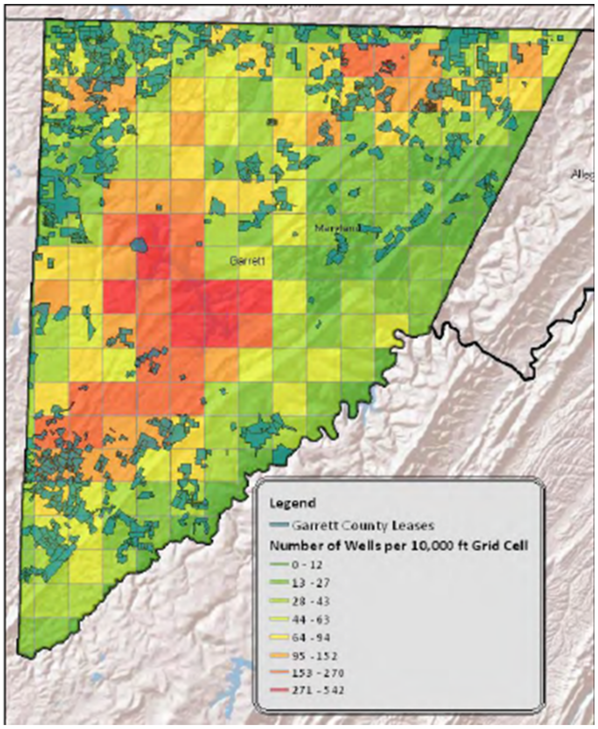


Figure 15-9: Location of Private Wells in Garrett County

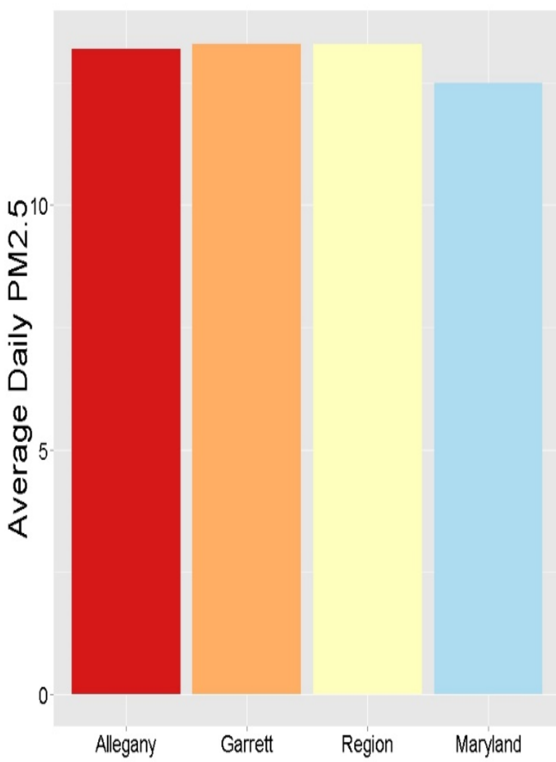


Figure 15-10: Average Daily PM2.5 Concentrations, 2011

15.4.2 Air

A wealth of scientific literature has shown relationships between PM exposure (e.g., coarse or fine particles, acute or chronic) and increased respiratory and cardiovascular health end points including increased mortality, hospital admissions, and emergency department visits [45, 46, 245–255]. Scientific literature suggests that exposure to PM may be associated with decreased lung function and increases in respiratory disease and symptoms such as asthma in children and children with asthma may have the greatest risk to $PM_{2.5}$ [256–266]. Other studies have shown that particulate matter contributes to higher cardiovascular mortality risks in elderly patients and sensitive populations particularly those with co-morbidities.

While no direct asthma data was collected, the average daily $PM_{2.5}$ concentrations were gathered (Figure 15-10). Studies have shown that $PM_{2.5}$ levels are associated with asthma development and increased asthma admissions to hospital emergency departments [267], so $PM_{2.5}$ concentrations may be an important issue for populations with persistent asthma. Across the groups, $PM_{2.5}$ concentrations were very high, with Allegany and Garrett counties almost equal to each other and the region $PM_{2.5}$ concentrations, all of which are higher than the $PM_{2.5}$ concentrations across Maryland. This is in line with the national trend that indicates asthma incidence nationally is on the rise [268, 269].

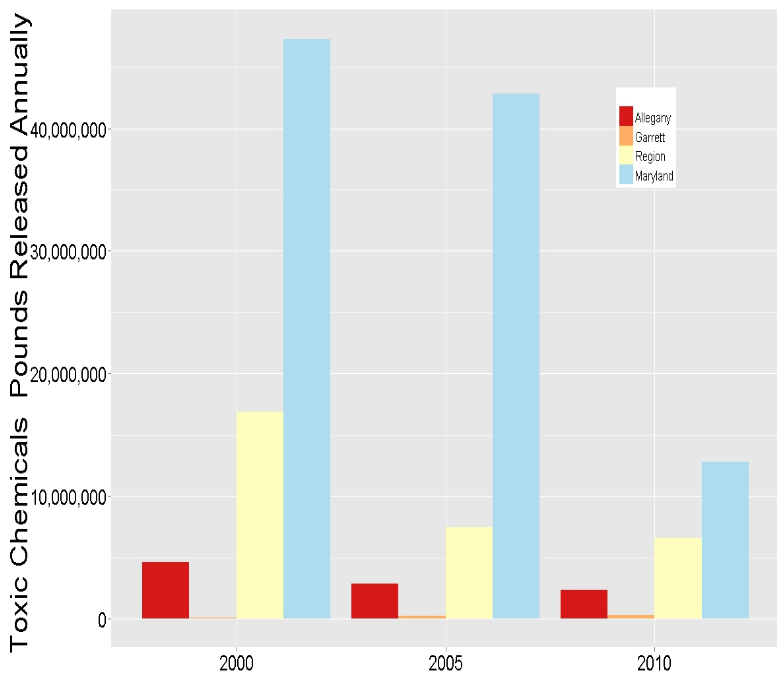


Figure 15-11: Total TRI Releases for 2000, 2005, and 2010

TRI facilities must report releases to air, water, and land, as well as the quantities of chemicals they recycle, treat, incinerate, or dispose of these chemicals on-site and off-site. In Figure 15-11 we see that total releases of chemicals reported to TRI have decreased from 2000 to 2010 for Allegany, Garrett, the region, and the state of Maryland. In 2000, total TRI releases in Allegany

County (4,585,316 pounds) were 40 times higher than the total TRI releases in Garrett County (112,785). In 2005, total TRI releases in Allegany County (2,879,309 pounds) were more than 10 times higher than the total TRI releases in Garrett County (224,787). In 2010, total TRI releases in Allegany County (2,312,628 pounds) were more than 10 times higher than the total TRI releases in Garrett County (269,727). TRI releases in Allegany were significantly higher than TRI releases in Garrett County over the ten-year period. Many of the chemicals reported by industry are known carcinogens, genotoxins, developmental toxins, reproductive toxins, mutagens, and can have chronic and acute health effects for exposed populations. Thus, there may presently be a high potential for adverse health outcomes for cancer due to environmental exposures and other endpoints in Allegany County compared to Garrett County.

15.4.3 National Scale Air Toxics Assessment (NATA)

The US Environmental Protection Agency (USEPA) National-Scale Air Toxics Assessment (NATA) estimates the cancer and respiratory risk of hazardous air pollutants (HAPs). HAPs are known to cause or are suspected of causing cancer or other serious health problems such as damage to the immune system, and neurological, reproductive, developmental, and respiratory problems [270–272] All 187 HAPs are addressed within NATA dataset, most of which are defined in the Clean Air Act.

In addition, for the air toxics for which information on chronic risks exists, the exposure concentration estimates are used to quantify potential health effects (cancer and non-cancer) from inhalation of air toxics using EPA's risk assessment and characterization framework [270]. Non-cancer risks are categorized as either respiratory or neurological hazards [270]. The census tract is the smallest analytical unit for which exposure and health risk estimates are provided in the NATA dataset. The cancer risk estimation is calculated from personal exposure. The relation of likelihood of contracting cancer and the exposure level is quantified by an USEPA developed cancer dose-response curve [270]. The NATA estimates cancer risk on the basis of the inhalation unit risk (IUR) factor, a measure of the cancer-causing potential of each air toxic [270]. The concentration of each pollutant in a given census tract is multiplied by its IUR in order to estimate individual lifetime cancer risk. Cancer risks are assumed to be additive and lifetime cancer risk from all air toxics present in a tract are summed to obtain the total estimated lifetime cancer risk for the tract. Estimated lifetime cancer risks are expressed by number of people per million, where "N" is the likelihood of contracting cancer out of one million people exposed to a specific concentration of an air pollutant continuously (24 hours/day) over a lifetime (defined as seventy years) [270, 271].

Respiratory risks are estimated using the concentration of the pollutant in the air believed to have no adverse effect on the lungs and air passages with constant exposure, referred to as the inhalation reference concentration [270]. To estimate respiratory risk for each census tract, a hazard quotient is calculated by dividing the ambient concentration of each pollutant in each tract by its inhalation reference concentration. A composite respiratory hazard index is then obtained by summing the hazard quotients of all air toxics present within that particular census tract. Index above one indicates the potential for respiratory problems over a lifetime of exposure while an index below one means a lifetime of exposure is not expected to cause adverse effects to the lungs and air passages [270].

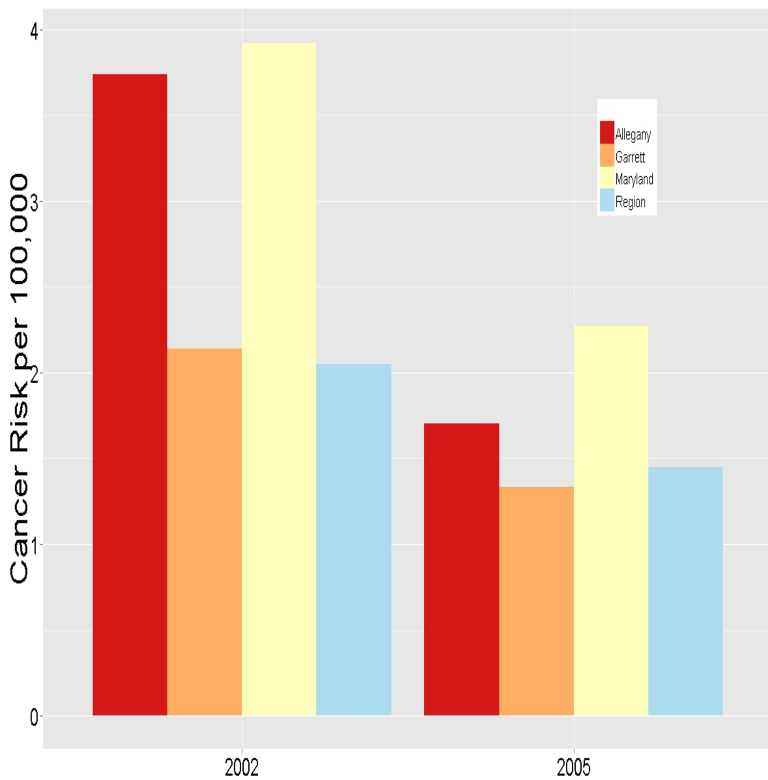


Figure 15-12: NATA Cancer Risk, 2002 and 2005

Figure 15-12 displays the lifetime cancer risk from air toxics. The estimated cancer risk for Allegany County was higher than then lifetime cancer risk for Garrett County and state of Maryland in 2002 and 2005. The estimated cancer risk changed significantly from 2002 to 2005 which could be due to a decrease in HAP levels or changes in how the estimated lifetime cancer risk from air toxics was calculated. Figure 15-13 displays respiratory risk for Garrett and Allegany, the region, and the state of Maryland. We observe that in 2002, the respiratory hazard score was above 1 for Allegany, Garrett, and the state of Maryland. This means that populations were at risk of respiratory problems including asthma, COPD, bronchitis, and other issues. We see that in 2005, the respiratory score decreased across the board with only Allegany and the state of Maryland receiving a score above 1. This decrease could be due to changes in the calculation or improvements in air quality. However, in 2005, citizens in Allegany were still at risk for negative respiratory health outcomes including vulnerable groups who have pre-existing conditions such as asthma who would be at a higher risk of hospitalization and emergency department visits. Additionally, respiratory health risks due to proximity to one or more pollution sources may be of concern to populations in the two counties currently burdened by air pollution from the oil and gas industry.

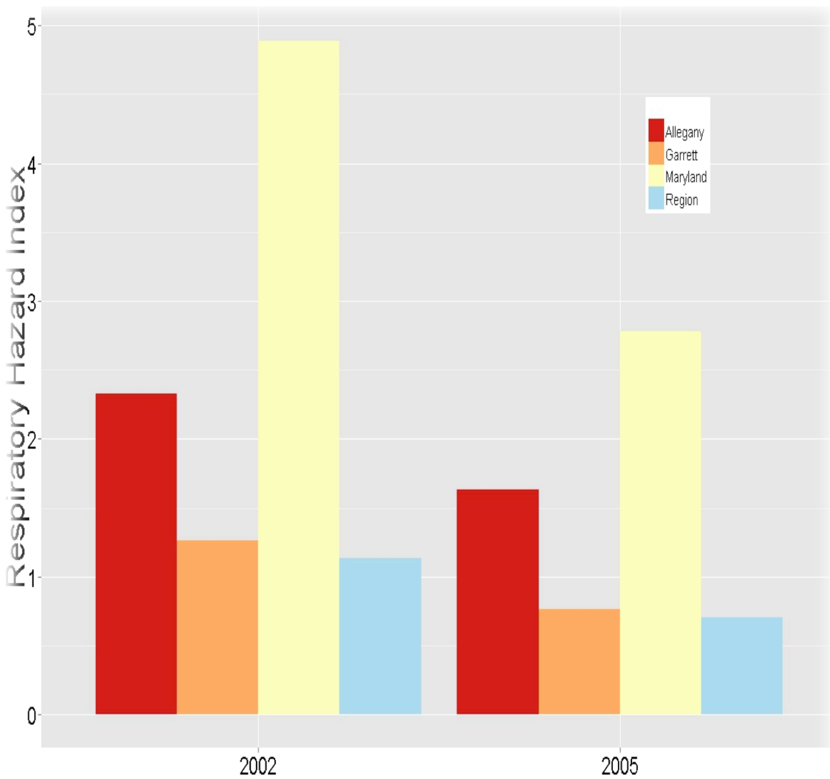


Figure 15-13: Respiratory Hazard Index, 2002 and 2005

15.5 Physical Health Indicators

The health profile of the residents of this region was compiled by using data collected on overall life expectancy, poor physical days, preventable hospital stays, chronic disease, major causes of morbidity and mortality, and birth outcomes. The collected data for Allegany and Garrett Counties (where UNGDP activities may take place) was compared to the health data of the region (Allegany and Garrett Counties in Maryland, Bedford, Fayette, and Somerset Counties in Pennsylvania, and Grant, Hampshire, Mineral, Preston, and Tucker Counties in West Virginia), and the State of Maryland for an overall health profile. We defined the region as Garrett and Allegany and other counties in neighboring states of West Virginia and Pennsylvania because the team thought the counties in the neighboring states had more in common with Western Maryland (culturally, sociodemographically including racial composition, occupational opportunities, geology, hydrology, topography, economy, history of oil and gas industry including conventional wells and UNGDP) than Allegany and Garrett have with other counties in Maryland.

15.5.1 Life Expectancy

Data on life expectancy was obtained from the CDC's Community Health Status Indicators website [273]. As displayed in Table 15-2, Garrett County has the highest average life expectancy at 78.2, compared to Allegany County (77.4) and the state of Maryland (67.8). The regional average life expectancy of Maryland, West Virginia, and Pennsylvania was lower than both Allegany County and Garrett County at 76.7.

Table 15-2: Life Expectancy, 2009

	Allegany Co.	Garrett Co.	Maryland	Region
Life Expectancy	77.4	78.2	67.8	76.7

15.5.2 Poor Physical Health Days

Data on the number of poor physical health days in the past 30 days was obtained from the Behavioral Risk Factor Surveillance System (BRFSS) for 2006-2012 [274] As displayed in Table 15-3, Allegany County had the highest number of poor physical health days at 4.8, while Maryland had the lowest number (3.1). Allegany County had more poor physical health days than both Garrett County and Maryland.

Table 15-3: Poor Physical Health Days, 2006-2012

	Allegany Co.	Garrett Co.	Maryland	Region
Poor Physical Health Days	4.8 (4.2-5.3)	3.7 (3.1-4.2)	3.1 (3.0-3.2)	4.5 (3.6-5.5)

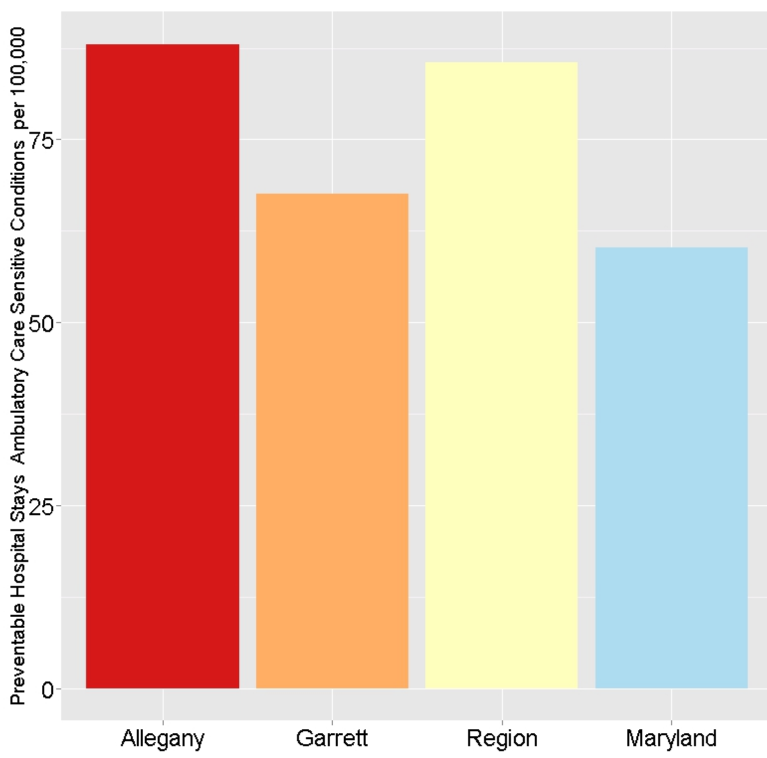


Figure 15-14: Preventable Hospital Stays, 2011

We obtained 2011 data from the University of Wisconsin County Health Indicators Project [275]. Figure 15-14 displays the Ambulatory Care Sensitive Conditions (ACSC) rate for preventable hospital stays in Allegany (88.0) and Garrett (67.6) counties was higher than the overall state rate (60.2). The ACSC rate for Allegany was higher than the rate for the both the region (85.6) and Garrett County.

15.5.3 Chronic Diseases

Chronic diseases examined in this study include adult hypertension, adult obesity, diabetes, and adult smoking.

15.5.3.1 Adult Hypertension

We obtained data on adults with high blood pressure for 2006-2012 from the Behavioral Risk Factor Surveillance System (BRFSS) [274]. Figure 15-15 illustrates that Both Allegany and Garrett counties had higher percentages of adults with high blood pressure (37% and 31%, respectively) in comparison to the State of Maryland (30%). In comparison to the region (34.3%), Allegany County has a higher percentage of adults with high blood pressure while Garrett County's percentage was lower.

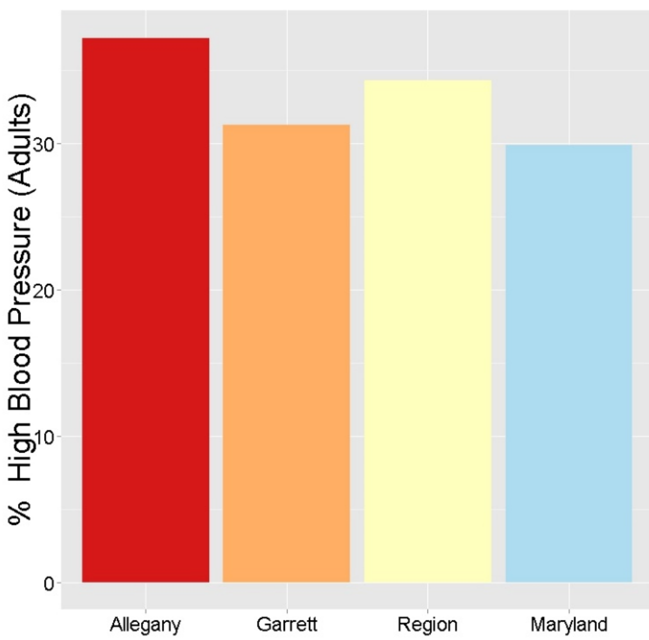


Figure 15-15: Percent of Adults with High Blood Pressure, 2006-2012

15.5.3.2 Adult Obesity and Diabetes

Other serious issues facing this area of Maryland are adult obesity and diabetes. Figure 15-16 shows the percent of obese adults and adults with diabetes in Allegany and Garrett counties in Maryland compared to the region and Maryland. This data was obtained for years 2006-2012 from BRFSS [274]. The percent of obese adults in Allegany and Garrett was 21% and 30%, respectively. While, percent with diabetes in Allegany and Garrett was 12% and 11%, respectively. The trends are seen mirroring each other, not surprisingly since obesity has been linked to the development of Type 2 Diabetes [24]. While both counties have lower percentages of obese adults and either equal or lower percentages of diabetic adults compared to the region (12%), they are both higher compared to the state of the Maryland (9.7%).

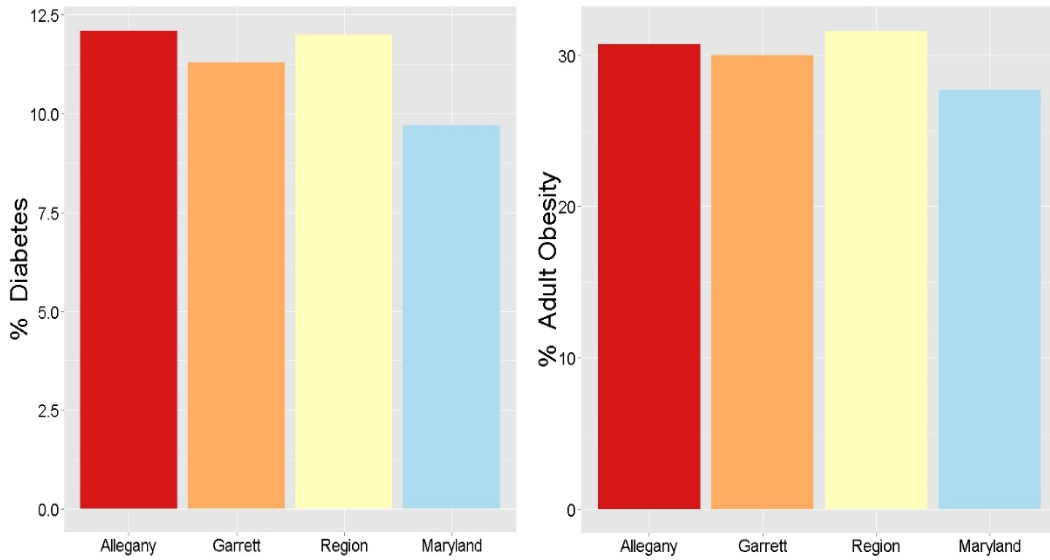


Figure 15-16: Percent of Obese Adults and Percent of Adults with Diabetes, 2006-2012

15.5.3.3 Adult Smoking

15.5.3.3.1 Adult Smoking

We obtained adult smoking data for the years 2006-2012 from BRFSS [274]. In both Allegany (23%) and Garrett (19.5%) counties, the percent of adults who smoke was much higher than the percent of adults who do the same across the state (15.4%). However, only the smoking rate for Allegany was higher than the smoking rate for the region (22.7%) (Figure 15-17).

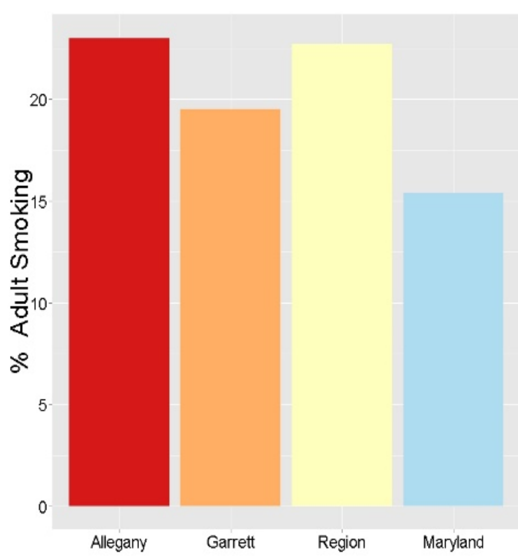


Figure 15-17: Percent of Adult Smokers, 2006-2012

15.5.4 Major Causes of Morbidity and Mortality

The morbidity and mortality of the residents of this region was compiled by using data collected on cancer, mortality, and birth rates. The collected data for Allegheny and Garrett Counties was compared to the health data of the State of Maryland for an overall health profile.

15.5.4.1 Cancer

We obtained cancer incidence data from the National Cancer Institute's (NCI) State Cancer Profile site [276]. As displayed in Table 15-4, prostate cancer, breast cancer, and colorectal cancer were the cancers with the highest incidence rates. Allegany County had the highest incidence rate for Non-Hodgkin's Lymphoma, while the Maryland, West Virginia, and Pennsylvania region had the lowest incidence rate. Allegany County also had the highest incidence rate for leukemia (16.2) and Garrett County had the lowest (9.1). For melanoma, Maryland had the highest incidence rate (21.2) and Garrett County had the lowest incidence rate (16.3). For breast cancer, Maryland had the highest incidence rate (128.0), while the Maryland, West Virginia, and Pennsylvania region had the lowest incidence rate (111.8). For prostate cancer, Maryland had the highest incidence rate (157.2) while Garrett County had the lowest (113.3). The Maryland, West Virginia, and Pennsylvania region had the highest incidence rate, 24.7, for bladder cancer, while Maryland had the lowest incidence rate, 19.2. For colorectal cancer, Allegany County had the highest incidence rate (52.1), and Maryland had the lowest incidence rate (41.5).

Table 15-4: Cancer Incidence Rates, 2006-2010

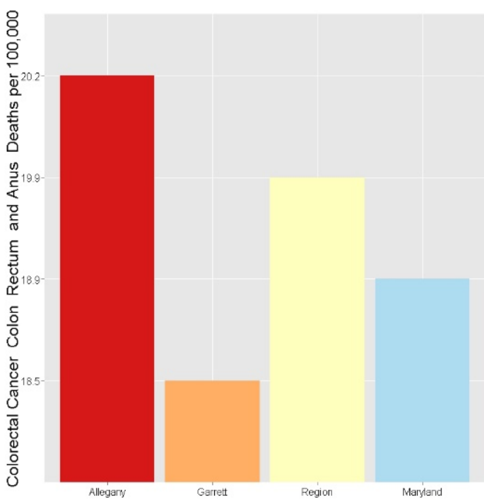
Cancer Type	**Allegany Co.**	**Garrett Co.**	**Maryland**	**Region**
Non-Hodgkin's Lymphoma	23.6 (19.4- 28.6)	20.5 (14.7-28.1)	17.8 (17.3-18.3)	16.2 (12.6-20.5)
Leukemia	16.2 (12.6-20.5)	9.1 (5.2-14.9)	11.2 (10.8-11.6)	13.3 (9.4-18.3)
Melanoma	17.1 (13.4-21.6)	16.3 (10.7-23.8)	21.2 (20.6-21.7)	17.1 (12.5-23.0)
Breast Cancer	114.0 (100.7-128.8)	118.9 (98.0-143.3)	128.0 (126.2-129.7)	111.8 (92.0-136.2)
Prostate Cancer	146.6 (131.3-163.4)	113.3 (93.1-137.0)	157.2 (155.0-159.3)	137.8 (115.3-164.7)
Bladder Cancer	20.1 (16.4- 24.4)	21.6 (15.5-29.6)	19.2 (18.7-19.7)	24.7 (19.4-31.4)
Colorectal Cancer	52.1 (45.9- 59.0)	43.1 (34.2-53.7)	41.5 (40.7-42.2)	50.3 (40.6-62.3)

Cancer Mortality

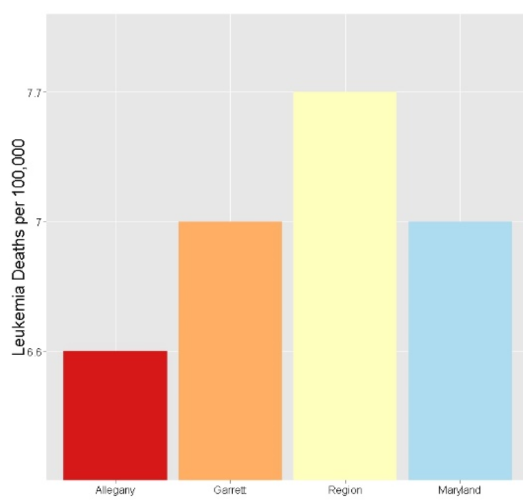
Cancer data chosen for analysis was based on a known relationship between a particular cancer and an exposure of concern that occurs during the UNGDP process and community concerns. Cancer mortality data was chosen from the following:

- Colorectal cancer
- Leukemia
- Melanoma
- Multiple myeloma
- Non-Hodgkins lymphoma
- Prostate cancer
- Bladder cancer
- Breast cancer
- Cancer deaths per 100,000

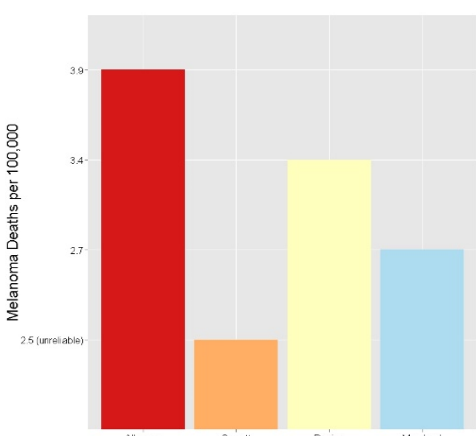
For this part of the baseline health assessment, we obtained data on mortality for various cancers using the following ICD-10 codes: Non-Hodgkin's lymphoma (C82-C85); Multiple myeloma and immunoproliferative neoplasms (C88,C90); Leukemia (C91-C95); Malignant melanoma of skin (C43); Malignant neoplasm of breast (C50); Malignant neoplasm of prostate (C61); Malignant neoplasm of bladder (C67); and Malignant neoplasms of colon, rectum and anus (C18-C21).



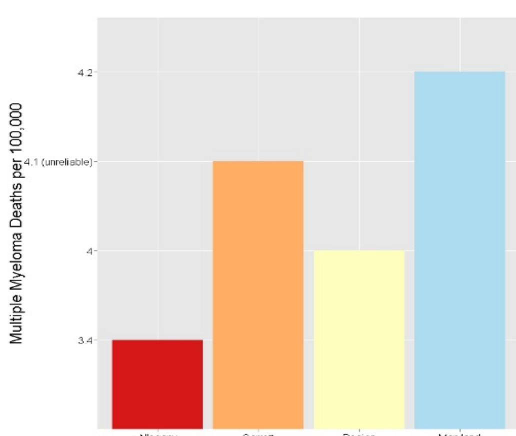
a. Colorectal Cancer



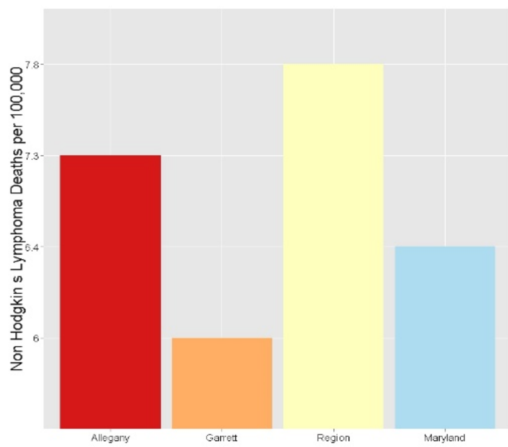
b. Leukemia



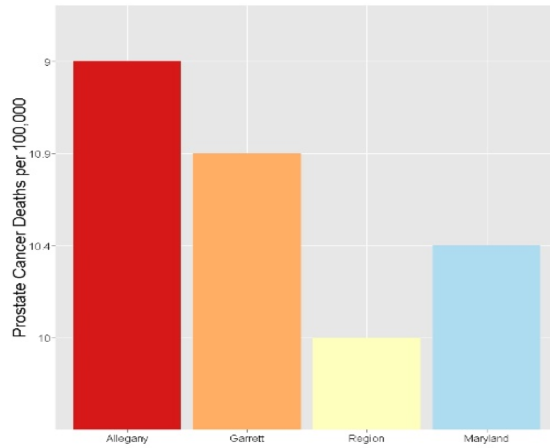
c. Melanoma



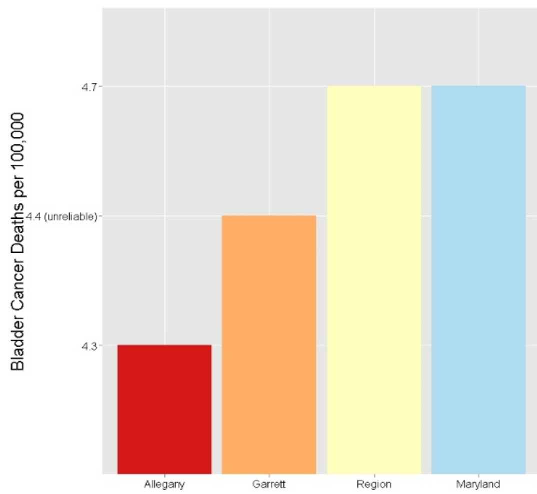
d. Multiple Myeloma



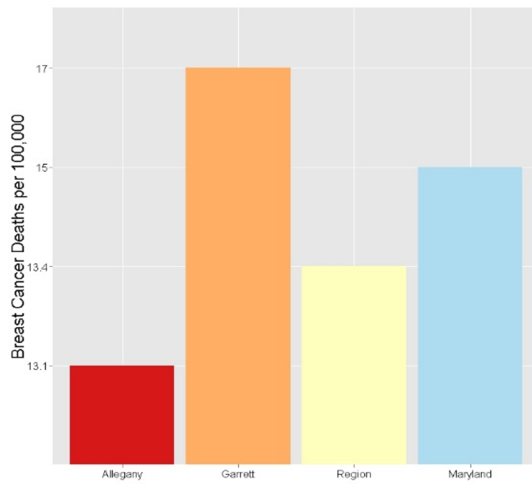
e. Non-Hodgkin's Lymphoma



f. Prostate Cancer



g. Bladder Cancer



h. Breast Cancer

Figure 15-18: Number of Deaths from Various Cancers per 100,000 (Age-Adjusted) in Allegany and Garrett Counties Compared to Maryland and the Region (2000-2010), Source: National Cancer Institute

Figure 15-18 shows the number of deaths per 100,000 from the cancers of interest previously mentioned in Allegany and Garrett counties compared to the region and all of Maryland. Overall, the top three cancers in Allegany and Garrett counties combined that result in the highest numbers of deaths were colorectal, breast, and prostate cancers. Deaths from these cancers were higher in these counties compared to the region and State of Maryland overall. Furthermore, compared to the leading causes of death from cancer nationwide, these counties' rates of colorectal cancer deaths were higher [277].

We obtained data on various cancers from CDC Wonder on cancer mortality for Allegany, Garrett, the region, and the state of Maryland [278]. The ICD-10 codes for the cancers included: Malignant neoplasms of lip, oral cavity and pharynx (C00-C14), Malignant neoplasm of esophagus (C15), Malignant neoplasm of stomach (C16), Malignant neoplasms of colon, rectum and anus (C18-C21), Malignant neoplasms of liver and intrahepatic bile ducts (C22), Malignant neoplasm of pancreas (C25), Malignant neoplasm of larynx (C32), Malignant neoplasms of trachea, bronchus and lung (C33-C34), Malignant melanoma of skin (C43), Malignant neoplasm of breast (C50), Malignant neoplasm of cervix uteri (C53), Malignant neoplasms of corpus uteri and uterus, part unspecified (C54-C55), Malignant neoplasm of ovary (C56), Malignant neoplasm of prostate (C61), Malignant neoplasms of kidney and renal pelvis (C64-C65), Malignant neoplasm of bladder (C67), Malignant neoplasms of meninges, brain and other parts of central nervous system (C70-C72), Hodgkin's disease (C81), Non-Hodgkin's lymphoma (C82-C85), Leukemia (C91-C95), Multiple myeloma and immunoproliferative neoplasms (C88,C90), Other and unspecified malignant neoplasms of lymphoid, hematopoietic and related tissue (C96), All other and unspecified malignant neoplasms (C17,C23-C24,C26-C31,C37-C41,C44-C49,C51-C52,C57-C60,C62-C63,C66,C68-C69,C73-C80,C97), In situ neoplasms, benign neoplasms and neoplasms of uncertain or unknown behavior (D00-D48).

Overall, the combined numbers of deaths from cancer in Allegany and Garrett counties are slightly higher than the total cancer deaths in the region and Maryland, with Allegany County having a higher number of deaths compared to Garrett.

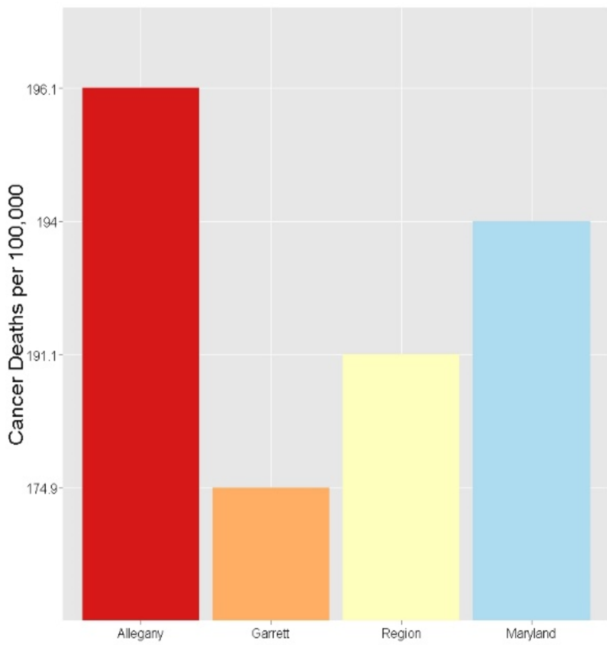


Figure 15-19: Total Cancer Deaths per 100,000, 2000-2010

15.5.4.2 Other Mortality Data

Mortality data was analyzed by examining chronic respiratory disease deaths, flu deaths, cardiovascular disease deaths, cerebrovascular disease deaths, septicemia deaths, and all- cause mortality.

15.5.4.2.1 Chronic respiratory disease deaths

We obtained data on chronic respiratory deaths from CDC Wonder using the following ICD-10 codes (Bronchitis, chronic and unspecified (J40-J42), Emphysema (J43), Asthma (J45-J46), and other chronic lower respiratory diseases (J44, J47) [278]. The number of deaths in Allegany (54.5/100,000) and Garrett counties (51.4/100,000) due to chronic respiratory disease were higher than both the number of deaths per 100,000 in the region and state for the same disease (Figure 15-20).

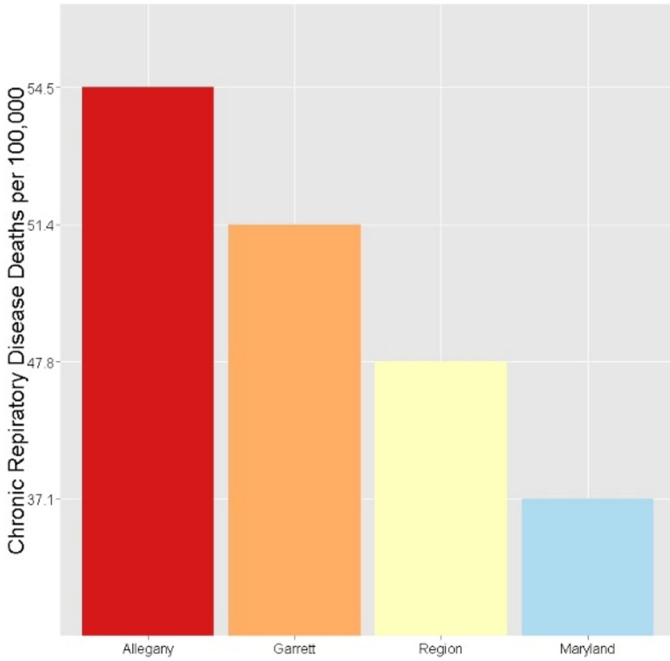


Figure 15-20: Total Chronic Respiratory Deaths per 100,000, 2000-2010

15.5.4.2.2 Flu deaths

We obtained data on influenza and pneumonia mortality from CDC Wonder using the following ICD-10 codes (Influenza (J09-J11), Pneumonia (J12-J18) [278]. The number of deaths contributed to flu in Allegany County is higher than the number of flu deaths in Garrett County, yet both are lower than the number of deaths from flu in the state (Figure 15-21).

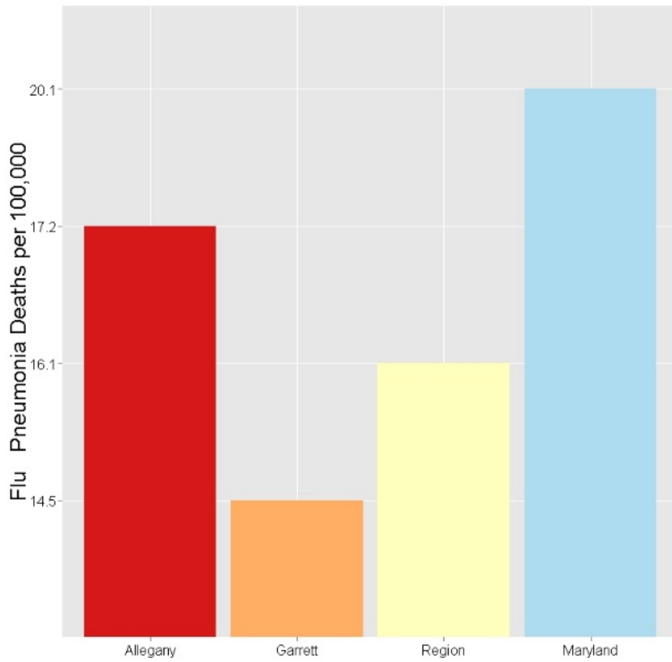


Figure 15-21: Total Flu and Pneumonia Deaths per 100,000, 2000-2010

15.5.4.2.3 Cardiovascular disease deaths

We obtained heart disease mortality data using CDC Wonder [278] and the following ICD-10 codes: Hypertensive heart disease (I11); Hypertensive heart and renal disease (I13); Acute myocardial infarction (I21-I22); Other acute ischemic heart diseases (I24); Atherosclerotic cardiovascular disease, so described (I25.0); All other forms of chronic ischemic heart disease (I20,I25.1-I25.9); Acute and sub-acute endocarditis (I33); Diseases of pericardium and acute myocarditis (I30-I31,I40); Heart failure (I50); and All other forms of heart disease (I26-I28,I34-I38,I42-I49,I51). We found that the cardiovascular disease mortality rate for Allegany County (275.6) was significantly higher than the rate for Garrett, the region, and the state of Maryland. This disparity in cardiovascular disease mortality could be due to a number of factors including exposure to air pollution, health behaviors, lifestyle, or genetic factors [45].

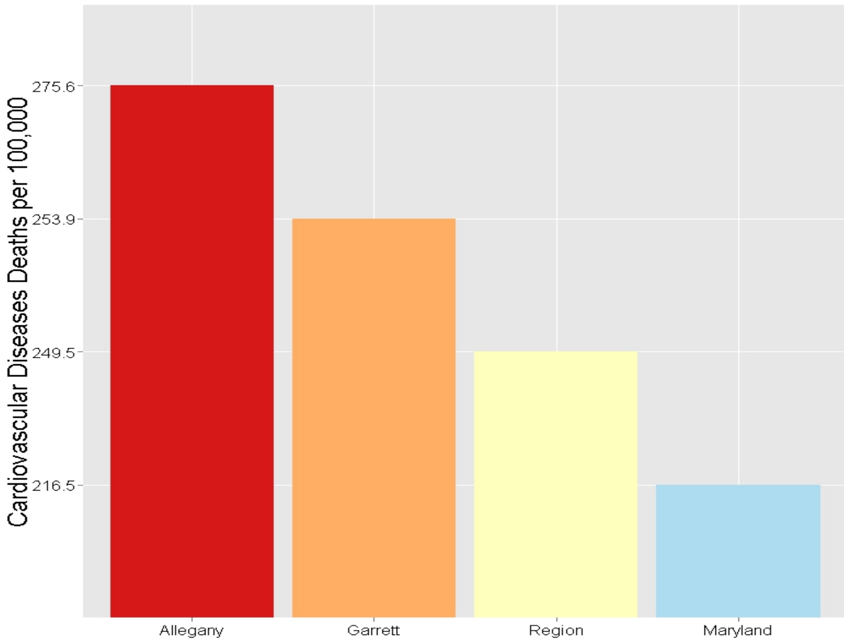


Figure 15-22: Cardiovascular Disease Deaths per 100,000, 2000-2010

15.5.4.2.4 Cerebrovascular disease deaths

We obtained data on cerebrovascular disease mortality from CDC Wonder using the following ICD-10 codes (I60-I69) [278]. The rate of stroke-related mortality for Allegany County (59/100,000) was higher than the mortality rates for Garrett, the region, and the state of Maryland.

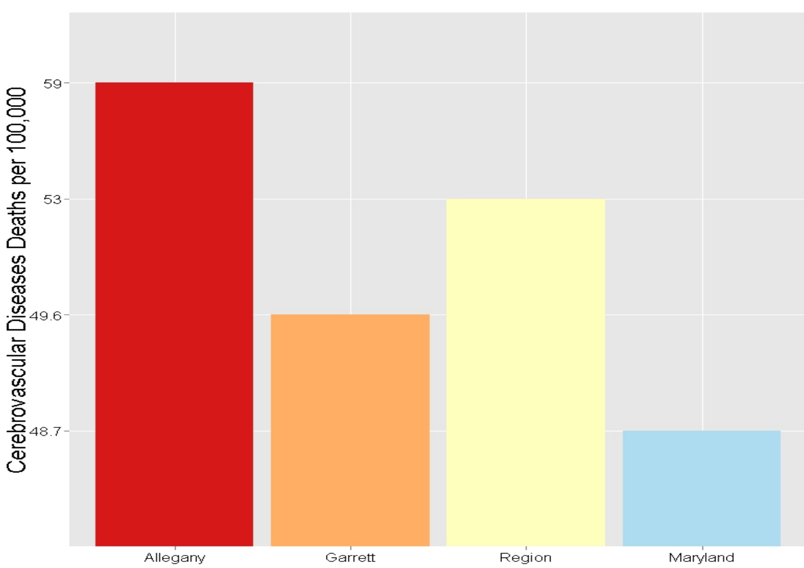


Figure 15-23: Cerebrovascular Disease Deaths per 100,000, 2000-2010

15.5.4.2.5 Septicemia deaths

Data on Sepsis (septicemia) mortality was obtained through CDC Wonder using the following ICD-10 codes (A40-A41) [278]. Septicemia is an illness that affects all parts of the body that can happen in response to an infection and can quickly become life-threatening. In severe cases of sepsis, one or more organs fail. During the worst case scenario, sepsis causes a decrease in blood pressure, the heart to weaken, and septic shock which can lead to organ failure and death. Patients who develop sepsis have an increased risk of complications and death and face higher healthcare costs and longer treatment. Sepsis is a response to an infection. When there is an infection, the immune system releases chemicals to fight the infection. The chemicals sometimes cause body-wide inflammation, which can lead to blood clots and leaky blood vessels. This impairs blood flow, which damages the body's organs by depriving them of nutrients and oxygen. People with weakened immune systems, infants and children, elderly citizens, and people with chronic diseases are at risk from this condition. We found that the septicemia mortality rate for Allegany County was 21/100,000. This rate is twice as high as the rate of Garrett County and also higher than the rates of the region and the state of Maryland.

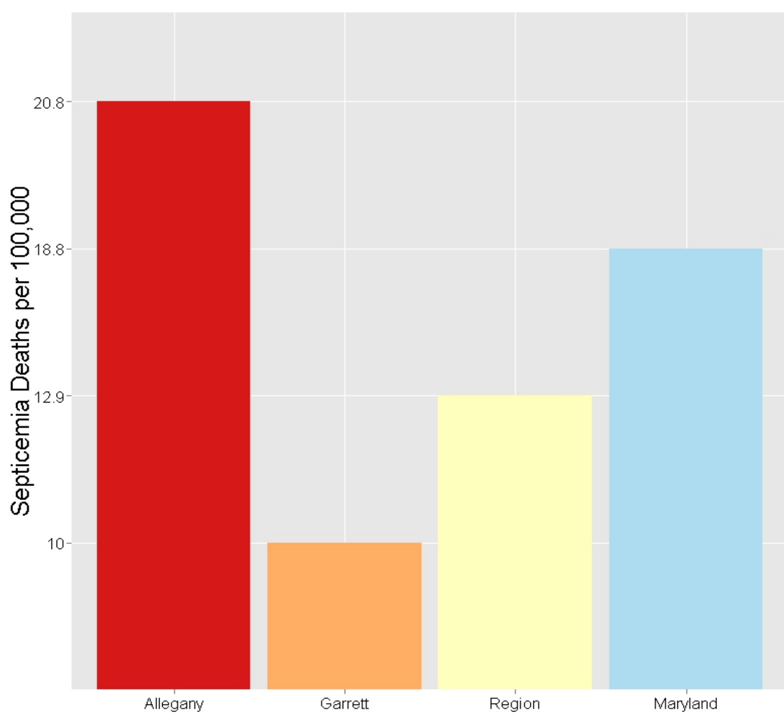


Figure 15-24: Septicemia Deaths per 100,000, 2000-2010

15.5.4.2.6 All-Cause mortality

All-cause mortality rates for Allegany (853) and Garrett (808) were higher than the rate for Maryland (768).

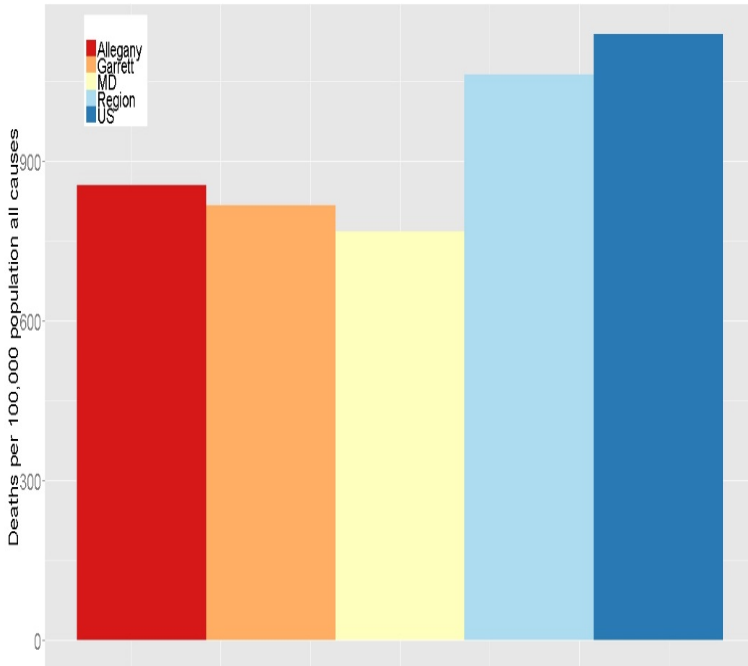


Figure 15-25: All-Cause Mortality, 2000-2010

15.5.4.3 Birth Outcomes

Birth outcomes were analyzed by examining low birth weight, premature births, and infant mortality.

15.5.4.3.1 Low birth weight and premature births

We obtained data on percent low birth weight (< 2800 grams) and premature births for Allegany, Garrett, the region, the state of Maryland, and the U.S. from the Health Indicators Warehouse and National Vital Statistics System for 2006-2012. The percentage of premature births in Allegany (13%) was higher than the percentages for Garrett (12%), MD (12.9%), region (11.6%), and the United States (12.2%). Percentage of babies born with low birth weight (LBW) in Allegany (9.1%) was higher than % low birth weight for Garrett (7.5%), MD (9%), region (8%), and the United States (8.2%).

15.5.4.1 Infant mortality

We obtained data on infant mortality for Allegany, Garrett, the region, the state of Maryland, and the US from the Health Indicators Warehouse. Infant mortality rates of 8.4 deaths/1000 births (Allegany) and 10.8 deaths/1000 births (Garrett) were higher than the rates for the MD (7.2 deaths/1000 births), and US (6.9 births/1000 deaths).

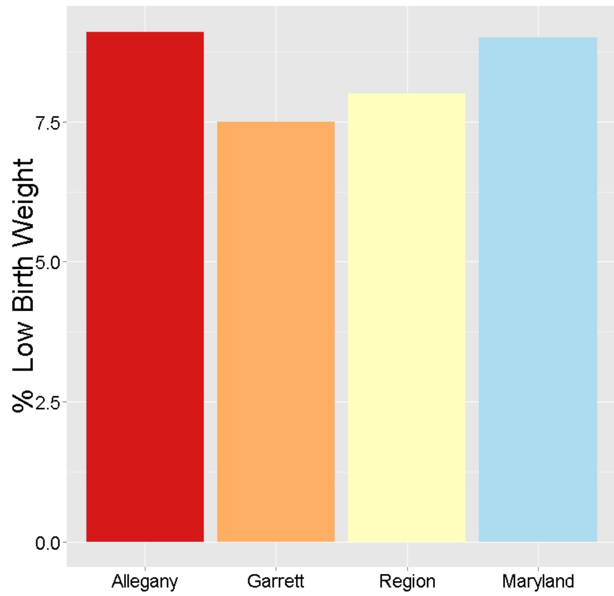


Figure 15-26: Percent Low Birth Weight, 2006-2012

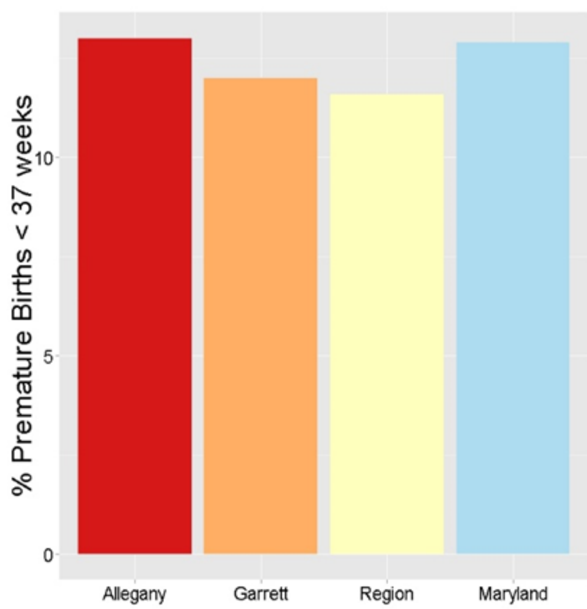


Figure 15-27: Percent Premature Births and Low Birth Weight, 2006-2012

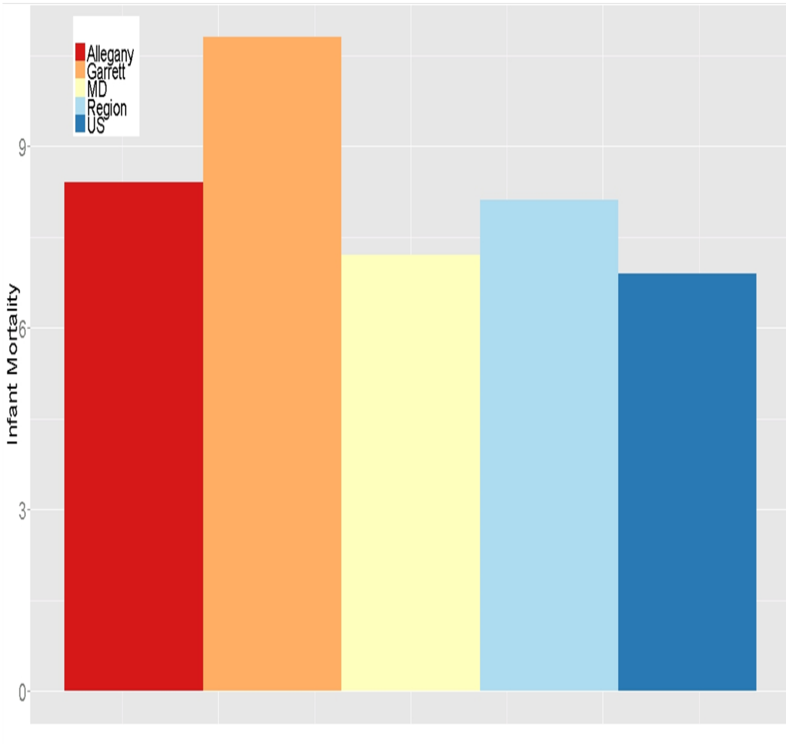


Figure 15-28: Infant Mortality, 2006-2010

15.6 Social Determinants of Health

Many factors work together to affect the health of individuals and populations. Factors such as genes and biology, individual behavior, physical and social environments, and health care services have considerable impact on health. However, there is growing evidence that the genetic composition of individuals and populations and the lifestyle choices, such as diet and exercise that comprise individual behavioral determinants have considerably less impact on health than factors related to social circumstances, physical environments, and access and quality of health care services (WHO, 2008). Health services, the social environment, and the physical environment are significant drivers of population health outcomes and constitute what we call the social determinants of health (SDH).

SDH are the complex, integrated, and overlapping social structures and economic systems that include the social environment, physical environment, and health services. In order to determine the baseline health of citizens of Allegany and Garrett counties, we obtained available information regarding rates of sexually transmitted infections (STIs), violent and nonviolent crime, injuries, substance abuse, mental health, and suicide.

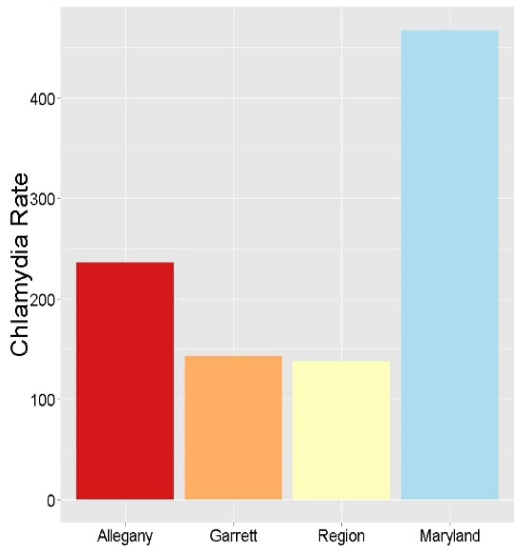
15.6.1 Sexually Transmitted Infections (STIs)

Information regarding STIs for 2011 was obtained from County Health Rankings (Chlamydia) and the Health Indicators Warehouse (Gonorrhea). In Allegany County, the incidence of chlamydia was 236 per 100,000 population and 190 per 100,000 for gonorrhea; in Garrett

County, the incidence of chlamydia was 143 per 100,000 and 29.9 per 100,000 for gonorrhea. These rates are low when compared to the State of Maryland. The prevalence of HIV was 179.6 per 100,000 in Allegany County and 23.2 per 100,000 in Garrett County. HIV rates in both counties are well below the 2011 Maryland state average of 632.9 per 100,000.

Table 15-5. Sexually Transmitted Infections (STIs), 2011

Area	Chlamydia Rate (per 100,000)	Gonorrhea Rate (per 100,000)	HIV Rate (per 100,000)
Allegany	235.6	41.5	179.6
Garrett	143.1	29.9	23.2
Maryland	466.9	110.8	632.9
Region	137.9	214.4	66.6



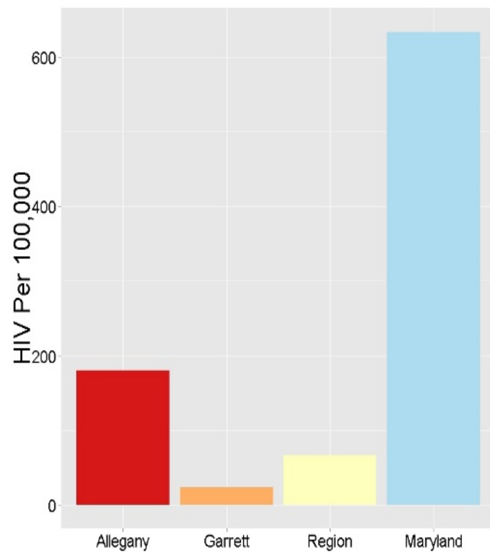


Figure 15-29: Chlamydia Rate, 2011 and HIV Rate, 2010 per 100,000

15.6.2 Crime

Information regarding violent and property crime was obtained from the Maryland Governor's Office on Crime Control and Prevention Crime Statistics Report for 2000, 2005, and 2010. Data regarding homicides was obtained from County Health Rankings and the National Center for Health Statistics for 2010. In Maryland, violent crime included murder, rape, robbery, aggravated assault and property crime included offenses such as breaking and entering, larceny theft, and motor vehicle theft. The State average for 2010 was approximately 3,549.2 reported incidents per 100,000 population, and marked the "lowest ever reported" crime rates for Maryland. For the years obtained, total arrests for violent and property crimes peaked in 2010 for Allegany County, with a total of 2,878 incidents reported, contributing to an overall crime rate of 3,957.6 reported incidents per 100,000, slightly higher than the state average. Crime rates are a lower in Garrett County, fluctuating between 530 and 550 incidents reported per year with a crime rate between 1,742.8 per 100,000 and 1,856.2 per 100,000.

In Garrett County, crime rates across all categories remain steady and lower than the Maryland State averages, fluctuating slightly over the 10-year period between 2000 and 2010. In Allegany County, similar to regional data, there is a slow but steady increase in most crime categories in this same period. This increase runs counter to statewide trends, which demonstrate major decreases in crime rates across all categories in the last decade. In Allegany County, the rate of reported property crimes increases from 2107 in 2000, to 3528.6 in 2010, an increase from 2,812 per 100,000 to 3,528.6 per 100,000. The Maryland State average during this same time period witnessed a decrease from 4,048.6 incidents per 100,000 in 2000 to 3,001.8 incidents per 100,000 in 2010. Allegany County also witnessed similar increases in violent crime rates, in 2000 there were 271 incidents report at a rate of 361.7 per 100,000, and in 2010 this number had increased to 312 incidents and 429 per 100,000. These rates are still lower than the Maryland State average of 547.4 incidents per 100,000 but are steadily increasing while the statewide numbers are decreasing. Allegany County violent crime rates run parallel to regional rates: in the Western Maryland, West Virginia, and Pennsylvania region, the violent crime rate per 100,000 was highest in 2010, at 621.7, and lowest in 2000, at 492.4. Homicide rates, as reported in the County Rankings Data shows that rates in both counties are quite low, much lower than the Maryland State average of 9.3 homicides per 100,000. In Garrett County, the rates were so low that the data was reported as unreliable. Maryland Crime Statistics estimates the murder rate to be approximately 2 per 100,000 for 2011. In Allegany County the homicide rate for 2011 was 2.3 per 100,000 (1.2-4.0 95 CI).

Table 15-6. Total Crime, 2010

Area	Total Crime Incidents (#)	Total Crime Rate (per 100,000)
Allegany	2,878	3957.6
Garrett	532	1791.5
Maryland	204,916	3549.2
Region	1154.9	2139.6

Table 15-7. Violent and Property Crime, 2010

	Violent Crime		Property Crime	
Area	Incidents (#)	Rate (per 100,000)	Incidents (#)	Rate (per 100,000)
Allegany	312	429.0	2566	3528.6
Garrett	49	165.0	483	1626.5
Maryland	31,604	547.4	173,312	3001.8
Region	197	621.7	957.8	1531.8

15.6.3 Injuries

Data for deaths resulting from unintentional injuries were obtained from Health Indicators Warehouse, National Vital Statistics System for the years 2006-2010. Injuries include unintentional injury mortality, accidental poisonings, alcohol-impaired driving deaths, motor vehicle traffic deaths, fall deaths, and drownings all per 100,000. The total mortality rate from unintentional injury was 41 per 100,000 for Allegany County and 40.5 per 100,000 for Garrett County, both counties have much higher rates than the Maryland State average of 25.5 per 100,000, yet lower than the overall region. Both are slightly higher than the national average of 39.9 per 100,000. Information collected on accidental poisonings, drownings, and fall deaths revealed very low mortality rates that were too small to be reliably reported. Mortality from motor vehicle traffic deaths were also measured, with a mortality rate of 12.1 per 100,000 for Allegany County and a rate of 21.6 per 100,000 in Garrett County. Maryland averages 10.7 traffic deaths per 100,000.

Table 15-8. Unintentional Injuries, 2006-2010

Area	**Unintentional Injury Mortality Rate (per 100,000)**[6]	**Motor Vehicle Death Rate (per 100,000)**
Allegany	41.0	12.1
Garrett	40.5	21.6
Maryland	25.5	10.7
Region	51.2	20.3

[6] 2000-2010 rate

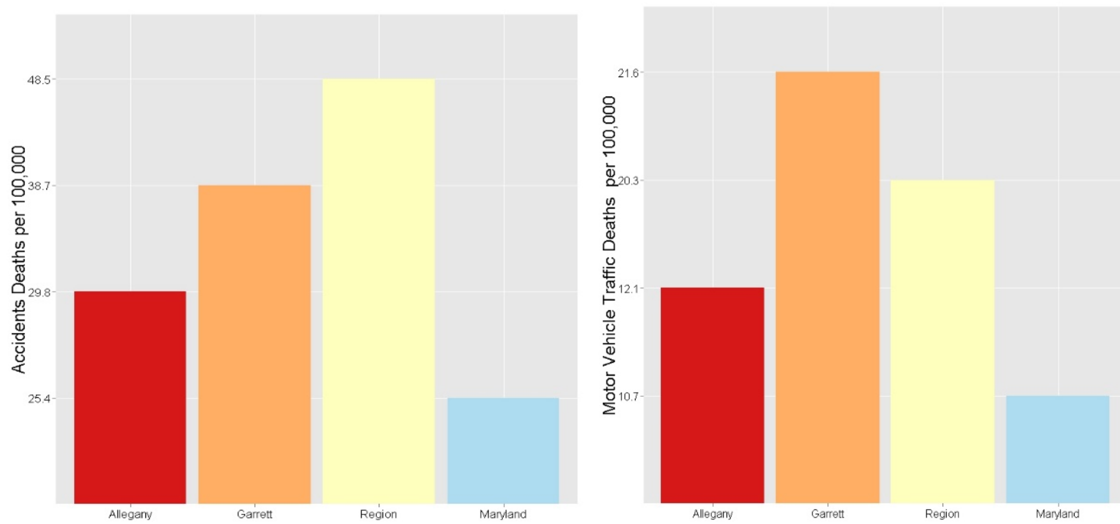


Figure 15-30: Total Accidental Deaths and Motor Vehicle Deaths per 100,000, 2006-2010

Information on alcohol impaired driving deaths was obtained from the 2014 County Health Rankings Information and the Fatality Analysis Reporting System. The percentage of driving deaths that were a result of alcohol impairment has been estimated 29.4 % for Allegany County (15/51 deaths) and 41% for Garrett County (16/39 deaths). Statewide estimates suggest that 33% or 867/2626 deaths in Maryland can be attributed to alcohol-impairment while the Western Maryland, West Virginia, and Pennsylvania region had the largest percentage of alcohol-impaired drivers, at 42.1% or 196/469 deaths.

Table 15-9: Alcohol-Impaired Driving Deaths, 2008-2012

Area	**Alcohol-Impaired Driving Deaths (#)**	**Driving Deaths (#)**	**% Alcohol-Impaired Driving Deaths**
Allegany	15	51	29.4
Garrett	16	39	41.0
Maryland	867	2626	33.0
Region	196	469	42.1

	Allegany Co.	**Garrett Co.**	**Maryland**	**Region**
Alcohol-Impaired Driving Deaths (#)	15	16	867	196
Driving Deaths (#)	51	39	2626	469
% Alcohol-Impaired Driving Deaths	29.4	41.0	33.0	42.1

Data on suicide including intentional self-harm by discharge of firearms and intentional self-harm by other and unspecified means and their sequelae were obtained from CDC Wonder Mortality from 2000-2010. The total mortality rate from intentional self-harm (suicide) for Allegany County was 12.1 (9.7-14.1 95%CI) per 100,000 and 11.5 (8.2-15.8 95%CI) per 100,000 for Garrett County. These rates are significantly higher than the state average of 8.7 (8.2-15.8 95% CI) per 100,000 and lower than the regional average of 13.9 per 100,000.

Table 15-10. Suicide, 2000-2010

Area	Suicide Mortality (per 100,000)
Allegany	12.1
Garrett	11.5
Maryland	8.7
Region	13.9

15.6.4 Mental Health

Data on mental health specific to residents of Allegany and Garrett counties were obtained through the County Health Rankings Database and the Health Indicators Warehouse. Mental health was measured by the County Health Rankings as mentally unhealthy days (or the number of reported "mentally unhealthy days" per month among adults over age 18). A related measure tracks the percentage of adults over 18 who report not having sufficient social-emotional support. In the period 2006-2012, Allegany reports an average of 3.8 mentally unhealthy days per month, and Garrett County reports 3.6 mentally unhealthy days per month. Rates for both counties are higher than the Maryland average of 3.2 mentally unhealthy days per month. Data based on the Behavioral Risk Factor Surveillance System measured adult responses to the question "How often do you get the social and emotional support you need?" In Allegany County 18.7% of adults felt that they did not receive enough support, and in Garrett County this number approximately 20.0%, while the Maryland State average is approximately 19.8%.

Table 15-11. Mental Health, 2006-2012

Area	Mentally Unhealthy Days (days/month)	Perceived Social Support (%)
Allegany	3.8	18.0
Garrett	3.6	20.0
Maryland	3.2	19.8
Region	3.9	19.2

15.6.5 Substance Abuse

Substance abuse data were extracted from the Health Indicators Warehouse, with measures for adult binge drinking and excessive drinking, collected from the period 2006-2012. The Behavioral Risk Factor Surveillance System was used for self-reported data on binge drinking[7] and excessive drinking.[8] In Allegany County 16.5% of adults over 18 years of age report binge drinking and 17.3% report excessive drinking, slightly higher than the state averages. In Garrett County, these rates were similar, 16.0% adults admit to binge drinking and 18.2% report excessive drinking. Although both counties report slightly higher rates when compared to Maryland State averages (14.4% binge drinking and 15.7% for excessive drinking), wide margins of error could account for these differences. Information on other types of substance abuse are more difficult to obtain. However measures from the National Community Health Status Indicators for 2009 includes a count of the number of recent drug users, estimating that 4,597 people in Allegany County and 1,758 people in Garrett County are recent drug users.

Table 15-12. Substance Abuse, 2006-2012

Area	Binge Drinking (%)	Excessive Drinking (%)	Recent Drug Use (#)
Allegany	16.5	15.5	4,597
Garrett	16.0	17.3	1,758
Maryland	14.4	15.4	N/A
Region	13.5	13.2	N/A

[7] Sample respondents age 18+ who drank 5 or more drinks for men, 4 or more drinks for women, at one or more occasions in the past 30 days [286].

[8] Sample respondents age 18+ who drank more than two drinks per day on average (for men) or more than one drink per day on average (for women) or who drank 5 or more drinks during a single occasion (for men) or 4 or more drinks (for women) during a single occasion [286].

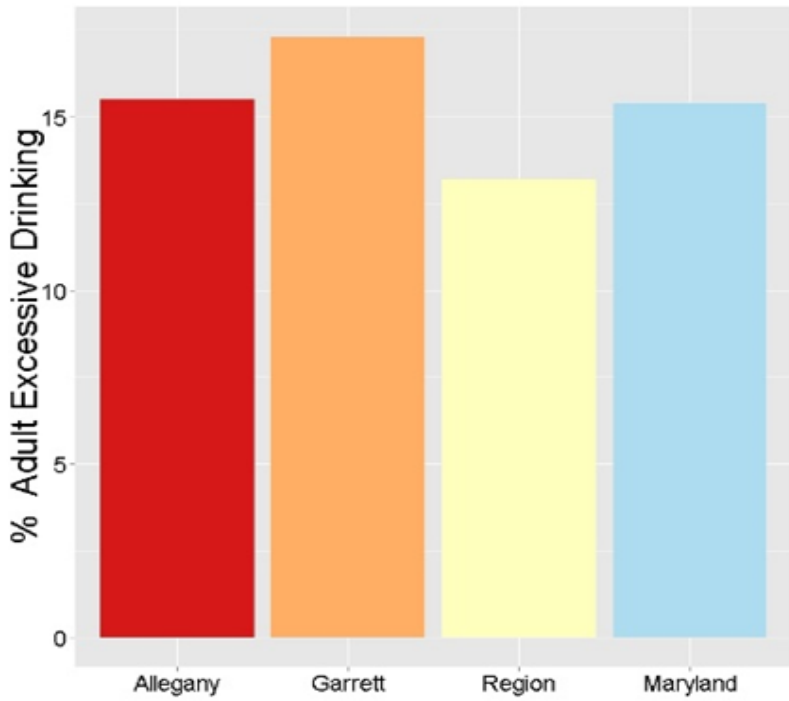


Figure 15-31: Percent Adult Excessive Drinking

15.7 Health Care Infrastructure

Health care infrastructure is fundamental to the provision and execution of health services and a well-coordinated, high-quality infrastructure provides the capacity to prepare for and respond to both acute (emergency) and chronic (ongoing) issues related to a community's health. A robust healthcare infrastructure includes a capable, well-distributed, and culturally competent workforce; qualified institutional agencies such as private and public medical services, hospitals, and emergency transport services capable of assessing and responding to public health needs; and high performance and coordinated informational systems to support quality patient care and clinical communication [279]. Availability, access, and quality of local clinical and public health services can be limited in some communities, due to low population density, low rates of insured patients, and limited public resources.

15.7.1 Providers

To assess the healthcare infrastructure of Allegany and Garrett counties, the team obtained information regarding rates and ratios of primary care physicians, dentists, and mental health providers to the population from the 2014 County Health Indicators Project, University of Wisconsin. Allegany County has 44 primary care providers (at a rate of 58.9 per 100,000 and a ratio of 70.7 to the population), 50 dentists (rate 61.0 and ratio of 68.3), and 82 mental health providers (rate of 100.1 and ratio of 41.6). Garrett County has 15 primary care providers (rate of 49.9 and ratio or 83.5), 11 dentists (rate of 36.2, ratio of 115.0), and 12 mental health providers (rate of 39.5, ratio of 105.5). These rates are, on average, much lower than the statewide averages, especially for mental health providers (rate 146.7, ratio 28.4), indicating a critical shortage of providers in both Allegany and Garrett counties.

Table 15-13. Health Care Infrastructure

Area	Primary Care Providers (rate)	Mental Health Providers (rate)	Dental Health Providers (rate)
Allegany	58.9	100.1	61.0
Garrett	49.9	39.5	36.2
Maryland	88.2	146.7	67.9

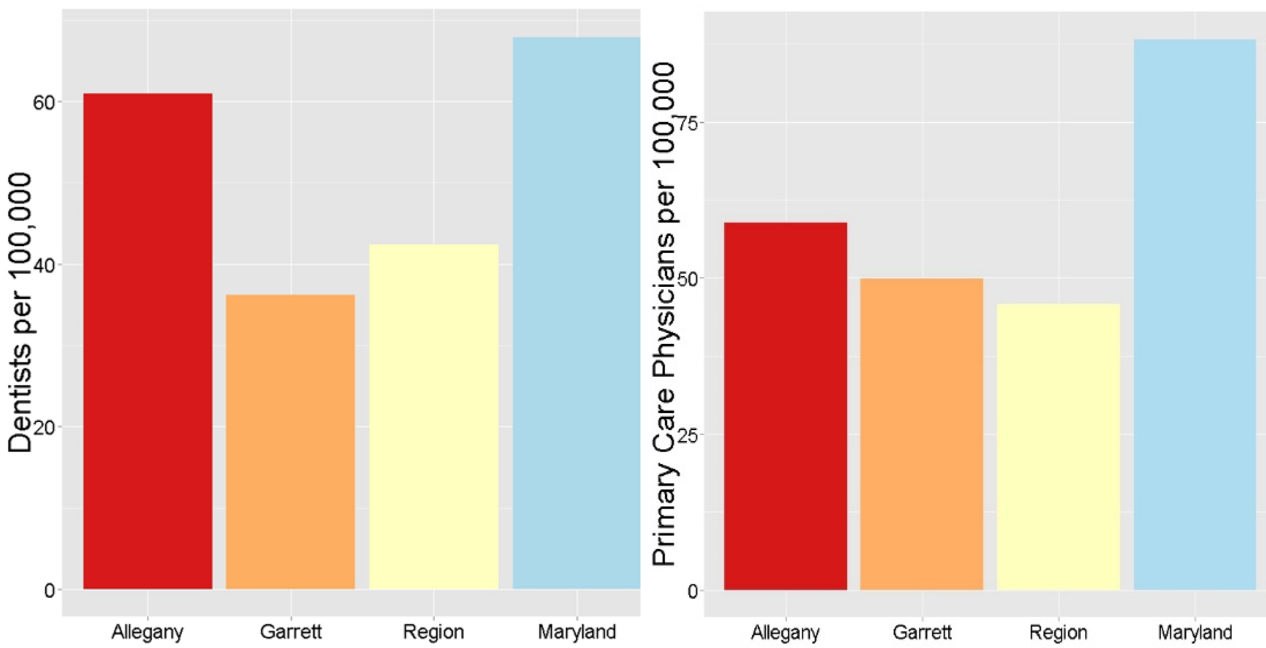


Figure 15-32: Number of Dentists, 2012 and Primary Care Physicians, 2011 per 100,000

15.7.1.1 Health Professional Shortage Area/Medically Underserved Area

According to HRSA, Health Professional Shortage Areas (HPSAs) are federal designations for shortages of primary medical care, dental or mental health providers [280–282]. These designations may be geographic (a county or service area), demographic (low income population) or institutional (comprehensive health center, federally qualified health center or other public facility) [283]. Allegany County is a designated HPSA for primary care for low-income populations, mental health care for Medical Assistance populations, and dental care for

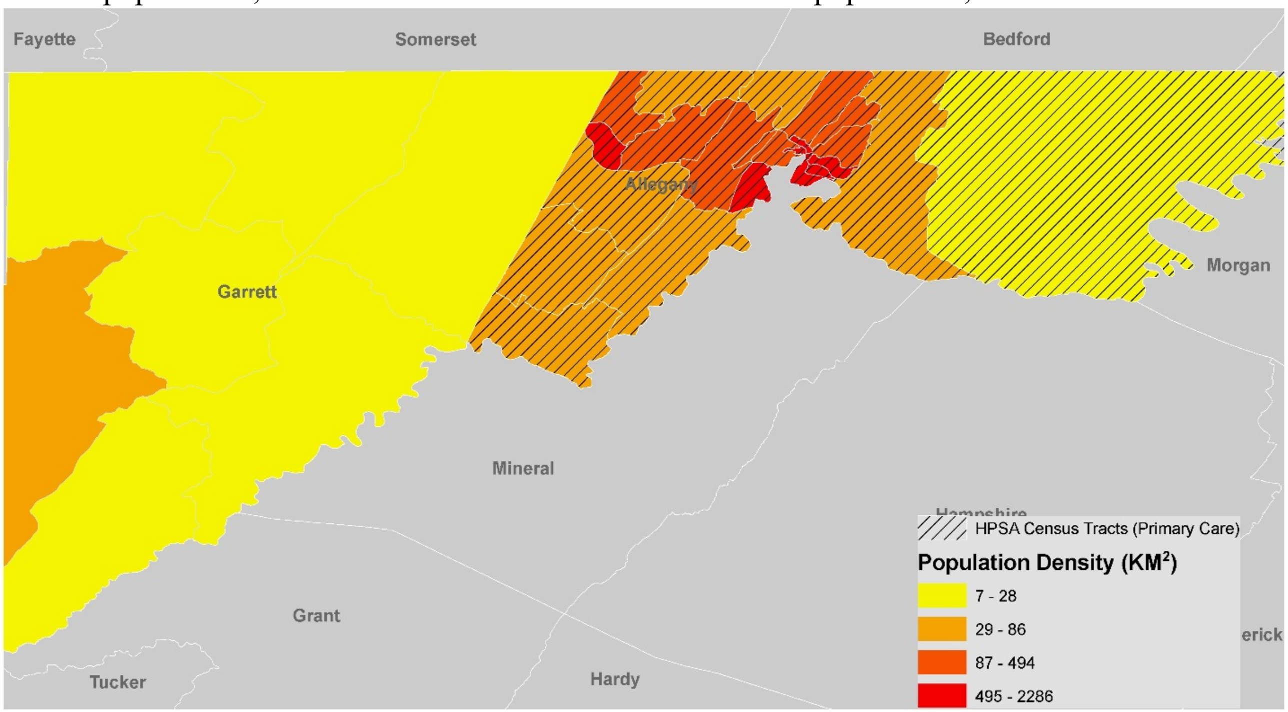


Figure 15-33: HPSA Designations in Allegany and Garrett Counties, 2013

Medical Assistance populations [284]. Allegany County has a critical need for specialty providers including vascular surgery, urology, as well as dentists willing to provide care for adults with no insurance or Medical Assistance [285]. Garrett County is a designated HPSA for primary and mental health care, and dental care for Medical Assistance populations.

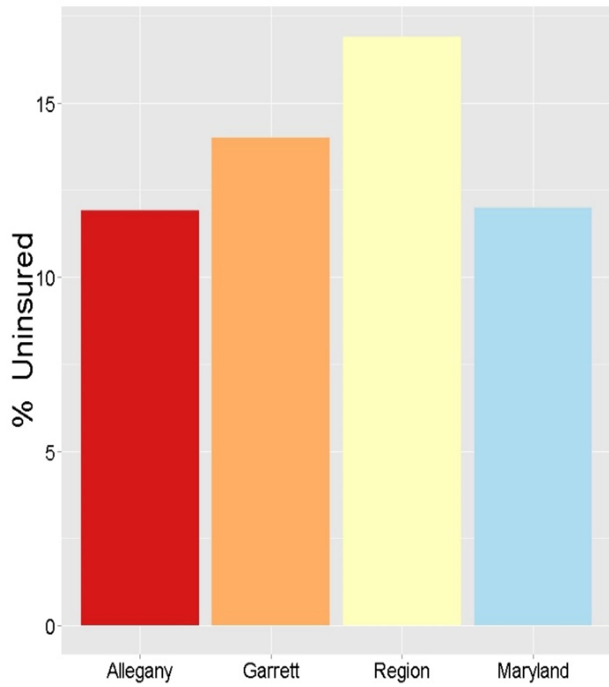


Figure 15-34: Uninsured Populations, 2011

Medically Underserved Areas (MUA) are locations designated by HRSA in which residents have a shortage of personal health services. All of Garrett County is considered an MUA, while substantial portions of Allegany County (Orleans, Lonaconing, Oldtown, and Cumberland) also qualify as MUA [284].

15.7.2 Insurance Status

The team also obtained information on insurance status of individuals living in Garrett and Allegany counties from the County Health Rankings Database. In 2011, there were an estimated 6,532 uninsured individuals living in Allegany County, approximately 11.9% of total population, including 4% of children. In Garrett County, an estimated 3,473 individuals were uninsured, approximately 14% of the total population. In the State of Maryland, an average of 12% of the total population is uninsured, with most counties having between 8-16% of the total population uninsured. Compared to the region (16.9%), the percent uninsured in Maryland and in the two counties was lower; this could be due to the state's health care exchange program.

16 APPENDIX 2

Table 16-1: Health Effects Associated with Chemicals Used During UNGDP

Chemical Name	CAS Number	IARC	EPA IRIS	CAL EPA	ATSDR Cancer Effects	ATSDR Target Organs
1-methoxy-2-propanol	107-98-2			Alimentary		
Acetaldehyde	75-07-0	2B	B2	Respiratory, Eyes		
Acetone	67-64-1					Hematological, Neurological
Acetophenone	98-86-2		D			
Acrylamide	79-06-1	2A	Likely		Reasonably anticipated to be a human carcinogen	Neurological, Reproductive
Aluminum	7429-90-5			Neurotoxicity, Immunotoxicity	None	Musculoskeletal, Neurological, Respiratory
Aluminum chloride	1327-41-9					Musculoskeletal, Neurological, Respiratory
Aluminum oxide (alpha-Alumina)	1344-28-1					Musculoskeletal, Neurological, Respiratory
Aluminum sulfate hydrate	10043-01-3					Musculoskeletal, Neurological, Respiratory

Chemical Name	CAS Number	IARC	EPA IRIS	CAL EPA	ATSDR Cancer Effects	ATSDR Target Organs
Ammonia	7664-41-7				None	Dermal, Ocular, Respiratory
Ammonium acetate	631-61-8		D			
Antimony pentoxide	1314-60-9			None		Cardiovascular, Respiratory
Antimony trichloride	10025-91-9			None		Cardiovascular, Respiratory
Barium sulfate	7727-43-7		D	None	None	Cardiovascular, Gastrointestinal, Reproductive
Benzene	71-43-2	1	A	Carcinogenicity (leukemia)	Known to be a human carcinogen	Hematological, Immunological, Neurological
Benzene, C10-16, alkyl derivatives	68648-87-3					
Benzenemethanaminium	3844-45-9	3				
Benzoic acid	65-85-0		D			
Benzyl chloride	100-44-7	2A	B2			
Boric acid	10043-35-3			None	None	Cardiovascular, Development
Boric oxide	1303-86-2				None	Cardiovascular, Development
Butanol	71-36-3		D			
Coconut fatty acid	68603-42-9	2B				

Chemical Name	CAS Number	IARC	EPA IRIS	CAL EPA	ATSDR Cancer Effects	ATSDR Target Organs
diethanolamide						
Copper	7440-50-8		D	Digestive	None	Gastrointestinal, Hematological, Hepatic
Copper iodide	7681-65-4				None	Endocrine
Copper sulfate	7758-98-7				None	Gastrointestinal, Hematological, Hepatic
Crotonaldehyde	123-73-9		C			
Crystalline silica - quartz (SiO2)	14808-60-7	1				
Cumene	98-82-8	2B	D			
Cyclohexane	110-82-7					
Cyclohexanone	108-94-1	3				
d-Limonene	5989-27-5	3				
Di (2-ethylhexyl) phthalate	117-81-7	2B	B2	Carcinogenicity	Reasonably anticipated to be a human carcinogen	Reproductive
Dibromoacetonitrile	3252-43-5	2B				
Diesel	68334-30-5				None	Dermal, Hepatic, Neurological, Ocular, Respiratory
Diesel	68476-30-2				None	Dermal, Hepatic, Neurological, Ocular, Respiratory

Chemical Name	**CAS Number**	**IARC**	**EPA IRIS**	**CAL EPA**	**ATSDR Cancer Effects**	**ATSDR Target Organs**
Diesel	68476-34-6				None	Dermal, Hepatic, Neurological, Ocular, Respiratory
Diethanolamine (2,2-iminodiethanol)	111-42-2	2B				
Dimethyl formamide	68-12-2	3				
Ethanol (Ethyl alcohol)	64-17-5	#				
Ethylbenzene	100-41-4	2B	D	Hepatoxicity	None	Developmental, Neurological
Ethylene glycol (1,2-ethanediol)	107-21-1				None	Developmental, Renal
Ethylene glycol monobutyl ether (2-butoxyethanol)	111-76-2	3	Not likely to be carcinogenic to humans		None	Hematological, Hepatic
Ethylene oxide	75-21-8	1			Known to be a human carcinogen	Dermal, Developmental, Neurological, Ocular, Renal
Formaldehyde	50-00-0	1	B1		Known to be a human carcinogen	Dermal, Gastrointestinal, Immunological, Respiratory
Furfural	98-01-1	3				
Furfuryl alcohol	98-00-0					
Hydrocarbon mixtures	8002-05-9				None	Dermal, Hematological,

Chemical Name	CAS Number	IARC	EPA IRIS	CAL EPA	ATSDR Cancer Effects	ATSDR Target Organs
						Neurological
Hydrogen chloride (Hydrochloric acid)	7647-01-0	3				None
Hydrogen fluoride (Hydrofluoric acid)	7664-39-3				None	None
Hydrogen peroxide	7722-84-1	3				
Hydrogen sulfide	7783-06-4					Neurological, Ocular, Respiratory
Inorganic salt	7446-70-0					Musculoskeletal, Neurological, Respiratory
Iron oxide (Ferric oxide)	1309-37-1	3				
Isopropanol (Isopropyl alcohol, Propan-2-ol)	67-63-0	3				
Kerosene	8008-20-6					Dermal, Hepatic, Neurological, Ocular, Respiratory
Lead	7439-92-1	2B	B2	Carcinogenicity Developmental neurotoxicity, Cardiovascular	Reasonably Anticipated to be a Human Carcinogen	Cardiovascular, Developmental, Gastrointestinal, Hematological, Musculoskeletal, Neurological, Ocular, Renal, Reproductive
Magnesium silicate hydrate (talc containing	14807-96-6	1				

Chemical Name	CAS Number	IARC	EPA IRIS	CAL EPA	ATSDR Cancer Effects	ATSDR Target Organs
asbestiform fibers)						
Medium aliphatic solvent petroleum naphtha	64742-88-7					
Morpholine	110-91-8	3				
Mullite	1302-93-8					
N-heptane	142-82-5		D			
Naphthalene	91-20-3	2B	C		Reasonably anticipated to by a human carcinogen	Hematological, Hepatic, Neurological, Ocular, Respiratory
Nitrilotriacetic acid	139-13-9	2B				
Nylon fibers	25038-54-4	3				
Octyltrimethylammonium bromide	57-09-0			Carcinogenicity		
p-Xylene	106-42-3			Neurotoxicity	None	Developmental, Hepatic, Neurological, Renal
Phenol	108-95-2	3	D	Neurotoxicity	None	Dermal, Hematological
Phosphoric acid	7664-38-2			Respiratory		
Potassium carbonate	584-08-7			Respiratory		
Potassium iodide	7681-11-0				None	Endocrine
Propylene oxide	75-56-9	2B	B2	Reproductive/ Development, Respiratory, Eye irritation		

Chemical Name	CAS Number	IARC	EPA IRIS	CAL EPA	ATSDR Cancer Effects	ATSDR Target Organs
Silica (crytalline)	7631-86-9	1		Respiratory		
Sodium bromate	7789-38-0		B2			
Sodium chlorite	7758-19-2	3	D	Hematotoxicity, Neurotoxicity	None	Ocular, Respiratory
Sodium hydroxide (Caustic soda)	1310-73-2			Eyes, Skin, Respiratory	None	None
Sodium tetraborate decahydrate	1303-96-4				None	Cardiovascular, Developmental
Stabilized aqueous chlorine dioxide	10049-04-4		D	Hematotoxicity, Neurotoxicity	None	Dermal, Neurological, Ocular, Respiratory
Stannous chloride dihydrate	10025-69-1					
Straight run middle petroleum distillates	64741-44-2				None	Dermal, Gastrointestinal, Neurological, Respiratory
Sulfuric acid	7664-93-9	1		Respiratory	Known to be a human Carcinogen	Dermal, Respiratory
Thiourea	62-56-6	3				
Toluene	108-88-3	3		Reproductive/ Development, Headache, Dizziness, Sensory irritation	None	Cardiovascular, Neurological

Chemical Name	CAS Number	IARC	EPA IRIS	CAL EPA	ATSDR Cancer Effects	ATSDR Target Organs
Xylene	1330-20-7	3		Central nervous system impairment, Respiratory, Eye irritation	None	Developmental, Hepatic, Neurological, Renal
Zinc chloride	7646-85-7		D		None	Gastrointestinal, Hematological, Respiratory
Zinc oxide	1314-13-2		D		None	Gastrointestinal, Hematological, Respiratory

[#]Ethanol is Group 1 carcinogen through ingestion route.