Letter Health Consultation

RESIDENTIAL CARBON DIOXIDE SAMPLING
MORRISDALE, GRAHAM TOWNSHIP,
CLEARFIELD COUNTY, PENNSYLVANIA

Public Health Evaluation of Carbon Dioxide Air Monitoring Data
in Multiple Residences

October 2020

pennsylvania
DEPARTMENT OF HEALTH

Bureau of Epidemiology, Division of Environmental Health Epidemiology
625 Forster Street | Room 933 | Health and Welfare Building
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Disclaimer

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Contact Information

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From: Pennsylvania Department of Health
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Harrisburg, PA
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10/06/2020

To: Ann DiDonato
On-Scene Coordinator
US EPA Region 3
Philadelphia, PA

Dear Ms. DiDonato,

The Pennsylvania Department of Health (DOH) prepared this letter health consultation (LHC) to evaluate indoor air sampling data collected in residences in Graham Township, Clearfield County, Pennsylvania in December 2019. Since October 2019, at the request of EPA Region 3 (EPA) Removal program, the Agency for Toxic Substances and Disease Registry Region 3 (ATSDR) and DOH have been involved with evaluating several residences built on formerly mined areas with elevated indoor air carbon dioxide (CO_2) levels. This LHC summarizes potential health effects related to exposure to CO_2 and volatile organic chemicals (VOC) levels at the concentrations detected in the residences.

BACKGROUND

The residences are located on land that was originally surface mined for coal by Thompson Brothers Coal Company and Avery Coal Company. Historically, the companies reclaimed portions of the mining lease and returned it to “original” contours and amended with alkaline material (i.e., calcium carbonate) as required by their surface mining permit for acid mine drainage measures. In the late 1980’s, Pennsylvania Department of Environmental Protection (PA DEP) – Hawk Run District Office notified property owners on the portions of the mine that had not been reclaimed, that PA DEP was the process of forfeiting the outstanding bond. Amerikohl Mining, Inc. had submitted a proposal on behalf of the International Fidelity Insurance Company to finish the reclamation of the mine as the Avery Coal Company, Inc. failed to finish reclamation activities. Around 2000, the reclaimed property was approved for residential development with the first home being built in 2005.

In 2010, a homeowner contacted the Pennsylvania Bureau of Abandoned Mine Reclamation (BAMR) regarding concerns about CO_2 intrusion. BAMR investigated and confirmed that the home had a serious CO_2 gas intrusion problem. In 2011, BAMR requested technical assistance from the federal Office of Surface Mining (OSM). OSM determined that calcium carbonate incorporated into the spoils during reclamation was reacting with acid mine drainage with CO_2 as a byproduct. OSM made recommendations to the homeowner that included a range of CO_2 mitigation actions from increasing air exchange to completely relocating the house. The homeowner completed all recommendations except the physical relocation of the house. As a result, the indoor CO_2 levels were reduced until 2019 when indoor CO_2 monitors began to register increasing CO_2 levels. The homeowner reported symptoms consistent with exposure to elevated levels of CO_2 in family members and requested help from PA DEP Northcentral Region. PA DEP reached out to EPA to request that EPA follow up with the resident.

EPA requested public health support from ATSDR in September 2019, including assistance speaking directly with affected residents. ATSDR conducted a site visit in October 2019 and spoke with two separate homeowners. In November 2019, EPA requested a technical assistance email from public health agencies regarding the public health implications of CO_2 levels in two homes in support of further characterization work at this site. DOH provided a technical assistance email in December 2019. As a result, EPA conducted indoor air monitoring at the site.

EXPOSURE PATHWAY

Exposure to contaminants of concern is determined by examining human exposure pathways, which have five parts:

1. A source of contamination (e.g., industrial facilities utilizing hazardous materials);
2. An environmental medium that can hold or move the contamination (e.g. water, soil, or air);
3. An exposure point at which people could come into contact with a contaminated medium (e.g., private residential well water or a building into which vapors enter);
4. An exposure route (e.g., ingestion or inhalation); and
5. A population that could come in contact with the contaminants.

For a completed pathway, all five parts must exist and exposure to a contaminant must have occurred, is occurring, or will occur (ATSDR, 2005a[1]).

For this site, the exposure pathway of concern while inside the residences is the inhalation of gases. The five parts of the exposure pathway are present or could be present at this site as follows:

1. Source: CO_2 is a byproduct of calcium carbonate reacting with acid mine drainage.
2. Environmental medium: Indoor air can hold and transport CO_2.
3. Exposure point: People could become exposed within their residences if the gas enters their homes, contaminating the indoor air.
4. Exposure route: People could inhale CO_2 that may be present in the indoor air.
5. Population: The residents are the potentially exposed population of concern.

INDOOR AIR MONITORING AND SAMPLING

EPA collected air samples using an Area RAE monitor to detect CO_2 and oxygen (O_2) along with SUMMA canisters over a 24-hour sample period to detect volatile organic compounds and tentatively identified compounds, total gaseous non-methane organics, C1–C6 hydrocarbons and fixed gases.

There are currently eight private residences built on, or adjacent to, the reclaimed mining property. Four of the residences (House #1, 2, 3, & 4) and the nearby outdoor acid mine drainage (AMD) treatment facility were sampled (see Table 1). A home (House #5) was sampled with handheld instruments in October 2019 and had reported levels of indoor CO_2 at 1,200 ppm. The owners did not grant access for the December 2019 stationary indoor air monitoring. The remaining residents were contacted by EPA but never granted access for any indoor air sampling or further monitoring.

RESULTS

Carbon dioxide was detected in the residences at concentrations ranging from 314 to 7,023 ppm (see Table 1). Oxygen levels in the residences ranged from 20.1 to 20.9 percent. Since oxygen levels in air are typically around 21 percent (NASA, 2016[2]), it is possible that oxygen was being displaced within the residences by the high levels of CO_2.

Table 1: Measured CO_2 Levels from Four Homes and the Outdoor Acid Mine Drainage Treatment Facility in December 2019

Sampling Location	Range of CO_2 levels (ppm)	Range of O_2 levels (%)
House #1	2,135 - 6,600	20.1 - 20.6
House #2	960 – 5,425	20.4-20.9
House #3	1,357 - 7,023	20.2 - 20.6
House #4	314-1670	20.9 (stable)
AMD Treatment Facility	320	Not collected

Volatile Organic Compound (VOC) samples were also collected at 4 homes using SUMMA canisters. House #1, #2 and #4 each had one VOC chemical above ATSDR air screening values. All other VOCs were below air screening values and not found at levels of public health concern. The three contaminants that exceeded environmental and health-based screening values include: acrolein, which was detected at a maximum concentration of 2.5 micrograms per cubic meter, an MRL of 0.004 mg/kg/day has been derived for intermediate-duration (µg/m^3) in House #1, isopropanol, which was detected at 2300 ppm in House #2, and naphthalene, which was detected at 12 µg/m^3 in House #4.

House #1 VOC: It is notable that acrolein is ubiquitous in the environment and is generated by both natural and anthropogenic (manmade) processes. It is present in vehicle exhaust and is commonly present in outdoor air. It is a common contaminant found in outdoor air and forms during the combustion of organic matter such as tobacco and fuels like gasoline and oil. Smoking one cigarette can generate acrolein concentrations of 450 to 840 µg/m^3 acrolein within 10 to 13 minutes. The levels of acrolein within the air of a typical home range between less than 0.05 and 27 ug/m^3 but can be higher if tobacco is smoked in the home. In urban and rural air, average acrolein levels have been measured at levels around 0.46 µg/m^3 and 0.27 µg/m^3, respectively. However, in several large cities acrolein has been measured at levels as high as 12.8 µg/m^3. Close to vehicle exhaust pipes, acrolein levels 10 to 100 times higher may occur.

The primary effects from chronic inhalation exposure to acrolein in humans consist of general respiratory congestion and eye, nose, and throat irritation. Studies in rats showed the Lowest Observable Adverse Effect Level (LOAEL) is 916 ug/m^3 acrolein, based on nasal squamous and epithelial metaplasia. This is 366 times greater than the highest indoor air level reported for the home. Additionally, the ATSDR acute (exposure up to 14 days) Minimum Risk Level (MRL) is 6.9 ug/m^3 and is based on nose and throat irritations and a decrease in respiratory rate in humans exposed to acrolein, with a LOAEL of about 687 ug/m^3. This acute exposure LOAEL is more than 274 times greater than the maximum indoor air level found in the home. An MRL of 0.004 mg/kg/day has been derived for intermediate-duration. In a study, human volunteers exposed to acrolein vapors for 35 minutes reported statistically significantly more nose irritation at 595 ug/m^3, throat irritations at 985 ug/m^3, and a decrease in respiratory rate at 1374 ug/m^3. In all of these studies, health effects were seen at much greater concentrations than those found in the home.

House #2 VOC: Isopropanol (also called 2-propanol, 'rubbing alcohol', or isopropyl alcohol) is found in many household products. Isopropanol is widely used as a disinfectant at home, in hospitals, and in industry; as a solvent in the production of hair and skin products; as an antifreeze agent in fuel systems; in windshield washers; in lens cleaners; and in racing motor fuels. The maximum isopropanol level found in the indoor air was from 660 - 2300 ug/m^3. These levels are well below levels expected to cause any acute or chronic health effect levels. The isopropanol levels found throughout the home were at least tenfold lower. In a study using rats, the no-observed-effect level (NOAEL) for isopropanol was 1,226,500 ug/m^3 (500,000 ppbV). In humans, odor thresholds begin at about 90,000 ug/m^3 (37,000 ppbV) isopropanol and the critical effect of isopropanol is irritation of the respiratory system, eyes, and mucous membranes. Very high concentrations may cause central nervous system effects such as dizziness, nausea, hypotension, and hypothermia. Irritation in the human nose and throat has been reported at exposure levels around 1,000,000 ug/m^3 (400,000 ppbV) isopropanol. The levels found in the home are not at levels of concern for non-carcinogenic health effects. Additionally, isopropanol is not considered a carcinogen.

House #4 VOC: Naphthalene is a white crystalline powder that is produced from coal tar and has the characteristic odor of mothballs. It is naturally present in fossil fuels such as petroleum and coal and is produced when wood or tobacco is burned. Naphthalene is used as a moth repellent, disinfectant, and deodorizer. It is also used in making concrete, plasterboards, rubber, paints, and as a tanning agent in the leather industry. The major commercial use of naphthalene is in the manufacture of polyvinyl chloride (PVC) plastics. Its major consumer use is in moth repellents and toilet deodorant blocks.

ATSDR's chronic MRL for naphthalene is 3.7 µg/m^3 [ATSDR 2005]. The lowest exposure level in both mice and rat studies, 52,400 µg/m^3, was a lowest observed adverse effect level (LOAEL) in both sexes of both species for lesions in nasal olfactory epithelium and respiratory epithelium. Applying the EPA approach for inhalation dosimetry, a human equivalent LOAEL of 1,048 µg/m^3, based on the rat data, was selected as the point of departure for the chronic inhalation

MRL. The uncertainty factor was 300 (10 for use of a LOAEL; 3 for extrapolation from animals to humans with dosimetric adjustment used in MRL derivation; 10 for human variability).

The highest detected level of naphthalene in the home was 12 ug/m^3. This is well below the LOAEL (i.e., 52,400 µg/m^3 associated with lesions in nasal olfactory epithelium and respiratory epithelium) in both mice and rat animal studies. It is also significantly below (about 87 times) the human equivalent LOAEL of 1,048 µg/m^3, based on the rat data, and therefore, adverse health effects are unlikely from chronic exposures to naphthalene.

These three VOCs and the levels at which they were detected can be attributed to indoor sources. EPA discussed these indoor air results with each homeowner individually.

PUBLIC HEALTH IMPLICATIONS OF CO_2 EXPOSURE

Carbon dioxide is a colorless and odorless gas under normal temperature and pressure conditions, and it is ubiquitous in ambient air. Safety guidelines related to CO_2 are typically developed to regulate workplace exposures. The Occupational Safety and Health Administration's (OSHA) "immediately dangerous to life and health" (IDLH) value for CO_2 is 40,000 ppm based on acute inhalation toxicity data in humans. OSHA also regulates workplace 8-hour permissible exposure limit (PEL) to CO_2 at 5000 ppm. (NIOSH, 1994[3])

In their 2012 paper, Satish et al[4]. reported cognitive effects at 2,500 ppm CO_2 when compared to exposure at 600 ppm (see Table 2 below). The cognitive effects were marginal or dysfunctional regarding decision-making performance metrics. At 1,000 ppm CO_2, compared with 600 ppm, performance was moderately diminished on most decision-making performance metrics.

Table 2: Carbon Dioxide Levels, Potential Health Effects, and Comments

Levels (ppm)	Potential Health Effects	Comments
250-400	None expected	Typical outdoor range
400-1000	None expected	Typical indoor range
>1000	Drowsiness, potential cognitive effects, headache,	Consistent indoor levels >1000ppm suggest there's a potential issue with air exchange. CO2 monitors should be considered.
>2500	Cognitive effects (Satish et al 2012)	An indoor evaluation is prudent to determine source(s) of CO_2. Temporary actions to mitigate need to be implemented (e.g., increase air exchange, sealing basement floor and foundation, …)
>5000	Metabolic acidosis	Unusual indoor conditions; Permanent actions to mitigate need to be implemented (e.g., sub-slab depressurization system, perimeter trenching with active exhaust system, house re-location, …).
>40,000	Death	Immediately Dangerous to Life and Health (IDLH)

CONCLUSIONS AND RECOMMENDATIONS

Due to the heavier-than-air and asphyxiation hazard properties of CO_2, combined with the under-characterized etiology of the source of the CO_2, public health agencies are concerned with the immediate and long-term health and safety of exposed residents in Houses #1, 2, and 3. Some of the properties have been reported to have residents or regular visitors who are particularly vulnerable to CO_2 exposure based on age and/or pre-existing medical conditions such as chronic obstructive pulmonary disease (COPD), heart ailments, or asthma.

Three of the four houses had reported indoor CO_2 levels above health effect levels reported in the scientific literature. CO_2 concentrations in House #4 showed a maximum of 1,670 ppm which is significantly less than other indoor monitoring locations and was noted during the continuous monitoring event shortly after set-up while a large crew of EPA and contractors were in the home. The levels of CO_2 dropped significantly following the crew exiting the home. The observed lower level of CO_2 in house #4 compared to the other sampled homes is likely due the lack of basement or any below-grade living space, as home construction consists of living area atop a crawlspace. The CO_2 measurements at the outdoor AMD treatment facility were consistently around 320 ppm.

There are the immediate concerns at this site (i.e., current homes with elevated indoor CO_2 levels and the 4 homes that were not sampled) and a longer-term issue related to undeveloped parcels within this development as well as any future development on the adjacent reclaimed mining properties.

PADOH recommends that:

- PA DEP, BAMR or EPA take actions to mitigate the elevated indoor CO_2 levels in the three homes sampled in December 2019.
- PA DEP, BAMR or EPA should attempt to convince the 4 homes owners that were not sampled to allow indoor CO_2 evaluation.
- EPA provide a copy of this letter and the December 2019 sampling report to all residences and County/Township officials.
- BAMR provide educational materials to residences and County/Township officials.
- County/Township officials should consider implementing institutional controls (e.g., notification upon request for building permit, septic permit, land use variances, etc.).
- PA DEP, BAMR and County/Township officials should provide a public service announcement (PSA) to developers and real estate companies/agents regarding the potential for elevated indoor CO_2 levels on reclaimed mining properties.

There also maybe a need to evaluate other reclaimed mining properties under public use (e.g., residential, child daycare, nursing home) especially if acid mine drainage conditions are expected in the presence of substrates that can generate CO_2.

Please contact me with any questions you may have regarding this letter health consultation.

Sincerely,

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