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AN ENVIRONMENTAL CASE STUDY INVOLVING CARBON MONOXIDE INFILTRATION OF NEARBY RESIDENCIES DURING SEWER TRENCHING

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This paper describes EPA's response to a hazardous condition that developed in residential homes involving high levels of carbon monoxide near a sewer construction project that required the use of explosives to fracture sandstone. The use of an explosive that has a very negative oxygen balance and the results of leaving overburden in place generated large quantities of CO under very high pressures within the bedrock. The explosion gases caused residents in one home to become ill.

The problem was corrected by using a radon mitigation system. The area below the slab was depressurized using a 6" pipe fan.

INTRODUCTION

In the fall of 1988 an incident occurred in Southeastern Pennsylvania resulting in exposure of residents to carbon monoxide and subsequent hospitalization of two children. This paper will describe the activities of Region III, Air Management Division, with respect to the uniqueness of this particular indoor air incident involving: effect of development of a residential area, investigative techniques employed, description, relevant facts and actions taken immediately, and future recommendations.

OBSERVATIONS AND DISCUSSION

A Southeastern Pennsylvania township sewer authority was extending their gravity sewer system to allow hookup of a planned new residential development. Trench blasting was initiated to a depth of 30 feet prior to excavating and laying a sewer for homes on half-acre lots.

Blasting commenced November 3, 1988 and continued through November 8; at that time, two children in an adjacent home to the blast area were hospitalized with CO poisoning. Back calculations based on blood work showed they were exposed to 3-4% CO. No other organics or abnormal blood constituents were present. Three to four homes were found to have elevated CO (2000 ppm in the highest home). One sampling result also showed methane gas to be present (1-2%). Interestingly, one home with a radon mitigation system had 0 ppm CO in the basement but substantial levels in the radon exhaust vent outlet.

After becoming aware of the incident, EPA Region III's response was to visit the site and attempt to evaluate the available facts and get further information on the geology of the site, historical record, fracture trace analysis, infrared thermal analysis, aerial photography and trench blasting activities in the area of the affected homes. Ground Penetrating Radar (GPR) also was later used and proved helpful.

Many other governmental groups responded to the call from the township for assistance.[1] Pennsylvania Department of Environmental Resources (PADER) sent the following: Environmental Emergency Response Office (lead),[2] Bureau of Deep Mine Safety[3] (Harrisburg), and Bureau of Air Quality Control[4] (Bethlehem). U.S. EPA - Emergency Response and Preparedness Section (Technical Assistance Team), and Projects Management Section (Indoor Air). On the local side the Bucks County Emergency Team, Township Fire Company and Fire Marshall were on the scene.

EPA investigators considered the following sources of carbon monoxide:

1. Home Heating Appliances
2. History (possible old abandoned dump sites etc)
3. Geology
4. Trench blasting activities

The first item to be considered, especially during the heating season, as a source of carbon monoxide would logically be a defective heater or flue. The homes involved had gas-fired hot air heating systems. Based on inspection of the unit, the number of

homes simultaneously involved, and the lack of any change when the units were shut down, this suspected cause was exonerated.

Another potential source was the possibility of buried trash or manure pits that could be smoldering or burning either before or as a result of the use of explosives. Long-time area residents were questioned about the possibility of an old abandoned trash or waste dump. A historical review was made of past land uses.

Thermal imagery infrared surveys were done. The flyover was conducted at night and the sensor was calibrated to show minimal heat sources which were then indicated on the image as white areas. Nothing was discovered that could indict this source.

Having eliminated the first two possibilities, we reasoned that geology and/or the explosives were the source and mechanism for the infiltration of carbon monoxide into these residences. Geology could have contributed in two ways. One way was simply by carbon content of the material burning or smoldering. Another way could be channels leading to gas seepage from the carbon monoxide source into the residences.

As part of our thinking process, the influence of geology had been discussed within EPA and also with the United States Geological Survey (USGS). The thrust of the questions centered around the possibility of high organic rock flashing or containing pockets of CO. Previous radon studies in the area by EPA had shown the area to be part of the Newark Basin a prehistoric lake bed formed during the Triassic period (180M-230M years ago). This basin received sediments deposited in varying climates resulting in three formations being laid down (Brunswick, Lockatong and Stockton). It is not uncommon to find channelized carbon rich lignified wood deposits in the Stockton formation. Since this formation underlies the affected homes, there was a conceivable mechanism for CO generation.[5] These thoughts were dismissed because of the lack of any underground burning and because other homes in the area were found to have normal CO levels.

Fracture traces were determined by obtaining stereo film pairs with 66% overlap during a day overflight at 1200' elevation. The fracture trace analyses disclosed numerous possible pathways through the geological formation.[6] This was later confirmed by a ground penetrating radar computer enhanced photo that showed minor rock fractures at a positive angle in the area below the basements of the affected homes.[7]

Explosives were then considered. Our immediate appraisal of the data led us to believe that the trench blasting was the primary source of the carbon monoxide. Initial calculations indicated that up to 40% carbon monoxide could be present in the fume generated. Fume is a term used for toxic gases generated by explosives in the explosives industry. According to the Blasters Manual[8], conditions of use can drastically shift the types of gases produced. The types of explosives used were ANFO (Ammonium Nitrate + fuel oil) and TNT.

The percent of fuel oil in the ANFO is critical as to the type and amount of fumes produced. Too much oil increases the production of CO while too little oil increases the oxides of

nitrogen. ANFO with about 6% by weight has the maximum theoretical energy and the highest detonation velocity with NO_x and CO combustion gases at a minimal (near 0%). The ANFO used at the incident site was said to contain 6% fuel oil.

The combustion products are more straightforward with the use of TNT. Carbon monoxide concentration is 35-38% depending on the TNT density and about 5% methane is also produced. Some of combustion products are calculated and shown in table 1.

After careful consideration we concluded that a combination of circumstances--geology, barometric fluctuations and trench blasting--led to the described indoor air incident. We requested a meeting at ETI[9] Wilmington, Delaware to review these facts. All present were in concurrence with these conclusions. Letters were sent to ETI, EPA Headquarters and to all Regional offices alerting them to potential hazards of trench blasting near residential areas.

A letter was sent to a large explosive manufacturer on December 30, 1988 asking for their help in alerting the explosive industry and those serviced by it. The company in turn notified the Institute of Makers of Explosives on January 19, 1989, by telephone and a report describing the blasting parameters used at the incident site was forwarded at a later date. The institute placed the item on their docket for the upcoming spring 89 meeting. The Board of Governors at that time put out a bulletin advising all 30 members involved in manufacturing and distribution of explosives about this problem. Labeling has been revised. In addition, IME alerted the Bureau of Mines and they are now evaluating this problem as part of revising their fume classification system.

It is unique that the information from previous radon evaluations in the area was helpful with respect to geology. The presence of a radon mitigated home indicated its effectiveness in soil gas and carbon monoxide removal.

CONCLUSION

A hazardous condition developed in residential homes involving high levels of carbon monoxide near a sewer construction project that required the use of explosives to fracture sandstone.

Blasting during sewer trenching is a standard practice but in this case a high percentage of "nitropel" (TNT) was used to enhance rock fracturing. The use of "nitropel" which has a very negative oxygen balance and the results of leaving significant amounts of overburden in place generated large quantities of CO under very high pressures as well as smaller quantities of methane. This allowed migration of the gases through the numerous fractures and fissures in the area into the homes. Ammonium Nitrate/fuel oil (ANFO) was also used as part of the charge in each hole. Although ANFO when blended correctly should not generate CO (traces) it contribution to the problem, if any, could not be ascertained because of suspension of the blasting.

The explosion gases caused two boys in one home who were watching television in the basement to become ill. Upon being admitted to a hospital emergency room blood samples from the boy revealed high levels of CO. Subsequent monitoring in the home

revealed potentially lethal levels of CO.

It is significant that a radon mitigation system proved useful in both preventing the gases from entering one home and eliminating CO in another home with the highest concentration. The inference is that this technique will work for other problem gases such as pesticides and other organics located or generated in the region of the building slab.

In order to quantify the use of the sub-slab suction method on non-radon soil gases, EPA is now funding a study using radon test homes. The object is to correlate the environmental, soil gas, and structural dynamics of the home with previous radon results.

ACKNOWLEDGEMENT AND REFERENCES

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TABLE I

CALCULATED DETONATION PRODUCTS/NOXIOUS GASES

EXPLOSIVES	DENSITY (g/cc)	TOTAL GASES (m/100g)	CO (m/100g)	CH_4 (m/100g)	CO (%)	CH_4 (%)
TNT	1.65	3.244	1.130	0.174	34.8	5.4
	1.60	3.272	1.171	0.173	35.8	5.3
	1.50	3.327	1.254	0.170	37.7	5.1
AMMONIA DYNAMITES						
(SPEC. GEL 60)	1.46	2.923	0.000	-	-	-
(SPEC. GEL 75)	1.40	3.395	0.000	-	-	-
DYNAMITES						
(TRENCHRITE)	1.20	3.052	0.071	0.000	2.3	-
AMMONIUM NITRATE WATER GELS						
(TOVEX TR-2)	1.20	3.284	0.047	0.000	1.4	-
(TOVEX 650TR)	1.20	3.000	0.086	0.000	2.9	-
ANFO (94/6)	0.85	4.378	0.033	0.000	0.8	-
ANFO (94.6/5.4)	0.85	4.329	0.000	-	-	-

0.000 MEANS LESS THAN (0.0001)
-, MEANS NONE CALCULATED