Industrial Hygiene

Risk and Exposure Assessment

Residential Airborne Fiber and Residual Residential Asbestos

at

XXXXXX
Boulder, CO 80303

Prepared for:
XXXXXXX
XXXXXXXX
Boulder, CO 80303

Prepared by:

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November 11, 2009

EXECUTIVE SUMMARY

On Friday, November 6, 2009, personnel from Forensic Applications Consulting Technologies, Inc. (FACTs) visited the subject property, a ranch style residence located at XXXXXXXX, Boulder, CO 80303. The purpose of the visit was to perform specific sampling and analysis to develop information needed to make an Industrial Hygiene statement of exposure to asbestos and subsequent risk from that exposure.

No part of the project was within the auspices of any regulatory body and was not covered by any regulation or regulatory body, including Colorado's Asbestos Regulation[1], and was not part of a compliance action or remediation action.

The sampling and risk assessment employed standard industrial hygiene practices, scientifically accepted and standard procedures and accepted and standard methodologies. No new methodologies were introduced or used in this assessment. Similarly, no new or untested scientific methodologies were used, and no new applications for otherwise accepted methodologies were employed. Data generated during this investigation were interpreted to the highest standard of care according to state of the art practices and state of knowledge.

Prior to the study, FACTs established[2] the following hypothesis:

> Regardless of actual sampling and analytical error, and presuming that total airborne fiber concentrations in the XXXXX residence are equal to total asbestos fibers, there is an unacceptable risk due to airborne asbestos fibers.

FACTs then collected from the residence three air samples for total airborne fibers, and ten microvacuum samples for the analysis of asbestos; the results of which were to be used to support the hypothesis. Using diligent, reasonably aggressive techniques and sampling protocols, the results of the sampling and analysis failed to support the hypothesis. Therefore, FACTs rejects the primary hypothesis and accepts the null hypothesis:

> Regardless of actual sampling and analytical error, and presuming that total airborne fiber concentrations in the XXXXX residence are equal to total asbestos fibers, there is no evidence of an unacceptable risk due to airborne asbestos fibers.

The field work was performed by the author of this report. Mr. Connell was assisted in the field by Ms. Christine Carty, Technician.

This report discusses our techniques, rationale, observations, conclusions and recommendations. The appendices of this report include a DVD of videos and photographs taken during our field investigation.

[1] Regulation 8 Part B, (5 CCR 1001-10, Part B)

[2] Letter to XXXXXX XXXXXX, Nov. 5, 2009

INTRODUCTION

History:

Based on interviews with the resident of the subject property, the resident desired to hire a contractor to clean the residential air ducts. Prior to cleaning the ducts, the resident contracted with XXXX Environmental Inc. (XEI) who, on September 30, 2009, performed a "Limited Asbestos Inspection" at the property "to facilitate duct cleaning." XEI reported that they performed a building survey for asbestos in compliance with State and Federal regulations. XEI concluded that none of the materials they tested (associated with the duct work) contained asbestos.

The resident contracted with Monster Vac (a duct cleaning firm) to clean the duct work. The resident reported that Monster Vac visited the property to clean the ducts on October 24, 2009.

The resident reported that she was dissatisfied with the work by Monster Vac when, after the visit by Monster Vac, the resident observed visible clouds of dust coming from the duct interior when she activated the forced-air furnace.

The resident became concerned about the possibility of asbestos and, using a resourceful and imaginative (but non validated) sampling method, placed double-sided tape in the air stream of the duct system. The resident collected four similar tape samples for analysis of asbestos. The double sided tape was submitted to XXXXXXX Environmental Laboratories for asbestos analysis. XXXXXXX reported no detectable asbestos, by PLM, in four of the samples, and visually estimated an asbestos content of 10% chrysotile in one tape sample collected from the kitchen.

On November 5, 2009, FACTs prepared a sampling protocol and proposed data quality objectives to assess the risk from residual asbestos exposure at the property.

On Friday, November 6, 2009. FACTs visited the subject property and performed the field investigation and collected samples.

Structure

Built in the1960's, the structure is a 1,000 square foot ranch with a 275 square foot attached garage. The residence has a residential forced-air furnace system and passive ventilation. A poured concrete foundation wall forms an earthen floored crawlspace through which heating air ducts traverse. Since the work by FACTs was exclusively an exposure and risk assessment and not a building survey or building inspection of any kind, inspection of the crawlspace was outside the scope of work.

Weather

On the day of our visit, the weather was seasonably warm (high 60's to low 70's °F), the barometric pressure was normal at approximately 24.4 inches of mercury; falling in mid

afternoon and returning by the end of the sampling day. There was no appreciable wind during the sampling day.

SAMPLE COLLECTION

Hypothesis Testing

Sampling of any kind should be designed to answer a very specific question. The more narrow the question, the tighter the quality of the data necessarily becomes.

In the case of this subject property, FACTs was attempting to evaluate the extant exposures and to qualitatively place those exposures into a risk categorization. Our hypothesis became:

> Regardless of actual sampling and analytical error, and presuming that total airborne fiber concentrations in the XXXXX residence are equal to total asbestos fibers, there is an unacceptable risk due to airborne asbestos fibers.

In a quantitative risk assessment, the modeler would consider the toxicological difference in asbestos mineralogy (serpentines vs. amphiboles), morphology (size and aspect ratio of fibers), dustiness (molecular hydration) and a variety of other modifying parameters. In a qualitative risk assessment, such as this, limited resources (financial and available data) limit the degree to which various modifiers will be employed and considered. The qualitative modifier is the term "acceptable" in our hypothesis which is based on professional judgment, supported by objective sample results, and using excessive lifetime cancer risk (ELCR) values compared to the risk management range of 1E-06 to 1E-04 that is generally used by US EPA. ELCR values exceeding this range may be used as *prima facie* evidence of an *unacceptable* attributable risk.

It is important to note that "qualitative" in no way limits the confidence of the conclusions, merely the *precision* and assumptions used.

Data Quality Objectives

Prior to the collection of any kind of environmental sample, data quality objectives (DQOs) should be established by which the results may be properly interpreted. The DQOs become the "guidelines" to determine the limitations and usefulness of the data. The DQOs describe the precision, accuracy, representativeness and comparability of the data thus derived from the sampling.

Frequently, an *a priori* decision criteria is established by which the data results may be judged. In this case, no *a priori* decision criteria was established since the classification of acceptable risk would be based on the totality of the circumstances with considerable input from the exposed population (occupants of the house). However, guidance on acceptability would be based on risk estimates from the US EPA Health Assessment Summary Tables and exposure considerations would be benchmarked against local, federal, and national consensus exposure standards.

ALL samples exhibit uncertainty; ALL analyses exhibit uncertainty. It is well established that concentrations of contaminants in a structure exhibit lognormal or even parametric distributions; large variations in contaminant concentrations are seen over very short distances.

Furthermore, it is a well established and a standard sampling precept that short term samples exhibit large temporal variations.[3] Generally, the geometric standard deviation of interday and intraday airborne concentrations lie between 1.2 and 2.5 geometric standard deviations.[4]

As such, FACTs recognizes that a single day of monitoring cannot be used as absolute truth or a definitive metric for exposure. However, a single day of monitoring designed to aggressively bias potential exposures higher than normal, and when aggressively performed in conjunction with other sampling activities, results in good *confidence* that the normal variations would typically result in exposures considerably less than those observed during the day of monitoring. Therefore, the type of sampling protocol can be used to speak to the issue of a reasonable upper limit of potential exposures. The use of aggressive biased sampling is a type of sampling known as "authoritative judgmental biased" sampling. This type of sampling is not designed to estimate "representativeness" but rather to purposely bias the results high, and attempt to demonstrate a reasonable worst case scenario.

To address both precision and accuracy, FACTs used standard accepted sampling and analysis protocols from national consensus standards organizations and those developed by the US Department of Health and Human Services, National Institutes of Occupational Safety and Health (NIOSH). The NIOSH methods are "validated" methods each of which have considerable scientific foundation and widespread acceptability. The precision and accuracy of the analysis performed is well documented in the literature supporting the methods and will not be discussed further here.

To address comparability, FACTs chose to benchmark the results of the testing against nationally and internationally accepted exposure standards for fibers and asbestos.

Based on the totality of the results, FACTs concludes that the precision and accuracy of the data are within the normally accepted tolerances for the methods employed; that the representativeness of the samples has been appropriately addressed in an *a priori* manner, that the comparability of the samples is based on nationally accepted benchmarks and risk estimates and therefore, the data are complete to the extent that the data meet the *a priori* data quality objectives for the study.

[3] Ayer, HE, Burg J, *Time Weighted Averages Vs. Maximum Personal Sample* (Presented at the AIHA Conference, Boston, MA, 1973)

[4] NIOSH Occupational Exposure Sampling Strategy Manual, HEW Publication Number 77-173 (1977)

Methodology

Air Sampling

The air sampling was performed using the NIOSH 7400 Method (Fibers) as the foundation. The objective of the air sampling was to obtain as low a reportable detection limit of airborne fibers within as short a period of time as was reasonable.

Three high volume area air sampling pumps were pre-calibrated using a primary standard. Each of the pumps was allowed to operate for 30 minutes prior to calibration with a calibration cassette in line. The pumps we adjusted to collect approximately one cubic meter of air per hour, resulting in the collection of approximately eight cubic meters of air during the sampling period.

Electrical static charges across the sampling cassette become significant at these flow rates. FACTs used electrically conductive sampling cowels which were grounded to larger metal objects in the room to dissipate the static charges.

To agitate the air and break up stratification, and attempt to mix the air in the residence as much as reasonably possible, FACTs employed three axial fans to continuously move air throughout the structure during the sampling period. FACTs employed two large (20 inch) axial box fans and one smaller 12 inch axial fan to agitate the air in the structure. The two box fans were placed in the east and west hallways, and the smaller fan was placed in the spare room which constituted the only "dead air" space in the residence. Additionally, the ceiling fan in the master bedroom was operated during sampling.

In spite of the warm outdoor temperatures, FACTs operated the force air furnace during the sampling period by setting the temperature control to 80°F.

During the sampling period, all doors and windows were kept closed.

During the sampling period, FACTs personnel used the resident's domestic vacuum cleaner and thoroughly and aggressively vacuumed each of the available areas of the area rugs in the residence. FACTs personnel also vacuumed various areas of hardwood floor.

During the sampling period, FACTs shook various items of clothing and bed clothing.

During the sampling period, FACTs performed all other sampling activities which included aggressively disturbing various surfaces for microvacuum sampling.

Each of the air sampling cassettes was placed in the center of the room wherein they were located, and the cassettes were mounted on a tripod at an elevation of approximately one meter from the floor (See Photographs).

The samples were operated from 10:00 until 16:09 on the same day. As the samples were harvested, the pump calibrations were verified against a primary calibration standard.

Sample cassettes were packaged in their original shipping containers and carefully hand delivered to the analyzing laboratory under chain of custody.

The table below presents the air monitoring information:

Sample ID	Location	Pre-Cal Mean (l/min)	Post-Cal Mean (l/min)	Pre:Post RPD	Volume m3
NF110609-01	Living Room	23.2	24.6	12%	8.6
NF110609-02	Kitchen	22.7	25.3	11%	8.8
NF110609-03	Baby's Room	23.7	22.9	4%	8.6

Table 1
Air Monitoring Information

Each of the pumps exhibited a slight drift in air flow rate during the sampling period (expressed as "relative percent difference," RPD). The drift is a normal sampling error and does not compromise the integrity of the data.

Each sample was submitted for analysis by phase contrast microscopy (PCM) according to the NIOSH 7400 Method. Contrary to common misconception, the method, although used almost exclusively for enumeration of *asbestos* fibers, cannot confidentially differentiate an asbestos fiber from other nonasbestiform fibers. The method exclusively counts all fibers exhibiting specific morphological features. For the purposes of presenting the worst reasonable case scenario, FACTs made the *a priori* statement that it would consider ALL fibers enumerated by the method as asbestos fibers regardless of the actual composition of the fibers being counted.

Vacuum Samples

The vacuum samples were collected using a standard Industrial Hygiene microvacuum sampling procedure,[5] as a guideline. After an area had been selected and measured, a commercially available 25 mm diameter, extended-cowl cassette, fitted with mixed cellulose ester (MCE) membrane was attached to a commercially available Industrial Hygiene air sampling pump. The pump was adjusted to draw approximately 4 liters of air per minute at approximately 2 inches of water column pressure. The cassette was opened to present an "open face" and the selected areas were vacuumed with the cassette. Samples were maintained in control of FACTs personnel at all times, and were submitted by hand to the analyzing laboratory under chain of custody.

The table below presents the sampling information for the vacuum samples:

[5] ASTM Method D 5756-02

Sample ID	Location and Surface	Surface Area (cm2)
NF110609-04	Living room couch seat cushion; cloth	2,906
NF110609-05	Living room area rug, textile	3,226
NF110609-06	Baby's room, baby's clothing, nylon, cotton, rayon	1,806
NF110609-07	Baby's room, baby's mattress, cotton bedclothes	5,479
NF110609-08	Baby's room, area rug, textile	2,787
NF110609-09	Spare room, bed clothes	2,650
NF110609-010	Master bedroom, bed clothes, synthetic textile	5,426
NF110609-011	Master bedroom, clothing, cotton and synthetics	2,787
NF110609-012	West bathroom/Hall, area rug, textile	2,427
NF110609-013	East hallway, area rug, textile	6,271

Table 2
Location of Microvacuum Samples

Each of the samples was submitted for standardized polarized light microscopy (PLM), point counting method. One of the samples, NF110609-07, was submitted for confirmation analysis by the more definitive transmission electron microscopy (TEM) method.

Field Blank

Field blanks were not part of our DQOs, and none were submitted.

Field Duplicates

Field duplicates were not part of our DQOs and none were submitted.

Cross Contamination

Cross contamination cannot occur within a single study area. The entire residence, and all chattels therein was considered a single, unique study area.

SAMPLE RESULTS

Air Samples

Airborne fiber sample results can be expressed in a variety of ways. Most of the occupational risk assessments to asbestos have historically been based on PCM results using enumeration methods such as the NIOSH 7400 Method or its predecessor,[6] which had similar counting attributes. Using these methods, results are expressed as total fibers per cubic centimeter of air sampled (f/cc). To differentiate TEM values some publications also refer to "PCM f/cc" or "PCM s/cc" and different variations on the theme of number of fibers (or structures) per unit volume of air.

[6] NIOSH P&CAM 239

Additionally, traditionally, risk is assumed to be highest for individuals who are exposed early in life, and in most risk models for cancer, the age at first exposure is assumed to be zero (birth) and the exposure episode is then extrapolated out over 70 years (or, as in this case, averaged out over 70 years). Our model rejects the so-called "one hit hypothesis"[7] and instead assumes that risk of cancer continually drops after cessation of exposure begins. This assumption is reasonable for this type of risk assessment.

Asbestos is both a naturally occurring mineral as well as an important industrial material. Although all sources of asbestos are ultimately from a natural source, the generation of asbestos fibers in the air can be from man-made products or natural wind erosion of asbestos deposits. Regardless of the method of generation, asbestiform fibers are considered to be ubiquitous in man's environment[8] and occur even in remote non-industrialized geographical locations.[9] As a benchmark, it has been reported elsewhere that outdoor ambient airborne fiber concentrations range from 0.0003 f/cc in rural areas to 0.002 f/cc in urban areas.[10]

Other pertinent benchmarks used for comparison would include the State of Colorado Maximum Allowable Asbestos Level (MAAL) [11] of 0.01 f/cc. The MAAL is that concentration threshold permitted by the Colorado Department of Health for all public access areas.

Other benchmarks would include the US Mine Safety Health Administration occupational time-weighted average (TWA), full-shift permissible exposure limit for miners of 0.1 f/cc. Similarly, the US Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit, (also expressed as a time weighted average) is also 0.1 f/cc. Normally, occupational limits are not appropriate for comparing nonoccupational residential exposures, however, in the case of asbestos, much of the foundational risk modeling has been based on occupational estimates, and therefore, as seen later, we have converted the air monitoring performed at the subject property into occupational equivalents to allow estimates of ELCR.

In interpreting our data, our job was made somewhat easier by the fact that each of the three air samples all the same fiber concentration result (not too surprising since one of

[7] Detailed discussion of the "one hit hypothesis" is beyond the scope of this discussion.

[8] Corn M, *Airborne Concentrations Of Asbestos In Nonoccupational Environments*, Ann. Occup Hyg., Vol 38. No 4. pp 495-502, 1994

[9] Kakooei H, Yunesian M, Marioryad H, Azam K, *Assessment of airborne asbestos fiber concentrations in urban area of Tehran, Iran*, Air Quality, Atmosphere & Health, Volume 2, Number 1, Pages 39-45, March, 2009

[10] Corn M, *Airborne Concentrations Of Asbestos In Nonoccupational Environments*, Ann. Occup Hyg., Vol 38. No 4. pp 495-502, 1994

[11] Regulation 8 Part B, (5 CCR 1001-10, Part B)

the objectives of the fans was to break up stratification). In each case, the laboratory reported the final fiber concentration as 0.002 f/cc.

We assumed that unlike an 8-hour occupational exposure, the occupants of the subject property occupied the residence for an average of 12 hours per day; therefore we increased the occupational equivalent exposure proportionally to 0.003 f/cc. Similarly, unlike an employee who goes to work an average of 250 days per year, we assumed the occupants of the subject property occupy their house 365 day per year and increased the occupational equivalent daily TWA exposure accordingly to 0.004 f/cc. We assumed the occupants will be in the house exposed to 0.002 f/cc under these exposure conditions for five years.

Lab result as reported	0.002	f/cc
Sample Time	369	minutes
Time spent in residence per day (assumed)	12	hours
Fiber counts expressed as an 8 H TWA	0.003	f/cc
Days per year spent in the residence (assumed)	365	days
Fiber counts expressed as an occupational equivalent	0.004	TWA yearly exposure
Years in house (assumed)	5	years
Fiber years based on lab result	0.015	f/years
Fiber year expressed as an occupational year	0.022	f/years
Chronic Daily Exposure Concentration attributed from the study house (averaged over 70 years)	0.00021 (2.1E-4)	f/cc
US EPA Slope factor (HEAST 1989)	8.05E-07	Unitless
Inhalation Unit Risk Factor (US EPA 2004)	0.23	f/cc
Excess Cancer Lifetime Risk from a five year exposure in the study residence	4.93E-05	
Excess Cancer Lifetime Risk (expressed differently)	1 in 20,300	

Table 3
"Walkthrough" of Assumptions and Decision Rationale

Based on our qualitative approach, the risk posed by the fiber counts in the subject property are 4.9 E-5 which is within the 1E-6 to 1E-4 used by the US EPA. And therefore, may be used as *prima facie* evidence that an unacceptable risk does not exist.

FACTs also looked at a other risk models methods and similarly did not observe an unacceptable risk, and indeed for some models, the risk was too low to calculate (the model lacked sensitivity at the reported values and/or exposure durations inside the study home). For example, the US EPA provides a "quick and dirty" summary of risk vis-à-vis lifetime asbestos fiber years in its "Integrated Risk Information System":

II.C.1. Summary of Risk Estimates

Inhalation Unit Risk — 2.3E-1 per (f/mL)

Extrapolation Method — Additive risk of lung cancer and mesothelioma, using relative risk model for lung cancer and absolute risk model for mesothelioma

Air Concentrations at Specified Risk Levels:

Risk Level	Concentration
E-4 (1 in 10,000)	4E-4 f/mL
E-5 (1 in 100,000)	4E-5 f/mL
E-6 (1 in 1,000,000)	4E-6 f/mL

Text Box 1
Text From the US EPA IRIS

In our model, as can be seen, we have made every attempt to express the exposures in the residence as the highest reasonable exposures predictable; both through our sampling techniques as well as through mathematical manipulations and assumptions. However, we cannot honestly lose sight of the fact that since the assumptions and sampling techniques drive the risks artificially high, another review of the data could with equal validity demonstrate that the risks are very much lower than we have presented here.

For example, when we look at the laboratory reports, we see that of the fibers reported, the laboratory subjectively found that only 80% of the fibers observed were consistent with asbestiform fibers. One could, with reasonable articulation take 80% of the observed fiber concentrations (which would equal 0.0016 f/cc), and articulate that the aggressive sampling techniques performed by FACTs easily tripled the observed fiber concentrations, and the actual reasonable five year attributable fiber year concentrations may be as low as 2.2E-5 fiber year.

Microvacuum Samples

Can the air samples be used in the absence of any other data? Yes, Industrial Hygienists can compose retrospective risk analyses in the absence of any empirical or objective data, however, the *confidence* of the assessment is lessened in the absence of actual data.[12]

For this reason, FACTs elected to collect samples of residual dust in the residence to see if the samples were consistent with the observed airborne concentrations.

If the microvacuum samples contained elevated asbestos concentrations, FACTs would "flag" the air samples and decrease the confidence in the air samples to predict exposure.

Results by Polarized Light Microscopy

In the table below, we have presented the results of the PLM analysis of the microvacuum samples:

Sample ID	Location and Surface	Asbestos Content Visual Estimate (%)
NF110609-04	Living room couch seat cushion; cloth	None Detected
NF110609-05	Living room area rug, textile	None Detected
NF110609-06	Baby's room, baby's clothing, nylon, cotton, rayon	None Detected
NF110609-07	Baby's room, baby's mattress, cotton bedclothes	Analyzed by TEM
NF110609-08	Baby's room, area rug, textile	None Detected
NF110609-09	Spare room, bed clothes	None Detected
NF110609-010	Master bedroom, bed clothes, synthetic textile	None Detected
NF110609-011	Master bedroom, clothing, cotton and synthetics	None Detected
NF110609-012	West bathroom/Hall, area rug, textile	None Detected
NF110609-013	East hallway, area rug, textile	None Detected

Table 4
Results of Microvacuum Samples

No asbestos was detected in the microvacuum samples by PLM. These data lend support to the very low airborne fiber concentrations actually observed. Taken together, each data set increases the confidence in the other data set.

Results by Transmission Electron Microscopy

Can one place confidence in the PLM results above? Generally, one can place very good confidence in the PLM results as presented. However, as a quality assurance check on the PLM results, FACTs arbitrarily selected one of the microvacuum samples, Sample

[12] Armstrong TW, Boelter F, Rasmuson JO, *Exposure Reconstruction*, Chapter 17 of *Mathematical Models for Estimating Occupational Exposure to Chemicals* Second Ed (Keil, Simmons, and Anthony Eds), AIHA Publishers, 2009

NF110609-07, and submitted that sample for confirmatory analysis of asbestos by transmission electron microscopy.

Even by the more definitive TEM analysis technique, the laboratory reported no asbestos detected.

CONCLUSIONS

- All models are wrong – some models are useful.
- All samples incur error.
- All analyses exhibit uncertainty.

Although each of these statements are true, we also consider the totality of the circumstances; the use of validated analytical methodology, the total number of samples collected, the employment of time tested and internationally accepted sampling techniques, and the wealth of epidemiological data that is based on these techniques, and the use of confirmatory sampling. Under these circumstances, one is compelled to reject the primary hypothesis tested during this study and conclude that in spite of our best attempts to support our hypothesis, we were unable to find objective data for that support.

We are therefore, compelled to conclude that there is no significant exposure to asbestos in the study residence.

RECOMMENDATIONS

FACTs does not make any specific recommendations regarding decontamination or cleaning operations for the property. The levels of contaminant estimated to be present at the subject residence already appear to be extremely low and below those concentrations that FACTs and regulatory bodies would establish as cleanup thresholds.

We hope the information contained in this discussion has been timely and useful.

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