Case Study

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An Indoor Environmental Quality Investigation of the Fayette County (Pennsylvania) Courthouse

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Abstract
The National Institute for Occupational Safety and Health (NIOSH) conducted a health hazard evaluation (HHE) investigation in the basement of the Fayette County Courthouse in Uniontown, Pennsylvania. Employees had reported a variety of health complaints including headaches, throat irritation, eye irritation, nausea, fatigue and nasal/sinus symptoms. Potential causes of the complaints included excessive mould/mildew, lack of air flow, odours and high dust levels. A number of locations showing signs of water incursion or leakage were found to have mould growth. The air flow provided by the ventilation systems in most areas was inadequate, although temperature, relative humidity and carbon dioxide levels largely met published recommendations. Levels of common volatile organic compounds were all below established exposure limits, and only toluene was found in concentrations above established odour thresholds.

Introduction

The Fayette County Courthouse in Uniontown, Pennsylvania, is a three-storey masonry building with a basement, constructed in 1890–1891. In 1927, a three-storey annex was built connected to the original building by corridors on each floor. Approximately 200 employees work at the courthouse, which houses county courtrooms, judges' chambers, veteran's office, law library, Pennsylvania State University Agricultural Extension office and Row offices (i.e. the offices of the County Commissioners, Controller, Prothonotary, Recorder of Deeds, Coroner, Sheriff, Public Defender, District Attorney, Register of Wills, Treasurer, Jury Commissioner and Clerk of Courts).

The National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from about 50 employees in the Row Offices. These employees reported a variety of health complaints including headaches, throat irritation, eye irritation, nausea, fatigue and nasal/sinus symptoms. Potential causes of the health complaints included excessive mould/mildew, lack of air flow, odours and high dust levels. All 50 employees who reported complaints worked in the basement of the facility.

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Methods

NIOSH investigators conducted a walk-through survey of the courthouse basement to develop a better understanding of the health complaints and identify potential problem areas (e.g. areas with possible mould growth, stained ceiling tiles, odours, etc.). In subsequent visits to the courthouse: (A) air samples were collected for volatile organic compounds (VOCs); (B) IEQ parameters (i.e. temperature, RH and CO_2) were measured; (C) flow measurements of the ventilation systems were taken; (D) swab samples were collected in areas where mould contamination was suspected and (E) a visual boroscopic inspection was conducted in areas where suspected mould seemed to penetrate into wall cavities.

Volatile Organic Compounds

The VOC samples were taken at the locations shown in Figures 1 and 2. Instantaneous VOC samples were taken in evacuated silanized 0.4 L and 1 L minicanisters (Entech Instruments, Simi Valley, CA). One-week time-weighted average (TWA) samples were taken with Entech 6 L canisters connected to TWA samplers. The TWA samplers restricted the flow into the canisters such that they took one week to fill.

The VOC analysis system for the 0.4 L and 1 L canisters consisted of an Entech Model 7032-L MiniCan Autosampler and 7100 pre-concentrator and an Agilent Technologies (Palo Alto, CA) Model 5890 gas chromatograph (GC) with a Model 5972 mass selective detector (MS). The 6 L canisters required an Entech Model 7016 CA 16 Sample Autosampler and were analysed using an Entech 7100 pre-concentrator connected to an Agilent Technologies 6980N gas chromatograph and a 5973N mass selective detector. The 7100 pre-concentrators were programmed for the U.S. Environmental Protection Agency (EPA) TO-15 canister analysis using Microscale Purge and Trap Water Management to rid the samples of most of the water and carbon dioxide without losing the VOCs [1]. After pre-concentration, the samples were rapidly injected onto HP-5MS 30 m × 0.32 mm × 0.25 μm columns. The gas chromatographs were programmed with an initial oven temperature of −30°C which was held for 2 min. The oven temperature was then ramped at $8°C \cdot min^{-1}$ until a temperature of 220°C was reached. The temperature was then held constant for 5 min. The total run time for a sample was approximately 38 min. The resulting chromatograms were analysed for compound identification and concentration using Agilent Technologies Chemstation software.

Prior to running samples collected at the courthouse (unknowns), a GC–MS calibration curve was developed by running five concentrations of a TO15-62 component analytical reference standard (Restek Corp., Bellefonte, PA): 0.005, 0.010, 0.015, 0.020 and 0.025 parts per million by volume (ppm) [2]. Four internal standards (bromochloromethane, bromofluorobenzene, 1,4-difluorobenzene and chlorobenzene-d5) were added to each sample (calibration standards and unknowns) at a concentration of 0.0138 ppm. These internal standards were added to ensure the CG–MS system performed to specifications during each canister analysed. For compounds identified in the unknowns that were also present in the analytical reference standard, the concentrations were calculated directly from the calibration curve. For compounds in the unknowns that were not in the standard, they were tentatively identified by the software and the concentration was determined based on the response of toluene.

Indoor Environmental Quality Parameters

Continuous IEQ monitoring occurred for one week in the Prothonotary Records Storage Area (Pro1 in Figure 1) using a TSI Q-Trak Model 8551 (TSI Inc., St. Paul, MN). This area was selected because of a noticeable damp, musty odour. The Q-Trak was calibrated for temperature and RH by the manufacturer in accordance with their standards and recommendations. Just prior to use, the instruments were calibrated for CO_2 with certified gas standards provided by the manufacturer. Measurements were taken once per minute for the week. The instantaneous IEQ measurements were conducted in locations that either felt warm and humid during the walk-through or where employees had expressed concerns (Figures 1 and 2). Instantaneous measurements were for temperature and RH only using Model 445580 Humidity/Temperature Pens (Extech Instruments Corp., Waltham, MA). The pens were calibrated for RH using 33% and 75% RH calibration standards provided by the manufacturer. The IEQ parameter monitoring was done in parallel with the VOC sampling described previously.

Swab Samples for Mould

Swab samples for mould were taken by rubbing a sterile cotton swab over approximately four square inches of areas with potential fungal growth (Figure 2). Three swabs were collected in the Vending Area. These came from the chilled water fan coil units above the drop ceiling. Two swab samples were taken from surfaces inside

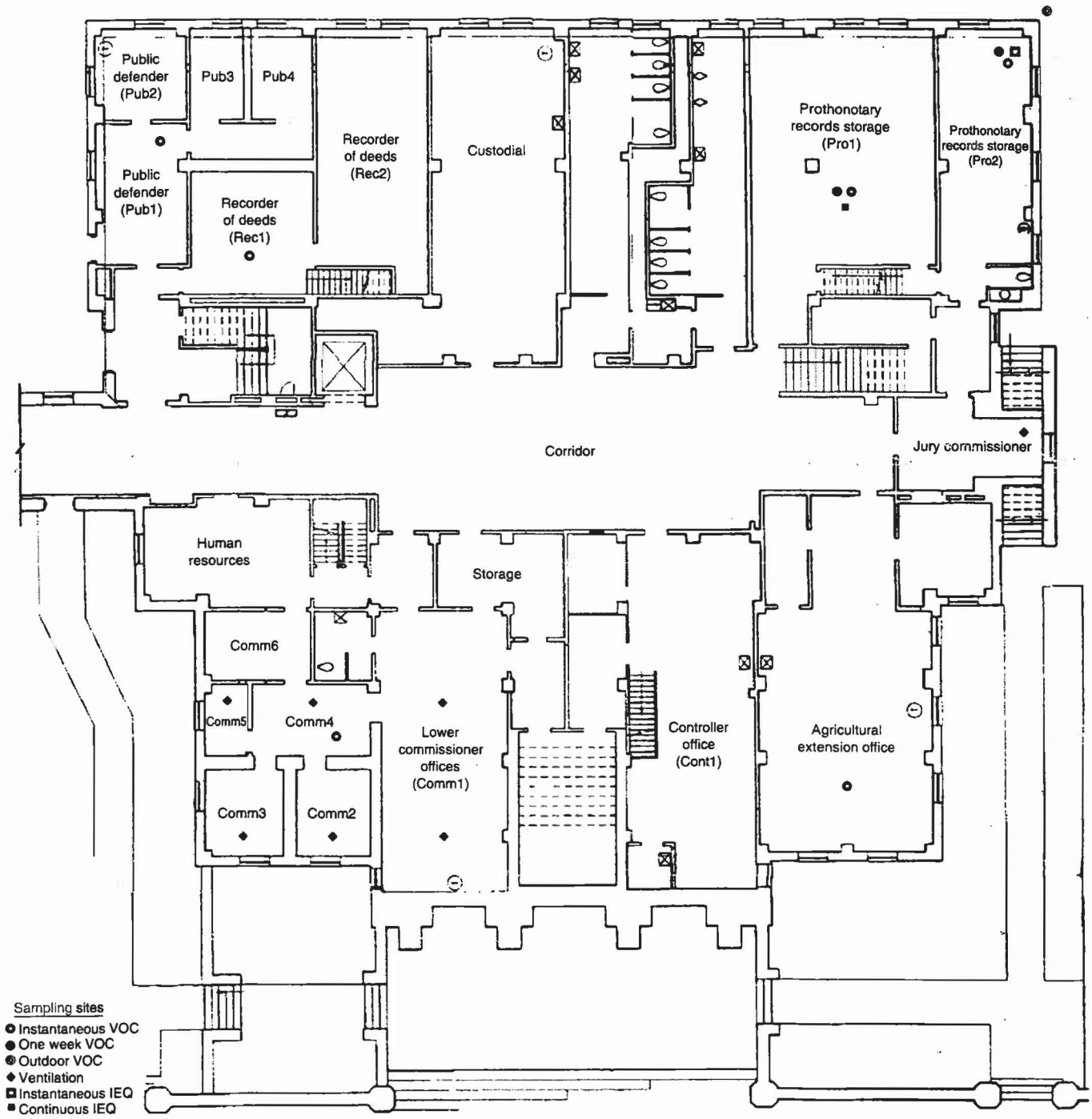

Fig. 1. Sampling locations in basement of the Fayette County Courthouse annex.

the adjacent Records Storage Room. Four swab samples were collected in the basement District Attorney's Office (from a supply vent, steam pipes in the ceiling, a wall and a ceiling tile). Finally, two swab samples were gathered in the Coroner's Office from a potentially fungi-contaminated wall. The swab samples were analysed for fungal contamination by P&K Microbiology Services, Inc. (Cherry Hill, NJ) by counting the number of colonies cultured on DG18 and 2% malt extract agar media.

Ventilation Measurements

Ventilation measurements were recorded in the most problematic areas of the courthouse basement

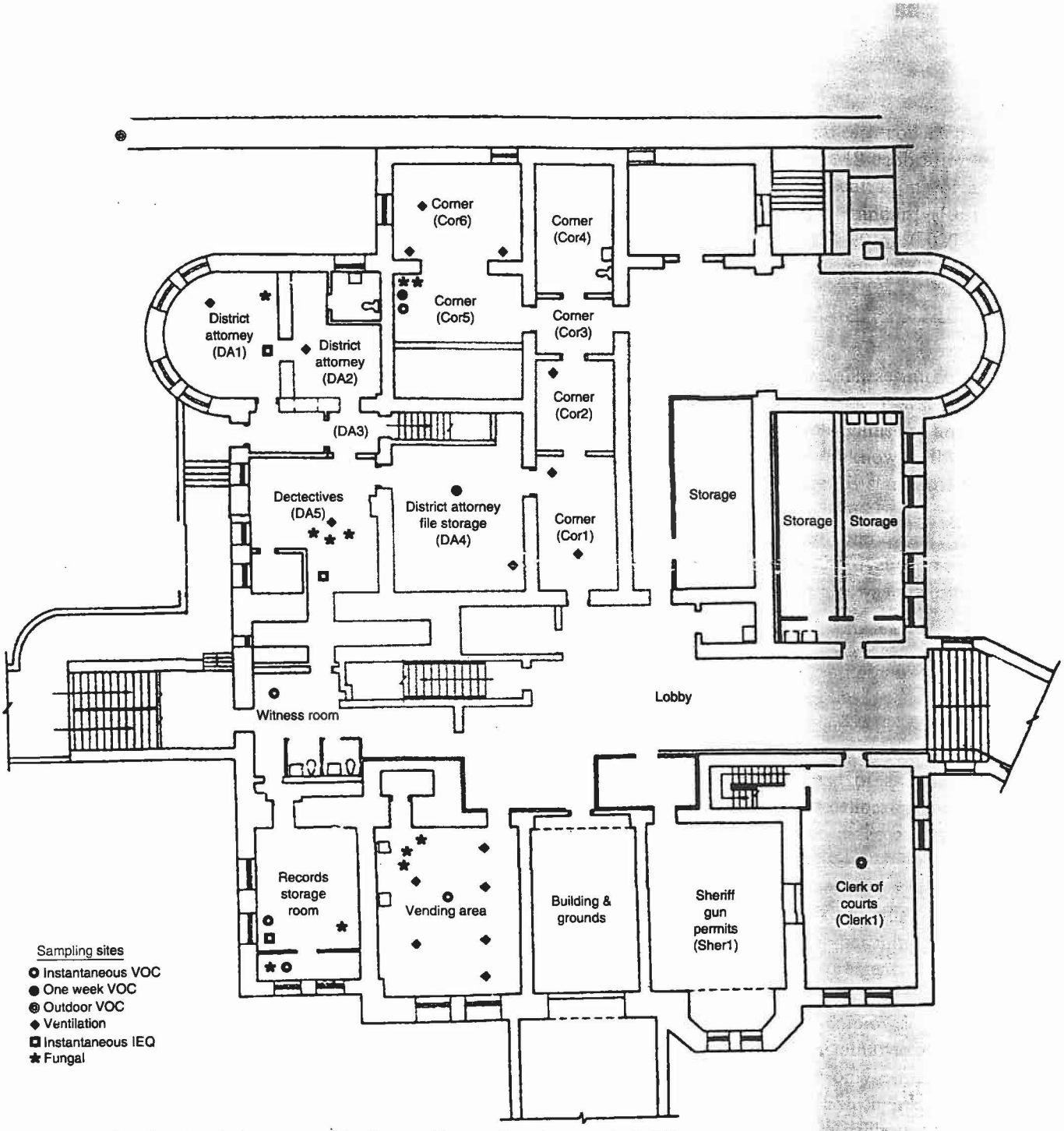

Fig. 2. Sampling locations in basement of the Fayette County Courthouse main building.

(Figures 1 and 2). In most locations, air flow measurements were taken on 2-foot-square supply and return vents using a TSI AccuBalance® Plus Air Capture Hood, Model 8373. When the vents were of a size other than 2-foot-square, either a TSI Model AM-600 (11.5 inch round) or AM-1200 (8.5 × 24 inch) airflow horn with a TSI Model 8386 VelociCalc® Plus multi-parameter ventilation meter was used. All of the ventilation instruments were calibrated by the manufacturer in accordance with its procedures and specifications.

Medical Interviews

Of the 50 HHE requesters, 35 provided both their name and contact telephone number(s). Four workers, selected on the basis of respiratory symptoms reported on the HHE request, were interviewed by telephone by a NIOSH occupational health physician.

Table 1. Volatile organic compounds found in canister samples collected at the Fayette County Courthouse (in ppm)[a]

Compound	Limit of detection (LOD)	Limit of quantitation (LOQ)	Maximum concentration	Location(s) of maximum concentration[b]
Benzene	0.00018	0.00061	0.002	Pro2
1,3-Butadiene	0.00017	0.00057	0.006	Pro2
2-Butanone	0.00022	0.00073	0.026	Vending Area
Chloroform	0.00016	0.00054	0.003	Pro2
Chloromethane	0.00018	0.00060	0.008	Cor5
1,2-Dichloroethane	0.00019	0.00064	0.016	Pro2
1,2-Dichloroethene	0.00017	0.00057	0.002	Pro2
1,2-Dichloropropane	0.00020	0.00067	0.208	Pro2
Ethyl benzene	0.00027	0.00091	0.005	Pro2
Dichlorodifluoromethane	0.00021	0.00069	0.002	Pub1, Cor5 and Pro2
Hexane	0.00017	0.00055	0.002	Cor5
Methylene chloride	0.00017	0.00057	0.010	Vending Area
4-Methyl-2-pentanone	0.00015	0.00050	0.022	Pub1
2-Propanol	0.00116	0.00385	0.169	Pro2
Styrene	0.00029	0.00096	0.004	Cor5
Tetrachloroethene	0.00026	0.00087	0.018	Cor5
Toluene	0.00024	0.00080	0.468	Cor5
1,1,2-Trichloroethane	0.00022	0.00074	0.004	Pro2
Trichloroethene	0.00024	0.00079	0.021	Pro2
1,2,4-Trimethylbenzene	0.00027	0.00091	0.009	Rec1
1,3,5-Trimethylbenzene	0.00027	0.00091	0.030	Rec1
Vinyl acetate	0.00015	0.00050	0.007	Clerk1
o-, *m*- & *p*-Xylene	0.00081	0.00270	0.025	Rec1

[a]Values are parts compound per million parts air (ppm).
[b]See locations on Figures 1 and 2.

Results and Discussion

General Observations

Peeling paint was noticed in a number of areas. General housekeeping was poor in some areas of the basement. Water stains and/or damaged plaster were noticed in the following areas; the Lower Commissioners' Offices; Public Defender's Office; Sheriff's Gun Permits Office; and the Witness Room. In some locations, it was clear that steam and/or water pipes were leaking above the suspended ceiling tiles. Dirty, potentially mouldy vents were found in the Vending Area and the Witness Room. A number of other locations were noted as potentially having fungal contamination.

Volatile Organic Compounds

A total of 54 air samples were analysed for VOCs. A summary of the sampling results is presented in Table 1. With one exception, all measured concentrations were lower than the NIOSH Recommended Exposure Limits (RELs), Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs) and established odour thresholds. The exception was an instantaneous sample in the Coroner's Office (Cor5 in Figure 2), where the concentration of toluene exceeded the odour threshold but remained orders of magnitude below either the REL or PEL. The outside air samples (Figures 1 and 2) contained many of the same compounds found in the indoor samples. Benzene, 2-butanone, 1,2-dichlorethane, dichlorodifluoromethane, methylene chloride, toluene, trichloroethene and xylenes were found in all four outside air samples taken. Ethylbenzene, 4-methyl-2-pentanone and vinyl acetate were found in only one sample each. The concentrations of the compounds found in the outside air samples were very low (0.001–0.003 ppm). None of the other compounds listed in Table 1 were detected in any of the outside air samples.

The method of defining and determining odour thresholds varies widely which leads to a significant range of odour thresholds in the literature. Individuals may also respond differently to the same odour. At a given concentration, one person may smell and recognise the odour, while another person may barely notice it. The odour threshold values reported in the literature are

often for a single compound with no other chemicals present. There is very little information regarding the effects of mixtures of VOCs at the low concentrations found in this building. The cumulative concentration of all VOCs present may have a perceptible odour to some individuals which could potentially lead to discomfort and/or complaints similar to those expressed by the workers at the Fayette County Courthouse.

Indoor Environmental Quality Parameters

Continuous IEQ parameters were monitored in the Prothonotary Records Storage Area (Pro1 in Figure 1). The CO_2 levels ranged from 440 ppm to a maximum of 762 ppm (average of 503 ppm). The two spikes are probably due to courthouse employees being in the storage room searching for and obtaining files. At the beginning of the sampling period, the temperature was approximately 71.2°F (21.8°C), which was the minimum over the entire period. The temperature immediately started to increase and generally continued to rise over the rest of the sampling period. The maximum temperature reached 79.4°F (26.3°C) (average of 77.0°F, 25.0°C). The relative humidity in the area fluctuated daily over the sampling period with a minimum of 27.3% and a maximum of 46.0% (average of 39.3%).

ASHRAE provides recommended temperature and humidity ranges for various environments so that a majority of occupants would find the environment thermally comfortable. For typical public office buildings, the recommended range for temperature is 70°–74°F during the winter and 74°–78°F during the summer [3]. The ASHRAE recommended level for relative humidity is between 20% and 30% in the winter and 50%–60% during the summer [3]. Similarly, OSHA recommends that indoor temperatures be maintained between 68°F and 76°F with the relative humidity in the range of 20%–60% [4]. As temperature increases beyond 76°F, air quality is perceived as degraded regardless of the actual quality. Relative humidity below 30% may produce discomfort from dryness, yet the RH should be at the lowest possible level (within the recommended range) in order to inhibit microbiological growth.

Indoor CO_2 concentrations are normally higher than the generally constant ambient or outdoor concentration (300–350 ppm). When indoor CO_2 concentrations exceed 800 ppm in areas where the only known source is exhaled breath, inadequate ventilation is suspected. Elevated CO_2 concentrations suggest that other indoor contaminants may also be increased [5]. In the Prothonotary Records Storage Area (Pro1), the maximum CO_2 concentration remained below the maximum recommended level of 800 ppm for the entire week-long sampling period. However, the temperature exceeded the ASHRAE and OSHA recommended maximum temperatures on two occasions (the readings were taken in the fall, so both summer and winter recommendations were considered). During one afternoon, the relative humidity was <30% with a minimum of 27.3%. Otherwise, the relative humidity level was within the recommended range during the sampling period.

The instantaneous temperatures, taken with the temperature/humidity pens ranged from 72.5–78.8°F (22.5–26.0°C). The instantaneous humidity readings were ranged from 42 to 53%. The back of the Prothonotary Records Storage Area (Pro2) exceeded the recommended temperatures by approximately 3.0°F. The instantaneous humidity readings were all within the recommended values.

For the most part, the indoor environmental quality factors were largely within recommended guidelines. The most notable exception was the temperature in the Prothonotary Records Storage Area. However, this slightly elevated temperature should not pose any problems since the room is used so infrequently. When people do enter the room, it is only for a few minutes at a time.

Swab Samples for Mould

Of the 11 fungal swab samples taken, five had low levels of contamination (<10,000 colony forming units [CFUs]) four had medium to heavy contamination (100,001–1,000,000 CFUs) and two had heavy contamination (>1,000,000) [6]. Only one of the three samples from the fan-coil units in the Vending Area showed significant fungal contamination. This sample resulted in approximately 800,000 total CFUs consisting of 71% *Cladosporium* and 29% *Penicillium*. Samples from the adjacent Records Storage Room showed that no fungi were present. The four swab samples from the District Attorney's Office (DA1 and DA5) showed a range of 2500 CFUs to 5,235,000 CFUs. The predominant genus was *Penicillium* with small amounts of *Rhodotorula* and *Stachybotrys*.

The potentially contaminated area on the wall in the Coroner's Office (Cor5) appeared to consist of two different species of fungi. Part of the area was very light in colour while the rest was very dark, almost black. A swab sample was taken from each of these areas. The sample of the lighter contamination yielded 4,300,000 CFUs (95% *Scopulariopsis*). The sample of the black contamination from in the same area yielded 800,000 total

CFUs (50% *Scopulariopsis*, 20% *Sporothrix*, 17% *Penicillium*, 10% *Aspergillus*). These are some of the most common indoor fungi [7]. Since the outside of the wall was apparently heavily contaminated with fungi, a boroscope was used to look inside the wall. The boroscopic examination revealed that the inside of the wall was also heavily contaminated.

During the visual inspection, additional areas of potential fungal contamination were identified, such as the Sheriff's Gun Permits Office and the Clerk of Courts' Storage Room (Clerk1). Although swab samples were not taken in every area, all locations of potential fungal growth were associated with noticeable water leaks and incursions into the courthouse.

Excessive fungal contamination may be responsible for the small percentage of courthouse employees who experienced symptoms such as mucous membrane irritation, runny nose and upper airway congestion. This contamination may also explain the occurrence of less common symptoms such as breathing difficulties. The types and severity of symptoms depend in part on the types and amount of the fungi, the extent of the individual's exposure and the susceptibility of the individual (for example, whether they have pre-existing allergies or asthma). In general, excessive exposure to fungi may produce health problems by several primary mechanisms, including: (1) allergy or hypersensitivity, (2) irritant effects, (3) infection and (4) toxic effects.

There are essentially no exposure guidelines for fungi in air. Therefore, it is not possible to distinguish between safe and unsafe levels of exposure by inhalation. However, moisture intrusion along with nutrient sources such as building materials or furnishings allow fungi to grow indoors. It is extremely important, therefore, to keep the building interior and furnishings dry to prevent unwanted fungal growth. Areas which have poor air circulation and a source of moisture are likely to be sources for fungal amplification. Attempts to link surface contamination to airborne concentrations of fungal organisms are often difficult. Presently, there are no strict numerical guidelines which are appropriate for assessing whether surface fungal contamination poses a health risk.

Ventilation Measurements

Table 2 contains the airflow measurement results and the calculated air changes per hour (ACH) for the locations where measurements were taken. Each of the basement offices/rooms had a small individual chilled-water fan-coil unit(s) for ventilation. The Commissioners' Offices had two fan-coil units. Each unit was connected to three vents and was controlled by wall thermostats. One supply vent (located in Comm2) was blocked with tape and paper, while another supply vent (located in Comm5) was adjusted to restrict air flow as much as possible.

The District Attorney's Office (DA1) had a chilled-water fan-coil unit controlled with a wall-mounted thermostat. The supply was through a vent in the ceiling. The return air entered a grille in the ceiling attached to ductwork with an in-duct filter. Heat was supplied independently of the ventilation system by an electric wall heater. The District Attorney's File Storage Area (DA4) also had one fan-coil unit that did not work because the electric motor was seized up. When a ceiling panel was removed in the Detectives' Area of the office (DA5) to access the chilled-water fan-coil unit, it was discovered that one of the steam pipes was wrapped with plastic sheeting and duct tape. Inside the plastic sheeting was standing water. The top of the ceiling tile below this patch had water damage and heavy fungal contamination. There was a steam radiator above the ceiling but it could not be determined if this was still in use. This office was supplied by the same fan-coil unit as the District Attorney's Office (DA1).

The Vending Area had three chilled-water fan-coil units mounted above the drop ceiling. Each unit was connected to two round supply vents via flex duct. The condensate drained into a pan and then to a sink via plastic tubing. All three units and their ducts were noticeably dirty.

The Coroner's Office had one chilled-water fan-coil unit. In addition, it had a separate unit to supply fresh air located in the corner of the conference area (Cor5). There were two supply vents in the arch wall between the conference area (Cor5) and the office area (Cor6). Two thermostats were located in the hallway outside the Coroner's Office but it could not be determined which fan-coil unit(s) they controlled.

For office buildings, ASHRAE recommends 4–10 ACH [3]. All offices where measurements were taken did meet these requirements. The Lower Level Commissioners', Coroner's and District Attorney's Offices are each comprised of a number of rooms. Although the offices as a whole met the air exchange requirement, a number of individual rooms in each office did not meet the requirement since there was no air supply (Table 2). In addition to total ACH, ASHRAE Standard 62.1-2004, Ventilation for Acceptable Indoor Air Quality, recommends outdoor air supply rates of 17 cubic feet · min^{-1} per person (cfm per person) for office spaces and 7 cfm per person for reception areas [8]. The standard also provides estimated maximum occupancy figures for each

Table 2. Room volumes, ventilation measurements and calculated air exchanges per hour

Location	Room volume (ft^3)	Supply (cfm)	Fresh air supply (cfm)	Total supply (cfm)	Air exchanges (number per hour)
Lower commissioners–total	7342	1273	NA	1273	10
Comm1	4149	570	NA	570	8
Comm2	726	0	NA	0	0
Comm3	726	185	NA	185	15
Comm4	697	445	NA	445	38
Comm5	281	73	NA	73	16
Comm6	763	NA	NA	NA	0
District attorney–total	6770	497	40	537	5
Assistant DA (DA1)	1369	145	NA	145	6
DA2	1251	110	40	110	5
DA3	146	NA	NA	NA	0
File storage (DA4)	2123	0	NA	40	1
Detectives (DA5)	1881	242	NA	242	8
Coroner total	5631	558	96	654	7
Cor1	1189	85	NA	85	4
Cor2	756	95	NA	95	8
Cor3	360	NA	NA	NA	0
Cor4	1081	NA	NA	NA	0
Cor5	910	90	96	186	6
Cor6	1335	288	NA	288	13
Vending Area	2916	772	NA	772	16

NA – Not applicable because there were no air supply vents in the area.

area [8]. Only the District Attorney's Office and the Coroner's Office were found to have a measurable fresh air supply. There were desks for four detectives in the District Attorney's Office (DA5). Following the ASHRAE fresh air recommendation, the fresh air supply to this room should be 68 cfm. Roughly 60% of the recommended amount (40 cfm) was coming into the area. This was too low for the four employees who could potentially be working in this area at the same time. The Coroner's Office met the fresh air requirement with 96 cfm, since only two people worked in this office.

Overall, the ventilation systems had a number of problems in addition to the inadequate supply of outside air. Most were not operating properly, having inoperative blowers and supply vents that had been sealed. They were also dirty, which could further reduce their efficiencies. Operating with 100% recycled air, as was the case for half of the systems, is not recommended. Working in areas with little or no outside air can lead to perceptions of stuffiness, lethargy, etc. Increasing the amount of fresh air to meet the ASHRAE criteria could resolve some of the complaints of the courthouse employees.

Medical Interviews

All four individuals interviewed reported work-related symptoms consistent with asthma (wheeze, chest tightness or cough). Onset of respiratory symptoms occurred from 6 months to 11 years after date of hire and 5 months to 3 years prior to time of interview. One individual reported a physician diagnosis of asthma, a history of positive skin testing for mould and dust mite allergens (after date of hire), wheezing and chest tightness twice weekly, and strong evidence the symptoms were work-related (no symptoms at home in the evenings or on days not at work). In the four workers interviewed, non-respiratory work-related symptoms included: migraine headaches in two workers; fatigue in two workers burning eyes in two workers and sneezing in one worker.

Conclusions

The NIOSH IEQ investigation of the courthouse revealed a number of deficiencies, most notably in terms of ventilation, water leaks and general housekeeping. Yet, as with most IEQ investigations, there were no solid links between measured parameters and the reported health complaints or illnesses. Often there are not clear solutions to the underlying problems. This is due to the lack of information on which solid, quantitative recommendations can be made. The recommended approach was to make stepwise

improvements to the courthouse, based on the available sampling data, until employees no longer experience their symptoms.

NIOSH recommended that all ventilation systems be upgraded to provide overall air exchange rates and outdoor air supply rates in accordance with ASHRAE recommendations. Since hidden mould and moisture-damaged building materials are sometimes associated with building occupant health effects, NIOSH also recommended that repairs be made to prevent further water incursion into the courthouse and that mould and moisture-damaged materials be cleaned or removed with appropriate containment to minimise exposure to building occupants. While surface fungal contamination was present, there are no guidelines relating surface contamination levels to health problems and no links between surface fungal contamination and airborne concentrations. Further, there are no established health-based standards for acceptable levels of biological agents in the air, and the results from limited, short-term air sampling may be misleading. Thus, NIOSH did not conduct routine air sampling for mould as part of this indoor air quality evaluation or recommend air sampling for mould as improvements are made.

Disclaimer

The findings and conclusions in this manuscript are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health. Mention of commercial product or trade name does not constitute endorsement by the National Institute for Occupational Safety and Health or the Centers for Disease Control and Prevention.

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