<u>Summary of Indoor Environmental Sampling at Sherwood Middle School</u>

<u>Shrewsbury, MA</u>

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I. Background

The purpose of this report is to provide an initial evaluation of the indoor environmental sampling conducted at Sherwood Middle School in Shrewsbury, MA. The Massachusetts Department of Public Health (MDPH) Bureau of Environmental Health (BEH) was contacted by the Shrewsbury Board of Health and asked to evaluate health concerns, particularly breast cancer, originally voiced by several teachers at the school. MDPH/BEH staff attended two meetings with school staff (June 12, 2008, and March 11, 2009), the second of which resulted in a commitment to conduct focused environmental testing for constituent(s) that have been suggested in the scientific/medical literature as possibly being associated with breast cancer risk.

To further investigate breast cancer, BEH is working with school officials to obtain information on the population of teachers beginning with the earliest diagnosis date for which uniform employment data is available. This information will allow MDPH to calculate cancer rates and determine whether the rate of breast cancer is unusual at the school. The findings will be summarized in another report once these activities are complete.

Following the March 2009 meeting, MDPH/BEH conducted a comprehensive literature review and determined that current breast cancer research is focusing on compounds with estrogen-like properties, notably polychlorinated biphenyls (PCBs). Hence, MDPH/BEH proceeded to design a sampling plan and conduct PCB testing of the indoor environment of the Sherwood Middle School, contracting with Weston & Sampson for sampling and analytical laboratory tasks.

The Sherwood Middle School was built in 1964. From 1964-1983, Sherwood Middle School served grades 7 & 8; from 1983-1997 the school served grades 5, 6, & 7; and from 1997-2004 the school served grades 6, 7, & 8 (personal communication with Nancy Allen, Town of Shrewsbury). Thus, the maximum number of years any single student could have attended the middle school was four years (i.e., a fifth grader in 1996-1997 continuing for 6, 7, & 8th in subsequent years). According to the Massachusetts Department of Elementary and Secondary Education 2008-2009 Profile, Sherwood Middle School currently serves children in grades 5 and 6. The school enrolled 917 students (459 male, 458 female) in the 2008-09 school year, including 456 students in the 5th grade and 461 students in the 6th grade. During the 2008-2009 school year, there were a total of 65 teachers working at the school.

Polychlorinated biphenyls or PCBs were used in a wide variety of building materials in structures constructed before the late 1970s (MacLeod et al., 1981; Kuusisto et al., 2007). PCBs are stable organic chemicals, used in products from the 1940s through the late 1970s for desirable features such as non-flammability and electrical insulating properties (Balfanz et al., 1993; Currado et al., 1998; Vorhees et al., 1999). By 1977 companies in the United States stopped manufacturing PCBs (Herrick et al., 1999) and PCBs were banned by the U.S. EPA in 1979. Prior to the manufacturing ban, PCBs were used for a variety of different purposes (e.g., the application of PCB oil to control road dusts) including their use in closed system transformers or fluorescent light ballasts (Wallace et al., 1996; Staiff et al., 1974; MacLeod et al., 1981; and Currado et al., 1998), and caulking or joint sealants (Kohler et al., 2005; Herrick et al., 2004). Products made with PCBs before the ban may still be in use today in older buildings, as the federal ban did not apply to items already in place in existing buildings at the time of the ban (Wallace et al., 1996).

II. Methods

Overview

Three MDPH/BEH programs were involved in developing the sampling protocol, monitoring the field sampling, and evaluating the results: Indoor Air Quality (IAQ) Program, Community Assessment Program (CAP), and the Environmental Toxicology Program (ETP). The sampling objectives were designed to answer the following questions: 1) Are detectable concentrations of PCBs present in the indoor environment of the Sherwood Middle School? 2) Are detectable concentrations of PCBs present in areas of the school accessible to students and staff? 3) If PCBs are present at the school, what could be the likely source(s) and could the concentrations present exposure opportunities of health concern?

Two types of samples were identified for testing: surface wipe and air samples. Surface wipe samples were taken in areas that would be frequently accessible, such as desks and lab table tops. Further, worst-case scenario wipe samples were taken in areas that would be seldom cleaned, and hence accumulate dust, such as the tops of bookcases or edge of windowsills. In addition, 24-hour air samples were taken in two classrooms at a level 4-5 feet off the ground that would represent an approximate breathing zone for standing or seated children or adults.

Classrooms to be sampled were identified prior to actual sampling with input from the Shrewsbury Board of Health and the Sherwood Middle School nurse. An outdoor air sample was collected outside a second floor classroom window, away from any possible sources of combustion, in order to establish a background reading. The 20 wipe samples were collected between 4 and 6 PM on June 12, 2009, and the air samples were measured over 24-hours, from 4PM on June 12^{th} to 4PM on June 13^{th} respectively. The timing of sample collection in the late afternoon allowed for samples to be taken without disruption to regular school day activities and to restrict access to sample locations in order to prevent cross-contamination of media (wipe surfaces and air). All ventilation systems in the building were shut down during sample collection in order to estimate a worst case scenario for evaluation (i.e., no fresh air exchange in rooms where air samples were collected). Samples were sent to Test America, a subcontractor to Weston & Sampson, for analysis for total PCBs (Aroclors) using US Environmental Protection Agency (EPA) methods. Aroclor is the industrial trade name for commercially produced mixtures of PCBs.

Wipe Sample Collection

Twenty indoor locations were selected for wipe sampling in selected classrooms on the main floor, second floor and basement level. See Figures 1, 2, and 3, for an overview of sample locations on each floor, respectively.

Wipe samples were collected using a National Institute for Occupational Safety and Health (NIOSH) surface wipe method (CA DTSC, 2003). Each wipe sample was collected over a designated 10 centimeter by 10 centimeter surface area (100 cm^2) in selected locations in 13 school rooms. Each 100 cm^2 surface area sampled was wiped horizontally, vertically, then horizontally again. See Figures 4-16 for schematic diagrams of wipe sample locations within each of the 13 rooms sampled.

Fifteen out of the 20 wipe samples were collected from locations on the main floor (1 sample in room 117, 2 samples in room 119, 3 samples in room 120, 2 samples in room 122, 2 samples in room 137, 2 samples in room 138, and one sample each in the following rooms: teacher's lounge, stage room, and the cafeteria (see Figure 1). Two out of the 20 samples were collected from locations on the second floor (1 sample in room 208, and 1 sample in room 237) (see Figure 2). Three out of the 20 samples were collected from locations on the basement level (2 samples in room 011, and 1 sample in the art room) (see Figure 3). Two trip blanks were brought along for quality assurance/quality control (QA/QC) purposes.

Surfaces on tops of bookcases and cabinets were visibly dusty, thus wipes from these areas would represent a worst case scenario, where potential contaminants could collect over time and be left undisturbed. Since access to these areas would be infrequent, exposure opportunities are expected to be low. Surfaces of lab tops, desks, and counters were less dusty, and wipes here would be more representative of actual exposure opportunities, as these surfaces would be likely to be frequently touched and accessed.

Air Sample Collection

A total of three 24-hour air samples were collected using EPA method TO-10A (EPA 1999). A trip blank was brought along for QA/QC purposes. All of the air sampling units were calibrated to a flow rate of 4 liters per minute (4 L/min.). The final air sample volume collected for each of the three samples over the 24-hour sample duration was 5760 L.

Two of the 3 air samples were collected indoors, one in room 120 on the main floor, and the other in room 138, also on the main floor. Figure 17 contains a photographic overview of Sherwood Middle School and the relative locations of rooms 120 and 138, which are located in separate wings of the school building. Figures 4 and 5 contain schematic diagrams that demonstrate air sample locations in classrooms 120 and 138, respectively, relative to wipe sample locations. The photos in Figures 19 and 20 demonstrate the locations of the air sampling units within rooms 120 and 138, respectively. The air sample collection probe was placed at breathing zone level, approximately 4-5 feet from the ground.

The third air sample taken was a background sample, collected using a probe placed outside of a 2nd floor classroom window, away from any potential combustion sources. Figure 18 shows a photo of the set up for the background sampling unit.

Wipe Sample Analysis

Wipes were sent to Test America, in Westfield, MA with intact chain of custody. The wipe samples were analyzed according to EPA method SW846 in two parts (EPA 2007). The first part was EPA 3580A, using hexane extraction (EPA 1992). The second part was EPA 8082, a TSCA approved analytical method for detection of PCBs (Aroclors) by gas chromatography (EPA 2007; memorandum from Kim Tisa, EPA TSCA PCB coordinator, Region 1, 2009). MDPH chose EPA 3580A as an extraction method, based on a discussion with Test America in regards to achieving the lowest possible detection limit, in this case, 0.10 µg/wipe. The California Department of Toxic Substance Control (CA DTSC) has established a clean up guidance level of 0.10 µg/wipe.

Wipe samples were analyzed for the following Aroclors: PCB-1016, PCB-1221, PCB-1232, PCB-1242, PCB-1248, PCB-1254, PCB-1260, PCB-1262, and PCB-1268. Test America conducted QA/QC analysis using 2 trip blanks, 2 lab control duplicates, 2 laboratory method blanks, and surrogate recovery.

Air Sample Analysis

Air samples were sent to Test America, in Burlington, VT with intact chain of custody. The air samples were analyzed according to EPA method TO-10A, "Determination of Pesticides and Polychlorinated Biphenyls in ambient air using low volume polyurethane foam (PUF) sampling followed by gas chromatographic/multi-detector detection (GC/MD)" (EPA, 1999).

Air samples were analyzed for the following Aroclors: PCB-1016, PCB-1221, PCB-1232, PCB-1242, PCB-1248, PCB-1254, and PCB-1260. Test America conducted QA/QC analysis using the trip blank and laboratory method blanks.

III. Methods for Initial Screening of Results

Health assessors use a variety of health-based screening values, called comparison values, to help decide whether compounds detected in environmental samples might need further evaluation. These comparison values include cancer risk evaluation guides (CREGs) and environmental media evaluation guides (EMEGs), which are values that have been scientifically peer-reviewed or derived using scientifically peer-reviewed values and published by the U.S. Agency for Toxic Substances and Disease Registry (ATSDR). CREG values provide information on the potential for carcinogenic effects, while EMEG values are used to evaluate the potential for non-cancer health effects.

Chronic EMEGs correspond to exposures lasting one year or longer in a residential setting. CREG values are derived assuming a lifetime of daily exposure (i.e., 70 years) in a residential setting.

If the concentration of a compound exceeds its comparison value, adverse health effects are not necessarily expected. Rather, these comparison values help in selecting compounds for further consideration. For example, if the concentration of a chemical in a medium (e.g., air) is greater than the CREG for that medium, the potential for exposure to the compound should be further evaluated for the specific situation to determine whether cancer health effects might be possible. Conversely, if the concentration is less than the CREG, it is unlikely that exposure would result in cancer health effects.

For surface wipes, ATSDR has no comparison values but the U.S. EPA has a regulatory clean-up standard of 10 micrograms PCBs per 100 square centimeters (10 $\mu g/100cm^2$) for wipes collected from indoor residential surfaces that have been affected by a spill of a low-concentration PCB mixture (40 CFR 761.125). In addition, the California Department of Toxic Substance Control has published a recommended clean-up guideline for PCBs on surface areas in schools of 0.1 $\mu g/100cm^2$. This recommended guideline for California is intended to be protective of short and long term exposures involving dermal contact and incidental ingestion (CA DTSC 2003).

For air samples, results were compared with the ATSDR CREG of 0.01 microgram per cubic meter (0.01 $\mu g/m^3$) (ATSDR 2009). If any air sample had at least one detectable Aroclor, the total PCB concentration of the sample was reported in two ways. The first was to sum the total of all Aroclors detected; the second was to assume that all non-detected Aroclors in the samples were present in the sample at a concentration of one-half the reporting limit (see Table 1 for reporting limits).

IV. Results

Wipe Sample Results

Wipe sample results are presented by room and location in Table 1. PCBs were detected in 11 out of 20 wipe samples. Wipe detections in these 11 samples ranged from 0.1 $\mu g/100cm^2$ to 1.2 $\mu g/100cm^2$.

Ten of the 11 samples were taken in locations that are likely infrequently touched, e.g., top of bookcases. One sample (0.13 $\mu g/100cm^2$) was taken in room 208, on a black-topped counter next to the sink, in the left-hand corner of the room from the doorway.

Results from wipe samples indicate that all samples were below the U.S. EPA standard for regulatory clean up in residential units (10 $\mu g/100cm^2$). Further, samples taken from more frequently accessed areas were generally non-detect or similar to the CA DTSC guideline (0.1 $\mu g/100cm^2$.

Air Sample Results

Air sample results are also reported in Table 1. The two indoor locations sampled for analysis of PCBs in air were classrooms 120 (0.2695 $\mu g/m^3$, assuming non-detected Aroclors are equivalent to ½ the reporting limit; or, 0.227 $\mu g/m^3$, calculated using the sum of detected Aroclors) and 138 (0.2295 $\mu g/m^3$, assuming non-detected Aroclors are equivalent to ½ the reporting limit; or, 0.187 µg/m3, calculated using the sum of detected Aroclors), both on the main floor in separate wings of the building. The predominant Aroclor identified in air samples was 1242. No PCBs were detected in the background air sample above the 0.017 $\mu g/m^3$ reporting limit. All values exceed the ATSDR CREG (0.01 $\mu g/m^3$) for PCBs in air.

V. Discussion

Results from indoor wipe sampling at the Sherwood Middle School revealed that samples taken from more frequently accessed areas were generally ND or similar to the CA DTSC guidance level and well below the U.S. EPA regulatory clean-up level for residential units. Areas that were sampled because they were visibly dusty and likely cleaned less often are less likely to be accessed, and, hence, present lower exposure opportunities, however, do suggest more aggressive cleaning is warranted. We would not expect health concerns based upon exposure opportunities to PCBs at levels measured in wipe samples.

It is important to note that surface wipe samples are generally taken to help determine where more aggressive cleaning may be necessary, not to assess health risks, as no health-based comparison values are available. The U.S. EPA and CA DTSC cleanup levels cited here are useful in determining the need for more aggressive cleaning in the school. While most results of wipe samples were non-detect or similar to the CA DTSC guideline, certain areas (e.g., the windowsills and other areas not cleaned on a routine basis) should be inspected and cleaned with greater frequency.

The U.S. EPA has classified PCBs as a probable human carcinogen (EPA IRIS, 1997). This classification is based on a number of occupational and epidemiological studies in humans, and clear evidence of carcinogenicity in animal studies. Due to their chemical stability, PCBs are persistent organic pollutants in ambient and indoor environments (Hermanson & Hites, 1989), and they are known to be bioaccumulative (accumulate in biological tissue, i.e., fatty tissue) due to their lipophilic properties (Decastro et al., 2006).

Indoor air sample results from classrooms 120 and 138 were above the ATSDR CREG (0.01 $\mu g/m^3$). When an air sample exceeds a CREG adverse health effects are not necessarily expected but the exposure to the compound is further evaluated to determine if cancer effects might be possible. Estimated exposure dose and theoretical cancer risk calculations were performed to further evaluate opportunities for exposure or health concerns. The theoretical cancer risk calculation estimates an excess cancer risk in terms of the proportion of the population that may be affected by a carcinogenic substance over a lifetime of exposure (ATSDR, 2005). In other words, an estimated cancer risk of 1 in a million ($1x10^{-6}$) would mean that there is a probability of one additional cancer over background levels in a population of one million people. The U.S. EPA derives cancer slope factors for use in theoretical cancer risk calculations, and these are derived based on conservative models, which extrapolate results from higher experimental doses to low dose environmental exposures.

In order to calculate estimated cancer risks from the levels of PCBs measured in the indoor air, we assumed a reasonable daily exposure for 180 days per year (school days) for 35 years (approximate number of years of service at the school for the longest serving employee) for adults, and daily exposure for 180 days per year, for 4 years for students. This type of evaluation is to present the worst case scenario in terms of cancer risk. Assuming an 8 hour daily exposure (school/work day) the theoretical excess cancer risk calculated for adults was approximately 1 in 100,000 ($1x10^{-5}$). In other words, for adults the risk estimate would result in 1 excess cancer in a population of 100,000. For children the risk estimate was approximately 1.6 in a million ($1.6x10^{-6}$). In other words, for children the risk estimate would result in approximately 1-2 excess cancers in a population of one million. ATSDR considers theoretical cancer risks estimated between $1x10^{-4}$ and $1x10^{-6}$ as presenting low cancer risks. However, it is important to note that increased risk for any given individual so exposed cannot be ruled out. Based on the most conservative exposure assumptions, we would not expect health concerns (i.e., cancer) for children based on PCBs measured in indoor air at Sherwood Middle School.

A number of important factors should be considered in assessing the estimated cancer risk for adults: 1) at the time of testing the ventilation system was turned off and all of the windows were closed, thus, the measured air concentration of PCBs is likely to be overestimated compared to daily operations during a regular school day with all the ventilation systems operating; 2) the risk estimate assumes the same air concentration over 35 years, although it is possible that air exposure may be more recent, depending on room conditions (i.e., burn out of PCB containing fluorescent light ballasts); and 3) the risk estimate assumes teachers were exposed to this level for the entire work day every work day over 35 years.

To further evaluate the possible source(s) of PCBs detected in the two indoor air samples, MDPH/BEH Indoor Air Quality (IAQ) program staff conducted a visual evaluation of the building on July 15, 2009, with particular attention paid to areas where air and wipe samples were taken. For Room 120 (0.2695 $\mu g/m^3$), IAQ staff examined the window frame and its caulking, the unit ventilator (univent), the lab table, the light fixtures and the general conditions of the room. The air sampling unit was positioned to take air measurements within the breathing zone of seated or standing children or staff (4-5 feet above the floor). The sampler was located on a TV stand in the room, under a fluorescent light fixture (see Figure 19).

The following conditions were observed in Room 120:

- The window frames were sealed on the interior (see Figure 21) and exterior (see Figure 22) seams with caulking. While the exterior caulking was found degraded, the interior caulking is intact. If wind conditions were to impinge the northeast corner of the building, the interior caulking would serve as a barrier to airborne movement of friable exterior window caulking.

- The windows of Room 120 face northeast and are sheltered by portable classroom (see Figure 23).

- The univent exterior grill had deteriorated caulking and was partially missing (see Figure 24). On the day of air sampling, the univent was deactivated.

- Three wipe samples were available for Room 120. One was from the top of a cabinet in front of the windowsill. No PCBs were detected in this sample. A second sample from the top of a lab table at the front of the room was also ND,

- The wipe sample on top of the bookshelves nearest the door is in the area most likely to be impacted based on airflow and was below the EPA clean up standard and slightly above the CA DTSC guideline.

- If levels of PCBs in air were consistently high we would expect to see higher levels in wipe samples taken near these bookshelves.

In Room 138, the location of the second indoor air sample (0.2295µg/m^3) was below fluorescent lights (see Figure 20), and the inside window caulking appeared intact. Two wipe samples were taken, one at the top of a metal bookshelf under a vent in the closet (ND) and a second from the top of a bookshelf (0.16 µg/100 cm^2).

Aside from caulking, the possibility that light ballasts containing PCBs may be a potential source of PCBs in the indoor air was also considered. Deteriorating and/or aging products containing PCBs, such as older fluorescent light ballasts, may be a source of PCB contamination in the indoor environment (Wallace et al., 1996; MacLeod et al., 1981; and Staiff et al., 1974). Though older light ballasts may still be in use today, the manufacturers' intended lifespan of these ballasts was 12 years (Wallace et al., 1996; Staiff et al., 1974). Existing light ballasts that were manufactured before the 1979 ban were designed to accompany fluorescent bulbs in use at the time of manufacture, and, before 1974, these ballasts were not constructed with thermal protective switches to prevent overheating, leaking, smoking and blowing out (Staiff et al., 1974). In addition to potential fire hazards, PCBs can volatize in air, when these older light ballasts blow out.

Our determination that ballasts are the likely source is based on the following:

- A number of light ballasts remain in the building that were originally installed when the school was built in 1964, placing the age of some ballasts at 45 years old.
- The life expectancy for light ballasts is around 12 years (Staiff et al., 1974).
- The rooms where PCBs were detected in air (Classrooms 120 and 138) have light fixtures with ballasts containing PCBs. According to Robert Cox, Superintendent of Public Buildings, Room 120 has 15 fixtures, of which 10 are PCB containing ballasts, and Room 138 has 24 fixtures, of which 22 are PCB containing ballasts. Some of the light fixtures in these rooms had lights where bulbs were out, but not yet replaced (see Figure 25).
- Turning on light fixtures where one or more burned out bulbs remain on the circuit has been shown experimentally to overheat ballasts. Under heat stress, the ballasts may release PCB vapors (Staiff et al., 1974). Note in Figure 19 that the air sampling unit for classroom 120 was placed below a light fixture with one light out.
- The room lights were likely on all day before sampling began, since sampling occurred at the end of the school day. The lights were turned off for the sample duration, after the sampling equipment was set up. Lights were turned back on the next day before the sampling ended and the sampling unit was dismantled.

Thus, given the fact that window caulking in rooms 120 and 138 is intact and wipe samples closest to the windows did not show detectable PCB levels; that PCB containing ballasts are located in these rooms; that overhead lights in these rooms clearly had at least some malfunctioning light bulbs; and that burned out lights that remain in fixtures can result in overheating of the light ballasts, resulting in small releases of PCBs, indicate that the light ballasts appear to be the source of PCBs in air samples in these rooms.

Conclusion

Based upon all of the information reviewed for this report the MDPH does not believe that exposure to PCBs at levels detected in the Sherwood Middle School present unusual cancer or non-cancer concerns for students or teachers in the short of long term. The MDPH, however, believes that steps should be taken to reduce and/or eliminate opportunities for exposure to PCBs by addressing concerns associated with light ballasts in the school.

Recommendations

The following recommendations are provided:

1. MDPH/BEH recommends that more aggressive cleaning of surfaces not routinely cleaned (e.g. windowsills, bookcases) be undertaken and regularly conducted.
2. The Operation & Maintenance (O&M) Plan developed for maintenance staff regarding prompt replacement of burned out bulbs to reduce overheating and stress on the ballasts should be strictly adhered to. In addition, the O&M plan calls for ballasts to be replaced immediately if they appear to be in disrepair.
3. MDPH/BEH will work with the Department of Elementary and Secondary Education (DESE) to provide notification to all schools in MA so that similar attention can be paid to this issue consistently.
4. MDPH should provide the results of the sampling and analysis effort to the Office of Science & Technology Policy of the White House (OS&TP) to address PCBs in older light ballasts and possible exposures.
5. While it is unlikely that appreciable serum PCB levels would result from exposure to the school environment alone, blood testing may address any exposure concerns for individual staff. MDPH/BEH will offer, upon request, blood testing for serum PCB analysis to Sherwood Middle School staff.

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Appendix A

Exposure Calculations and Cancer Risk Assessment

In order to further assess contaminants, such as PCBs, and possible health related concerns, calculations are made to estimate the amount of a contaminant that people may come into contact with each day (i.e., exposure dose). These calculations account for several factors that are specific to the location and the medium being analyzed. The maximum concentration is the highest amount of the contaminant found during sampling for each medium, i.e., air. This is a conservative assumption since it is unlikely that an individual would be continuously exposed to the highest concentration. Exposure frequency is the rate of exposure within a given time period. For Sherwood Middle School, it is estimated that students and teachers are inside the school for 180 days per year and could be exposed each day. Exposure duration is the length of time of a continuous exposure. For students and teachers, this is estimated to be 4 and 35 years, respectively. The averaging time is the number of days in which an exposure is averaged. For cancer concerns, the default value is the number of days in a 70-year lifespan. Once the exposure dose is calculated, it is multiplied by the cancer slope factor to produce a theoretical cancer risk (e.g., 1 in a million, or 1×10^{-6}). The cancer slope factor for PCBs is 2 $(mg/kg/day)^{-1}$ (U.S. EPA 1997a).

Air exposures include inhalation rates, which are the volume of air that children and adults breathe each day. The maximum average inhalation rate for children ages 9-14 years (grades 5-8th) is approximately 14 cubic meters per day (14 m^3/day) or 4.7 m^3 per 8 hour school day (EPA 2008). For adults, the average inhalation rate is 15.3 m^3/day or 5.1m^3 per 8 hour work day (U.S. EPA 1997). The average body weight for children ages 9-14 years was estimated as 45.48 kg, using the U.S. EPA Child-Specific Exposure Factors Handbook (2008). For adults, the average body weight used in the exposure calculation is 70 kg (ATSDR, 2005).

Using the maximum total PCB concentration in air in the classrooms sampled, 0.2695 µg/m^3, the following is the exposure dose and theoretical cancer risk calculations for adults and children:

<u>Adult</u>

Maximum Concentration of PCBs:	**0.2695 µg/m^3**
Inhalation Rate (8 hour):	**5.1 m^3/day**
Exposure Frequency:	**180 days/year**
Exposure Duration:	**35 years**
Conversion Factor (CF):	**0.001 mg/µg**
Body Weight:	**70 kg**
Averaging Time (70 years):	**25,550 days**
Cancer Slope Factor:	**2 mg/kg/day^{-1}**

$$ExposureDose = \frac{Concentration * InhalationRate * ExposureFrequency * ExposureDuration * CF}{BodyWeight * AveragingTime}$$

Exposure Dose = 4.84 x 10^{-6} mg/kg/day

Theoretical Cancer Risk = Exposure Dose x Cancer Slope Factor

Theoretical Cancer Risk = 1 x 10^{-5}

Child (9-14 years old)

Maximum Concentration of PCBs:	**0.2695 µg/m^3**
Inhalation Rate (8 hours):	**4.7 m^3/day**
Exposure Frequency:	**180 days/year**
Exposure Duration:	**4 years**
Conversion Factor (CF)	**0.001 mg/µg**
Body Weight:	**45.48 kg**
Averaging Time (70 years):	**25,550 days**
Cancer Slope Factor:	**2 mg/kg/day^{-1}**

$$ExposureDose = \frac{Concentration * InhalationRate * ExposureFrequency * ExposureDuration * CF}{BodyWeight * AveragingTime}$$

Exposure Dose = 7.85 x 10^{-7} mg/kg/day

Theoretical Cancer Risk = Exposure Dose x Cancer Slope Factor

Theoretical Cancer Risk = 1.6 x 10^{-6}

Figure 1. Schematic overview of main floor and sampling locations

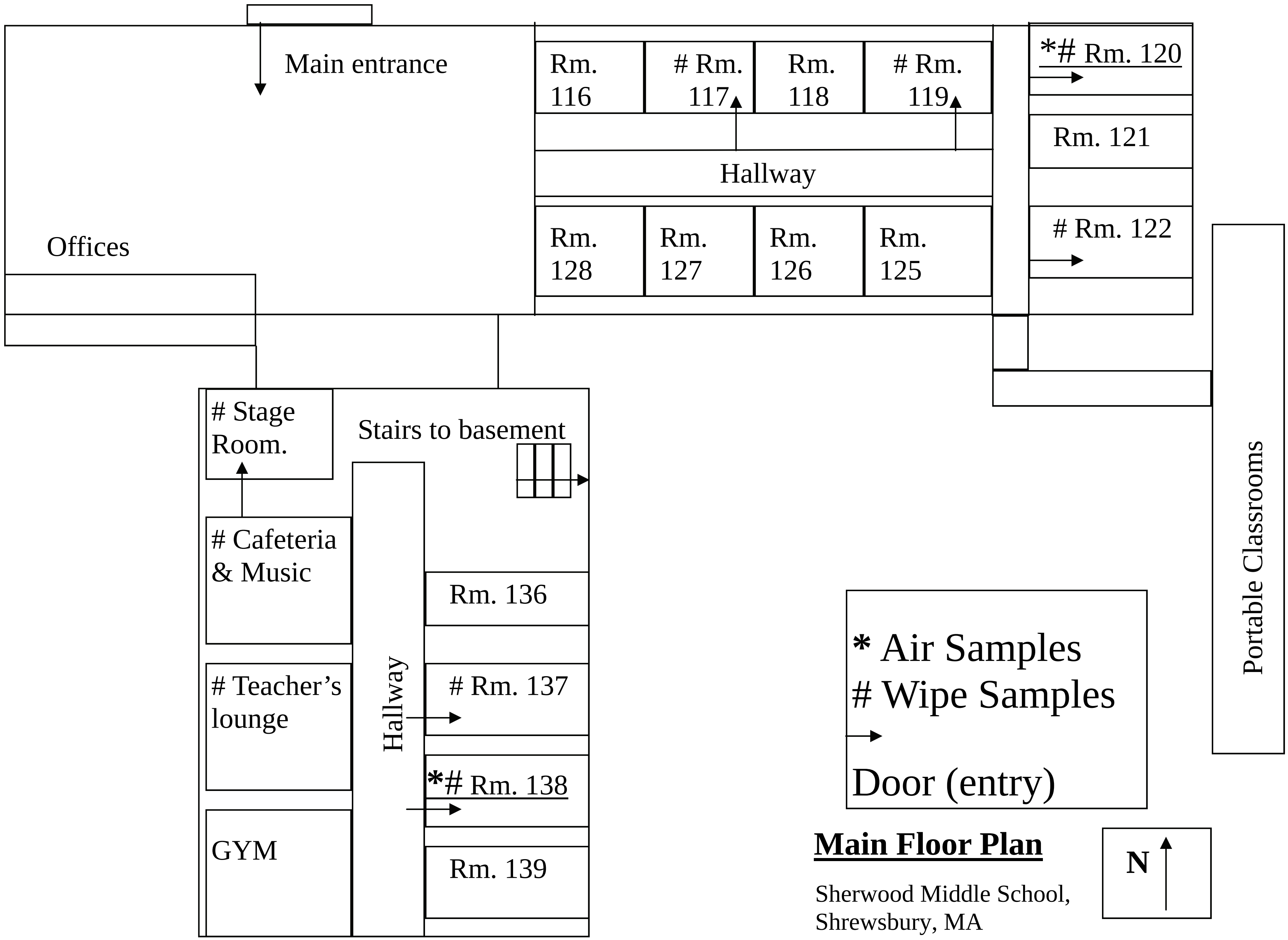


Figure 2. Schematic overview of second floor and sampling locations

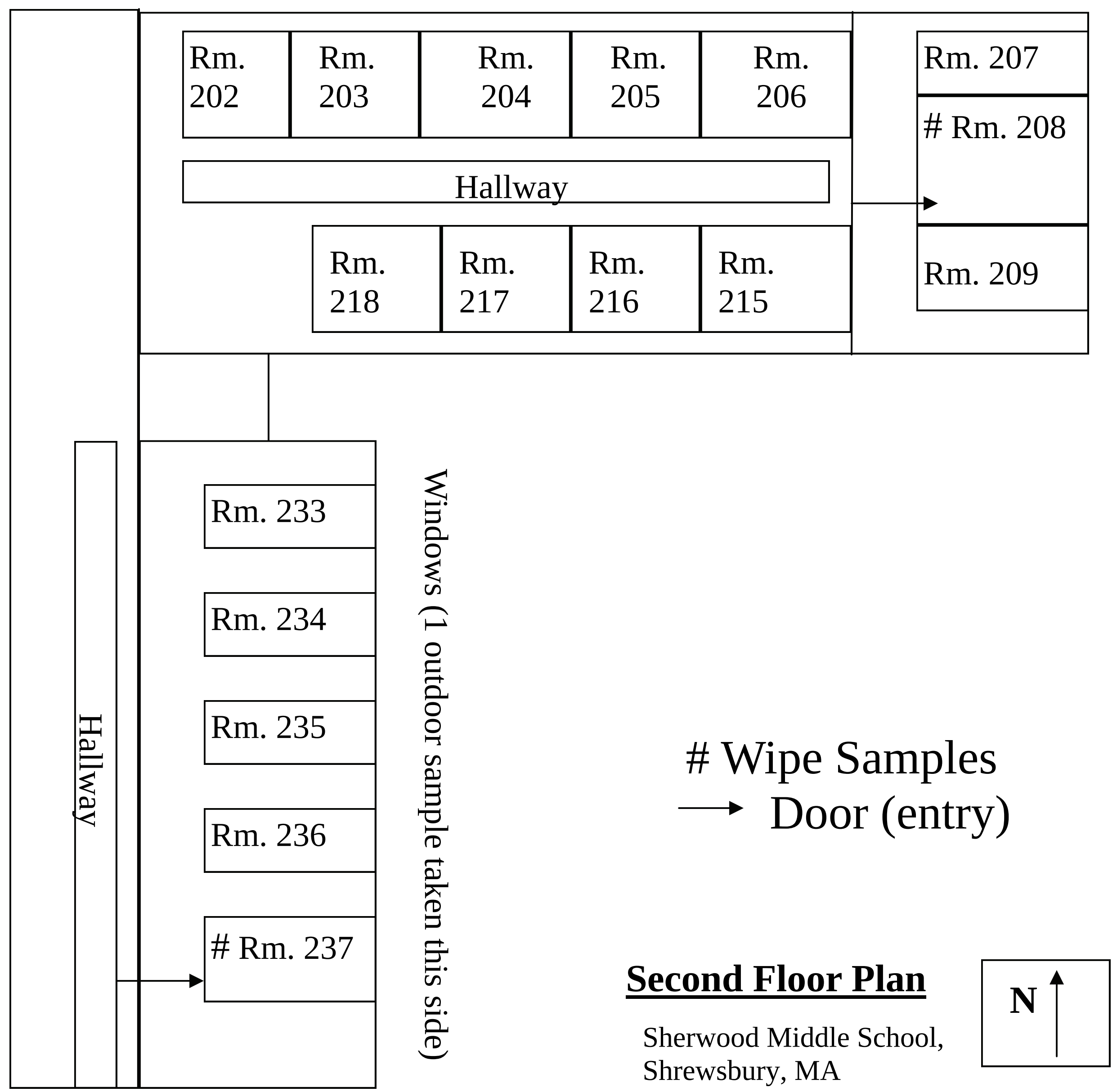


Figure 3. Schematic overview of basement and sampling locations

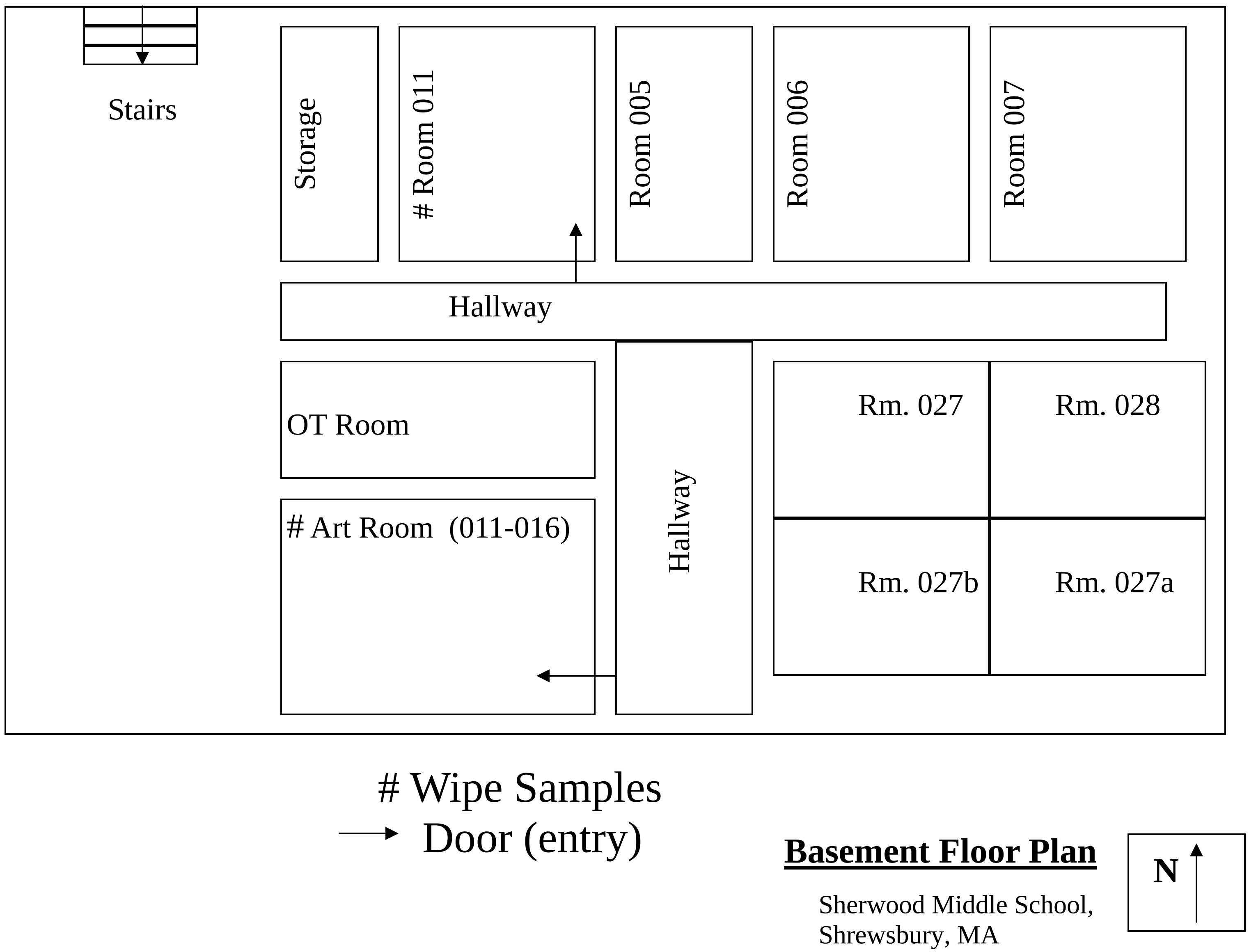
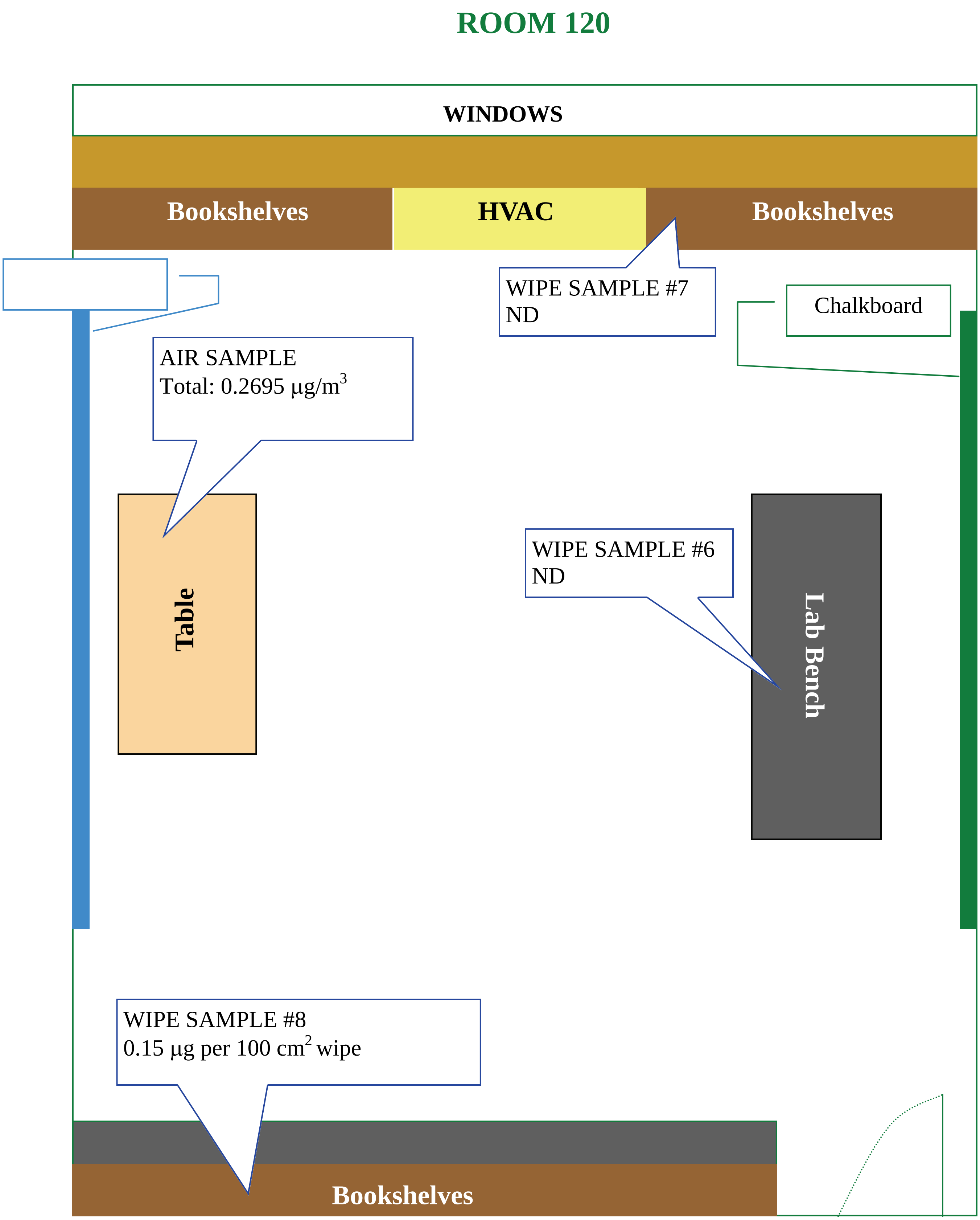


Figure 4. Room 120 air and wipe sample locations and results



ROOM 138 (not to scale)

Figure 5. Room 138 air and wipe sample locations and results

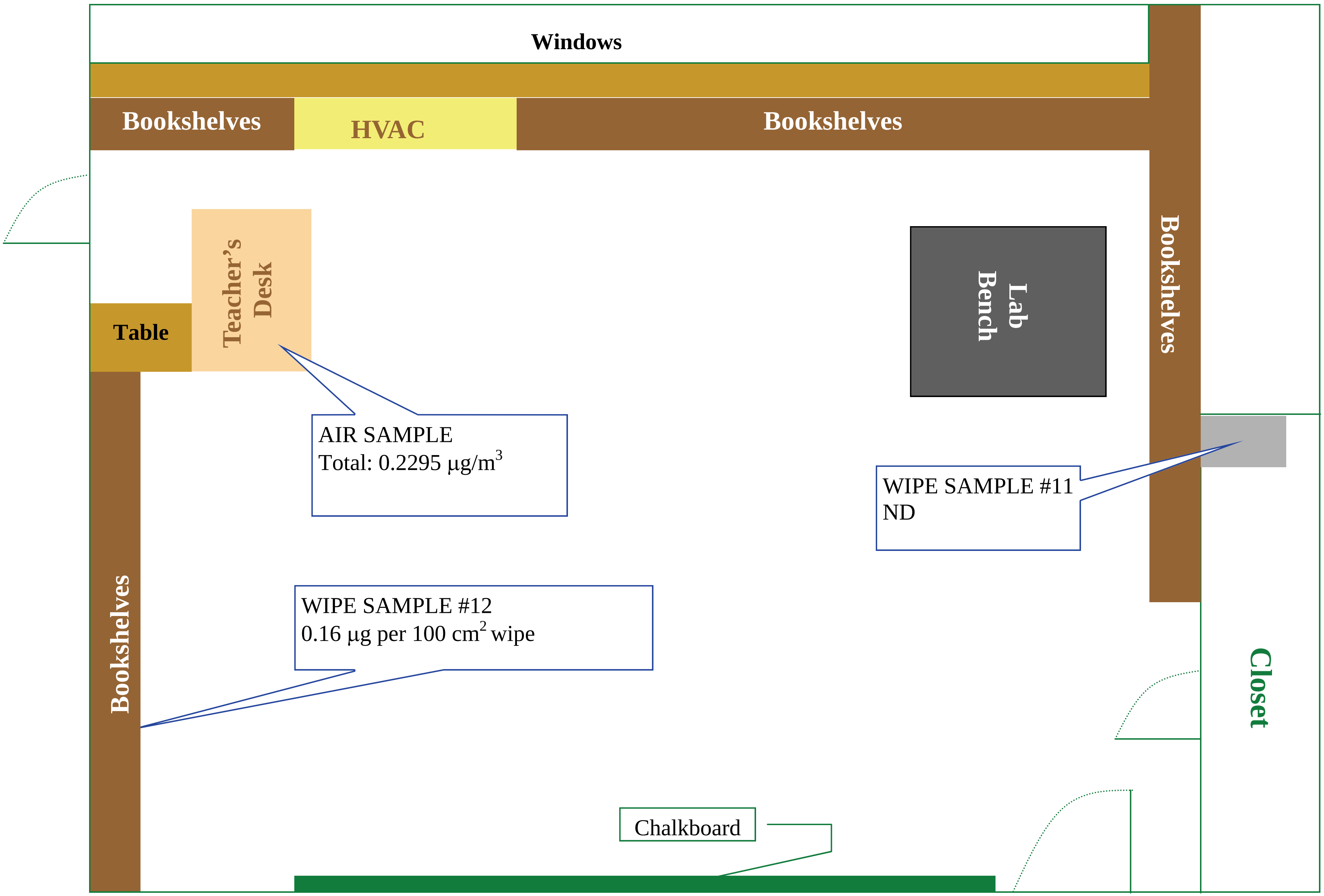


Figure 6. Room 117 wipe sample location and result

ROOM 117 (not to scale)

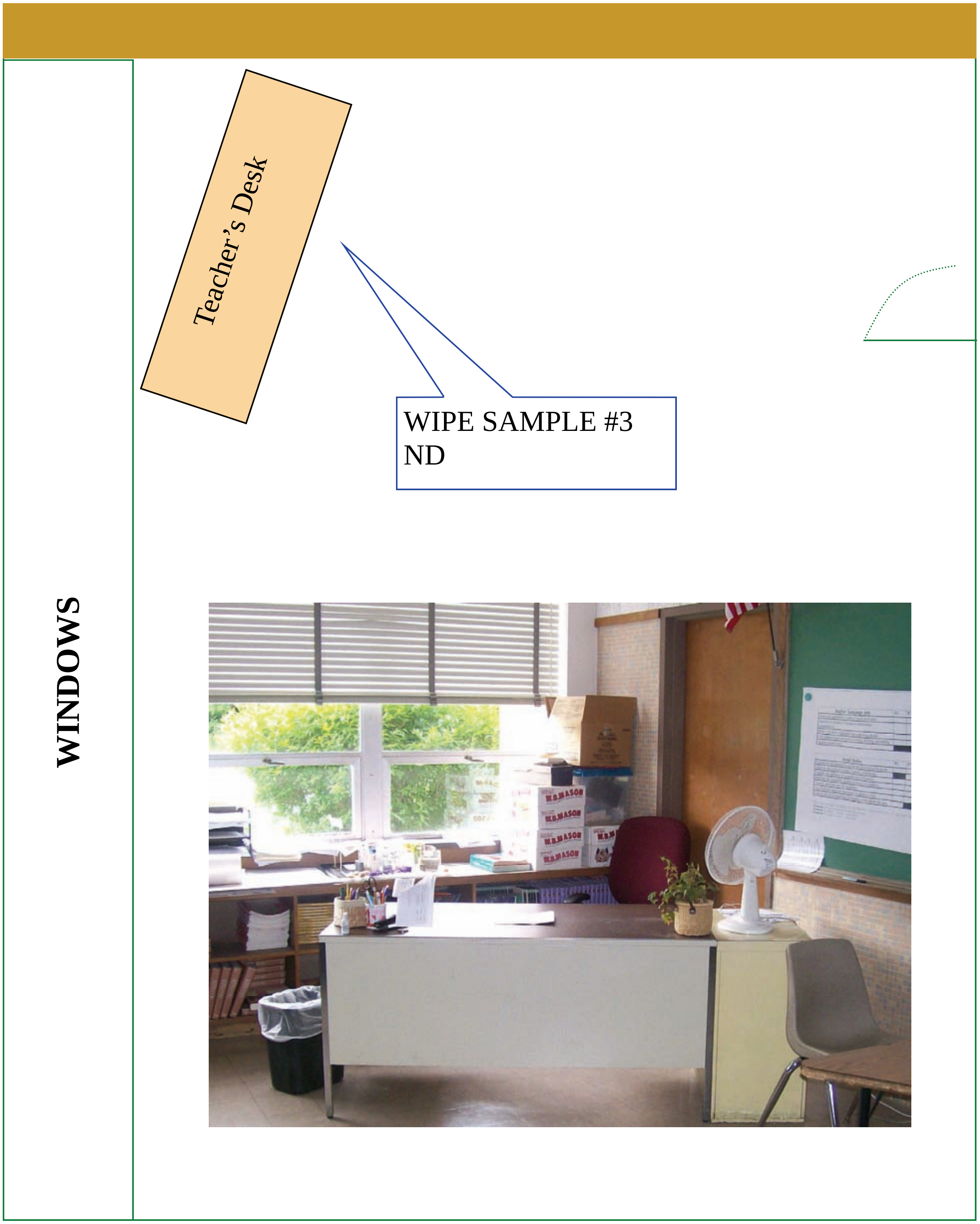


Figure 7. Room 119 wipe sample locations and results

ROOM 119 (not to scale)

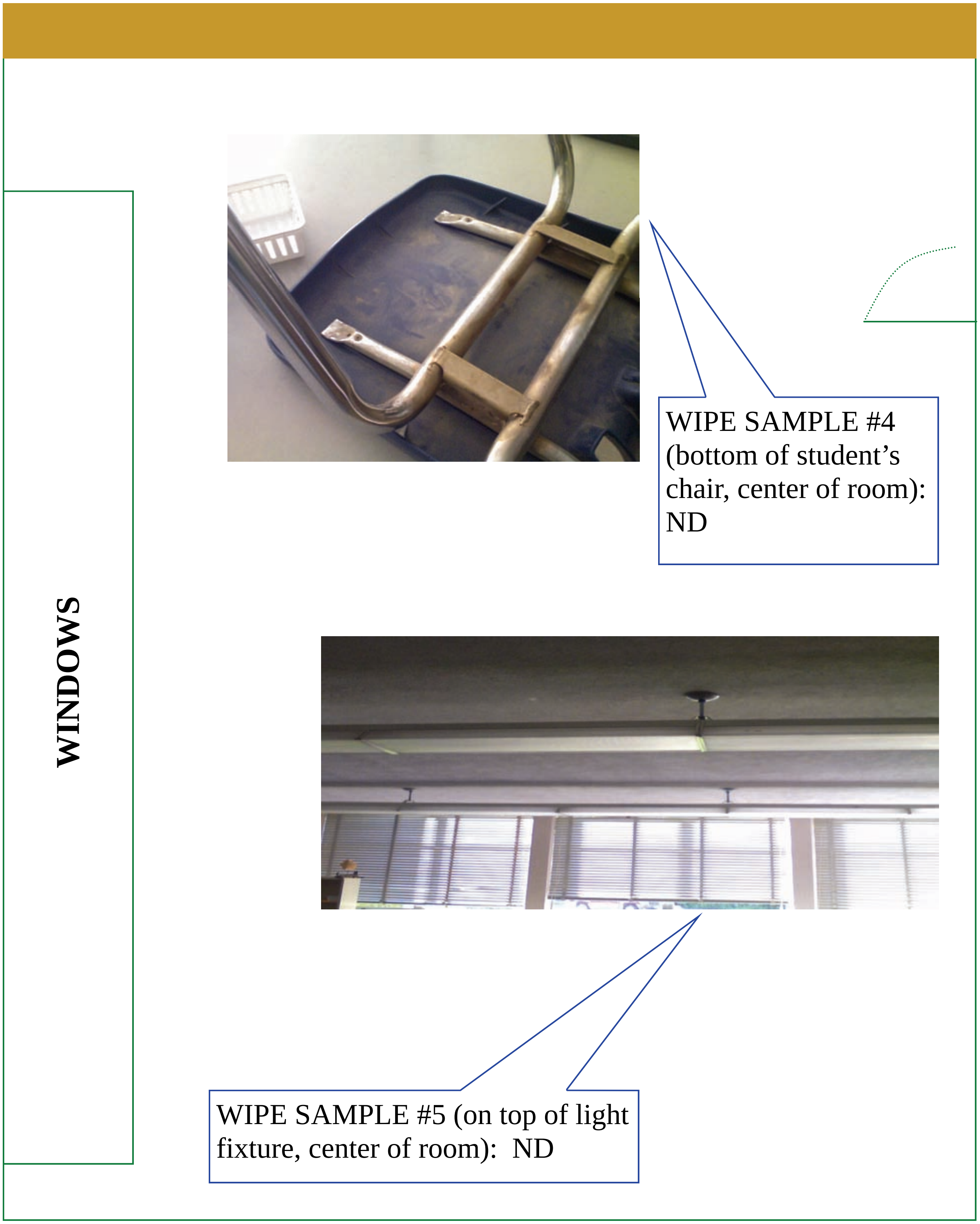
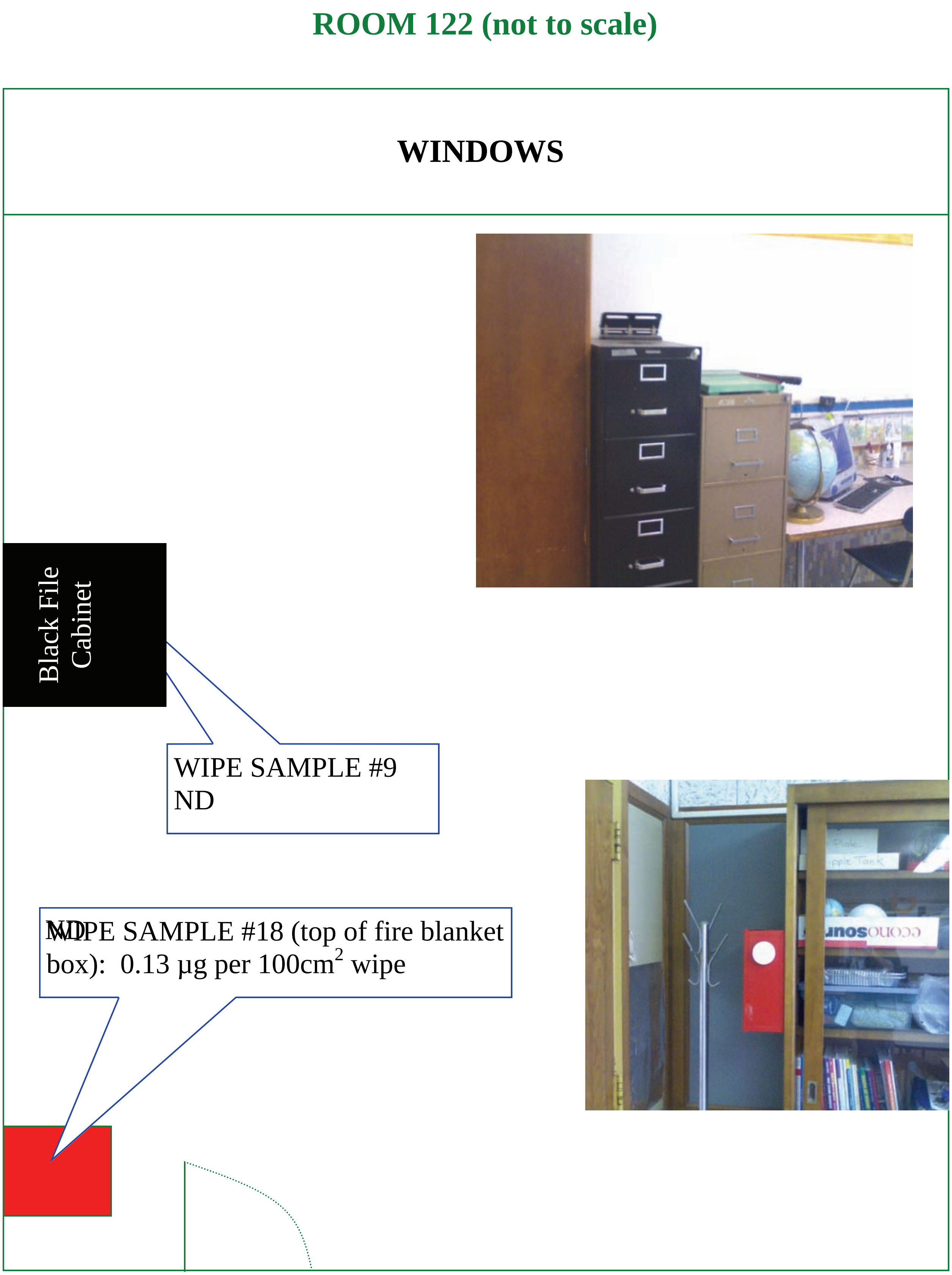


Figure 8. Room 122 wipe sample locations and results



ROOM 137 (not to scale)

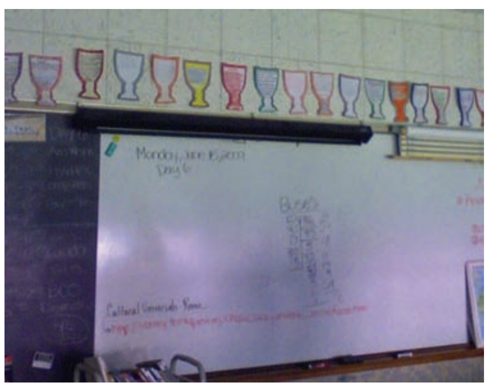
Figure 9. Room 137 wipe sample locations and results

WINDOWS

Windowsill (back left corner)

WIPE SAMPLE #10:
1.2 µg per 100cm^2 wipe

WIPE SAMPLE #19 (top of black projector screen): 0.22 µg per 100 cm^2 wipe

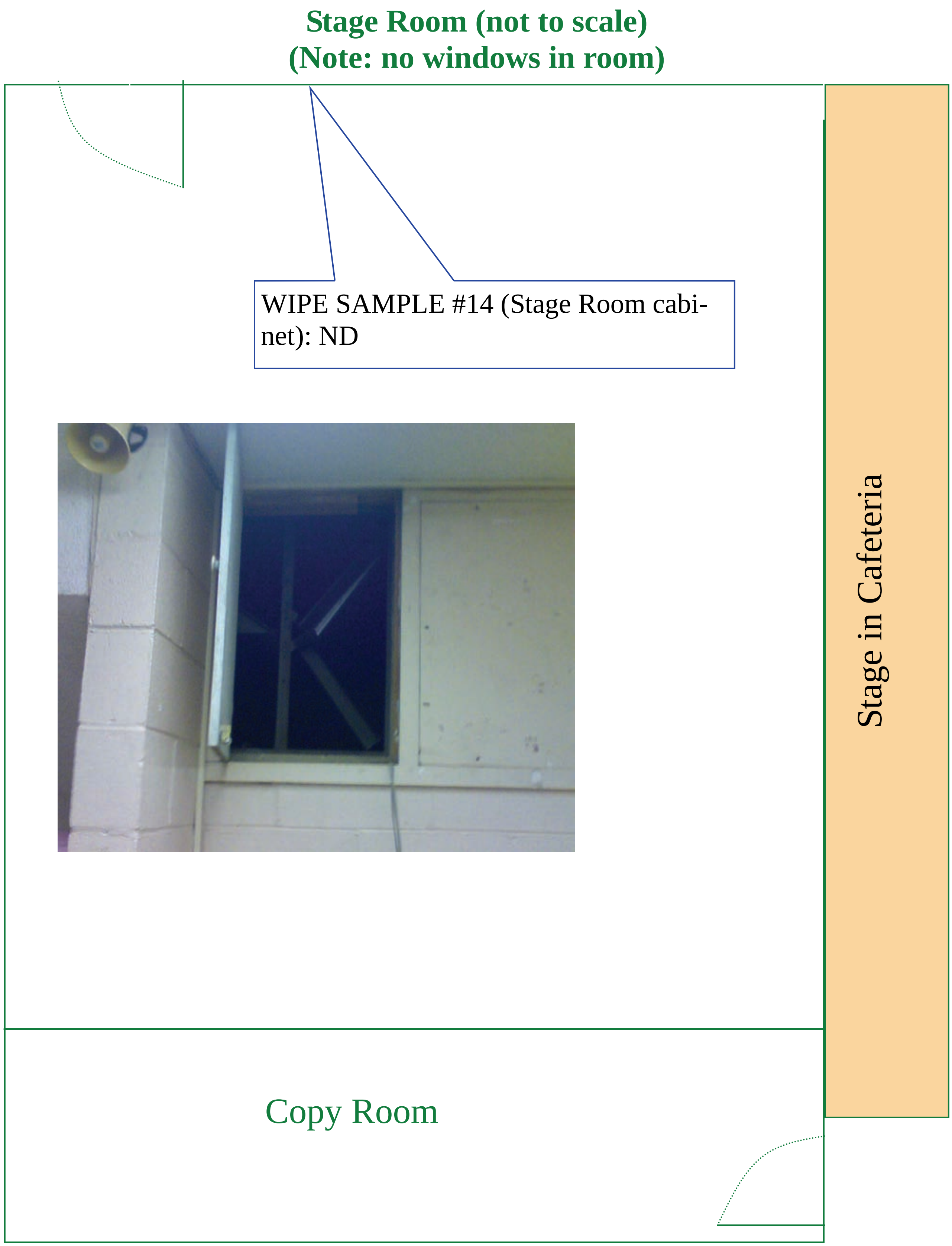


Black Projector Screen

Figure 10. Teacher's lounge wipe sample location and result

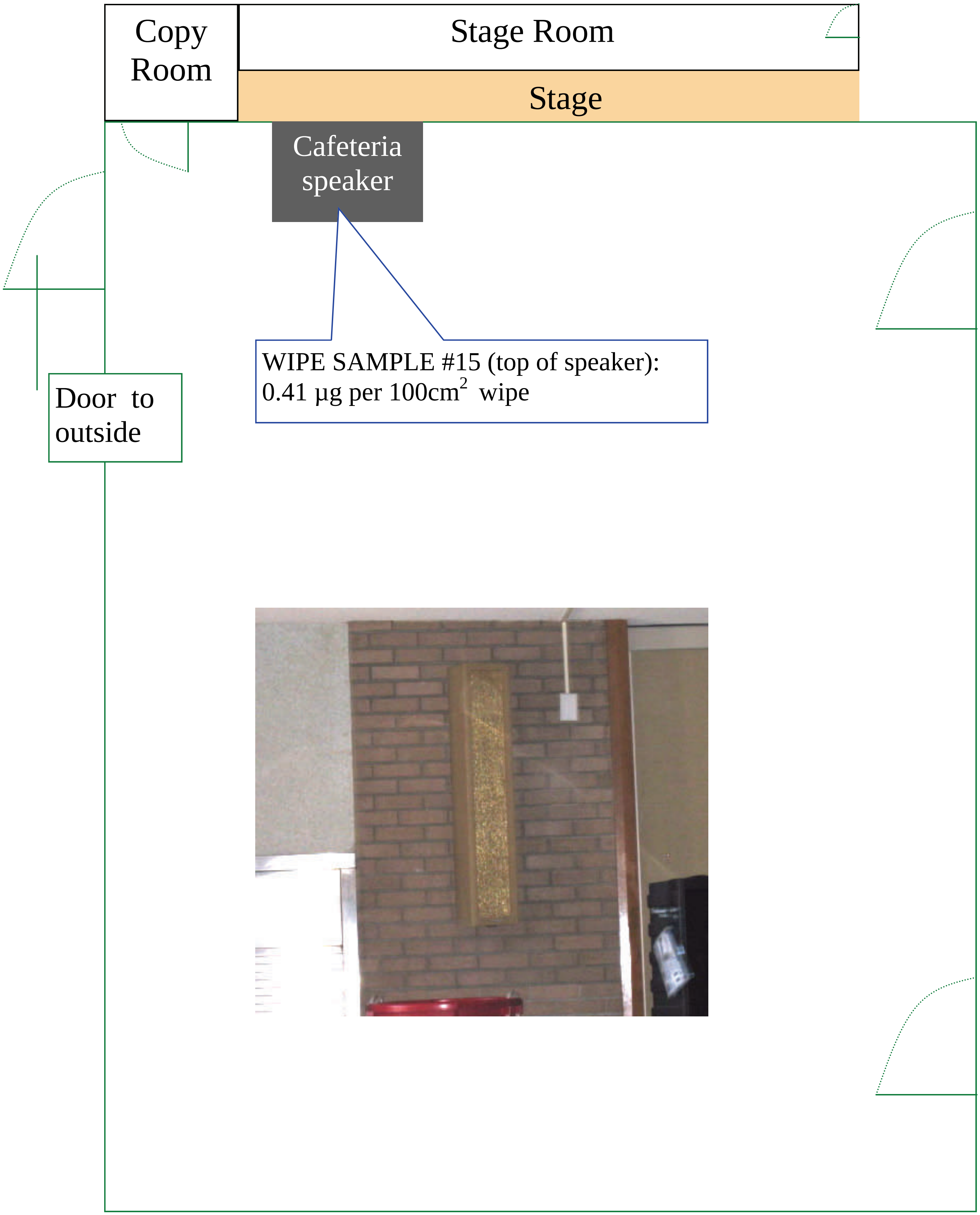
Teacher's Lounge (not to scale)

Figure 11. Stage Room wipe sample location and result



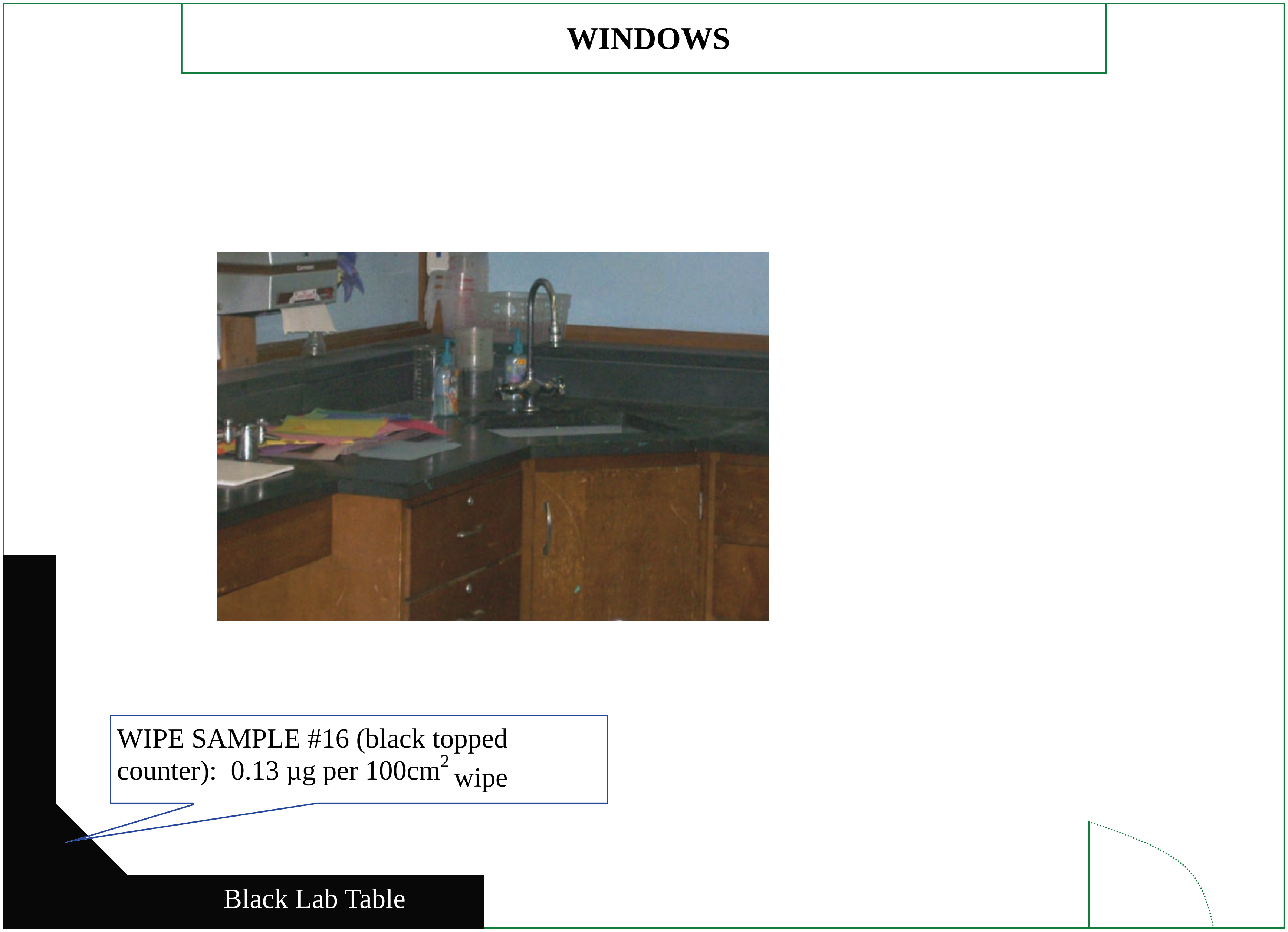
Cafeteria (not to scale)

Figure 12. Cafeteria wipe sample location and result



ROOM 208 (not to scale)

Figure 13. Room 208 wipe sample location and result



ROOM 237(not to scale)

Figure 14. Room 237 wipe sample location and result

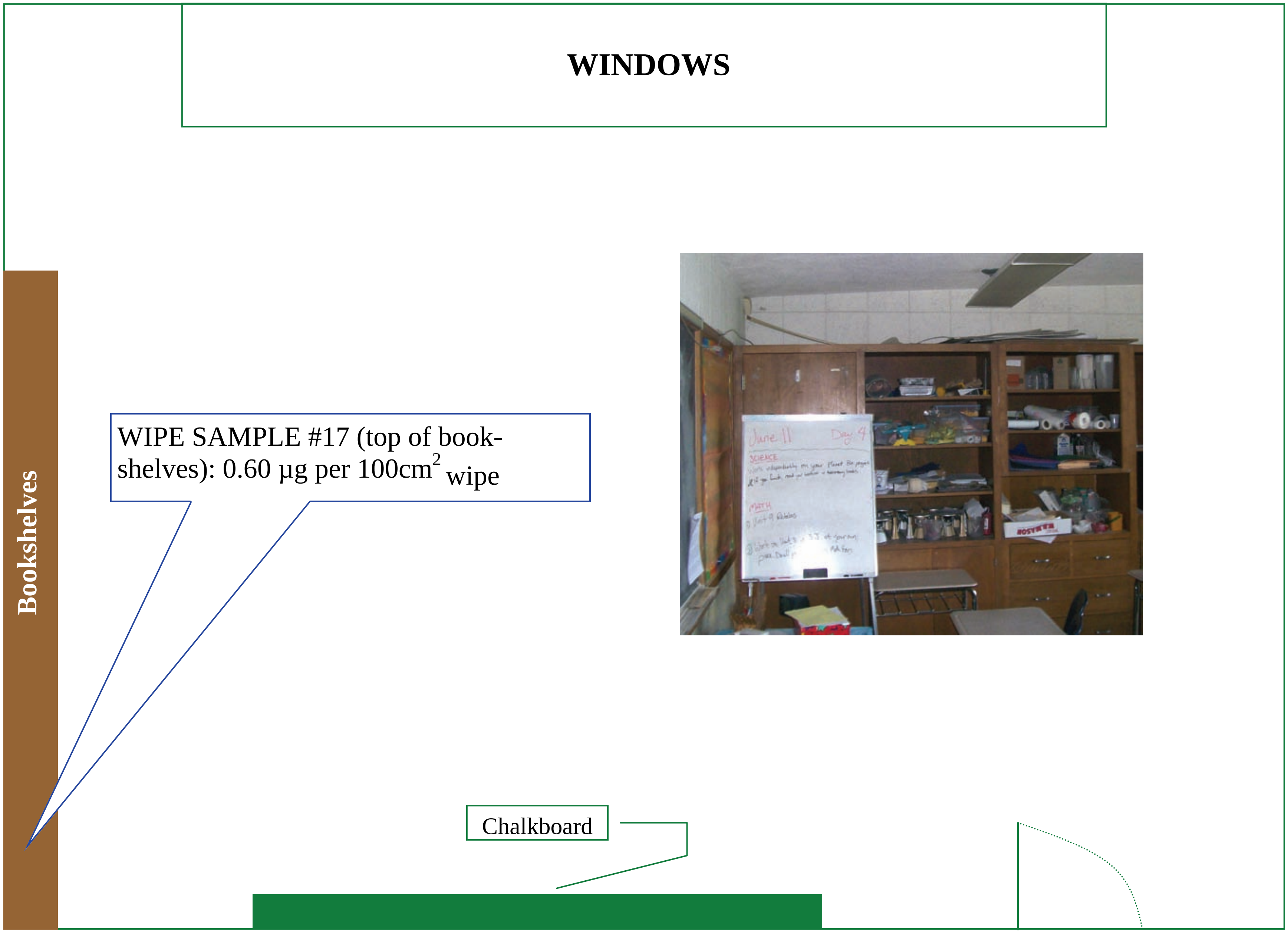


Figure 15. Room 011 wipe sample locations and results

ROOM 011 (Not to scale)

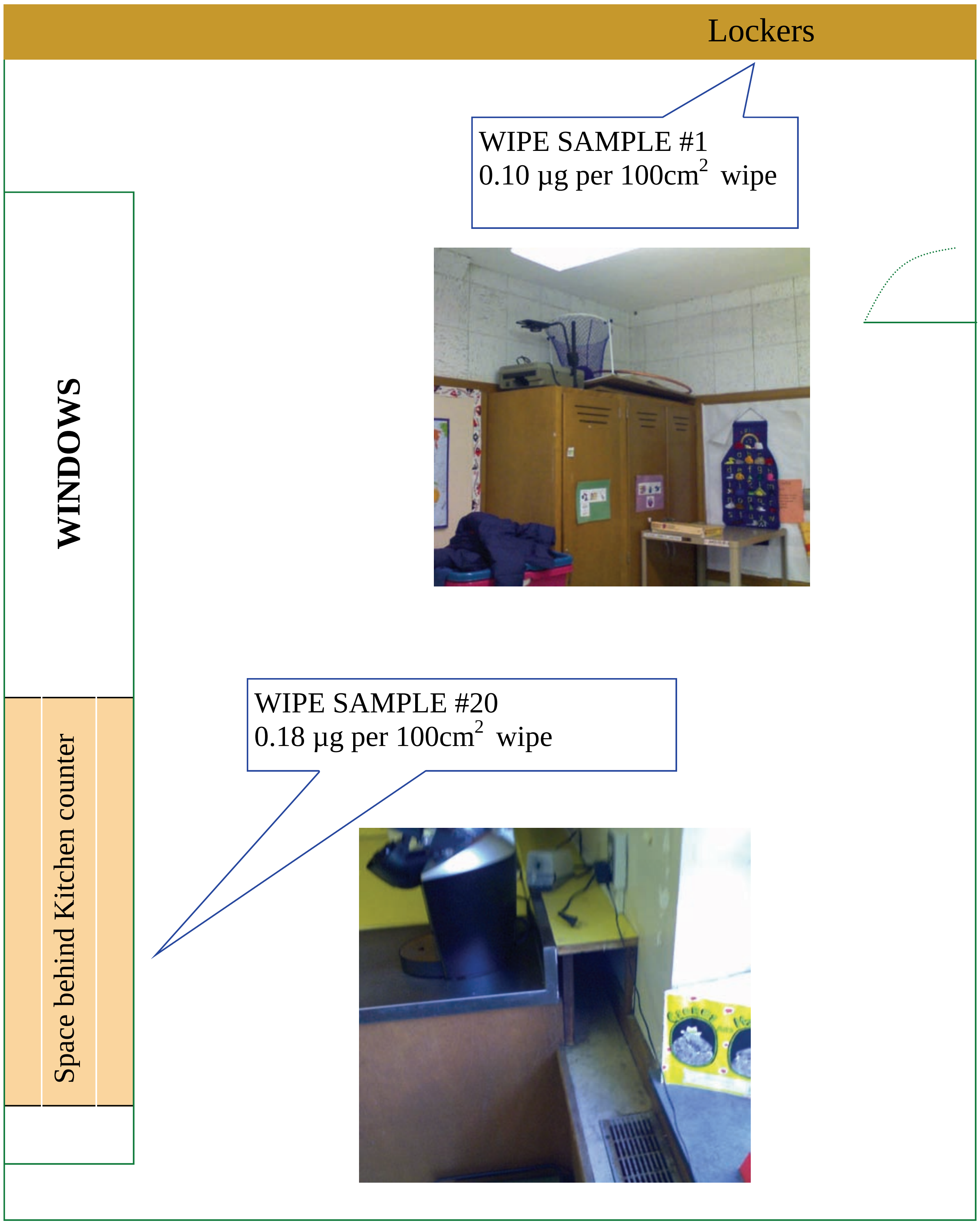


Figure 16. Art Room (011-016) wipe sample location and result

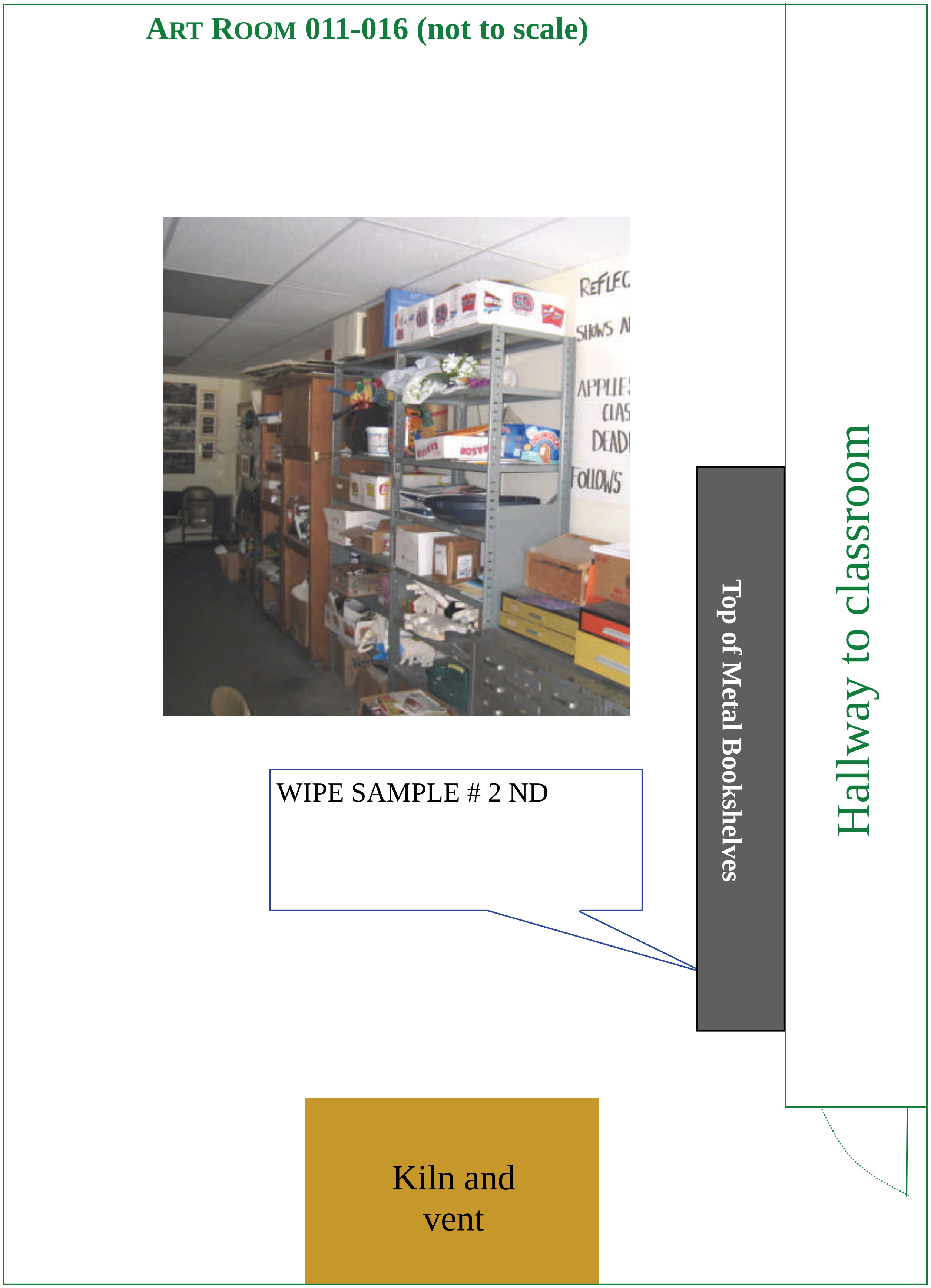


Figure 17. Overhead photo of Sherwood Middle School Classrooms 120 and 138 where air sampling occurred

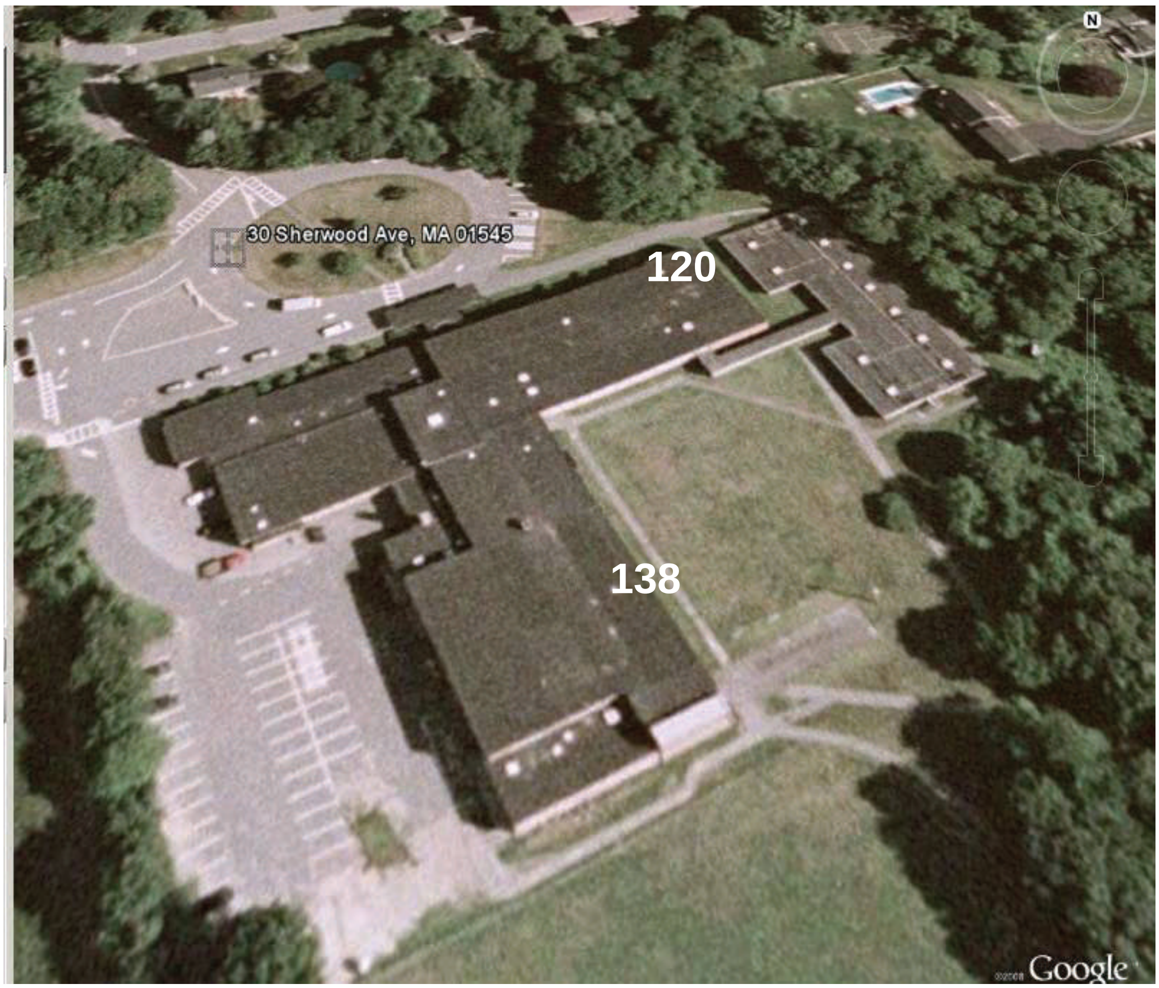


Figure 18. Air Sampling Pump (Outdoor/Background Sample)

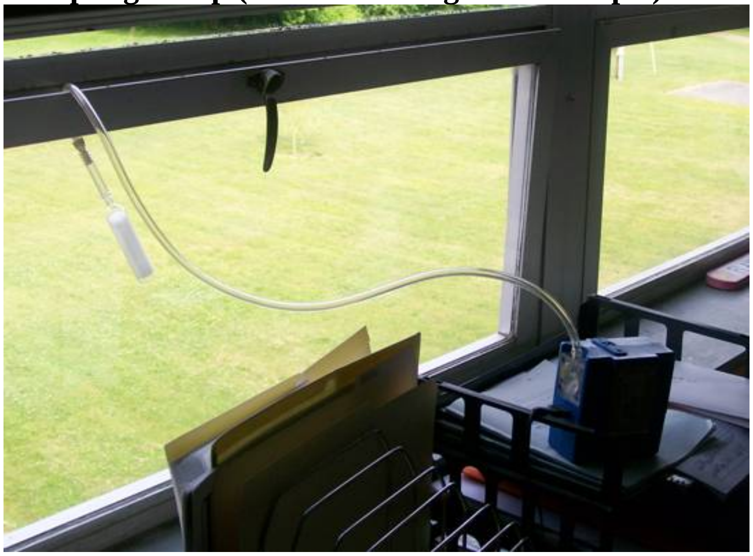


Figure 19. Air Sample Room 120

Arrow shows approximate area where air sample was taken, in the back of the room on a table opposite the lab bench (tables/desks were removed at time of photo). Note area is located underneath a light fixture with bulbs out.

Figure 20. Air Sample Room 138

Arrow shows approximate area where air sample was taken, on top of a teacher's desk adjacent to bookshelves on left. Note area is located under the light fixtures. There were some bulbs out in the room (not shown).

Figure 21. Room 120 Window Frame Interior Caulking

Figure 22.   Room 120 Window Frame Exterior Caulking

Figure 23. Portable Classrooms Shielding Room 120 Windows From Wind Impingement

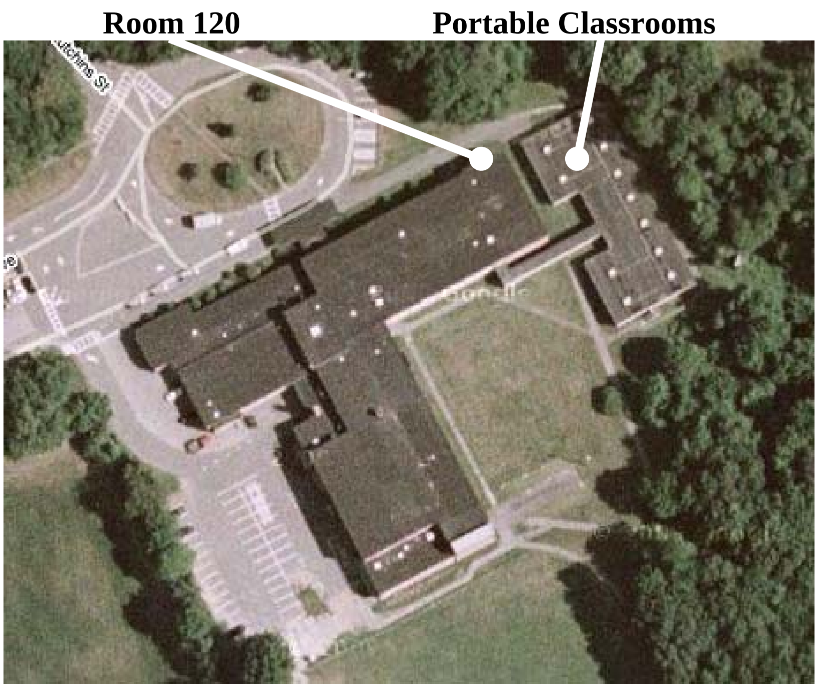


Figure 24. Room 120 Univent Fresh Air Intake Grill, Note Caulking Condition

Figure 25. Sampler Approximate Location, Note Darkened Light Above Sample Location

Table 1: Wipe and Air analytical results for PCBs at Sherwood Middle School in Shrewsbury, MA
Sample dates: wipes (6/12/09); air (6/12 - 6/13/09)

Sample Number	Room Number	Location in Room	Wipe Results (µg per 100 cm^2 wipe)	Reporting Limit (µg per 100 cm^2 wipe)	CA DTSC wipe clean up standard (per 100cm^2 wipe)*	Air Results (Rooms 120 and 138 only; µg/m^3)**	Reporting Limit (µg/m^3)	Comparison value (air; ATSDR 2009)
1	011	Top of lockers to the right of door	0.1	0.1	0.1 µg/wipe			
2	011(016) - Art Room	Top of the metal bookshelves	ND	0.1	0.1 µg/wipe			
3	117	Teacher's Desk	ND	0.1	0.1 µg/wipe			
4	119	Bottom of students chairs	ND	0.1	0.1 µg/wipe			
5	119	Top of lighting fixture	ND	0.1	0.1 µg/wipe			
6	120	Top of black (lab) table in front of classroom	ND	0.1	0.1 µg/wipe	Aroclor-1242: 0.13; Aroclor-1254: 0.097; Total PCBs: 0.227 (0.2695)	0.017	ATSDR CREG: 0.01 µg/m^3
7	120	Top of cabinet in front of windowsill	ND	0.1	0.1 µg/wipe			
8	120	Top of bookshelves	0.15	0.1	0.1 µg/wipe			
9	122	Top of the black file cabinet on left side from door	ND	0.1	0.1 µg/wipe			
10	137	Windowsill in back left corner of the room from door	1.2	0.1	0.1 µg/wipe			
11	138	Top of metal bookshelf under vent, in closet to right of door.	ND	0.1	0.1 µg/wipe	Aroclor-1242: 0.10; Aroclor-1254: 0.087; Total PCBs: 0.187 (0.2295)	0.017	ATSDR CREG: 0.01 µg/m^3
12	138	Top of bookshelves	0.16	0.1	0.1 µg/wipe			
13	Teacher's Lounge	Top of the window curtain	0.21	0.1	0.1 µg/wipe			
14	Stage Room	Cabinet to left of clock	ND	0.1	0.1 µg/wipe			
15	Cafeteria	Top of speaker	0.41	0.1	0.1 µg/wipe			
16	208	Black topped counter on the left from door	0.13	0.1	0.1 µg/wipe			
17	237	Top of the bookshelves	0.6	0.1	0.1 µg/wipe			
18	122	Top of fire blanket box	0.13	0.1	0.1 µg/wipe			
19	137	Top of the black projector screen	0.22	0.1	0.1 µg/wipe			
20	011	In space behind the kitchen counter near window	0.18	0.1	0.1 µg/wipe			
Background		Out 2nd floor window, away from combustion sources				ND	0.017	

*Note: CA DTSC clean up standard for PCBs on surface areas (0.1 µg per 100 cm^2 wipe) is protective of teachers and students based on long-term dermal exposure to contaminated surfaces and incidental ingestion from hand-to-mouth activity (CA DTSC 2003). EPA clean up standard for PCB spills is 10 µg/100cm^2 wipe (EPA 1991).

**Note: Detected Aroclors reported for air. Total PCBs are calculated 2 ways: 1) sum of detected Aroclors, and 2) assuming non-detected Aroclors are equivalent to 1/2 of the reporting limit (value in parenthesis). Samples were analyzed for the following 7 Aroclors: 1016, 1221, 1232, 1242, 1248, 1254, and 1260. Air sample protocol and analytical method: EPA TO-10A (low-volume PUF sampling followed by GC/MD for determination of pesticides and PCBs in ambient air; 2nd edition, EPA 1999).