

September 27, 2017

Mr. Jeff Klenk  
Howard County Public School System (HCPSS)  
10910 Route 108  
Ellicott City, MD 21043

RE: Indoor Air Quality Assessments during Renovations at Waverly Elementary School  
Project #J17-1037 (August 24 and September 2, 15 & 22, 2017)

Dear Mr. Klenk,

Aria Environmental, Inc. (AE) is pleased to present this report of findings for indoor air quality assessments conducted at Waverly Elementary School (Waverly). Jeff Klenk of HCPSS requested AE start making frequent visits to Waverly to monitor indoor air quality that may be affected by the current major renovation of the school. The visits discussed in this report were performed on August 24, and September 2, 15 & 22, 2017 and included work site observations, and real-time measurements for particles, indoor air quality parameters (temperature, humidity, carbon monoxide (CO) and carbon dioxide (CO<sub>2</sub>)) and volatile organic compounds (VOCs). These assessments were performed by Julie Barth, CIH, CSP, LEED Green Associate of AE. Presented below are observations and recommendations made based upon conditions readily observed on the reported dates.

### **Particles**

Particulate matter or PM is the term for a mixture of solid particles and liquid droplets found in the air. It does not distinguish between the types of particles in the air (e.g., pollen, skin cells, soil, etc.). Particulate matter includes "inhalable coarse particles," with diameters larger than 2.5 micrometers and smaller than 10 micrometers (PM<sub>10</sub>) and "fine particles," with diameters that are 2.5 micrometers and smaller (PM<sub>2.5</sub>). A micrometer is also called a micron and is one millionth of a meter. To put these particle diameters in perspective, the average human hair is about 70 micrometers in diameter – making it 30 times larger than the largest fine particle. Particle loads expected to be a part of the school environment include carpet and clothing fiber, soil tracked in from outside, paper dust and dust and fibers from building materials.

ASHRAE Standard 62.1–2010 suggests target indoor concentrations for PM<sub>2.5</sub> and PM<sub>10</sub> of 15 µg/m<sup>3</sup> and 50 µg/m<sup>3</sup>, respectively. These concentrations are taken from the EPA's National Ambient Air Quality Standards (NAAQS) based on annual arithmetic means deemed acceptable for outdoor air quality. Occupational standards and guidelines for particles are nearly an order of magnitude higher than concentrations typically found in non-occupational settings and are not appropriate for comparison. Particle measurements were taken with an Aerocet 531 particulate monitor. The particle monitor takes a two minute averaged sample of particle concentrations in 5 size fractions (PM<sub>1</sub>, PM<sub>2.5</sub>, PM<sub>7</sub>, PM<sub>10</sub> and total suspended particles (TSP)). Results of particulate monitoring are presented in Tables 1, 2 and 3.

Indoor Air Quality Assessments during Renovations at Waverly Elementary School  
August 24 and September 2, 15 & 22, 2017

**Discussion of Particle Results for August 24, 2017**

The PM<sub>2.5</sub> particle concentrations ranged from 1 to 63 µg/m<sup>3</sup> and PM<sub>10</sub> particle concentrations ranged from 7 to 412 µg/m<sup>3</sup> in the hallways outside the construction zones on August 24, 2017. The school was occupied by teachers, staff and construction workers on this day prior to the start of the school year. PM 2.5 concentrations were above the target concentration in five areas and PM 10 concentrations were above the target concentrations in six locations near the construction zone as well as in the non-construction zones with staff activity. Furniture was being assembled and installed in the Media Center and school supplies were being opened and unboxed in most classrooms. Results of particulate monitoring on August 24, 2017 are presented in Table 1.

**Table 1 – Results of Particulate Monitoring Waverly Elementary School on August 24, 2017**

Location	Time	PM1 (µg/m <sup>3</sup> )	PM2.5 (µg/m <sup>3</sup> )	PM7 (µg/m <sup>3</sup> )	PM10 (µg/m <sup>3</sup> )	TSP (µg/m <sup>3</sup> )
Classroom 205 2 <sup>nd</sup> Floor	11:40 AM	0	1	5	7	16
Classroom 209 2 <sup>nd</sup> Floor	11:43 AM	0	2	11	15	21
Classroom A125	12:10 PM	0	4	20	27	35
Lobby	12:15 PM	0	6	63	<b>89</b>	141
5 <sup>th</sup> Grade Pod 631 Classroom 4	12:21 PM	0	<b>15</b>	152	<b>235</b>	364
Media Center (new furniture and cabinets being installed)	12:26 PM	1	<b>22</b>	221	<b>352</b>	559
4 <sup>th</sup> Grade Pod 620 Center	12:31 PM	2	<b>21</b>	283	<b>412</b>	640
Classroom C115	12:35 PM	1	6	31	42	49
Classroom B136	12:39 PM	1	<b>15</b>	120	<b>173</b>	259
Workroom C125	12:43 PM	6	<b>63</b>	165	<b>209</b>	303
Outside	12:48 PM	0	1	3	3	4

Bold-faced results indicate results above target concentrations.

**Discussion of Particle Results for September 2, 2017**

The PM<sub>2.5</sub> particle concentrations ranged from 0 to 2 µg/m<sup>3</sup> and PM<sub>10</sub> particle concentrations ranged from 0 to 30 µg/m<sup>3</sup> on September 2, 2017. PM 2.5 and PM 10 particle concentrations were all below the target concentrations in all locations. The building was mostly unoccupied because it was a Saturday and because LEED air testing was being performed. Results of particulate monitoring on September 2, 2017 are presented in Table 2.

**Table 2 – Results of Particulate Monitoring Waverly Elementary School on September 2, 2017**

Location	Time	PM1 (µg/m <sup>3</sup> )	PM2.5 (µg/m <sup>3</sup> )	PM7 (µg/m <sup>3</sup> )	PM10 (µg/m <sup>3</sup> )	TSP (µg/m <sup>3</sup> )
Media Center	9:53 AM	0	2	21	30	41
Pod 630 Common Area	10:34 AM	0	0	0	0	0
Front Lobby	10:36 AM	0	0	2	2	3
Classroom A125	10:39 AM	0	0	0	0	1
Gym	10:42 AM	0	1	3	4	5
Hall Near Minc Area	10:44 AM	0	0	3	4	6
4 <sup>th</sup> Grade Pod 620 Commons	10:49 AM	0	0	2	3	4

Indoor Air Quality Assessments during Renovations at Waverly Elementary School  
August 24 and September 2, 15 & 22, 2017

<b>Location</b>	<b>Time</b>	<b>PM1 (<math>\mu\text{g}/\text{m}^3</math>)</b>	<b>PM2.5 (<math>\mu\text{g}/\text{m}^3</math>)</b>	<b>PM7 (<math>\mu\text{g}/\text{m}^3</math>)</b>	<b>PM10 (<math>\mu\text{g}/\text{m}^3</math>)</b>	<b>TSP (<math>\mu\text{g}/\text{m}^3</math>)</b>
Classroom C115	10:42 AM	0	0	2	2	2
Classroom C208	10:56 AM	0	0	4	4	7
Hall Near C212	10:59 AM	0	0	6	8	11
Outside	11:02 AM	0	1	4	5	5

Bold-faced results indicate results above target concentrations

**Discussion of Particle Results for September 15, 2017**

The PM2.5 particle concentrations ranged from 1 to 6  $\mu\text{g}/\text{m}^3$  and PM10 particle concentrations ranged from 8 to 106  $\mu\text{g}/\text{m}^3$  on September 15, 2017. PM 2.5 concentrations were all below the target concentration. PM 10 particle concentrations were above the target concentrations in four locations in non-construction zones with student activity. The building was occupied with students, teachers, staff and construction workers during this monitoring period. Results of particulate monitoring on September 15, 2017 are presented in Table 4.

**Table 3 – Results of Particulate Monitoring Waverly Elementary School on September 15, 2017**

<b>Location</b>	<b>Time</b>	<b>PM1 (<math>\mu\text{g}/\text{m}^3</math>)</b>	<b>PM2.5 (<math>\mu\text{g}/\text{m}^3</math>)</b>	<b>PM7 (<math>\mu\text{g}/\text{m}^3</math>)</b>	<b>PM10 (<math>\mu\text{g}/\text{m}^3</math>)</b>	<b>TSP (<math>\mu\text{g}/\text{m}^3</math>)</b>
Outside	3:16 PM	0	0	1	2	4
Front lobby	3:22 PM	0	1	8	11	20
First Hall Near 304	3:31 PM	0	5	22	31	43
Hall Near A132	3:33 PM	0	4	23	35	61
Media Center (1 Person)	3:38 PM	0	1	6	8	10
Pod 620 Common Area (Students Everywhere)	3:41 PM	0	5	50	<b>103</b>	217
Classroom 622 – 2 Temp AC (20+ Students)	3:43 PM	0	5	38	<b>56</b>	93
Classroom 623-2 Temp AC (20+ Students)	3:46 PM	0	6	69	<b>106</b>	193
Classroom 623-1-Temp AC	3:49 PM	0	6	47	<b>69</b>	110
Hall @ Containment Near C127	3:52 PM	0	4	24	39	62
Center of 5 <sup>th</sup> Grade Pod (No Students)	3:55 PM	0	3	16	21	30

Bold-faced results indicate results above target concentrations

**Discussion of Particle Results for September 22, 2017**

The PM2.5 particle concentrations ranged from 2 to 27  $\mu\text{g}/\text{m}^3$  and PM10 particle concentrations ranged from 11 to 260  $\mu\text{g}/\text{m}^3$  in the areas monitored on September 22, 2016. Some areas had PM 2.5 and PM 10 particle concentrations above the target concentrations in locations near the construction zones, as well as in the non-construction zones with teacher activity. Students had the day off from school and teachers were present for a professional learning day on the day of monitoring. Because students were not present, some doors were being used by construction workers that would not be used on a normal school day such as the door in the Media Center. The containment door in the first hallway is not used for construction egress anymore, according to the construction management, and will be sealed up.

Indoor Air Quality Assessments during Renovations at Waverly Elementary School  
August 24 and September 2, 15 & 22, 2017

The carpet in the Media Center showed dusty boot prints and construction dust on the door hardware and bookshelves near the construction entrance. This door should not be used for construction egress unless absolutely necessary for life safety purposes. Results of particulate monitoring on September 22, 2017 are presented in Table 4.

**Table 4 – Results of Particulate Monitoring Waverly Elementary School on September 22, 2017**

Location	Time	PM1 ( $\mu\text{g}/\text{m}^3$ )	PM2.5 ( $\mu\text{g}/\text{m}^3$ )	PM7 ( $\mu\text{g}/\text{m}^3$ )	PM10 ( $\mu\text{g}/\text{m}^3$ )	TSP ( $\mu\text{g}/\text{m}^3$ )
Front Lobby	10:33 AM	0	5	31	37	49
1 <sup>st</sup> Containment area in first hallway	10:35 AM	1	<b>23</b>	94	<b>130</b>	190
Classroom A127	10:42 AM	3	<b>15</b>	49	<b>54</b>	57
Classroom A123	10:47 AM	2	11	37	42	45
Center Hallway in MINC Area	10:50 AM	2	<b>15</b>	61	<b>72</b>	84
Gym	10:52 AM	0	2	10	14	19
5 <sup>th</sup> Grade Center of Pod (630's)	11:06 AM	3	<b>15</b>	48	<b>55</b>	62
620 Classroom Area Center of Pod	11:09 AM	3	14	58	<b>75</b>	103
Media Center	11:17 AM	3	<b>18</b>	105	<b>146</b>	199
Conference Room 303	11:33 AM	4	<b>27</b>	94	<b>111</b>	135
Classroom C115	12:38 PM	0	2	9	11	12
Hallway near New Elevator 1 <sup>st</sup> Floor of New Edition	12:40 PM	0	2	14	18	23
Hallway in Center of 2 <sup>nd</sup> Floor of New Edition	12:43 PM	1	7	46	<b>67</b>	98
Classroom C203	12:46 PM	0	4	17	22	28
Classroom C208	12:57 PM	0	3	13	17	23
Hallway at Containment (plastic doors) in back of School near Rm C127	1:05 PM	3	12	176	<b>260</b>	350
Outside	1:09 PM	0	6	36	44	61

Bold-faced indicates results outside of recommended comfort ranges or target concentrations.

### **Indoor Air Quality Measurements**

Industry guidelines or standards for seasonal temperature and humidity ranges for thermal comfort are established by the American Society for Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) standard 55-2013. These ranges are presented in Table 5. The U.S. Environmental Protection Agency (EPA) recommends maintaining indoor relative humidity below 60% and ideally between 30 and 50%. Low humidity is expected in buildings that do not add humidity during the heating season. The comfort ranges are only set for the Summer and Winter seasons when temperatures are usually consistent. There are no Fall or Spring ranges because these seasons can include both heating and cooling modes of HVAC operation. Carbon dioxide and carbon monoxide measurements are used to assess ventilation system performance. The exhaled breath of building occupants is the main indoor source of carbon dioxide; therefore, the build-up of

Indoor Air Quality Assessments during Renovations at Waverly Elementary School  
August 24 and September 2, 15 & 22, 2017

carbon dioxide indicates inadequate ventilation. Results of temperature, relative humidity, carbon dioxide and carbon monoxide monitoring are presented in Tables 6-9 below.

**Table 5- Acceptable Ranges of Temperature and Relative Humidity in Summer and Winter<sup>a</sup>**

Relative Humidity	Winter Temperature	Summer Temperature
30%	68.5°F – 76.0°F	74.0°F – 80.0°F
40%	68.5°F - 75.5°F	73.5°F – 79.5°F
50%	68.5°F - 74.5°F	73.0°F – 79.0°F
60%	68.0°F - 74.0°F	72.5°F – 78.0°F

<sup>a</sup>adapted from ASHRAE Standard 55-2013

**Real Time Volatile Organic Compounds Measurements**

Instantaneous measurements for volatile organic compounds (VOCs) were collected using a ppbRae 3000 monitor calibrated using isobutylene gas. This instrument is used as a screening tool for VOCs in general with a limit of detection of 1 ppb. VOCs include a variety of chemicals, some of which may cause adverse health effects. Concentrations of many VOCs are generally higher indoors than outdoors. VOCs are emitted by many common products including paints, paint strippers, cleaning supplies, building materials, furnishings, fuels, office equipment and supplies, glues, and permanent markers, as well as cosmetics, perfumes and other personal hygiene products. These products can release organic compounds while being used or stored. It is important to note that the measurements taken are instantaneous and are intended to aid the inspector in detecting potential sources of VOC contamination. A VOC source is suspected when the measured concentration is significantly higher than the outdoor concentration or if a spike in concentration is seen in one location compared to others. Results of VOC monitoring are also presented in Tables 6-9 below.

**Discussion of IAQ and VOC Measurements for August 24, 2017**

The indoor temperatures for August 24, 2017 ranged from 72.5°F to 77.9°F. Measurements in classrooms and occupied areas of the school were within the recommended summer comfort ranges. Indoor relative humidity measurements were all between 44.3% and 61.9% which is mostly within the recommended range of 30 to 60%.

Carbon dioxide concentrations ranged from 294 to 442 ppm within indoor occupied areas. The concentration of concern for carbon dioxide is set by ASHRAE standard 62.1 as 700 ppm above outdoor air. On the day of monitoring, the outdoor air concentration of carbon dioxide was 243 ppm; therefore, concentrations were within the comfort parameters in all areas monitored. Measurements were made during a day when the building was occupied with teachers, staff and construction workers only prior to the start of the school year.

Carbon monoxide is mainly attributed to incomplete combustion. Concentrations of CO ranged from 0.0 ppm to 0.9 ppm for all indoor and outdoor locations monitored and were below the ASHRAE concentration of concern (9 ppm).

Indoor concentrations of VOCs measured on August 24, 2017 ranged from 321 to 4,066 ppb, and the outdoor measurement was 0 ppb. The concentrations in the Classroom A125 (4,066 ppb) and 4<sup>th</sup> Grade Classroom pod center (1,040 ppb) are higher than what would be considered normal building background and are most likely a result of the new carpet tile adhesive used in both areas recently. The other measurements are considered low and do not indicate any obvious

Indoor Air Quality Assessments during Renovations at Waverly Elementary School  
August 24 and September 2, 15 & 22, 2017

source of VOCs above a normal building background level. Results of IAQ and VOC monitoring on August 24, 2017 are presented in Table 6.

**Table 6 – Results of Indoor Air Quality (IAQ) Measurements  
at Waverly Elementary School on August 24, 2017**

Location	Time	Temperature (°F)	Relative Humidity (Rh%)	Carbon Monoxide (CO)	Carbon Dioxide (CO <sub>2</sub> )	Volatile Organic Compounds (VOCs)
Classroom 205 2 <sup>nd</sup> Floor	11:40 AM	74.7	49.2	0.0	308	321
Classroom 209 2 <sup>nd</sup> Floor	11:43 AM	72.5	<b>61.9</b>	0.1	386	591
Classroom A125	12:10 PM	77.9	44.3	0.9	352	<b>4,066</b>
Lobby	12:15 PM	74.6	57.5	0.0	294	384
5 <sup>th</sup> Grade Pod 631 Classroom 4	12:21 PM	75.4	53.5	0.0	393	670
Media Center (new furniture and cabinets)	12:26 PM	76.7	56.6	0.0	387	787
4 <sup>th</sup> Grade Pod (620s) Center	12:31 PM	77.6	51.4	0.0	442	<b>1,040</b>
Classroom C115	12:35 PM	75.7	55.8	0.0	345	532
Classroom B136	12:39 PM	74.2	57.1	0.0	364	531
Workroom C125	12:43 PM	73.3	57.1	0.0	308	419
Outside	12:48 PM	75.1	49.2	0.0	243	0

Bold-faced indicates results outside of recommended comfort ranges or target concentrations.

**Discussion of IAQ and VOC Measurements for September 2, 2017**

The indoor temperatures for September 2, 2017 ranged from 70.3°F to 73.5°F. Measurements in classrooms and occupied areas of the school were below the recommended summer comfort ranges. Outdoor temperatures were lower than usual for the summer and may have contributed to lower indoor temperatures. Indoor relative humidity measurements were all between 56.2% and 62.2%, with some measurements slightly above the recommended range of 30 to 60%.

Carbon dioxide concentrations ranged from 243 to 374 ppm within indoor occupied areas. The concentration of concern for carbon dioxide is set by ASHRAE standard 62.1 as 700 ppm above outdoor air. On the day of monitoring, the outdoor air concentration of carbon dioxide was 263 ppm; therefore, concentrations were within the comfort parameters in all areas monitored. Measurements were made on a Saturday when the building was mostly unoccupied.

Carbon monoxide is mainly attributed to incomplete combustion. Concentrations of CO ranged from 0.0 ppm to 0.8 ppm for all indoor and outdoor locations monitored and were below the ASHRAE concentration of concern (9 ppm).

Indoor concentrations of VOCs measured on September 2, 2017 ranged from 225 to 1,200 ppb, and the outdoor measurement was 0 ppb. The concentrations in the Gym (1,200 ppb) were higher than what would be considered normal building background and are most likely a result of the newly varnished wooden floor. The other measurements are considered low (<1,000 ppb) but variations in concentrations indicate sources of VOCs above a normal building background level

Indoor Air Quality Assessments during Renovations at Waverly Elementary School  
August 24 and September 2, 15 & 22, 2017

that are most likely related to new building materials, new furniture and school supplies. Results of IAQ and VOC monitoring on September 2, 2017 are presented in Table 7.

**Table 7 – Results of Indoor Air Quality (IAQ) Measurements  
at Waverly Elementary School on September 2, 2017**

Location	Time	Temperature (°F)	Relative Humidity (Rh%)	Carbon Monoxide (CO)	Carbon Dioxide (CO <sub>2</sub> )	Volatile Organic Compounds (VOCs)
Media Center	9:53 AM	73.5	56.2	0.0	276	615
Pod 630 Common Area	10:34 AM	<b>71.1</b>	57.0	0.0	245	251
Front Lobby	10:36 AM	<b>70.3</b>	<b>60.7</b>	0.0	264	501
Classroom A125	10:39 AM	<b>71.4</b>	<b>62.2</b>	0.0	251	865
Gym	10:42 AM	<b>71.4</b>	58.0	0.0	374	<b>1,200</b>
Hall Near MINC Classrooms	10:44 AM	<b>72.0</b>	<b>61.2</b>	0.0	367	907
4 <sup>th</sup> Grade Pod 620 Commons	10:49 AM	<b>71.6</b>	58.4	0.0	256	275
Classroom C115	10:42 AM	<b>71.9</b>	57.2	0.0	243	270
Classroom C208	10:56 AM	<b>71.7</b>	57.5	0.0	300	225
Hall Near C212	10:59 AM	<b>71.7</b>	58.4	0.0	272	307
Outside	11:02 AM	63.7	65.1	0.8	263	0

Bold-faced indicates results outside of recommended comfort ranges or target concentrations.

**Discussion of IAQ and VOC Measurements for September 15, 2017**

The indoor temperatures for September 15, 2017 ranged from 73.7°F to 81.9°F. Measurements in classrooms and occupied areas of the school were mostly within the recommended summer comfort ranges. Indoor relative humidity measurements ranged from 48.6% to 60.0%, and all but one measurement were below 60%.

Carbon dioxide concentrations ranged from 450 to 1,330 ppm within indoor occupied areas. The concentration of concern for carbon dioxide is set by ASHRAE standard 62.1 as 700 ppm above outdoor air. On the day of monitoring, the outdoor air concentration of carbon dioxide was 337 ppm; therefore, concentrations were within the comfort parameters in all areas monitored except for two locations (Classrooms 622 and 623-2) that were 1,108 ppm and 1,330 ppm, respectively. Each of these classrooms had over 20 students in them. Measurements were made during a normal school day when the building was fully occupied, which could have contributed to elevated carbon dioxide readings.

Carbon monoxide is mainly attributed to incomplete combustion. Concentrations of CO ranged from 0.0 ppm to 0.9 ppm for all indoor and outdoor locations monitored and were below the ASHRAE concentration of concern (9 ppm).

Indoor concentrations of VOCs measured on September 15, 2017 ranged from 11 to 830 ppb, and the outdoor measurement was 0 ppb. The measurements are considered low (<1,000 ppb) but variations in concentrations indicate sources of VOCs above a normal building background level that are most likely related to new building materials, new furniture and school supplies. Results of IAQ and VOC monitoring on September 15, 2017 are presented in Table 8.



Indoor Air Quality Assessments during Renovations at Waverly Elementary School  
August 24 and September 2, 15 & 22, 2017

**Table 8 – Results of Indoor Air Quality (IAQ) Measurements  
at Waverly Elementary School on September 15, 2017**

Location	Time	Temperature (°F)	Relative Humidity (Rh%)	Carbon Monoxide (CO)	Carbon Dioxide (CO <sub>2</sub> )	Volatile Organic Compounds (VOCs)
Outside	3:16 PM	86.3	45.8	0.0	337	0
Front lobby	3:22 PM	78.0	48.6	0.9	450	11
First Hall Near 304	3:31 PM	73.8	54.5	0.0	572	203
Hall Near A132	3:33 PM	73.7	54.1	0.3	611	539
Media Center (1 Person)	3:38 PM	75.2	58.8	0.3	692	830
Pod 620 Common Area (Students Everywhere)	3:41 PM	76.8	<b>60.0</b>	0.0	841	509
Classroom 622 – 2 Temp AC (20+ Students)	3:43 PM	77.3	52.1	0.7	<b>1,108</b>	556
Classroom 623-2 Temp AC (20+ Students)	3:46 PM	<b>81.1</b>	55.6	0.3	<b>1,330</b>	596
Classroom 623-1-Temp AC	3:49 PM	<b>81.9</b>	49.9	0.8	981	580
Hall @ Containment Near C127	3:52 PM	77.2	58.7	0.9	625	528
Center of 5 <sup>th</sup> Grade Pod (No Students)	3:55 PM	75.7	57.5	0.1	536	358

Bold-faced indicates results outside of recommended comfort ranges or target concentrations.

**Discussion of IAQ and VOC Measurements for September 22, 2017**

The indoor temperatures for September 22, 2017 ranged from 69.5°F to 76.4°F. Measurements in classrooms and occupied areas of the school were mostly within the recommended summer comfort ranges with some exceptions where the temperatures were lower. The teacher in Classroom C208 was complaining about how cool it felt in her room, and she was wearing a fleece jacket. Indoor relative humidity measurements were between 53.4% and 75.8% and were mostly above the recommended maximum of 60%. Outdoor temperature and relative humidity were 78.0° F and 66.2%. Indoor conditions were similar to outdoor conditions in most areas. The construction managers are going to look into the outdoor air settings, and the building heating and cooling systems will be tested and balanced in the near future.

Carbon dioxide concentrations ranged from 300 to 586 ppm within indoor occupied areas. The concentration of concern for carbon dioxide is set by ASHRAE standard 62.1 as 700 ppm above outdoor air. On the day of monitoring, the outdoor air concentration of carbon dioxide was 257 ppm; therefore, concentrations were within the comfort parameters in all areas monitored. Measurements were made during a day when the building was occupied by teachers, staff and construction workers only.

Carbon monoxide is mainly attributed to incomplete combustion. Concentrations of CO ranged from 0.0 ppm to 0.3 ppm for all indoor and outdoor locations monitored and were below the ASHRAE concentration of concern (9 ppm).

Indoor concentrations of VOCs measured on September 22, 2017 ranged from 36 to 1,547 ppb, and the outdoor measurement was 0 ppb. The measurement in the Conference Room 303 in the Main Office area was influenced by the use of a permanent marker at the time of the



Indoor Air Quality Assessments during Renovations at Waverly Elementary School  
August 24 and September 2, 15 & 22, 2017

measurement. The other measurements are considered low (<1,000 ppb) but variations in concentrations indicate sources of VOCs above a normal building background level that are most likely related to new building materials, new furniture and school supplies. Results of IAQ and VOC monitoring on September 22, 2017 are presented in Table 9.

**Table 9 – Results of Indoor Air Quality (IAQ) Measurements  
at Waverly Elementary School on September 22, 2017**

Location	Time	Temperature (°F)	Relative Humidity (Rh%)	Carbon Monoxide (CO)	Carbon Dioxide (CO <sub>2</sub> )	Volatile Organic Compounds (VOCs)
Front Lobby	10:33 AM	76.4	53.4	0.1	418	0
1 <sup>st</sup> Containment area in first hallway	10:35 AM	75.1	58.7	0.1	513	145
Classroom A127	10:42 AM	<b>71.4</b>	<b>72.9</b>	0.3	427	810
Classroom A123	10:47 AM	<b>70.8</b>	<b>70.3</b>	0.0	428	795
Center Hallway in MINC Area	10:50 AM	<b>71.6</b>	<b>72.0</b>	0.0	507	720
Gym	10:52 AM	73.9	<b>74.5</b>	0.0	300	36
5 <sup>th</sup> Grade Center of Pod (630's)	11:06 AM	75.8	<b>73.3</b>	0.0	343	875
620 Classroom Area Center of Pod	11:09 AM	76.4	<b>60.0</b>	0.0	380	380
Media Center	11:17 AM	75.6	<b>63.4</b>	0.0	426	308
Conference Room 303	11:33 AM	<b>70.8</b>	<b>61.9</b>	0.0	586	<b>1,547</b>
Classroom C115	12:38 PM	75.0	<b>68.0</b>	0.0	358	133
Hallway near Elevator on 1 <sup>st</sup> Floor of New Edition	12:40 PM	74.6	<b>65.0</b>	0.0	330	134
Hallway in Center of 2 <sup>nd</sup> Floor of New Edition	12:43 PM	74.1	<b>65.0</b>	0.0	518	174
Classroom C203	12:46 PM	72.9	<b>66.5</b>	0.0	406	98
Classroom C208	12:57 PM	<b>69.5</b>	<b>64.1</b>	0.0	373	113
Hallway at Containment (plastic doors) in back of School near Rm C127	1:05 PM	<b>72.4</b>	<b>75.8</b>	0.0	532	255
Outside	1:09 PM	78.0	66.2	0.0	257	0

Bold-faced indicates results outside of recommended comfort ranges or target concentrations.

**Conclusions and Recommendations**

Based upon our observations and sampling results on August 24, 2017, September 2, 2017, September 15, 2017 and September 22, 2017 at Waverly Elementary School, additional measures are necessary to prevent construction dust and odors from entering the occupied areas of the school. Although the particle and VOC measurements were above the recommended concentrations in some areas, the school is fully occupied. Elevated concentrations are expected and are not entirely due to construction activities. The tiled floors were being kept clean of visible dust. The carpet in the Media Center showed boot prints and construction dust near the construction entrance on September 22, 2017. The doors to occupied areas from construction zones should not be used when faculty and staff are present even on a day when students are

Indoor Air Quality Assessments during Renovations at Waverly Elementary School  
August 24 and September 2, 15 & 22, 2017

not present. Any areas of construction egress should have sticky mats and air locks made of poly-sheeting, if possible, for control of dust.

Temperature and relative humidity measurements were shared with the construction management team and the outdoor air settings are going to be investigated and optimized. The building systems will also be tested and balanced as part of the construction project.

AE will continue to make weekly visits to Waverly Elementary School as requested. Thank you for choosing Aria Environmental, Inc. for your industrial hygiene consulting needs. Should you have any questions about the information contained herein, please do not hesitate to contact us at 410-549-5774.

Sincerely,  
Aria Environmental, Inc.

A handwritten signature in cursive script that reads "Julie Barth".

Julie Barth, CIH, CSP, LEED Green Associate