Aria Environmental, Inc.
INDUSTRIAL HYGIENE & SAFETY CONSULTANTS

November 3, 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 (September 28, October 5, 18, and 27, 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 September 28 and October 5, 18 & 27, 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_2)) 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 (PM10) and "fine particles," with diameters that are 2.5 micrometers and smaller (PM2.5). 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 PM2.5 and PM10 of 15 $\mu g/m^3$ and 50 $\mu g/m^3$, 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 (PM1, PM 2.5, PM 7, PM10 and total suspended particles (TSP)). Results of particulate monitoring are presented in Tables 1, 2 and 3.

Discussion of Particle Results for September 28, 2017

The PM2.5 particle concentrations ranged from 0 to 21 µg/m³ and PM10 particle concentrations ranged from 6 to 308 µg/m³ in the hallways outside the construction zones. The school was occupied as usual for a normal school day. PM 2.5 concentrations were above the target concentration in three areas and PM 10 concentrations were above the target concentrations in six locations near the construction zones as well as in the non-construction zones with staff and student activity. Results of particulate monitoring are presented in Table 1.

Table 1 – Results of Particulate Monitoring Waverly Elementary School on September 28, 2017

Location	Time	PM1 (µg/m³)	PM2.5 (µg/m³)	PM7 (µg/m³)	PM10 (µg/m³)	TSP (µg/m³)
Front Lobby	11:34 AM	0	3	17	23	42
1st Containment	11:38 AM	1	8	44	**57**	78
Hall in MINC area	11:41 AM	1	6	21	31	65
2nd Containment	11:44 AM	1	5	31	42	70
Gym (25 or more students)	11:46 AM	0	2	21	33	77
Pod Center (630s)	11:50 AM	1	6	31	43	65
Media Center at doors to construction	11:53 AM	1	**15**	97	**160**	257
Media Center at doors to construction	11:55 AM	0	**21**	225	**308**	461
Media Center near opposite doors	11:59 AM	1	10	76	**116**	180
Pod Center (620s)	12:01 PM	0	10	107	**157**	223
2nd Floor Addition Center	12:02 PM	0	1	10	14	28
Classroom C208 (no students)	12:04 PM	0	0	7	10	15
Classroom C203 (no students)	12:07 PM	0	0	7	11	16
1st Floor Addition Center	12:10 PM	0	0	4	6	11
Back Containment	12:13 PM	5	**21**	184	**305**	494
Outside	12:15 PM	0	1	12	14	20

Bold-faced results indicate results above target concentrations.

Discussion of Particle Results for October 5, 2017

The PM2.5 particle concentrations ranged from 0 to 14 µg/m³ and PM10 particle concentrations ranged from 6 to 71 µg/m³. PM 2.5 concentrations were below the target concentration in all areas monitored. PM 10 particle concentrations were above the target concentration in two locations with student activity. The building was occupied as usual for a normal school day. Results of particulate monitoring are presented in Table 2.

Table 2 – Results of Particulate Monitoring Waverly Elementary School on October 5, 2017

Location	Time	PM1 (µg/m³)	PM2.5 (µg/m³)	PM7 (µg/m³)	PM10 (µg/m³)	TSP (µg/m³)
Lobby	2:43 PM	0	2	12	15	24
1st Containment	2:47 PM	1	5	27	33	41

Location	Time	PM1 (µg/m³)	PM2.5 (µg/m³)	PM7 (µg/m³)	PM10 (µg/m³)	TSP (µg/m³)
MINC Hallway	2:49 PM	1	5	22	2	48
New Containment in center of Hallway	2:52 PM	0	4	17	22	32
Gym (60+ students)	2:55 PM	4	14	58	**71**	133
Pod Center (630s) (Full classes in all classrooms)	2:58 PM	1	11	57	**69**	91
Media Center	3:00 PM	0	2	12	15	20
Pod Center (620)	3:02 PM	0	3	17	27	47
1st Floor Addition Center	3:04 PM	0	0	6	11	39
2nd Floor Addition Center	3:07 PM	0	0	5	6	16
Classroom C208	3:11 PM	0	0	6	7	14
Classroom C203	3:14 PM	0	0	6	11	37
Back Containment	3:20 PM	0	2	10	18	63
Outside	3:23 PM	0	1	10	14	21

Bold-faced results indicate result0s above target concentrations

Discussion of Particle Results for October 18, 2017

The PM2.5 particle concentrations ranged from 0 to 28 µg/m³ and PM10 particle concentrations ranged from 5 to 135 µg/m³. PM 2.5 concentrations were above the target concentration in three areas, and PM 10 particle concentrations were above the target concentrations in the same three areas in non-construction zones with student activity and in two areas near construction containment walls/doors. Construction work on the roof could be heard and may have been affecting dust concentrations in these areas by vibration. The building was occupied as usual for a normal school day. Results of particulate monitoring are presented in Table 3.

Table 3 – Results of Particulate Monitoring Waverly Elementary School on October 18, 2017

Location	Time	PM1 (µg/m³)	PM2.5 (µg/m³)	PM7 (µg/m³)	PM10 (µg/m³)	TSP (µg/m³)
Lobby	11:27 AM	0	4	25	32	56
1st Containment	11:30 AM	0	4	41	**52**	84
MINC Hallway	11:32 AM	0	1	7	11	23
New Containment in center of Hallway	11:35 AM	0	2	21	31	53
Gym (60+ students)	11:37 AM	0	4	30	41	76
Pod Center (630s) (Full classes in all classrooms)	11:43 AM	3	**28**	114	**135**	158
Media Center	11:46 AM	2	**16**	55	**64**	79
Pod Center (620)	11:49 AM	3	**23**	90	**120**	192
2nd Floor Addition Center	11:52 AM	0	2	14	21	34
Classroom C208	11:55 AM	0	0	4	7	17
Classroom C203	11:58 AM	0	0	3	5	9

Location	Time	PM1 (µg/m³)	PM2.5 (µg/m³)	PM7 (µg/m³)	PM10 (µg/m³)	TSP (µg/m³)
1st Floor Addition Center	12:01 PM	0	1	2	5	11
Back Containment	12:04 PM	0	5	45	**59**	85
Outside	12:08 PM	0	1	3	7	21

Bold-faced results indicate results above target concentrations

Discussion of Particle Results for October 27, 2017

The PM2.5 particle concentrations ranged from 0 to 4 µg/m³ and PM10 particle concentrations ranged from 4 to 37 µg/m³ in the areas monitored. PM 2.5 and PM 10 particle concentrations were below the target concentrations in all locations monitored. Measurements were collected at the end of a normal school day. Results of particulate monitoring are presented in Table 4.

Table 4 – Results of Particulate Monitoring Waverly Elementary School on October 27, 2017

Location	Time	PM1 (µg/m³)	PM2.5 (µg/m³)	PM7 (µg/m³)	PM10 (µg/m³)	TSP (µg/m³)
Front Lobby	4:04 PM	0	1	10	15	48
1st Containment area in first hallway	4:06 PM	0	2	25	37	82
Center Hallway in MINC Area	4:09 PM	0	0	5	13	37
Classroom A125 (no students)	4:12 PM	0	0	2	4	10
Small Containment Door in Hallway	4:14 PM	0	2	14	21	46
5th Grade Center of Pod (630's)	4:16 PM	0	4	25	33	44
Media Center	4:19 PM	0	1	6	10	19
620 Classroom Area Center of Pod	4:26 PM	0	2	14	18	32
2nd Floor Addition Center	4:29 PM	0	1	8	10	13
1st Floor Addition Center	4:31 PM	0	0	3	4	6
Hallway at Containment (plastic doors) in back of School near Rm C127	4:33 PM	0	0	8	8	74
Outside	4:36 PM	0	1	6	9	15

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 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[a]

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

[a]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 September 28, 2017

The indoor temperatures for September 28, 2017 ranged from 69.6°F to 77.8°F. Temperature measurements in classrooms and occupied areas of the school were within the recommended comfort ranges. Indoor relative humidity measurements were all between 50.7% and 64.3% which are mostly within the recommended range of 30 to 60%.

Carbon dioxide concentrations ranged from 380 to 883 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 258 ppm; therefore, concentrations were within the below the target concentration in all areas monitored. Measurements were made during a normal school day. Carbon monoxide is mainly attributed to incomplete combustion. Indoor concentrations of CO ranged from 0.0 ppm to 6.5 ppm and the outdoor concentration was 0.0 ppm. All measurements were below the ASHRAE concentration of concern (9 ppm).

Indoor concentrations of VOCs measured on September 28, 2017 ranged from 0 to 250 ppb, and the outdoor measurement was 0 ppb. The measurements are considered low and do not indicate any obvious source of VOCs above a normal building background level. Results of IAQ and VOC monitoring are presented in Table 6.

Table 6 – Results of Indoor Air Quality (IAQ) Measurements at Waverly Elementary School on September 28, 2017

Location	Time	Temperature (°F)	Relative Humidity (Rh%)	Carbon Monoxide (CO)	Carbon Dioxide (CO_2)	Volatile Organic Compounds (VOCs)
Front Lobby	11:34 AM	77.8	50.7	4.5	545	140
1st Containment	11:38 AM	75.3	51.2	5.2	584	85
Hall in MINC area	11:41 AM	73.9	54.2	4.6	883	250
2nd Containment	11:44 AM	73.6	56.0	4.0	790	219
Gym (25 or more students)	11:46 AM	75.2	57.2	1.7	600	28
Pod Center (630s)	11:50 AM	75.0	**64.3**	6.5	654	0
Media Center at doors to construction	11:53 AM	75.8	**60.9**	3.6	520	64
Media Center at doors to construction	11:55 AM	76.8	**61.1**	2.7	768	49
Media Center near opposite doors	11:59 AM	76.1	57.9	2.7	575	83
Pod Center (620s)	12:01 PM	75.4	56.5	2.0	480	0
2nd Floor Addition Center	12:02 PM	74.5	56.2	0.7	490	0
Classroom C208 (no students)	12:04 PM	70.6	57.1	0.0	440	0
Classroom C203 (no students)	12:07 PM	69.6	**62.5**	0.0	463	0
1st Floor Addition Center	12:10 PM	71.7	**64.0**	0.0	408	0
Back Containment	12:13 PM	73.6	58.2	0.0	380	0
Outside	12:15 PM	76.6	42.3	0.2	258	0

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

Discussion of IAQ and VOC Measurements for October 5, 2017

The indoor temperatures for October 5, 2017 ranged from 72.7°F to 80.1°F. Measurements in classrooms and occupied areas of the school were below the recommended comfort ranges. Indoor relative humidity measurements were all between 44.5% and 61.3% with some measurements slightly above the recommended range of 30 to 60%.

Carbon dioxide concentrations ranged from 510 to 1,065 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 249 ppm; therefore, concentrations were within the comfort parameters in all areas monitored except for the measurement collected in the MINC Area hallway (1,065 ppm). Measurements were made on a normal school day. 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 October 5, 2017 ranged from 0 to 593 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 are presented in Table 7.

Table 7 – Results of Indoor Air Quality (IAQ) Measurements at Waverly Elementary School on October 5, 2017

Location	Time	Temperature (°F)	Relative Humidity (Rh%)	Carbon Monoxide (CO)	Carbon Dioxide (CO_2)	Volatile Organic Compounds (VOCs)
Lobby	2:43 PM	80.1	44.5	0.8	519	428
1st Containment	2:47 PM	76.5	46.8	0.1	618	545
MINC Hallway	2:49 PM	75.0	54.0	0.0	**1,065**	427
New Containment in center of Hallway	2:52 PM	74.0	51.8	0.0	675	493
Gym (60+ students)	2:55 PM	74.4	58.5	0.0	960	593
Pod Center (630s) (Full classes in all classrooms)	2:58 PM	76.1	56.6	0.0	625	484
Media Center	3:00 PM	76.0	53.5	0.0	706	408
Pod Center (620)	3:02 PM	75.8	52.9	0.0	550	201
1st Floor Addition Center	3:04 PM	74.3	55.7	0.0	561	0
2nd Floor Addition Center	3:07 PM	72.9	57.9	0.0	510	0
Classroom C208	3:11 PM	72.7	**60.4**	0.0	672	0
Classroom C203	3:14 PM	73.4	**61.3**	0.0	730	0
Back Containment	3:20 PM	72.9	59.1	0.0	555	30
Outside	3:23 PM	80.7	50.6	0.0	249	0

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

Discussion of IAQ and VOC Measurements for October 18, 2017

The indoor temperatures for October 18, 2017 ranged from 68.6°F to 72.8°F. Temperature measurements in classrooms and occupied areas of the school were mostly within the recommended comfort ranges. Indoor relative humidity measurements ranged from 40.2% to 46.7%, and all measurements were below 60%.

Carbon dioxide concentrations ranged from 466 to 745 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 284 ppm; therefore, concentrations were within the comfort parameters in all areas monitored. Measurements were made during a normal school day when the building was fully occupied. Carbon monoxide is mainly attributed to incomplete combustion. Concentrations of CO ranged from 0.0 ppm to 1.5 ppm for all indoor and outdoor locations monitored and were below the ASHRAE concentration of concern (9 ppm).

Indoor concentrations of VOCs measured on October 18, 2017 ranged from 0to 320 ppb, and the outdoor measurement was 0 ppb. The measurements are considered low (<1,000 ppb) but variations in concentrations indicate sources of VOCs that are most likely related to new building materials, new furniture and school supplies. Paint odors were observed throughout the building on this day. Results of IAQ and VOC monitoring are presented in Table 8.

Table 8 – Results of Indoor Air Quality (IAQ) Measurements at Waverly Elementary School on October 18, 2017

Location	Time	Temperature (°F)	Relative Humidity (Rh%)	Carbon Monoxide (CO)	Carbon Dioxide (CO_2)	Volatile Organic Compounds (VOCs)
Lobby	11:27 AM	71.6	40.2	0.9	466	270
1st Containment	11:30 AM	71.6	41.3	1.5	558	141
MINC Hallway	11:32 AM	71.2	45.3	1.3	671	61
New Containment in center of Hallway	11:35 AM	70.8	42.1	0.8	511	195
Gym (60+ students)	11:37 AM	68.6	44.3	0.9	697	161
Pod Center (630s) (Full classes in all classrooms)	11:43 AM	70.4	46.2	0.0	714	306
Media Center	11:46 AM	72.6	45.0	0.0	745	269
Pod Center (620)	11:49 AM	72.8	42.3	0.0	702	320
2nd Floor Addition Center	11:52 AM	71.3	40.5	0.0	549	0
Classroom C208	11:55 AM	70.0	425	0.0	705	0
Classroom C203	11:58 AM	71.0	43.1	0.0	737	0
1st Floor Addition Center	12:01 PM	70.1	40.4	0.0	507	0
Back Containment	12:04 PM	69.9	46.7	0.0	662	20-50
Outside	12:08 PM	68.1	38.6	0.1	284	0

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

Discussion of IAQ and VOC Measurements for October 27, 2017

The indoor temperatures for October 27, 2017 ranged from 70.1°F to 76.1°F. Temperature measurements in classrooms and occupied areas of the school were within the recommended comfort ranges. Indoor relative humidity measurements ranged from 35.6% to 47.9% and were below the recommended maximum of 60%. Outdoor temperature and relative humidity were 69.2° F and 38.6%.

Carbon dioxide concentrations ranged from 413 to 913 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 310 ppm; therefore, concentrations were within the comfort parameters in all areas monitored. Measurements were made at the end of a normal school day. Carbon monoxide is mainly attributed to incomplete combustion. Concentrations of CO ranged from 0.0 ppm to 0.6 ppm for all indoor and outdoor locations monitored and were below the ASHRAE concentration of concern (9 ppm).

Indoor concentrations of VOCs measured on October 27, 2017 ranged from 0 to 232 ppb, and the outdoor measurement was 0 ppb. The measurements are considered low (<1,000 ppb) but variations in concentrations indicate sources of VOCs that are most likely related to new building materials, new furniture and school supplies. Faculty reported observing glue and vehicle exhaust odors in the Team 5 pod. These odors were not observed by the industrial hygienist during the monitoring session. Results of IAQ and VOC monitoring are presented in Table 9.

Table 9 – Results of Indoor Air Quality (IAQ) Measurements at Waverly Elementary School on October 27, 2017

Location	Time	Temperature (°F)	Relative Humidity (Rh%)	Carbon Monoxide (CO)	Carbon Dioxide (CO_2)	Volatile Organic Compounds (VOCs)
Front Lobby	4:04 PM	72.9	36.5	0.6	436	0
1st Containment area in first hallway	4:06 PM	72.4	39.1	0.1	560	0
Center Hallway in MINC Area	4:09 PM	71.8	46.8	0.3	913	106
Classroom A125 (no students)	4:12 PM	70.3	47.9	0.1	775	118
Small Containment Door in Hallway	4:14 PM	70.1	42.3	0.0	538	68
5th Grade Center of Pod (630's)	4:16 PM	75.1	37.9	0.0	474	157
Media Center	4:19 PM	76.1	38.6	0.0	885	155
620 Classroom Area Center of Pod	4:26 PM	75.0	35.6	0.0	524	50
2nd Floor Addition Center	4:29 PM	72.4	36.8	0.0	488	0
1st Floor Addition Center	4:31 PM	71.1	37.5	0.0	413	0
Hallway at Containment (plastic doors) in back of School near Rm C127	4:33 PM	71.2	40.2	0.0	498	232
Outside	4:36 PM	69.2	38.6	0.0	310	0

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

Conclusions and Recommendations

Based upon our observations and sampling results on September 28 and October 5, 18 & 27, 2017 at Waverly Elementary School, measures are being taken to prevent construction dust and odors from entering the occupied areas of the school. Only a few measurements were above the recommended concentrations in a few areas during these 4 school visits. 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. Fluctuations of dust and VOC concentrations are influenced by the types of construction activities occurring and also by student and staff activities and are expected to vary over time.

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.

Julie Barth

Julie Barth, CIH, CSP, LEED Green Associate