Indoor Air Quality Assessment

Riverside Elementary School,

Shoal Harbour NL

Prepared for

NLESD

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Introduction

On November 2 and 17, 2016, the undersigned conducted an indoor air quality assessment at Riverside Elementary, Shoal Harbour, at the request of NLESD, as a result of indoor air quality concerns from the school community. The assessment consisted of:

- Measuring room temperature, relative humidity and carbon dioxide levels
- Measuring total volatile organic compound (TVOCs) levels
- Conducting a visual assessment for potential mould

This is a Kindergarten to Grade 6 school. The formal school day runs from approximately 8:35 am to 2:40 pm. Upon arrival at the school both days, I met with the Principal. He mentioned the main concerns dealt with general indoor air quality related issues.

Building Description

The school building was constructed in 1985 with major expansions in 1989,1991, and 2011. The building is a two-storey, steel frame and concrete block structure with a concrete slab-on-grade foundation.

The exterior walls consist of brick veneer and metal siding. The interior walls are constructed primarily of concrete block with some gyproc/drywall. Ceiling and ceiling finishes consist mainly of 2’ x 4’ acoustic lay-in tile, corrugated steel and some drywall. Floor finishes consist of 1’ x 1’ vinyl tile, vinyl sheet flooring, poured concrete, ceramic tile and rubber stair treads.

Interior lighting consists of fluorescent, incandescent and emergency backup lights. The school building is heated by electricity and hot water radiation provided through wall-mounted heaters.

Why Measure Carbon Dioxide?

Teachers, support staff and students spend up to 8 hours of their day at school. Therefore, maintaining adequate indoor air quality (IAQ) in their building is a top priority of NLESD and the Department of Education and Early Childhood Development. To maintain adequate indoor air quality it is important to provide outside air to dilute potential indoor air pollutants including odors and exhaust these contaminants along with moisture and odors.

Carbon dioxide (CO_2) is a natural component of the air outside. The amount of CO_2 in a given air sample is commonly expressed as parts-per-million (ppm)—the number of molecules of carbon dioxide per million molecules of air. The outdoor air in most locations contains about 400 ppm carbon dioxide. Higher outdoor CO_2 concentrations can be found near vehicle traffic areas, industry, and sources of combustion.

Carbon dioxide is a relatively simple air component to measure and since the outside concentration is relatively stable it is often used as an "indicator" of the adequacy of air delivery to a space. Since building occupants generate high levels of carbon dioxide in their breath (approximately 100 times higher than outdoor levels), the goal of ventilation is to maintain CO_2 levels in buildings at or below the recommended ASHRAE (American Society of Heating Refrigerating and Air-Conditioning Engineers) levels. ASHRAE's Technical "Frequently Asked Question" Document ID 35 states:

"CO_2 at very high concentrations (e.g. greater than 5000 ppm) can pose a health risk. … CO_2 at the concentrations commonly found in buildings is not a direct health risk, but CO_2 concentrations can be used as an indicator of occupant odors and occupant acceptance of these odors. At the activity levels found in typical office buildings, steady state CO_2 concentrations of about 700 ppm above outdoor air levels indicate an outdoor ventilation rate of about 15 cfm/person. Lab and field studies have shown that this rate of ventilation will dilute odors from human bioeffluents to levels that will satisfy a substantial majority of visitors in a space. … Thus indoor CO_2 concentrations of 1000 to 1200 ppm in spaces housing sedentary people is an indicator that a substantial majority of visitors entering the space will be satisfied with respect to human bioeffluents (body odor)".

Where indoor concentrations are elevated (compared to the outside air) the source is usually the building's occupants, as is the case in schools. People exhale carbon dioxide—the average adult's breath contains about 35,000 to 50,000 ppm of CO_2 (Richard Steane[1]). Without adequate ventilation to dilute and remove the CO_2 continuously generated by the occupants, along with body odors and other potential contaminants, CO_2 can accumulate in the classroom. Elevated CO_2 levels suggest inadequate make-up air within a building.

Regulatory Carbon Dioxide (CO_2) Levels

The American Conference of governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs), are the airborne permissible limits for NL workplaces, as regulated by the Occupational Health and Safety Branch, Service NL. The ACGIH have set an airborne limit of 5000 ppm for carbon dioxide. However it is not considered for air quality purposes to be an appropriate standard for assessing the adequacy of fresh air in classrooms. The Environmental Health Inspectorate, a branch of Service NL, has not established a specific limit for carbon dioxide in schools.

In the absence of relevant NL regulatory standards for schools, there are a number of guidelines used elsewhere that will be briefly discussed here.

1. Experiments to compare CO_2 Content of Inhaled and Exhaled air, http://www.biotopics.co.uk/humans/inhaledexhaled.html

Health Canada has established a CO_2 residential level of 3500 ppm based on biochemical changes that are detectable at the cellular level in the human body at a level of 7000 ppm (safety factor of

2). This standard is not particularly relevant to schools given the higher occupancy rates as compared to homes.

ASHRAE Standard 62, a guideline established by the American Society of Heating, Refrigerating, and air-conditioning Engineers, used by building designers, recommends maintaining carbon dioxide levels within 700 ppm above outdoor levels. If the ventilation rate is held at about 15 cfm per person, it is believed that the resulting steady-state CO_2 concentration mentioned above (approximately 1100 ppm) will be deemed acceptable to the majority of visitors entering that space from a body odour perspective and overall occupant comfort.

However, ASHRAE, section 1.3, states it has not written the standard for the regulation of existing buildings although the principles are the same. Section 1.2 and 2.4 acknowledges some of the new standard requirements may be unreasonable for existing buildings.

In the United Kingdom, schools are held to an 8 hour time weighted level of 1500 ppm for carbon dioxide. The UK's Building Bulletin 101, DfES (2006), uses carbon dioxide as an IAQ indicator for schools and goes on to prescribe a maximum concentration of 5000 ppm and a mean occupied concentration of 1500 ppm.

What about other indoor pollutants?

Clearly, elevated indoor CO_2 levels suggest inadequate outside ventilation air, and it follows that inadequate ventilation permits other potentially harmful air pollutants (i.e. volatile organic compounds, flu viruses, mold spores) to build up and potentially create health, productivity and performance, and comfort problems. Maintaining relatively low $C0_2$ levels should also assist in minimizing other potential contaminants that may be in the air.

Findings:

1. **Carbon Dioxide Instantaneous Readings Obtained During Walk-Through on November 2 and 17,2016**

Carbon dioxide readings were taken using a calibrated Gas AlertMicro 5 IR Gas Detector provided by EnviroMed Analytic Detection Services, and a calibrated Fluke 975 Airmeter. On both days, prior to measuring inside the school, outdoor readings were taken outdoors for comparison purposes. The reading for both days was 400 ppm CO_2.

A summary of all instantaneous carbon dioxide readings taken on November 2 and 17, 2016, is as follows:

Average CO_2 Level of all instantaneous readings on Day 1	1500 ppm
Average CO_2 Level of all instantaneous readings on Day 2	1190 ppm
Combined Average CO_2 Level of all instantaneous readings over both days	1330 ppm
Average CO_2 Level of all instantaneous readings from both days for rooms with mechanical ventilation	1140 ppm
Average CO_2 Level of all instantaneous readings from both days for rooms without mechanical ventilation	1500 ppm
Average CO_2 Level of all instantaneous readings from both days for rooms with mechanical ventilation & at least 1 open or partially open window	890 ppm
Average CO_2 Level of all instantaneous readings from both days for rooms with **no** mechanical ventilation & at least 1 open or partially open window	1440 ppm
Average CO_2 Level of all instantaneous readings from both days for rooms with mechanical ventilation & windows closed	1150 ppm
Average CO_2 Level of all instantaneous readings from both days for rooms with **no** mechanical ventilation & windows closed (excludes door status)	**1650** ppm
Average CO_2 Level of all instantaneous readings from both days for rooms with **no** mechanical ventilation & at least 1 open or partially open window, and door open	1380 ppm
Average CO_2 Level of all instantaneous readings from both days for rooms with **no** mechanical ventilation & at least 1 open or partially open window, and door closed	**2010** ppm
Average CO_2 Level of all instantaneous readings from both days for rooms with **no** mechanical ventilation & windows and door closed	**2780** ppm

The data obtained from the two day assessment is similar to others' findings for schools elsewhere throughout the world. There was a clear decrease in CO_2 levels on day 2 compared to day 1, from 1500 to 1190 ppm on average. This is likely due to the increased airflow rates resulting from opening doors and windows where practicable in accordance with NLESD's Natural Ventilation Policy.

It is also not surprising that mechanically ventilated rooms recorded lower CO_2 levels than naturally ventilated rooms, due to the increased airflow rates in these rooms. The lowest reductions in CO_2 levels, indicated by an average of 890 ppm, was in the category of combined open windows and mechanical ventilation, especially in the case where doors were open. Conversely, the highest average CO_2 reading, 2780 ppm, was found when windows and doors were closed, combined with no mechanical ventilation.

On the second day, there were a couple of particularly high CO_2 levels noted when classes contained multiple groups in the room at one time due to project display exhibitions.

It is evident that the classrooms along the length of the building on both levels, that are unventilated mechanically, have elevated CO_2 at times in relation to the mechanically ventilated areas of the building. Unventilated (mechanically) classrooms above 1500 ppm, at some point during the day include:

- Room 127
- Room 118
- Room 116
- Room 115
- Room 124
- Room 204
- Room 207
- Room 209
- Room 201
- Room 216
- Room 215
- Room 200
- Room 210
- Room 208

2. November 17,2016 Classroom 215

In addition to conducting instantaneous CO2 sampling throughout the building, a classroom was chosen, Room 215, after consultation with school administration, to be representative of worst case conditions as follows:

- lack of mechanical ventilation,
- relatively high student numbers throughout the day compared to other rooms (although within school cap numbers)

It is evident from the data that as the temperature starts to climb the CO_2 levels increase accordingly. This likely indicates that windows are insufficiently open compounded by poor outdoor air movement (i.e. no wind) The minimum, maximum, and average CO_2 value recorded over the sampling period was 1077 ppm, 1716 ppm, and 1332.

An excerpt from the walk through Fluke instantaneous CO2 data, helps to interpret the Gas AlertMicro 5 CO_2 datalogger data. Readings were typically below 1500 ppm when the door and windows were open or partially open, however when both windows were closed after lunch temperature and CO_2 levels increased to their maximum values. When I visited the classroom at 1:35 pm, a reading of 1644 was recorded on the datalogger, when the temperature was 23.6 C, and 27 people were present in the room. At that time, the room felt stuffy, so I asked the teacher if I could open the windows. Within minutes, levels began to drop. The windows in this room were on the leaward side, meaning air was actually going out the window, and make-up air was originating from the hall. The CO_2 levels in the hall were 850 ppm, at that time, so increasing air entry into the classroom via opening windows, increased the rate of hallway infiltration that contained a lower CO_2 level.

Excerpt from CO_2 sampling data:

Location	**Temp (C)** **CO_2 Level**	**# occupants**	**Mechanical Ventilation**	**Door status**	**# windows open**	**# windows closed**
Class 215 9:55 am	21 C **1600 pp**m	27	No	Open	2 Rm occupied since 8:25 am	
Room 215 10:28 am	**1450 ppm**			Open	2	
12:47 pm	**1150 ppm** 21 C	18		Open	1	1
1:35 pm	**1750 ppm** 23 C	26		open	Felt warm & stuffy so opened windows, hallway outside was 850 ppm	2
1:45 pm	**1300 ppm**					

3. VOC Readings

VOCs are a large group of carbon-based chemicals with similar chemical properties that have high vapor pressures at room temperature. Examples include acetone, toluene, hexane, xylene, etc.

Neither NL nor the Federal Government has set standards specifically for TVOC levels in non-industrial settings.

One practical approach for providing indoor air quality guidelines for VOCs has been to use the Total VOC (TVOC) approach as a general indication of the quality of air. This approach is generalized from published toxicological studies performed to determine the health effects elicited by humans exposed to mixtures of VOCs under controlled conditions.

The findings are as follows:

Concentration Range	Exposure Range	Health Effects
< 0.12 ppm	Comfort Range	No irritation or discomfort expected
0.12 to 1.2 ppm	Multifactorial Exposure Range	Odours, irritation and discomfort may appear in the presence of TVOC together with other thermal comfort factors and stressors
1.2 to 10 ppm	Multifactorial Discomfort Range	Further discomfort, complaints may be expected

Source: Health Canada:
"Indoor Air Quality in Office Buildings: A Technical Guide" (2007).

VOCs in schools can be found in: Building materials (Paints, paint strippers, wood preservatives, solvents) , cleaners, home and personal care products (cleansers, disinfectants, cosmetics, air fresheners, gasoline).

VOC readings were taken using a calibrated PhoCheck TIGER Photoionization Detector and MiniRae 3000.

On November 2, 2016, VOC levels ranged from 0 ppm to 0.9 ppm, with an average level throughout of approximately 0.2 ppm.

On November 17, 2016, for the vast majority of the day and throughout most areas there were no detectable levels of VOCs with the following exceptions. These detectable readings seemed to be associated with areas where food was eaten or lack of air movement was evident (i.e. upper rooms)

Room 207	0.1 ppm (during recess, foods eaten in class)
Room 215	0.1 ppm (during/after recess or lunch)
Room 216	0.1 ppm (during/after recess)
Room 243	0.1 ppm (during/after recess)
Room 244	0.1 ppm (during/after recess)
Room 245	0.1 ppm (during/after recess)
Room 246	0.1 ppm (during/after recess)
Cafeteria	0.1 ppm (during lunch)

While permanent markers, hand cleaners, foods and other sources of VOCs are typically used in schools, there is no indication of an accumulation of VOCs in the air provided when the natural ventilation policy is followed (Day 2 of sampling). For example, there was a clear improvement in VOC levels from November 2 to November 17, 2016. It is believed this is associated with the improvement in dilution air afforded on the second day of testing. The second day's average

VOC reading would fit into the no irritation or discomfort range level of less than 0.12 ppm as indicated in the table above.

4. Temperature Readings

Most guidance documents (i.e. Government of Alberta OHS IAQ Bulletin) pertaining to schools and commercial buildings recommend an indoor air temperature of about 22 C for maximum thermal comfort, assuming a relative humidity between 30 and 60 %.

Temperature and relative humidity levels throughout the building fell into this recommended range.

It is possible that relative humidity may be a problem at times depending on seasonal conditions (i.e. too low in winter and too high in spring, summer and early fall). However, during times of low humidity, humidification can be employed to alleviate sinus problems. I was informed that at least one individual using local humidification at the advice of their doctor. I mentioned to the individual to ensure that the device is effectively cleansed as per the manufacturer to prevent microbial growth within the unit.

In terms of ambient temperature throughout the school, the readings ranged from 20 to 24 C, over both days. However, the vast majority of the readings were in the 21-22 degree C range. These readings are in fairly close agreement with ASHRAE's ideal temperature of about 22 C.

Schools are encouraged to follow the natural ventilation policy as it relates to opening windows with the key objective of ventilating to the extent possible while preventing drafts or thermal discomfort. On both days of testing, the ambient temperature was quite favorable, 10 and 14 C, with virtually no wind on both days. As such, it would be expected that classroom windows would be opened to the greatest extent practicable given the unlikely event of drafts. There is no restriction placed on staff to limit heating usage to ensure adequate ventilation in non-ventilated classrooms. On the first day, it was clear that there was very few windows open compared to the second day. This negatively impacted air quality in terms of elevated carbon dioxide and VOC levels throughout the building. There was a marked improvement in these parameters on the second day. However, it is this author's opinion that additional improvements were possible in terms of CO_2 from opening windows more throughout the second day as well.

Observations:

1. Throughout the inspection of the building, no visible mildew/mould was noted in any of the classrooms.
2. The building has a mix of ventilation schemes ranging from natural ventilation only; to mechanical ventilation in halls; to mechanical ventilation in halls and classrooms. On both days, the systems were operational.
3. The school was not following the natural ventilation policy on November 2nd, however, on November 17th, a greater effort was made to comply with the natural ventilation protocol that involves opening windows and doors to the extent possible to maximize air

movement while avoiding drafts. As previously stated, the weather conditions on both days allowed for maximizing window opening due to comfortable temperatures and virtually no wind to create drafts. While the extent of window opening increased on the 2nd day, it could have been enhanced even further by more widespread usage.

4. As a follow-up to item 3, there were a number of rooms on both days, where upon entering, the room felt stuffy and excessively warm, and on rare occasions the smell of "body odor" was detectable. In these cases, without mechanical ventilation, often times doors and windows were closed. As a result, elevated carbon dioxide readings were associated with room occupant respiration of carbon dioxide accumulating without adequate dilution ventilation. In some of these circumstances, I asked if I could open windows, and subsequently monitored the reduction in CO_2 levels as a result. Significant reductions were noticeable within only a few minutes.

5. While the environmental conditions were favorable for opening windows, in terms of a mild outdoor temperature on both days, the lack of wind on both days indicates this assessment is likely to represent worst case conditions. Normally our weather conditions allow for windier conditions that increase ventilation rates throughout the building.

Discussion

Reliance on opening and closing windows to comply with the natural ventilation policy is less than ideal. However, in the absence of mechanical ventilation in classrooms, there will need to be some level of focus on following the natural ventilation policy issued by NLESD to maximize air dilution throughout the building as previously described.

While there are some limitations and challenges associated with natural ventilation, its use can greatly improve classroom air in instances where mechanical ventilation is absent. In order for the natural ventilation protocol to be truly effective throughout the building, opening of doors and windows needs to be building-wide in order to maximize cross-ventilation.

Opening multiple windows by smaller amounts reduce the problems associated with localized drafts. Doors and windows should be open, where practicable, even in classrooms not presently occupied during the day in order to enhance air movement throughout the space and lower overall CO_2 levels in the building. Recall that the halls serve as make up air for classes on the leaward side of the building.

Protocol adherence is more likely to occur as long as windows stay clean, obstruction free and hardware permits easy use (screens in place).

Conclusion

The indoor environment of Riverside Elementary has no apparent health concerns. However, for occupant comfort to be maximized:

1. Continue adhering to the natural ventilation policy
2. Ensure current HVAC system is functioning optimally

Recommendations

1. The contents of this report should be explained to staff as well as the purpose behind the Natural Ventilation Policy. The district/school management in consultation with the occupational health and safety committee should continue to promote the natural ventilation protocol.
2. In order to decrease CO_2 levels, fire doors should contain magnetic-“hold opens”, so that they can be normally opened to increase airflow between and within floors, while closing instantly in the event of an emergency.
3. Hallway windows should be opened as practicable throughout the day on both levels.
4. The performance of the HRV units in the modular classrooms should be assessed for performance. In the interim, CO_2 levels can be lowered by supplementing mechanical ventilation with opening windows as practicable.
5. Consideration should be given to enhancing the existing mechanical ventilation in the music room due to the high number of students present at times, as well as the lack of natural ventilation, and inability to open the door for practical reasons.
6. Consideration should be given to assessing the optimization of the existing mechanical ventilation system for the building.
7. As a follow-up to item 6, optimize hallway HVAC system performance as it relates to percentage of outdoor air.

Closure

This report was prepared for the Newfoundland and Labrador English School District, Eastern Region. If you have any questions or concerns please contact the undersigned.

Yours truly,

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