Indoor Air Quality Management

INDOOR AIR ENVIRONMENTAL ASSESSMENT

WAPASU CREEK WEST

   

For:

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May 04, 2015

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Attention: Chris O'Halloran

Re: Indoor Environmental Assessment at Wapasu Creek West

Please find attached our report, which describes our findings of the indoor air environmental assessment at Wapasu Creek West.

Observations and test results indicate:

- Toxigenic fungi in the crawlspace
- Toxigenic fungi in the ceiling areas of the building subjected to roof leaks
- Chemical compound (carbon disulfide) possibly used as a fungicide was 40 times over the guideline level
- Many reported health symptoms are strongly correlated with health effects from diesel, vehicle exhaust and fungi
- Numerous building code violations
- Mechanical system deficiencies
- Noise issues
- Building envelope deficiencies
- Substantial evidence of water intrusion

We have provided a list of recommendations.

Please let me know if you have any questions.

Yours sincerely,

Karen Rollins
IAQm

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1.0 Terms of Reference

Chris O'Halloran of United Food and Commercial Workers (UFCW) contacted Karen Rollins (IAQm) to conduct an indoor environmental assessment at several lodge accommodations north of Fort McMurray including Henday, Wapasu Creek Main, Wapasu Creek East, Wapasu Creek West, Beaver River, Athabasca, and Conklin. Complaints by the workers (kitchen, housekeeping, front desk) indicated possible indoor air quality and building envelope issues. A site visit was carried out August 18-22, 2014 to the lodges as well as the laundry facility. The purpose of the site visit was to become familiar with the layout of the buildings and interview key people so that we could develop a proposal for the indoor environmental assessment.

A proposal to conduct the indoor environmental assessment was developed in September 2014, revised, and issued on March 02, 2015. It included approach, methodology, schedule, cost and team qualifications. Since the buildings were of very similar construction and layout with the same types of mechanical systems and building use, we proposed to undertake a complete assessment at one of the lodges and address only specific concerns at the others. The lodge chosen by UFCW was Wapasu Creek West.

The on site assessment and air quality testing for Wapasu Creek West took place March 06-09 with additional long term data logging instruments set up to sample until March 19. This report summarizes our observations, test results, conclusions and recommendations.

1.1 Approach

Indoor environmental issues can be the result of many factors including indoor air contaminants, poor ventilation, thermal comfort, humidity, and noise. The site visit observations made August 2014, interviews with key people, and review of health questionnaires indicated a need to test for several indoor air contaminants and investigate building related causes.

Airborne particulates: The number one complaint from the workers was about the dust levels. This issue has seen some improvement over the past few years with the implementation of the 'boots off' policy and installation of portable air scrubbers. Of concern are the very small particles that might be inhaled deep into the lung and serve as a vector carrying other contaminants. We were interested in testing for PM2.5 and examining the mechanical system filters.

Diesel: Many workers complained of smelling diesel exhaust particularly in the morning when a hundred or more buses file in to pick up the oil field workers. They report cough, sleep disturbance, headaches, nausea and other symptoms related to diesel.

Fungi: There are reports of multiple roof leaks that occur in the spring with snowmelt and in summer when it rains. Recurring water intrusion may support fungi growth. The dirt-cover crawlspace under the building is also a concern as a fungal amplification source. There is evidence that water pools on the roof and accumulates and even flows under the buildings.

Acoustics: Noise from the ventilation systems and portable air scrubbers was identified as a possible issue during our visit in August. Many workers including housekeeping staff and front desk personnel work their entire shift in a noisy environment.

Temperature: Temperature was reported to be an issue especially in the summer in the bag up room and in the stairwells.

Relative humidity: Low relative humidity is one of the causes for nosebleeds, which are a common occurrence.

VOCs: Volatile organic compounds (VOCs) are a significant indoor air contaminant. Many of the health symptoms reported can be caused by VOCs.

BTEX: BTEX (benzene, toluene, ethylbenzene, xylene) are found near petroleum production sites and have harmful effects on the central nervous system. We were interested in determining if the general ambient air might be a significant source.

Mechanical equipment: Issues were identified that might be related to insufficient filtration systems, inadequate ventilation, and lack of control over temperature and relative humidity.

Building envelope: Water intrusion, flat roof, flashing details, dirt-covered crawlspace, and condensation on windows indicated a need to investigate the integrity of the building envelope.

1.2 Barriers and Limitations

Usually when we carry out an indoor air quality investigation we are provided architectural and mechanical drawings, maintenance records, free access to all parts of the building and building mechanical systems, and permission to interview building occupants and maintenance personnel. This is expected in a normal indoor air quality investigation. Limitations to this investigation included:

- Numerous requests for architectural, mechanical drawings and maintenance records from building management were unsuccessful
- Denied access to examine and sample the air in the crawlspace
- Lack of knowledgeable building mechanical and maintenance people were made available for us to interview
- Denied access to open up the furnaces to examine the state of the equipment, damper positions, airflow, and condition of the filter
- Denied access to the guest sleeping quarters
- Denied access to other buildings to conduct comparison air sampling and examination

Reviewing architectural and mechanical drawings is part of a comprehensive building evaluation and essential for coming up with recommendations and solutions. Architectural and mechanical drawings were not made available to us despite our repeated requests. These would have been useful for many reasons:

- floor plans for overall orientation and to assist in planning the sampling strategy
- wall sections and details are used for identifying building materials that were used in construction for evaluating building envelope integrity and possible VOC sources

- knowing where the weak points in building assembly are in order to predict or explain building envelop failure
- knowing what mechanical system loops feed which rooms to help with sampling strategy, building function evaluation and recommendations
- specifications and layout of the mechanical systems
- comparing test results with areas of the building that are different architecturally or mechanically
- comparing the intended design of the mechanical system to how it is actually performing
- ensuring the building was actually constructed or assembled as designed
- to use floor plans and details in our report
- aiding with solving indoor air quality issues, not just identifying them

Other limitations that we experienced had to do with the time of year, outdoor temperature, lower traffic volume, and snow cover. Ventilation performance could not be measured with our balometer since the outside temperature was above normal and the furnaces were not running. Snow, water and mud on the road keeps the dust level down and the dust problem was not as obvious this visit as it was when we were there in August. Many of the union staff told us that there is considerably more dust in spring and summer. Warmer temperatures meant fewer idling vehicles and probably less diesel exhaust that might have existed only a few days before when the temperatures were in the -30C range. With the lodges currently running at far less than capacity, the overall bus traffic and subsequent vehicle exhaust was less.

The sheer size of the building was a barrier since it was impossible to examine the hundreds of furnaces and related mechanical equipment in the four days we had on site. Instead we concentrated on the common areas (lobby, kitchen, dining rooms, laundry facilities, fitness rooms, recreation rooms, meeting rooms and an airport lounge) and reviewed the mechanical equipment in two of the wings.

However, there were some advantages to testing in March. The warmer temperatures and snowmelt on the roof enabled us to observe several locations where water was leaking into the building. Buckets and towels had been set out to catch the drips. We were informed that this is a common occurrence when the snow melts in the spring and in summer when it rains. Many of the water stained ceiling tiles had been replaced prior to our arrival. Nevertheless we still found many water stained ceiling tiles.

2.0 Contaminant Characteristics and Guidelines

Occupational exposure guidelines are for people who work an 8-hour shift five days a week. Workers at Wapasu Creek West work 10-hour days for 20 days in a row. Exposure guidelines need to be adjusted to compensate for this greater exposure during the longer work shift and decreased recovery time between shifts. Since the building is also where the workers live (a residence) we are using guidelines and standards that are suitable for the residential environment and for long-term 24-hour exposure.

2.1 Airborne Particulates

2.1.1 Airborne Particulates Characteristics

Airborne particulate matter is a mixture of organic and inorganic substances. Sources include the outdoor environment (soil, roads, agricultural dust, vehicles, industrial emissions, smoke from forest fires), people, animals, clothing, paper, building materials, tobacco smoke, fireplaces, rust, dust and dust mites, micro-organisms, inefficient vacuum cleaners and ventilation ducts. Secondary particulate matter may also be produced in the atmosphere through a number complex chemical processes. Particulates can come from both solid matter and liquid aerosols.

High particulate concentrations less than 10µm in size can be inhaled and irritate the lungs. The Canadian Environmental Protection Act has identified respirable particulate matter smaller than 10µm in diameter as being a toxic substance for human health (Government of Canada, 1999). Particulates may contain allergens or carry harmful chemical substances. The health effects will depend upon the concentration of particulates, toxicity of the substances carried on the particle, and individual susceptibility.

Fine particulate matter (PM2.5) is a general term for all small particles found in air measuring equal to or less than 2.5µm in aerodynamic diameter (Table 1). It is a complex mixture whose constituents vary in size, shape, density, surface area, and chemical composition. Health effects include respiratory symptoms, asthma aggravation, cardiovascular morbidity, and lung cancer.

Table 1: Size Categories of Respirable Particles

PM10	Particles of an aerodynamic diameter of less than 10µm
PM2.5 Fine Particles	Particles with a diameter less than 2.5µm
Ultra Fine Particles	Particles with a diameter less than 0.1µm or 100nm
Nanoparticles	Characterised by particles less than 50nm

2.1.2 Airborne Particulates Guidelines

Health Canada has no recognized threshold of health effects for indoor PM2.5. Health Canada recommends:

- indoor PM2.5 be lower than PM2.5 outside (having an indoor level that is greater than the outdoor level indicates a strong indoor source of PM2.5 that needs to be addressed)
- focusing on identifying the potential sources of contaminants, and then on improving air quality through source control, improved ventilation and other remedial measures such as air filtration.

The Council of Canadian Ministers of the Environment (CCME) established Canada-wide-standards (CWS) for ambient (outdoor) PM2.5 in 2000. The numerical target for the PM2.5 CWS is 30µg/m3 (24-hour average) (CCME, 2000). Alberta Environment has adopted this standard. Alberta's one-hour guideline for fine particulate matter is 80µg/m^3 (Alberta Environment, 2007).

In studies conducted by Health Canada in different Canadian cities, average indoor PM2.5 concentrations were less than 15 μg/m^3 (Health Canada 2010).

2.2 Diesel

2.2.1 Diesel Characteristics

Diesel engines are more efficient than gasoline engines, and they emit less carbon dioxide, carbon monoxide, and hydrocarbons. Therefore, diesel engines have some advantages over conventional gasoline engines in terms of global warming. However, they emit higher levels of oxides of nitrogen and fine particulate matter, which contaminate the environment.

Diesel engine exhaust is a complex mixture of gases and particulates. Gaseous compounds can include carbon dioxide, carbon monoxide, sulphur and nitrogen compounds, low molecular weight hydrocarbons (PAHs), water vapour, and oxygen. Diesel particulate matter (DPM) contains elemental carbon, organic compounds (including PAHs), metals, and other trace compounds.

Almost all particulates emitted by diesel engines are respirable (PM<10 microns). The size of diesel particulates that is of greatest health concern is in the categories of fine, ultra fine, and nano particles, less than 1μm. However the distribution of diesel particles have a bimodal character such that the particulates are represented in two separate size ranges (figure 1): most of the particulate numbers occur in an ultrafine size range of 0.01μm, however most of the diesel particulate mass occurs in the fine particle size range (0.05-1.0μm). A third size range for diesel particulates occurs in a courser size of 1.0-10μm).

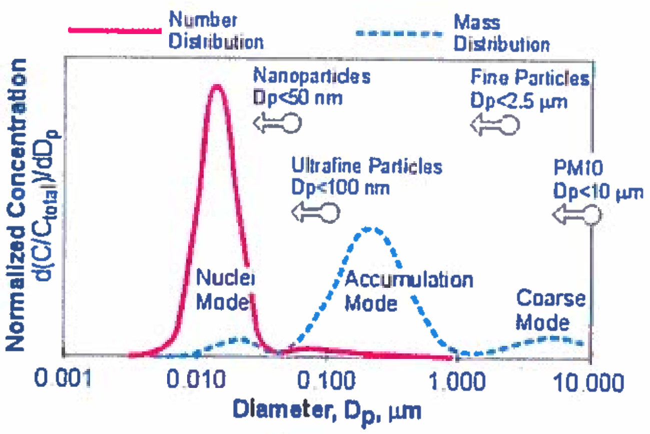

Fig. 1: Distribution of Diesel Particle Size

Short-term exposure to diesel engine exhaust can cause irritation of the eyes, throat, and bronchi, neuro-physiological symptoms such as light-headedness, nausea, and respiratory symptoms such as cough. Nosebleeds and skin rashes have been linked to exposure to diesel fumes. Diesel exhaust can initiate allergic reactions or increase immunological response to other allergens by damaging the immune system. There is danger not just from sudden acute exposures to diesel exhaust, but also from every day lower doses as well. Diesel exhaust can cause cancer (IARC, 2012).

2.2.2 Diesel Guidelines

In 2012 diesel exhaust was reclassified from a probable carcinogen to a known carcinogen. As with other carcinogens, there is no safe exposure level for diesel exhaust (CAREX Canada, 2013).

The guideline for diesel particulate matter (without including carcinogenic health effects) is 5$\mu g/m^3$ (0.005mg/m^3) for an 8-hour exposure (EPA, 2002).

2.3 Fungi

2.3.1 Fungi Characteristics

The term "fungi" is the biological classification of organisms that includes mould, yeasts, and mushrooms. Fungi are decay organisms. They colonize (grow on and consume) dead organic material, which includes building materials such as wood, drywall and fabrics. By doing this, they are merely fulfilling their mission within the natural ecosystem.

Fungi produce spores that under appropriate conditions can reproduce the entire organism. It is the combination of a source of spores, moisture or ambient humidity, surface temperature, and the availability of appropriate nutrients that lead to the success of fungal growth. As part of their metabolism, fungi can produce carbon dioxide, volatile organic compounds, alcohols, ketones, antibiotics, and mycotoxins. The volatile organic compounds are responsible for the 'musty' odours commonly associated with fungal growth.

Fungal-related human health effects include allergy, pathogenic infection and toxic illness.

Allergy: Fungi can cause Type I and Type III allergic reaction. Type I allergy symptoms include asthma, hay fever, and hives. Type III symptoms include fever, chills, rash, arthritis, and kidney damage.[1]

Pathogenic infection: Some fungi can cause pathogenic infection (grow on or inside a person's body: usually lungs, sinus, or skin). *Aspergillus fumigatus* can cause lung disease by growing in a person's lungs through inhalation of its spores. Pathogenic infection is rare and usually affects only immune compromised individuals (persons recovering from recent surgery, or people with immune suppression,

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[1] There are several types of allergy. Type I (immediate hypersensitivity) is an allergic reaction provoked by re-exposure to a specific antigen. Exposure may be by ingestion, inhalation, injection, or direct contact. The reaction is mediated IgE antibodies and produced by thé immediate release of histamine, which causes an inflammatory response. Symptoms vary from mild irritation to sudden death from anaphylactic shock. Treatment usually involves epinephrine, antihistamines and corticosteroids. Some examples include: asthma, hay fever, anaphylaxis, and hives. Type II (antibody-dependent hypersensitivity) allergy is normally directed against pathogens. Examples include hyperacute graft rejection, reactions to drugs such as aspirin and penicillin, and occupational diseases such as farmer's lung. Type III (immune complex hypersensitivity) allergy is a delayed response in which the antigen persists for long periods of time before a reaction occurs or levels build up over time. Examples include Lupus and rheumatoid arthritis. Symptoms include fever, chills, rash, arthritis, and kidney damage. Type IV (cell-mediated hypersensitivity) allergy is also a delayed response, usually 48-72 hours. Examples include Type 1 diabetes and poison ivy. Type V (stimulatory hypersensitivity) allergy impairs cell function causing diseases such as Graves' disease.

asthma, hypersensitivity pneumonitis, severe allergies, sinusitis, or other chronic inflammatory lung diseases). However, amount of exposure is also a factor. People not considered immune compromised, but with long term exposure to elevated levels of certain fungi spores can develop pathogenic infection. Some sinus infections are not bacteria-related (and therefore cannot be treated successfully by antibiotics), but fungi-related (Ponikau, et al., 1999).

Toxic Illness: Illness can result from exposure to the toxic chemicals (mycotoxins and microbial volatile organic compounds) produced by fungi. Some of these illnesses produce symptoms including dizziness, fatigue, inability to concentrate, headaches, nausea, shortness of breath, impaired vision, impaired co-ordination, learning impairment, liver and kidney damage, heart tissue damage, nervous system depression, respiratory distress, nose bleeds, bleeding of the lungs, and immune system depression. Only some fungi excrete chemicals that are harmful to human health and only under certain conditions. Little is known about long-term exposure to low levels of mycotoxins and the volatile organic compounds produced by fungi.

Fungi that produce toxins are called toxigenic fungi. *Stachybotrys chartarum* (or 'black mould') is the most commonly identified example, but many other fungi are capable of producing toxins. An identification analysis to the species level (not just to the *genus* level) is necessary to determine if a particular fungus is toxigenic. However, even if a toxigenic fungus is identified, it can never be certain that it is producing toxins. Reasons for that may depend on the substrate it is growing on, environmental conditions, life cycle, or many other factors. Much about the nature of fungi is still not fully understood. It is generally agreed by mycologists and indoor air quality experts that once a toxigenic fungus is identified, to assume it is producing toxins and to respond accordingly.

There are many variables to consider in making a health risk assessment for fungi. Some of these variables include:

1. the nature of the fungal material (allergenic, infectious, or toxic),
2. the amount of exposure (concentration of spores in the air and length of time people are exposed), and
3. the susceptibility of exposed persons (individual susceptibility varies with genetic predisposition, age, state of health, and concurrent exposures).

2.3.2 Fungi Guidelines

Health Canada considers that fungal growth in buildings poses a health hazard (HC, 2007). Health Canada does not have any exposure limits for fungi in buildings and recommends:

a) to control humidity and diligently repair any water damage to prevent mould growth
b) to clean thoroughly any visible or concealed mould growing in buildings

Further guidance has been offered by other organizations:

- Moisture intrusion, visible mouldy, wet, or soiled surfaces must be remediated following an established protocol (New York City, 2008).
- Fungal quantities, measured as colony-forming-units per cubic meter of air (CFU/m^3), should be lower inside compared to outside, and the "mix" (biodiversity) should be similar. An indoor fungal amplifier is suspected if there is one or more fungal species occurring as a significant

percentage of an indoor sample and not similarly present in outdoor samples (Health Canada, 1995).

- Dominance indoors by species of mould that are not predominant outdoors indicates an interior amplification site. This must be located and rectified (Health Canada, 1995).
- The confirmed presence of toxigenic fungi indicates that further investigation is necessary (HWC, 1987).
- Health Canada's protocol for mould recognition and management subscribes to the following phases: assess the magnitude of the health problems, identify problems in the building environment, identify indoor fungal amplifiers, communicate the health risk, and take remedial action (Health Canada, 1995).
- New York City guidelines state, "except in cases of widespread fungal contamination that are linked to illnesses throughout a building, building-wide evacuation is not indicated" (New York City, 2008).
- All building occupants should be protected from microbial exposure during testing and remedial action by using necessary equipment, methods and containment strategies, so that microbials are not transported to other zones (NYC, 2008).
- Moisture control is the primary factor in controlling microbial growth (CMHC, 2007).
- If porous materials such as fibreglass insulation, carpet, ceiling tiles, and plaster become contaminated with fungi, it is usual to discard these materials. Hard surfaces can be salvaged using a detergent or hydrogen peroxide solution (CMHC, 2007).
- The use of anti-microbial disinfectants, biocides, or bleach for the purpose of killing mould is not recommended. Mould remediation consisting of treatment only with a biocide or disinfectant has not been proven to be effective, necessary or beneficial because dead and dormant mould spores and mould fragments still have toxigenic and allergenic health effects, and therefore still present a health hazard. Encapsulation of mouldy areas is also not a recommended procedure because mould left in place will begin to grow if water is reintroduced in the future. Removal of all mouldy materials is the only effective mould remediation strategy (Lee & Rollins, 2009).
- Water damage from leaks, floods and plumbing failures should be repaired and remediated within 24 hours. Wet materials should be dried. Sewage-contaminated porous materials must be discarded. Water penetration or migration through the building envelope, and condensation within the interior or exterior wall assembly is to be avoided. A moisture meter and a thermographic camera are useful in detecting non-accessible or hidden wet areas. Do not over-humidify the building during the winter (CMHC, 2007).
- The presence of some genera such as *Alternaria, Arthrinium, Stachybotrys, Chaetomium* and *Ulocladium* may indicate a problem if not observed within any of the outdoor controls even though they may not account for a significant percentage of an indoor sample (Lee and Rollins, 2009).[2]

[2] These fungi are considered harmful to human health and their spores do not capture well with currently available air sampling methods, therefore one or two spores may indicate a concern. These fungi are indicator species for Alberta.

2.4 Volatile Organic Compounds

2.4.1 VOC Characteristics

Volatile organic compounds (VOCs) are chemical compounds that contain carbon and will off-gas into the air. VOCs off-gas when they reach their boiling point, which varies for each compound, but generally, their boiling point lies between 0°C and 260°C. The lower the boiling point, the more volatile the compound is considered to be. VOCs are precursor substances that through a series of complex photochemical reactions can result in the formation of ground-level ozone (O_3). Ground-level ozone is a respiratory irritant and one of the major components of smog.

Thousands of VOCs exist. Some examples of VOCs include: acetone, benzene, chlorinated solvents, dichlorobenzene, limonene, 4-phenylcyclohexene, toluene and xylene. Almost all materials release VOCs. Sources include: detergents, paints, pesticides, adhesives, cosmetic and personal care products, automotive products (oils, gasoline, automotive cleaners), building materials (pressed wood products, gypsum board, adhesive, plastic piping, vinyl or plastic wall coverings), vehicular exhaust, industrial emissions, tobacco smoke, and materials of biological origin (animal faeces, spores, pollen, metabolic products). Indoor concentrations of VOCs often exceed outdoor concentrations even in highly industrialized areas (average of 2 to 5 times higher).

Health effects depend on the type and dose of exposure to VOCs and sensitivity of the individual. Symptoms include: 1) eye, skin and respiratory tract irritation; 2) headaches; 3) central nervous system depression (fatigue, headache, drowsiness, dizziness, weakness, blurred vision, irritability, difficulty concentrating, fine motor deficits, cardiac arrhythmias); 4) carcinogenic effects; and, in high concentrations, 5) liver and kidney damage. People with environmental hypersensitivity often react to VOCs at very low concentrations.

The severity of these symptoms can vary. Some people report no health effects. Some report mild irritation while others are incapacitated and/or must give up many 'normal' activities in order to avoid exposure (such as going to public places). These severe reactions are known as a condition called "environmental sensitivities", which can be defined as follows:

> "Environmental sensitivities (ES) describes a chronic condition whereby a person has symptoms when exposed to certain chemicals or other environmental agents at low levels tolerated by most people. The symptoms may range in severity from mild to debilitating."

ES has also been called multiple chemical sensitivity, chemical intolerance, environmental hypersensitivity, environmental illness, toxicant-induced loss of tolerance, and idiopathic environmental intolerance.

There are human rights laws in Alberta that cover environmental sensitivities. In other words, building owners and managers have a legal obligation to provide healthy indoor air for all people, regardless of their individual sensitivity.

A report called "The Medical Perspective of Environmental Sensitivities" published by the Canadian Human Rights Commission clearly identifies this health obligation (Sears, 2007). One of our team members, Professor Tang Lee wrote sections of this report. Another report published by the Canadian Human Rights Commission called "The Legal Perspective on Environmental Sensitivities", discusses the health ramifications for people who had become environmentally sensitive due to exposure to environmental pollution (Wilkie and Baker, 2007). Accommodation for people with environmental sensitivities is treated similarly to people with disabilities and the medical devices needed for them such as an air filtration unit is tax deductible.

2.4.2 VOC Guidelines

Alberta Occupational Health and Safety Code, Schedule 1 has eight-hour occupational exposure limits for individual chemical substances developed for workers in the industrial environment (Government of Alberta, 2009a). Not all VOCs are listed in Schedule 1 of the regulations. To obtain a guideline applicable to residential environment, the occupational exposure limit is divided by 100.

When people are exposed to two or more substances the impact on their health is greater than simply adding the exposure risk for each substance: it is synergistic. Due to the infinite number of variables in multiple substance exposure, it is an impossible undertaking for toxicologists to determine their combined impact on humans. As such, the synergistic effects of exposure to multiple substances at varying concentrations are not studied.

2.5 BTEX

2.5.1 BTEX Characteristics

Benzene, toluene, ethylbenzene, xylene (BTEX) are types of volatile organic compounds called aromatic hydrocarbons. They are found in petroleum products such as gasoline and diesel fuel. They have harmful effects on the central nervous system and can cause headaches, dizziness, inability to concentrate, eye, nose and throat irritation.

Benzene

Benzene is a colourless sweet smelling liquid. Sources include the petrochemical industry, gasoline, crude oil, and cigarette smoke. It is used as a precursor to make other chemicals. Glues, paints, furniture wax and detergents may contain benzene. Benzene is a carcinogen and a mutagen and is a global health problem.

Ethylbenzene

Ethylbenzene is a colourless liquid that smells like gasoline. It is made from benzene and is used to make other chemicals such as styrene. It is found in solvents, adhesives, varnish and paint. Exposure to ethylbenzene can cause eye and throat sensitivity and dizziness. It is classified as a possible carcinogen.

Toluene

Toluene is a colourless gas that has a sweet pungent odour. It occurs naturally in crude oil fuels (including gasoline) and in the tolu tree. Toluene is produced during the process of making gasoline and other fuels from crude oil, in making coke from coal and as a by-product of styrene. Toluene is used in the production of nylon, plastic soda bottles and other organic chemicals. It is also used in making paints, paint thinners, fingernail polish, lacquers, adhesives, and rubber in some printing and leather tanning processes. Toluene may affect the nervous system. Low to moderate levels can cause tiredness, confusion, weakness, drunken-type actions, memory loss, nausea, loss of appetite, and hearing and colour vision loss. These symptoms usually disappear when exposure is stopped.

Xylene

Xylene has three forms: meta-xylene, ortho-xylene, and para-xylene (m-, o-, and p- xylene). These different forms are referred to as isomers, meaning that they have the same chemical formula, but a different chemical structure. Xylene is a colourless, sweet-smelling gas. It is mostly a synthetic chemical that is produced from petroleum. It also occurs naturally in petroleum and coal tar and is formed during forest fires. Xylene is used as a solvent in the printing, rubber, and leather industries. It is also used as a cleaning agent, a thinner for paint, and in paints and varnishes. It is found in airplane fuel, gasoline and cigarette smoke. Acute exposure to xylene can cause headaches, nausea and dizziness. The type and severity of health effects depends upon several factors including the amount of exposure and the length of time of exposure. Individuals also react differently to different levels of exposure.

2.5.2 BTEX Guidelines

Alberta Occupational Health and Safety Code (Government of Alberta, 2009a) Schedule 1 recommends an 8-hour occupational exposure limit for various substances. To obtain a guideline applicable to residential environment, the occupational exposure limit is divided by 100. Health Canada has a guideline for toluene.

Table 2: BTEX Guidelines

	8-hour occupational exposure limit[1]	Residential exposure limit	
Benzene	0.5ppm 1.6mg/m^3	0.005ppm or 5ppb 0.016mg/m^3 or 16μg/m^3	
Toluene	50ppm 188mg/m^3	24-hour 0.6ppm or 600ppb 2.3mg/m^3 or 2300μg/m^3 (Health Canada, 2011)	8-hour 4ppm or 4000ppb 15mg/m^3 or 15000μg/m^3 (Health Canada, 2011)
Ethylbenzene	100ppm 434mg/m^3	1ppm or 1000ppb 4.34mg/m^3 or 4340μg/m^3	
Xylene	100ppm 434mg/m^3	1ppm or 1000ppb 4.34mg/m^3 or 4340μg/m^3	

[1]Guideline from Alberta Occupational Health and Safety Code Schedule 1: Occupational Exposure Limits for Chemical Substances

2.6 Acoustic

2.6.1 Acoustic Characteristics

Noise has been recognized as an occupational hazard in workplaces for many years. Noise exposure guidelines for the workplace are set to prevent exposure to sound at volumes that can cause hearing damage. Excessive noise can cause hearing impairment, stress, psychological effects, hypertension, heart disease, changes in the immune system, fatigue, decreased job performance, and sleep disturbance (Table 3). Even at low levels and at both low and high frequencies, unwanted sounds can constitute health and safety hazards by increasing stress levels and impairing communication and concentration.

The indicators of potentially hazardous noise level include (CCOHS, 2014):

- Noise is louder than busy city traffic
- People have to raise their voice to talk to someone at one metre (3 feet) away
- At the end of work shift people have to increase the volume of their radio or TV to a level too loud for others
- After working for a few years at that workplace, employees find it difficult to communicate in a crowd or party situation where there are other sounds or many voices

Table 3: Health Effects and dBA Levels

Health Effect	dBA level
Sleep disturbance	40 (depends on individual susceptibility and noise characteristics)
Myocardial infarction	50 (continuous exposure at night)
Stress	55 (< 55 for continuous noise)
Extremely irritating	55-60 (depends on individual susceptibility and noise characteristics)
Cardiovascular problems	67
Hearing loss	80
Average human pain threshold	110
Eardrum rupture	150

2.6.2 Acoustic Guidelines

The noise criterion table (Table 4) developed by the National Research Council is a design guideline for the acceptable amount of background noise in a particular space (Warnock, 2001). The noise referred to is that which the building introduces to the room, which is primarily, but not limited to, HVAC systems (Cowan, 2007). The acceptable noise criterion levels will vary depending on the type of occupancy.

Noise Criterion (NC) level is a useful indicator to determine acceptable levels of noise for an indoor environment. These were developed primarily to assess the problem of speech communication in noisy environments. NC levels are informative by providing context to what is an acceptable level of indoor noise within an indoor environment. By comparing the acceptable Noise Criterion level in the following table against the sound level measurements of various spaces throughout Wapasu Creek West, we can evaluate whether the sound levels within the existing environment are acceptable in relation to spaces with similar uses and functionalities.

Table 4: Suggested Acoustical Criteria for Some Occupancies

	Recommended Minimum Sound Attenuation		Recommended Range for Background Noise, dB(A)	Reverberation Time, seconds
	ASTC	FIIC		
Multi-family homes	55	50	35-40	
Bedrooms in residences	55	50	30-35	
Private offices	45		40-45	
Meeting rooms	50		35-40	0,5
Bedrooms in hotels, motels and hospitals	50	50	35-40	
Classrooms up to 300 m^3	50		35-40	0,6
Cafeterias			40-45	0,8
Large lecture rooms, classrooms over 300 m^3	50		30-35	0,7
Gymnasiums			40-45	1,0
Libraries			40-45	0,7

2.7 Temperature

2.7.1 Temperature Characteristics

Temperature is a comfort parameter. It affects people's perception of air quality.

2.7.2 Temperature Guidelines

According to ASHRAE Standard 55 (ASHRAE, 2013a), the optimum temperature desired in an office environment is 20 – 24°C. The range takes into account the level of occupant activity and layers of clothing.

2.8 Relative Humidity

2.8.1 RH Characteristics

Relative humidity (RH) is a comfort parameter. It affects people's perception of air quality. Humidity levels above 60% can support mould and bacterial growth. Very dry conditions can lead to increased static electricity and health problems such as skin and respiratory tract irritation and nosebleeds. Low relative humidity can dry out nasal passages and reduce a person's defences against viral and bacteriological infections.

2.8.2 RH Guidelines

ASHRAE recommends a comfortable relative humidity of between 30-60%. However, this range is difficult and often impractical to achieve and maintain in Alberta's cold dry environment. In addition, RH above 30% can cause condensation and ice build-up on double pane window surfaces. A reasonable guideline for RH in the winter for Alberta is 20-30% (Government of Alberta, 2009b).

2.9 Guidelines Summary

Table 5: Guidelines Summary

	Guideline	Source
Particulate Matter (PM2.5)	Less than outside CWS 30µg/m³ (24-hour average)	Health Canada
Diesel exhaust (general)	No safe level	IARC
Diesel particulate (non-cancer)	5µg/m³ (8-hour)	EPA
Fungi	a) to control humidity and diligently repair any water damage to prevent mould growth b) to clean thoroughly any visible or concealed mould growing in buildings	Health Canada
VOCs	Specific guideline for each chemical compound	AB Occupational H&S Code Schedule 1 divided by 100
Benzene	0.005ppm or 0.016mg/m³	AB Occupational H&S Code Schedule 1 divided by 100
Toluene	24-hour: 0.6ppm or 2.3mg/m³ 8-hour: 4ppm or 15mg/m³	Health Canada
Ethyl-benzene	1ppm or 4.34mg/m³	AB Occupational H&S Code Schedule 1 divided by 100
Xylene	1ppm or 4.34mg/m³	AB Occupational H&S Code Schedule 1 divided by 100
Acoustics	35-40 (hotel bedrooms) 40-45 (office) 40-45 (cafeteria) 40-45 (gymnasium)	National Research Council of Canada
Temperature	20 – 24°C	ASHRAE
Relative Humidity	20-30%	Alberta Government

3.0 Methodology

3.1 Information Review

Information about the building and related issues was obtained from interviews with union representatives, workers on site, and Civeo's maintenance, management, and health and safety personnel. Information also came from an indoor air quality report conducted by Western Health & Safety in March 2013. Additional information was obtained from Civeo's Indoor Air Quality Management Plan and by searching the Internet on topics such as current and relevant guidelines for contaminants and equipment specifications.

3.2 Health Survey

In August 2014, IAQm developed health questionnaires and invited workers to respond. The questionnaires were assessed and a report was issued to UFCW on October 22, 2014.

3.3 Systematic Building Walkthrough

A preliminary building walkthrough took place at Wapasu Creek West and six similar buildings in August 2014. This visual assessment identified areas of water damage, building envelope deficiencies, and pollution pathways for diesel, airborne particulates, fungi and VOCs. It also identified the potential for noise, temperature, and relative humidity to cause issues. We viewed most indoor spaces and the immediate outdoor areas, several furnace closets, and had access to the roof at Henday.

The building walkthrough in March 2015 at Wapasu Creek West conducted for this report was a more thorough visual assessment. It took into account an examination of the current condition of indoor building materials (drywall, ceiling tiles, etc.), building envelope components (exterior walls, flashings, roof, floors, foundation, etc.), and building use. Violations to the Alberta Building Code were noted. A thermographic camera was used to help identify potential moist building materials that were not readily visible. Some ceiling areas were opened up for further examination.

Wapasu Creek Main and Wapasu Creek East were briefly examined when fungi sampling was conducted in the kitchen and lobby.

3.4 Mechanical Systems Assessment

The mechanical systems (furnaces, air intake, ductwork, rooftop units, air filtration) were examined. Due to the large scale of the building we were not able to examine all the mechanical equipment at Wapasu Creek West, but concentrated on the common areas and reviewed two of the Wings as a representative of the rest.

3.5 Environmental Monitoring

3.5.1 Airborne Particulates

Airborne particulates were measured using a Quest EVM-3 Indoor Air Quality Monitor with the PM2.5 filter. We used four monitors to take readings simultaneously in the kitchen, lobby, housekeeping, and bag-up room. The monitors were set up to run and take readings over a period of twelve days. Particulates were measured in $\mu g/m^3$. Data was downloaded and made into Excel files. Graphs were produced from the data.

Airborne particulates were also measured in spot locations using an Airborne Particle Counter. Readings were generally from two-minute samples.

3.5.2 Diesel

Diesel particulate matter (DPM) was collected over a period of four hours using DPM cassettes and an SKC air pump (with cyclone) calibrated at approximately 2L/min and analysed by an accredited lab using NIOSH Method 5040. The cyclone removes non-respirable particles (greater than 10µg) before they reach the cassette. DPM cassettes consist of an impactor with precision sapphire orifice, impaction substrate, and two heat-treated quartz filters. The impactor screens out respirable particles greater than 1.0µg. Particles less than 1.0µg are collected on the first filter and the second filter serves as a blank. Samples are analysed for organic and elemental carbon content using a thermal-optical analyser. The elemental carbon portion represents diesel particulate. NIOSH Method 5040 has an accuracy of about 16%.

In addition, diesel was measured using two Flir Airtec Diesel Particulate Monitors, which logged readings over a 24-hour period. We placed one monitor indoors (kitchen) and one outdoors (south side of the building) to give us information about source as well as indoor exposure level. The Flir Airtec Diesel Particulate Monitor consists of a prefilter with a cyclone and impactor to remove particles greater than 0.8 microns. The prefilter is the same that is used in the NIOSH 5040 test. Particles measuring smaller than 0.8 microns pass through the particle size selector to a filter cassette, where the optical transmittance of the filter is monitored by a laser and sensor. The optical transmittance is converted to an elemental carbon (EC) concentration using a factory calibration stored in the monitor.

3.5.3 Fungi

The concentration of airborne fungi was measured using two methods: airborne spore count (spore trap method) and viable fungi testing (RCS method).

The spore trap microbial sampling method involves using a cassette containing a filter that is placed over an air pump. Fungi spores and other debris found in the air are captured on the filter. Both viable and non-viable spores are captured. The lab technician examines the surface area of the filter under a microscope, counts the number of fungi spores, and identifies them. Results are available within a few days. Identification is to the genus level. It is used to identify the presence of *Stachybotrys*[3] or as a relative measure of concentration of spores in the air.

The RCS microbial sampling method provides the concentration of viable[4] fungal spores in the air. The pump draws in a known amount of air and impinges the spores in that volume of air onto an agar strip. When the agar strip is incubated, the concentration of fungal spores in the air (CFU/m^3 or colony forming units per cubic meter) can be calculated. This method is used when identification to the species level is desired. Species information is essential to make a health risk assessment. The different colonies growing on the agar strip are isolated and subjected to various lab tests. The tests take time (at least three weeks) to evaluate.

Several outdoor air samples were collected as controls to determine if the indoor fungi concentrations are due to outside infiltration or from an indoor amplification source. Samples from Wapasu Creek Main and Wapasu Creek East (kitchen and lobby) were obtained for comparison. The crawl space at Wapasu Creek West was tested by removing a ventilation grille and placing the instruments just inside.

One bulk sample of drywall in the women's gym furnace closet was obtained for analysis. It was collected using hygiene methods and placed in a plastic bag for transport to the lab.

Sampling took place in the morning of March 8. The temperature was about +4°C with 51%RH and there had been no precipitation for several days prior to the test. Viable samples arrived at the lab within three days of sampling. Since there was still snow on the ground it was expected that the outdoor samples would have low concentrations of fungi.

3.5.4 Volatile Organic Compounds

Volatile organic compounds were measured using a 1.4 litre canister to collect an air sample over a period of four hours. The air sample was analysed with a gas chromatograph-mass selective detector by an accredited lab using EPA Method TO-15. The VOCs with the highest concentration were identified.

3.5.5 BTEX

BTEX was measured using a 1.4 litre canister to collect an air sample over a period of four hours. The air sample was analysed with a gas chromatograph-mass selective detector by an accredited lab using EPA Method TO-15.

3.5.6 Acoustics

In evaluating the acoustic atmosphere of the indoor space, we sampled the sound pressure level readings in decibels (dBA). The TES 1358 Sound Analyzer (1/1 & 1/3 Octave Band Real Time Analyzer, Serial Number 061008997) was used to measure the space's sound pressure levels, which are called "decibels". The sound level in dBA represents what the human ear perceives as opposed to decibels

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3 *Stachybotrys* is one of the most harmful fungi that are known producers of mycotoxins and can be identified under the microscope.

4 Viable means capable of living, growing and reproducing. Non-viable means not able to grow. Allergens and toxins may still be associated with non-viable fungal spores, and therefore are considered a health risk. The RCS sampling method does not detect non-viable fungal spores. The spore trap sampling method detects both viable and non-viable spores.

(dB), which is a logarithmic expression of the absolute sound level.[5] The noise levels were compared with the Noise Criterion Table developed by the National Research Council.

3.5.7 Temperature

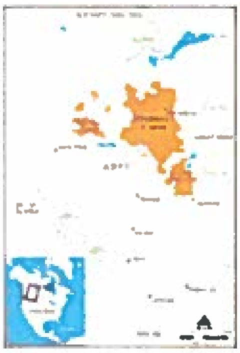
Temperature was monitored using a Quest EVM-3 Indoor Air Quality Monitor.

3.5.8 Relative Humidity

Relative humidity was monitored using a Quest EVM-3 Indoor Air Quality Monitor.

4.0 Observations and Results

Wapasu is a temporary housing settlement located 115 km north of Fort McMurray in the middle of the Alberta oil sands production area, which covers 140,000km^2 of boreal forest and muskeg (figures 2, 3 and 4). The Wapasu complex consists of three separately managed lodges: Wapasu Creek West, Wapasu Creek Main and Wapasu Creek East, and houses over 7,000 people (figure 5). Each lodge consists of multiple three storey prefab accommodation wings (figure 6) and a central one-storey structure (figure 7) that includes a lobby, kitchens, dining rooms, laundry facilities, fitness rooms, recreation rooms, meeting rooms and an airport lounge. All parts of the complex are prefabricated and assembled onsite. The décor is austere.



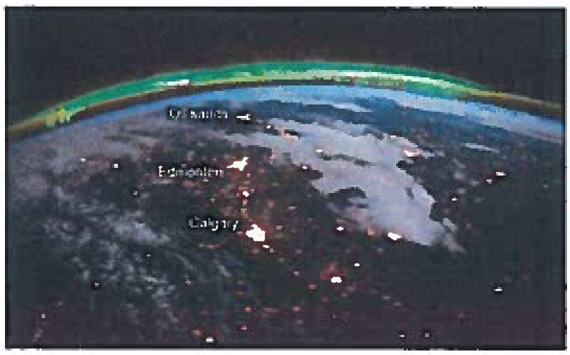


Fig. 2: The Athabasca or Alberta Oil Sands cover a significant portion of the province of Alberta. Fort McMurray is in a central location surrounded by oil sands related activities.
Fig. 3: Lights from the oil sands operations are visible from space.
Fig. 4: Potential for negative outdoor air quality due to proximity to the oil sands.

5 A-weighted decibels, abbreviated dBA, or dBa, or dB(a), are an expression of the relative loudness of sounds in air as perceived by the human ear. In the A-weighted system, the decibel values of sounds at low frequencies are reduced, compared with unweighted decibels, in which no correction is made for audio frequency. This correction is made because the human ear is less sensitive at low audio frequencies, especially below 1000 Hz, than at high audio frequencies.


Fig. 5: Areal view of the complex. Wapasu Creek West is in the foreground, Wapasu Creek Main is on the left, and Wapasu Creek East is across the top. The bus staging area is centrally located.
Fig. 6: Example of the three storey prefab accommodation wings (Wapasu Creek East).

Fig. 7: Front view of Wapasu Creek West and access to lobby.

4.1 Information Review

4.1.1 Indoor Air Quality Report

Western Health & Safety (WH&S) conducted an indoor air quality review at Wapasu Creek East, West and Main Front Desks in March 2013. IAQm's critique of that report includes:

1) When testing for fungi, WH&S used only spore trap method. We recommend RCS method as well because this provides information about species, which is required in order to predict health risk.
2) Although WH&S declared that their fungi testing did not indicate an indoor amplification source, a closer look at the lab report suggests that there might be an issue with fungi because *Penicillium/Aspergillus* were clearly present in several indoor locations but not outside, indicating indoor propagation.
3) WH&S measured total volatile organic compounds (TVOCs). The reason why IAQ investigators test for TVOCs is because it is easy and not very expensive. There are many

reasons why testing for TVOCs is inaccurate and misleading. These meters use only one specific gas for calibration and as a result many VOCs are not detected. A more accurate method is to test for individual VOCs, which requires GCMS analysis (Hodgson).

4) WH&S testing for airborne particulates was in the PM10 range. PM2.5 is considered more relevant in terms of health issues.
5) Contrary to what WH&S reported the carbon dioxide (CO_2) concentrations were not always within the guideline of 1000ppm. CO_2 concentrations exceeded 1000ppm daily and even went up to 3000ppm at Wapasu Creek East. At Wapasu Creek West CO_2 concentrations went over 1100ppm daily and up to 1800ppm.

4.1.2 Interviews

Interviews with union representatives, workers on site, and Civeo's maintenance, management, and health and safety personnel provided some relevant information about the building including:

- the lodge becomes considerably more dusty especially in the summer
- compliance to the boots off policy is estimated to be only 40%
- carpets have been removed because the airborne dust from the carpets set off the fire alarm
- dust issues are worse in the summer months
- dust will visibly accumulate on surfaces within 24 hours of being cleaned
- kitchen staff have to cover stored food to protect it from dust and insects
- the 'no idle' policy has improved vehicle exhaust issues, but compliance is not 100%
- kitchen staff members at Wapasu Creek East have experienced nausea and vomiting in the morning when vehicle exhaust enters the building via the makeup air units
- pickup trucks often idle in the parking lot all night long in winter
- the MUA units on the roof are direct fired natural gas units, and do not have a chimney to exhaust flu gases.
- the roof at Wapasu Creek West was redone in 2013
- water accumulates around and underneath the buildings, becoming stagnant standing water that stays for months to provide a breeding ground for insects and microbes
- there was a sewer leak into the crawlspace at Wapasu Creek Main about 2 years ago
- there is a lack of ventilation in the bag-up room so that it overheats and becomes stuffy especially on summer mornings
- the temperature in the kitchen is often too hot or too cold
- the stairwells overheat in summer
- there is often condensation on the windows in winter in the residential suites
- building residents often use portable humidifiers in their rooms
- water ponds on the roof due to inadequate roof slope and lack of drainage
- water leaks from the ceiling in multiple locations whenever it rains or in the spring when the accumulated snow and ice on the roof melts
- ceiling tiles are constantly being replaced due to water staining from roof leaks
- the health and safety committee is ineffectual as it lacks the authority and funding to make any changes

- housekeeping staff report lots of blood stains on pillows due to nose bleeds
- odours develop in the residential wings from time to time
- mould remediation activities have taken place at Beaver River, Conklin and Wapasu Creek East
- little black flies come into the MUA in the kitchen and settle on food storage items along with dust
- building management 'sprayed' just before our testing in an effort to minimise microorganism levels that would normally be present

4.1.3 Civeo's Indoor Air Quality Management Plan

Civeo's Indoor Air Quality Management Plan is comprehensive covering: statement of commitment, objectives, policy, identification of potential contaminants and their guidelines, establishment of internal performance criteria in the absence of guidelines, assigning accountability and responsibility, education and training, outlining operational procedures (equipment maintenance, pest control, hazardous materials, mould remediation), complaint response procedures, and provisions for regular review of the plan. Items that they might want to add to their plan include:

- securing necessary resources and budgeting
- procedures for correcting air quality problems caused by contaminants other than mould and provisions for implementing a follow up to confirm the effectiveness of the remediation
- design and construction of new buildings (Beaulieu, 1998)

Having this Indoor Air Quality Management Plan in writing is good, but we did not see any documentation to support that the plan is being followed or enforced. We did not see any completed mechanical equipment checklists, maintenance inspection forms, examples of complaint response forms, or evidence that the plan is reviewed.

4.2 Health Survey

In order to gather more information about health issues, IAQm distributed health questionnaires to workers in August (2014). IAQm assessed the questionnaires and issued a report to UFCW on October 22, 2014. Conclusions from the health survey analysis included:

1. The most common health issues included: cough, sleep disturbance, cold symptoms, headache, fatigue, runny nose, stiff joints and eye irritation (figure 8).

2. From the number of complaints received, types of health symptoms reported, and because most people felt better when not at work and worse as the work-week progressed, we can conclude that there are indoor environmental quality issues at Wapasu Creek and other lodges.

3. The health survey provided us with some direction on what types of contaminants we should test for and where we should test. There may be more than one indoor contaminant-related issue. The types of health issues indicate several possible contaminants primarily: airborne particulates, diesel, fungi, and VOCs.

4. Areas where we should set up our testing equipment should concentrate on the kitchen and lobby.

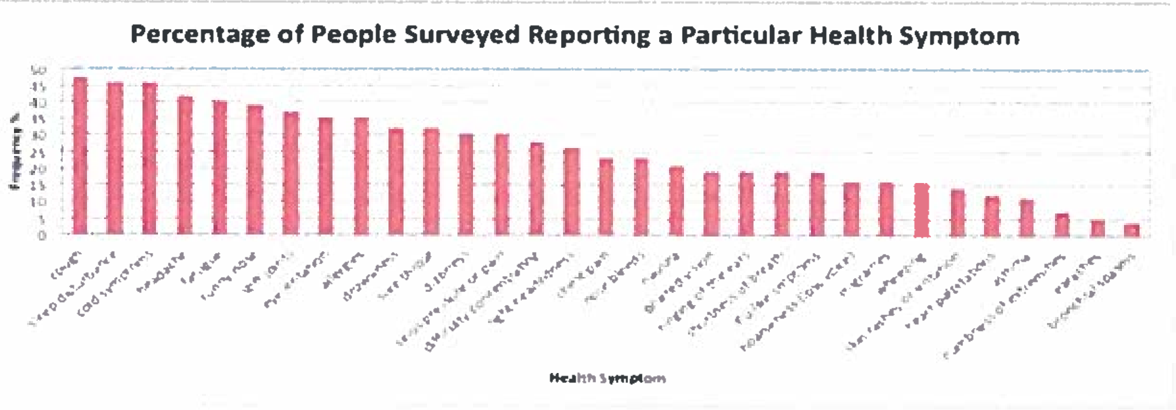


Figure 8: Aggregated Health Survey Results from Wapasu Creek East, West and Main (IAQm, 2014)

4.3 Systematic Building Walkthrough

4.3.1 Outdoor Environment

4.3.1.1 Ambient Air Quality

The quality of the ambient air is compromised by oil sands operations, in particular hydrogen sulphide gas (H_2S), other hydrocarbons, diesel and smoke from forest fires.

Health effects from H_2S include dizziness, headaches and breathing difficulties. According to Wood Buffalo Environmental Association, which monitors the air quality 24 hours/day in the oil sands region, the occasions where hourly measurements of H_2S exceeded the industry standard were over 400 hours in 2009 and frequency rate was rising.

Hydrocarbons are emitted in various oil sands operation including extraction and processing. Odours from some of the hydrocarbons are clearly apparent, but they vary depending on wind direction and other atmospheric conditions, as well as plant operation.

Forest fires are common in Alberta's northern boreal forest and are a major natural hazard. Particulates from forest fires have a measurable health impact even hundreds of kilometres from the source because the very small respirable particles become suspended in the air and travel over long distances. Health impacts include respiratory irritation, wheezing, tightness in the chest, and difficulty breathing. Remote work sites and camps occasionally are evacuated due to forest fire threat.

4.3.1.2 Vehicle Exhaust

Oil Sands employees are bussed in and out of the fenced guarded compound each day for work. In the morning buses line up and encircle the complex waiting their turn to enter the designated bus staging area (brass alley) for personnel pickup, a process that takes several hours (figure 9). At the end of the day, buses return to drop off their passengers. The buses run on diesel and because of the large number of buses the potential for compromising the outdoor air quality on busy cold winter mornings is high. For several hours every morning, buses are idling near the air intakes of the kitchen at Wapasu Creek West and Wapasu Creek East. Kitchen staff complain of dizziness, headaches and nausea especially in the mornings. Wapasu Creek East tends to have more problems with vehicle exhaust from the buses.

In addition, there are vehicle exhaust fumes from pickup trucks, especially in winter months when the vehicles are parked in the nearby parking lot and left to run all night or are parked for short periods of time while people come in to the Tim Horton's at Wapasu Creek Main. Vehicle exhaust from delivery trucks parked at the kitchen and laundry loading docks is also a concern due to their close proximity to the building's air intakes (figure 10).

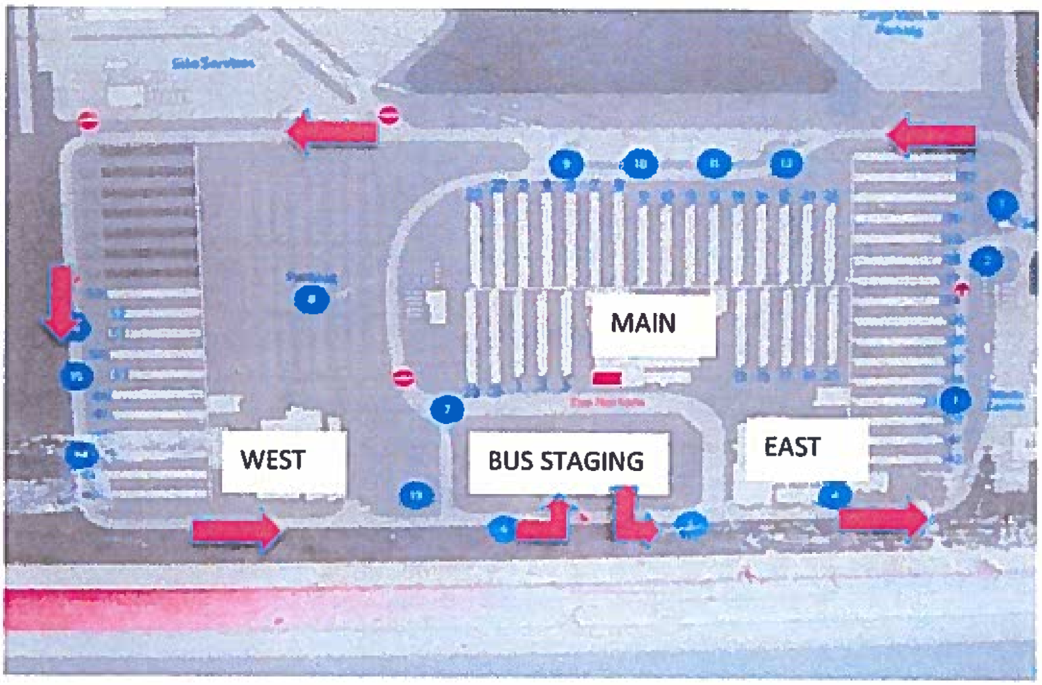


Fig. 9: Wapasu Creek West, Main and East showing bus staging area in the centre and bus traffic flow around.

Fig. 10: Delivery truck at kitchen loading dock with kitchen air intakes above.

4.3.1.3 Grading

The buildings are intended to be situated on a raised ground with gravel or sand base to accommodate groundwater drainage. Drainage is important because these factory manufactured housing units are constructed to be above grade with an unexcavated above-grade crawl space. If the crawl space is moist, then the foundation can be undermined and also create conditions for microbial propagation.

Article 5.6.2.2. of the Alberta Building Code, entitled Accumulation and Disposal, states:

1) Where water, snow or ice can accumulate on a *building*, provision shall be made to minimize the likelihood of hazardous conditions arising from such accumulation.
2) Where precipitation can accumulate on sloped or horizontal assemblies, provision shall be made for drainage conforming to the plumbing and drainage regulations made pursuant to the Safety Codes Act.

Article 5.7.1.1. of the Alberta Building Code, entitled Prevention of Accumulation and Ingress, states:

1) Except as provided in Sentence (3), the *building* shall be located, the *building* site shall be graded, or catch basins shall be installed so that surface water will not accumulate against the *building*.
2) Except as provided in Sentence (3), *foundation* walls shall be constructed so that surface water will not
   a) enter the *building*, or
   b) damage moisture-susceptible materials.

During our site examinations in August 2014 and March 2015, we noted that there are several locations where surface water is migrating into the crawl space (figures 11, 12 and 13). The channels in the ground in figure 12 are caused by water erosion as surface water runoff flows under the building. Some of the courtyard spaces between the wings are saturated with water causing mud to accumulate and the ponding of surface water to occur (figures 14 and 15). Attempted water management techniques include installing conduits through the crawl space to divert water toward another courtyard (figure 16). The saturated soil underneath the buildings will soften the soil and can undermine the foundation. The moisture can also cause microbial growth that can be drawn into the building from the crawl space through air intakes and penetrations through the floor of the units.

Figs. 11 & 12: Water migrating into the crawl space causes this ground erosion. Location: Henday.

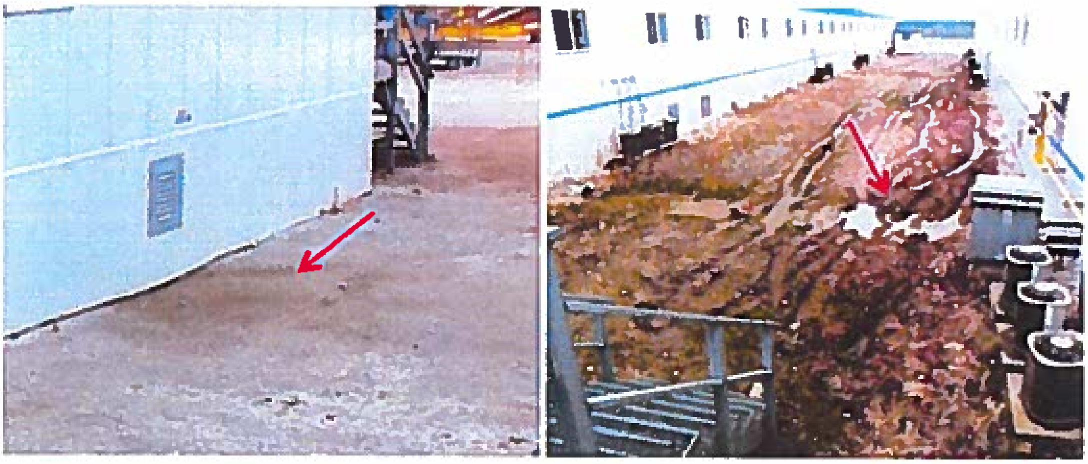
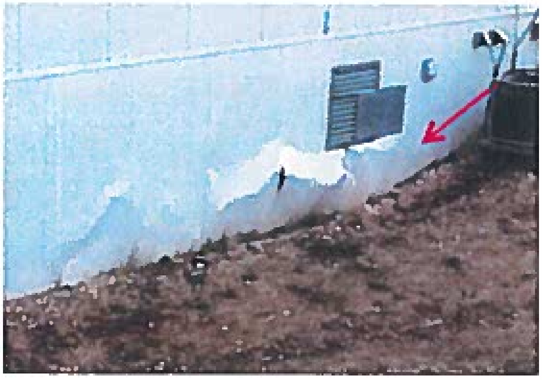


Fig. 13: Evidence of surface water runoff into the crawl space.
Fig. 14: Surface water is not draining away, but it migrating into the adjacent crawl space.

Fig. 15: Water accumulation near the building is a long-term problem as indicated by these cattails growing in a pond between wings at Wapasu Creek East.
Fig. 16: An attempt to manage the water accumulation is by letting surface water flow under the building through a culvert at Athabasca Lodge.

Inadequate skirting provides large gaps that allow rodents and other small animals to enter into the crawl space (figures 17 and 18). Evidence of feces deposits and damage to the insulation is due to these animals inhabiting the crawl spaces.



Figs. 17 & 18: Gaps in the foundation skirt allow animals to enter the crawl space.

Some crawl spaces are situated in a slight depression, which is lower than the surrounding grade. Furthermore, even when crawl spaces are situated on only a slight rise in grade, surface water can be directed toward the foundation due to ice damming and other impediments to proper dispersal of water. In some cases, water (or ice) accumulates against the foundation skirt (figure 19). It appears that attempts are made to temporarily prevent water from entering into the crawl space by building up snow against the foundation skirt. The snow will inevitably melt and flow into the crawl space. The negative grade slope toward the crawl space is in violation of article 9.14.1.2. of the Alberta Building Code, entitled Crawl Spaces, which states:

1) Drainage for crawl spaces shall conform to Section 9.18.

Section 9.18 is entitled Crawl Spaces. It discusses requirements for foundation, heating, access openings, ventilations, clearance, drainage and ground cover. Pertinent to our discussion here is article 9.18.5.1. of the Alberta Building Code, entitled Drainage, which states:

1) Except where it can be shown to be unnecessary, the ingress of water into a crawl space shall be controlled by grading or drainage.
2) Drainage of *foundation* walls shall conform to Article 9.14.2.1.
3) Drainage of the groundcover or floor-on-ground in the crawl space shall conform to Subsection 9.16.3.
4) Drains shall conform to Section 9.14.

Fig. 19: Surface drainage flows toward the building causes flooding the crawl space. Location: Wapasu Creek West.

4.3.2 Crawl Spaces

Viewing into the above-grade crawl spaces with some of the ventilation grilles open (figure 20) it is evident that they are flooded with water (figure 21). Furthermore, debris including organic material is left soaking in pools of water (figure 22). Insulation, which was not properly secured, is strewn throughout, perhaps by rodents or other animals that may occupy the crawl space (figure 23). Some of the debris has rotted and deteriorated such that it has become contaminated with mould. Standing water can also be a breeding ground for insects including mosquitoes.

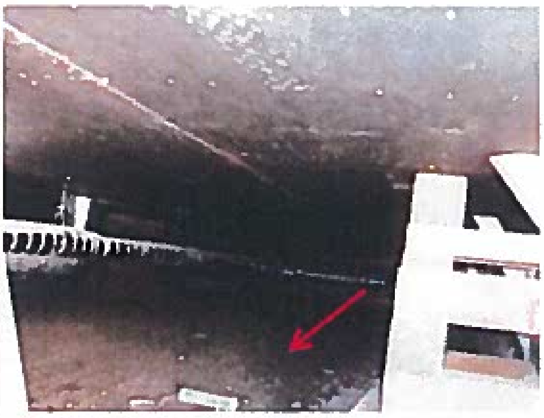


Fig. 20: Opening up some crawl space grilles at Wapasu Creek West to view inside.
Fig. 21: Mud on the ground inside the crawl space.

Fig. 22: Debris including insulation and wood are left inside this crawl space.
Fig. 23: This crawl space contains about 2" of standing surface water and ice.

There is no ground cover installed on the floor of these unheated crawl spaces. They are all simply dirt an gravel. Article 9.18.6.1 of the Alberta Building Code, entitled Ground Cover in Unheated Crawl Spaces, states the following:

1) Where a crawl space is unheated, a ground cover shall be provided consisting of not less than
    a) 50 mm of asphalt,
    b) 100 mm of 15MPa Portland cement concrete,
    c) Type S roll roofing, or
    d) 0.10 mm polyethylene.
2) Joints in sheet-type ground cover required in Sentence (1) shall be lapped not less than 100 mm and weighted down.

The crawl space under the kitchen at Wapasu Creek East (where mould remediation was in progress) revealed considerably more debris. In addition to insulation, there is discarded wood, paper, gypsum board and other materials throughout the crawl space we examined (figure 24). Of concern is that much of the organic debris is mouldy (figures 25 and 26). Mould spores can migrate up into the occupied areas through penetrations in the floor for ducting, plumbing and electrical services.



Fig. 24: Considerable amount of debris with some quite mouldy.
Fig. 25: Water saturated and mouldy debris in this crawl space.
Fig. 26: Debris including insulation and discarded wood pieces in crawl space.

In this crawl space, we noted that the ducting is not properly supported (figure 27). Electrical conduits are also not supported and they are dangling (figure 28). Article 9.33.4.1. of the Alberta Building Code, entitled Design of Heating and Air-conditioning Systems, states the following:

1) Heating and air-conditioning systems, including ducting, and mechanical heating and refrigeration equipment, shall be designed, constructed and installed to conform with good practice such as that described in
    a) the ASHRAE Handbooks and Standards,
    b) the HRAI Digest,
    c) the Hydronics Institute Manuals, and
    d) the SMACNA Manuals.

These standards and manuals specify the proper installation of ducting that includes support for ducts and electrical conduits.


Fig. 27: Ducting is not properly supported by the metal straps.
Fig. 28: Note the dangling conduit and the debris in this crawl space including mouldy wood.

Crawl spaces can be designed to be conditioned (heated) or to be unconditioned (vented). If the crawl space is to be heated, then the skirting must be insulated and no ventilation is required. However, if it is to be a vented cold space, then the insulation must be located in the ceiling of the crawl space, but is not required on the skirting.

Article 9.18.3.1. of the Alberta Buildings Code, entitled <u>Ventilation of Unheated Crawl Spaces</u>, states the following:

1) Unheated crawl spaces shall be ventilated by natural or mechanical means.
2) Where an unheated crawl space is ventilated by natural means, ventilation shall be provided to the outside air by not less than 0.1 m^2 of unobstructed vent area for every 50 m^2 of *floor area*.
3) Vents shall be
    a) uniformly distributed on opposite sides of the *building*, and
    b) designed to prevent the entry of snow, rain and insects.

All of the cold crawl spaces at Wapasu are vented with grilles. However, inexplicably, some of the skirting is insulated. The insulation on the skirting wall does not serve any purpose. Only the ceiling of the crawl space must be insulated as is the case in all of the buildings that we examined. Some of the wall insulation has fallen off due to inadequate support (figure 29). Wherever insulation is required, a vapour barrier is needed to prevent condensation in accordance to the building code.

Fig. 29: Insulation falling off the crawl space walls.

The importance of venting the crawl space is discussed in the appendix of the Alberta Building Code article A-6.2.2.7.(1), entitled Ventilation and Venting of Crawl Spaces and Attic or Roof Spaces, which states the following:

> The cross-reference to Part 5 pertains to unconditioned and unoccupied crawl spaces, and attic or roof spaces, which are effectively within the building envelope. Unconditioned and unoccupied crawl spaces are located between the ground cover below and the insulation, air barrier system and vapour barrier above. Venting of these spaces has implications for the performance of the building envelope rather than having direct effects on indoor conditions. The ventilation of conditioned or occupied crawl spaces and attic or roof spaces must comply with Part 6.
>
> The requirements in Part 5 are stated in terms of loads that must be resisted rather than in terms of building elements. Thus, the Code user will not find explicit references in Part 5 to crawl spaces, or attic or roof spaces. Part 5 makes reference to the need for venting environmental separators, i.e., the dissipation of heat or moisture.
>
> Sentence A-6.2.2.7.(1) requires that crawl spaces be ventilated either by natural (above-grade only) or mechanical means. High moisture levels within the crawl space can lead to problems such as the formation of mould, lifting of flooring or long-term damage to structural components.
>
> Crawl space ventilation cannot be expected to correct moisture-related problems caused by other factors like inadequate surface drainage from the foundation walls or improper protection against moisture from the ground. These conditions must be properly addressed so that crawl space ventilation can meet its intended objectives.
>
> Several factors favour the use of mechanical ventilation rather than reliance on natural drafts. Local conditions, such as areas with high water tables, may dictate the need for mechanical ventilation to remove excessive moisture.

Crawl spaces should be maintained at a negative pressure relative to the conditioned area above to prevent the migration of moisture into occupied areas. This can be achieved through the use of an exhaust fan and relying on air transfer through floor penetrations, such as pipes.

As noted earlier, the crawl spaces of these buildings do not have any ground cover. The building code warns about high moisture in these crawl spaces that can cause mould growth, lifting of the structure and damage to the structure.

Venting of the crawl spaces cannot be expected to correct moisture laden problems such as inadequate drainage as found in these buildings. The code recommends negative air pressure and the use of exhaust fans to prevent the moisture-laden air in the crawl spaces from migrating into the occupied spaces above through openings caused by penetrations such as pipes.

As noted above, article 5.7.1.1. of the Alberta Building Code, entitled Prevention of Accumulation and Ingress, states:

1) Except as provided in Sentence (3), the *building* shall be located, the *building* site shall be graded, or catch basins shall be installed so that surface water will not accumulate against the *building*.
2) Except as provided in Sentence (3), *foundation* walls shall be constructed so that surface water will not
    a) enter the *building*, or
    b) damage moisture-susceptible materials.

Steel columns are sitting on water puddles in these crawl spaces (figure 30). With freeze-thaw cycles and wet-dry cycles, the column at grade will deteriorate. The water will also compromise the soil bearing capacity underneath these columns resulting in building settlement and leaks.

Fig. 30: Surface water has migrated into this crawl space as seen around the steel columns.

Since these are all vented crawl spaces, the vents must be clear to allow airflow for moisture control. However, some of the vents are covered by snowdrift (figures 31 and 32) or from shovelling snow against the wall. Some of the grilles are partially blocked by snow (figure 33). Since blocked vents do not comply with the ventilation requirements, it is the responsibility of the building owners to ensure that these vents are not blocked. Consequences of blocked crawl space vents include higher humidity and the risk of mould growth. Considering that at the time of our examination spring thaw had melted most of the snow that would typically be in this area, it is likely that several more of these vents are blocked throughout the winter when crawl space ventilation is crucial.

Figs. 31 & 32: Crawl space vents are blocked by snowdrift.

Fig. 33: This air intake grille is partly covered with snow.

4.3.3 Building Envelope

4.3.3.1 Exterior Cladding

Some of the crawl space vents are damaged (figure 34) and require repair or replacement. The damaged skirting exposes untreated wood materials that are susceptible to moisture damage, especially when rainwater migrating down the wall above is directed behind the damaged skirting. Other ventilation grilles have separated from the skirting (figure 35) and simply need to be re-installed.


Figs. 34 & 35: These crawl space vents are damaged and require servicing.

The skirting of these units is installed to prevent animals from nesting inside the crawl space. This skirting must withstand weathering and thus durable weather-resistant materials are used. There are several locations where OSB wood is exposed to the elements. OSB wood cannot withstand weathering for any length of time and therefore should not be exposed (figure 36).

Fig. 36: Exposed OSB wood for the skirting will rot and is not an effective barrier to rodents.

Unprotected wood cannot be placed next to soil as it will wick up moisture and cause rot. The building code stipulates that wood must not be placed closer than 200 mm above grade. Article, 9.27.2.4.1 of the Alberta Building Code, entitled Protection of Cladding from Moisture, states:

> A clearance of not less than 200 mm shall be provided between finished ground and cladding that is adversely affected by moisture, such as untreated wood, plywood, OSB, waferboard and hardboard.

Any wood exposed or in contact with soil must be treated with preservatives. Article 4.2.3.2. of the Alberta Building Code, entitled Preservation Treatment of Wood, states:

1) Wood exposed to *soil* or air above the lowest anticipated *groundwater* table shall be treated with preservative in conformance with CSA O80 Series, "Wood Preservation," and the requirements of the appropriate commodity standard as follows:
    a) CSA O80.2, "Preservative Treatment of Lumber, Timber, Bridge Ties, and Mine Ties by Pressure Processes,"
    b) CSA O80.3, "Preservative Treatment of Piles by Pressure Processes," or
    c) CSA O80.15, "Preservative Treatment of Wood for Building Foundation Systems, Basements, and Crawl Spaces by Pressure Processes."
2) Where timber has been treated as required in Sentence (1), it shall be cared for as provided in AWPA-M4, "Care of Preservative-Treated Wood Products," as revised by Clause 6 of CSA O80 Series, "Wood Preservation."

There are several lengths of the skirting around the kitchen (figure 37) and corridors that have exposed and untreated OBS boards. The untreated wood is in direct contact with the ground and snow. The exposed wood is also at the floor header where water has severely rotted the wood framing (figure 38). This deterioration can compromise the structural properties of the wood framing, the insulation and cause mould growth.


Fig. 37: Entire length of this skirting around the kitchen has exposed untreated OSB wood.
Fig. 38: Water has rotted this OSB skirting and wood framing and can support mould growth.

There is a large OSB wood panel that is covering a portion of the exterior wall of the kitchen. Without a coating or cladding, the wood panel has been exposed to water for some time and the wood is flaking off. Water continues to migrate down the wood panel (figure 39). There is no flashing above the wood panel nor is there sheathing membrane over the OSB to prevent water from migrating behind the panel and into the wall assembly. The water may have caused damage inside the wall assembly. Flashing is required to be installed at every horizontal junction of exterior cladding. Article 5.6.2.2.4) of the Alberta Building Code, entitled Accumulation and Disposal, states the following:

> Junctions between vertical assemblies, and sloped or horizontal assemblies, shall be designed and constructed to minimize the flow of water from the sloped or horizontal assembly onto the vertical assembly.

Fig. 39: This OSB is wet and water damaged, allowing water to seep into the wall assembly.

All cladding of buildings must use materials that can withstand deterioration. Article, 9.3.2.9. of the Alberta Building Code, entitled Termite and Decay Protection, states:

5) Where wood is required by this Article to be treated to resist termites or decay, such treatment shall be in accordance with the requirements of
   a) CSA O80.1, "Preservative Treatment of All Timber Products by Pressure Processes,"
   b) CSA O80.2, "Preservative Treatment of Lumber, Timber, Bridge Ties, and Mine Ties by Pressure Processes,"
   c) CSA O80.9, "Preservative Treatment of Plywood by Pressure Processes,"
   d) CSA O80.15, "Preservative Treatment of Wood for Building Foundation Systems, Basements, and Crawl Spaces by Pressure Processes," or
   e) CSA O80.34, "Pressure Preservative Treatment of Lumber and Timbers with Borates for Use Out of Ground Contact and Continuously Protected from Liquid Water."

7) Wood that is required by this Article to be treated to resist termites or decay shall be identified by a mark to indicate its conformance to the relevant required standard.

4.3.3.2 Flashings

There are many locations with missing flashings and with penetrations that expose wood to weathering. Improperly installed or damaged corners expose the wood structure (figure 40). Poorly installed pipe supports penetrate the cladding and are not repaired (figure 41). Article 9.27.3.8. of the Alberta Building Code, entitled Flashing Installation, states:

1) Except as provided in Sentence (2), flashing shall be installed at
   a) every horizontal junction between cladding elements,
   b) every horizontal offset in the cladding, and
   c) every horizontal line where the cladding substrates change and where
      i) the substrates differ sufficiently for stresses to be concentrated along that line, or
      ii) the installation of the cladding on the lower substrate may compromise the drainage of moisture from behind the cladding above.

Fig. 40: This damaged corner exposes the wood to weathering.
Fig. 41: Improper pipe support installation exposes the wood to weathering.

Flashing is required and must be installed according to Alberta Building Code. There is head flashing above the window but it is simply caulked to the metal siding (figure 42). This is not the proper installation for flashing. The flashing must be inserted upward behind the metal siding to properly shed water away.

The Alberta Building Code requires that flashing must extend by not less than 10 mm over the front edge of the finished exterior wall and must include an end dam. Article 9.27.3.8.4 of the Alberta Building Code, entitled Flashing Installation, states:

d) lap not less than 10 mm vertically over the *building* element below, and