EMISSION SUMMARY AND DISPERSION MODELLING REPORT

Interior Heart and Surgical Centre Project (IHSC)

Kelowna General Hospital

Kelowna, British Columbia

Prepared for
PCL Constructors Westcoast Inc.

Report No. 11837exhaust **December, 2011**

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Executive Summary

Theakston Environmental has completed Microclimatic Analysis for the proposed Interior Heart and Surgical Centre and submits the proposed Laboratory Fume Hood Exhausts, Boiler Exhausts, Hot Water Heating Exhaust, and Emergency Diesel Generator Exhausts meet the recommended criteria for such installations.

Table 1 summarizes the source information, Table 2 summarizes potential volatile chemical emissions, and Table 3 summarizes the aggregate emissions for the NO_X sources.

AERMOD and ASHRAE analysis indicated the highest observed concentration from Laboratory Fume Hood exhausts, based upon a unit emission rate of 1*g/s,* was 844ug/m^3 and occurred at one of the Royal Building's fresh air intakes (Figure 6). This is a good result, as indicated in the chemical list (Table 2). Nonetheless, user controls may be required in instances where significant quantities of hazardous chemicals are to be used (as per protocol suggested in Table 2).

With respect to aggregate NO_X, the worst-case maximum aggregate NO_X concentrations, when exercising one emergency diesel generator in concert with operating the five boilers and one hot water heater at full capacity, were processed with AERMOD and the results are depicted in Figures 10 and 11. The highest POI concentration when modelled with AERMOD was 461ug/m^3 occurring at private residences, to the north of the proposed Centennial Building (Figure 11), well within the recommended limit for short term, non-sensitive receptors. The maximum concentration at a sensitive receptor was 417ug/m^3, occurring at the Royal Building's fresh air intake, situated to the northwest of the exhaust system (Figure 10). This concentration is within the recommended, very conservative, limit.

With respect to the EMS helicopters, which will be accessing a landing pad located at the north end of the roof of the Centennial Building, exhaust emissions resulting from take-off were assessed at the proposed Interior Heart and Surgical Centre. The Maximum NO_X concentration anticipated at the proposed IHSC is 409ug/m^3, occurring at the north face of the building. It should be noted that; *i)* the proposed IHSC fresh air intakes are located as far as reasonably possible from the aforementioned north face of the building, and *ii)* winds required to carry helicopter exhaust toward the proposed IHSC are infrequent. None-the-less, exhaust concentrations realized at the proposed will vary with the helicopter's flight path, and may result in concentrations higher than those listed, on occasion. It would be reasonable to expect people at the pedestrian level and in the hospital will be subject to fumes from the helicopter from time to time, however, the predicted concentrations are within the recommended criteria.

We submit the Laboratory Fume Hood Exhausts, Boiler Exhausts, Hot Water Heater Exhausts and Emergency Diesel Generator Exhausts meet the suggested criteria, as detailed in the attached. We trust you will find everything in order and welcome your questions or comments.

1. INTRODUCTION

Theakston Environmental, Consulting Engineers, Fergus, Ontario, were retained by PCL Constructors Westcoast Inc., Richmond, British Columbia to study by numerical analysis the proposed Interior Heart and Surgical Centre (IHSC) Project, situated on the east side of the existing Kelowna General Hospital. The retainer applies to analysis for exhaust gas dispersion, and to report on the anticipated impact the proposed exhaust gas emissions will have upon the subject building and immediate surrounds. Further, the Consultants were to make recommendations for mitigation deemed necessary. Ms. Patti Salary, of PCL Constructors Westcoast Inc., Richmond, British Columbia provided drawings. The co-operation and interest of the Client and their sponsors in all aspects of this study is gratefully acknowledged.

The specific objective of the study is to assess pollutant dispersion patterns for the volatile chemicals, boilers, and emergency diesel generators proposed for the Proposed Interior Heart and Surgical Centre. This was accomplished through analysis of numerical models that were developed to reflect the proposed IHSC site and pertinent surroundings. The results were analysed in preliminary design stage, and recommendations incorporated into the final design stage to ensure safe environmental conditions exist within the subject and surrounding buildings and at pedestrian levels. Variables such as stack height, location, exit velocity and potential exhaust gas toxicity were considered in analysis of the exhaust sources and recommendations were made in the event an exhaust system or systems should fail to perform as required.

The laboratory techniques and model analyses used in these Studies by the Consultants are recognized throughout the World for their practical and economical results. The main objectives of the analysis are:

1. To establish contacts with Technical representatives knowledgeable of the site and building processes.

2. To determine emission rates at the stack exits for the various exhaust gasses that are to be discharged from the proposed IHSC and any buildings of interest in the immediate surround.

3. To use a number of modelling techniques/models including the ASHRAE self-contamination model and AERMOD-PRIME, a recent upgrade to the Industrial Source Complex – Short Term Model (ISCST3) outlined by the U.S. Environmental Protection Agency, to determine the concentration of contaminants at the pedestrian level and critical points of impingement (POI).

4. To determine if the contaminant concentrations comply with the recommended guidelines. If problematic contaminant concentrations occurred, recommendations were made to control their release into the environment.

5. To publish a Consultant's report documenting the findings and recommendations.

We submit the proposed dispersion patterns for the volatile chemicals, boilers, and emergency diesel generators will meet current criteria.

2. FACILITY DESCRIPTION

The proposed Interior Heart and Surgical Centre is a four storey hospital building with the primary vehicular access from Pandosy Street. The bulk of the immediate area surrounding the proposed site consists of low to mid-rise residential and commercial buildings to the east and Okanagan Lake to the west, with mountainous terrain in the more distant surroundings. Figures 1 and 2 depict the site and its surrounds.

The proposed Interior Heart and Surgical Centre is located on the southeast corner of the existing Kelowna General Hospital with the Strathcona Building to the west and the proposed Centennial Building to the north. The fume hood exhausts, boilers, and hot water heaters are located at the north end of the building, while the generators are located at the south end of the building. Figure 3 depicts exhaust sources and critical Point of Impingement (POI) receptors considered in the analysis.

3. NUMERICAL DISPERSION MODELLING

The latest versions of the US EPA air dispersion models, ISC-PRIME and AERMOD-PRIME were used in this analysis. Lakes Environmental wrote a software package that pre and post processes input and output data for the AERMOD-PRIME model. This package was used in the preparation of this submittal, and the version used is titled, ISC-AERMOD View Version 7.1 Interface for the US EPA models. This package works with both ISC-PRIME and AERMOD-PRIME models. The ASHRAE self-contamination model (Appendix A) was used to determine concentrations close to the source release point (AERMOD-PRIME is not always intended to analyse self-contamination).

4. SOURCE SUMMARY

Table 1 summarizes the exhaust sources in terms of stack height, diameter, exit velocity, exhaust flow and exhaust temperature.

4.1. Fume Hood Exhaust Sources

4.1.1. Description and Source Data

The proposed fume hood exhaust sources are comprised of:

- Two (2) – Laboratory fume hood exhaust systems venting through 0.15m diameter exhaust stacks, at a velocity of 25.9m/s, to atmosphere, as depicted in Table 1 and Figure 3.

Each system discharges exhaust at a height that is above the immediate surrounds. Discharge elevation, when combined with high exit velocity, leads to favourable exhaust dispersion characteristics under most circumstances.

Fume Hood Exhaust System Design:

In hospitals, such as the proposed Interior Heart and Surgical Centre, work is carried out with a variety of chemicals, some of which may be carcinogenic, toxic, noxious, corrosive and/or odoriferous. Typically, the chemicals are used in specially designed fume hoods that dilute and exhaust the vapours. These exhaust systems must be designed to ensure that the resulting emissions do not re-enter the subject building or other buildings. In addition, the worst-case emissions must be within acceptable concentrations at operable windows, doors, air intakes and all locations with public access. These exhaust gasses and combustion vapours are discharged into the environment from free standing or roof-mounted stacks.

4.1.2. Fume Hood Emission Scenario

The emission rates from fume hoods and process exhaust are determined from anticipated chemical usage. Typically, the maximum emission rates are calculated based on an accident condition such as a broken or spilled container. For this study, the spill is assumed to cover the entire working surface of the fume hood, or that equivalent area in a room. In addition, it is assumed that only one spill occurs at any given time. This assumption is conservative since discussions with lab personnel from numerous facilities indicate that the frequency of accidental spills covering the entire fume hood floor is less than once a year.

4.1.3. Emission Rate Estimation

In the case of a spill in a fume hood, the emission rate of the chemical is determined from the evaporation rate from the chemical pool that is calculated using principles of convective mass transfer. The process is driven by the vapour pressure of the chemical, evaluated at the surface temperature of the chemical pool and the concentration of the chemical in the pool. This is a function of evaporative cooling, direct heat transfer between the chemical pool and airstream, and direct heat transfer between the chemical pool and fume hood table surface.

Mass transfer by convection from the chemical pool to the exhaust airstream occurs by way of molecular diffusion and bulk fluid motion. In a fume hood, the airstream in the region adjacent to the table is laminar, with typical velocities in the order of 0.5*m/s*, which is consistent with these types of fume hoods. Typical mass transfer problems are solved with empirical correlations relating the mass transfer flux to the density gradient across the concentration boundary layer.

4.2. NO_X Exhaust Sources

4.2.1. Description and Source Data

Most pollutants from diesel engines are emitted through the exhaust stack at temperatures considerably higher than ambient. Small amounts of total organic compounds (TOC) will escape from the crankcase due to blowby, and fuel evaporation from the fuel tank and related equipment. These losses are minor and nearly all of the TOC's are emitted through the stack. The primary pollutants from an internal combustion engine are NO_X, CO_2, CO, SO_X, unburned hydrocarbons (HC) and particulate matter (PM). In general, when the above emission rates are compared with the relevant standards, NO_X emissions ultimately control the emission scenario. Therefore, the NO_X emission rates for the boilers and diesel generators will be used in the calculations.

Guidelines for NO_X are typically written in terms of NO_2 (the maximum allowable NO_2, based on an hourly averaging time, is generally near 400*ug/m*^{3}). To convert this NO_2 limit to a NO_X limit, there are several approaches. The Ambient Ratio Method is a very sophisticated method and requires at least one year of NO_X and NO_2 data in the air shed. A simpler conversion method is proposed by the USEPA - Screen 3 modelling guide, which suggests assuming an NO_2/NO_X ratio of 0.75 (resulting in a NO_X limit of 533*ug/m*^{3} based on an NO_2 limit of 400*ug/m*^{3}). This corresponds well with the Ontario MOE NO_X limit of 500*ug/m*^{3} (1/2 hour averaging period) which is the equivalent of employing the Total Conversion Method (assuming all NO_X is converted to NO_2). With this in mind, Theakston has adopted a conservative 500*ug/m*^{3} NO_X limit for long term exposures and for sensitive receptors, such as hospitals, (which is the equivalent of 420*ug/m*^{3} when converted to a one hour averaging period). Typically, there is no limit for NO_X in an emergency situation. Further, Theakston has adopted a conservative limit 1,550*ug/m*^{3} NO_X limit for short term exposures at non-sensitive receptors.

Ambient Air Quality Guidelines for NO_2 concentrations are generally based on odour perception, and most people are likely to detect an odour at concentrations below levels that affect human health. Aldehydes are a secondary pollutant in diesel exhaust and are responsible for the readily recognizable odour and can be sensed with NO_2 concentrations below 100ug*/m*^{3}, by some individuals. As such, the aldehyde component of diesel exhaust is perceptible long before NO_2 becomes a health hazard and it is likely that there will be occasions of objectionable odour in the vicinity of the generators, at least to people with sensitive noses.

4.2.2. Boiler and Hot Water Heater Emission Scenario

The proposed boilers and hot water heater exhaust sources are comprised of:

- Condensing Boilers totalling 15MMBtu/h.
- Steam Boilers totalling 15MMBtu/h.

These sources are exhausting from near the north end of the proposed building.

4.2.3. Diesel Emission Scenario

Diesel emissions result from generator exercising, and maintenance operations, as well as emergency use. The current drawings indicate two diesel generators exhausting from the south end of the proposed building (Stacks 9 and 10 – Figure 3). The 1,500*kW* generators have 0.48*m* diameter stacks and, with the engines loaded, exhaust flow exiting at approximately 31.8*m/s*. The stacks are proposed to discharge at an elevation of 27.6*m* above grade, approximately 9.1*m* above the adjacent roof elevation. Since the generators will be exercised individually, the maximum emission occurs with one generator operating at full capacity, in concert with all the boilers and hot water heater also at full capacity.

4.2.4. Helicopters

The helicopter landing pad is located approximately 100m north of the IHSC, on the roof of the neighbouring Centennial Building. The emissions were assumed to come from a Bell Helicopter Emergency Medical Service (EMS) unit operating at take-off power, one of the larger EMS helicopters which has a maximum operating horsepower of 653 (used during take-off), while consuming 367lbs of fuel per hour. Under this take-off circumstance, NO_X will be emitted at a rate of 2.6lbs/hr. The emissions were measured in accordance with the Society of Automotive Engineers, Aeronautical Recommended Practices, Number 1179A and 1256A, and were provided to Theakston Environmental by the staff of Bell Helicopter.

5. MODELLING RESULTS

5.2.1 General

The concentrations at the selected POI and at the ground level were calculated using AERMOD-PRIME. The various emission scenarios and input parameters have been summarized in the previous sections. Figure 6 depicts the concentration at points of impingement (POI) such as air intakes on neighbouring buildings while Figure 7 depicts the ground level concentrations on the hospital grounds and in the nearby surroundings. Figures 8 and 9 depict NO_X concentrations at the selected POI and ground level concentrations resulting from boiler operation when a generator ***is not*** being exercised, while Figures 10 and 11 depict NO_X concentrations at the selected POI and ground level concentrations when a generator ***is*** being exercised.

As discussed in Section 3, POI that were located on the same building as the exhaust stacks (or too near for AERMOD to model effectively) were analysed using the ASHRAE Self-Contamination Model. The worst-case result for self-contamination is presented within Figure 8 with details in Appendix A.

5.2.2 Fume Hood Exhaust Source

The exhaust source summary is listed in Table 1 and the concentration results from AERMOD in Figures 6 and 7. Figure 6 depicts the fume hood exhaust system's behaviour at the various points of impingement (POI) and demonstrates that the maximum concentration observed from the lab exhaust was 844ug/m^3 occurring at the Royal Building's fresh air intake, situated to the northwest of the exhaust system. The worst-case for ground level concentrations is 778*ug/m*^{3}, occurring on the ground near the southwest corner of the Royal Building (Figure 7). The controlling concentration for the fume hood exhaust system is, therefore, 844*ug/m*^{3}.

The controlling POI concentration value was multiplied by 1.3 to account for the average error in the emission rate analysis (contained in Appendix B), yielding 1,097*ug/m*^{3}. Table 2 lists the concentrations observed at the controlling POI receptor for each of the chemicals listed as well as providing recommended levels of caution required for each chemical. The levels of caution range from none required, to working over a pan to limit potential spill area, to administrative controls, such as not permitting use of that chemical, or experienced personnel working with extreme caution.

5.2.3 NO_X Exhaust Sources

The worst-case maximum aggregate NO_X concentrations, without considering emergency diesel generator testing, were processed with AERMOD and the results are depicted in Figures 8 and 9. The maximum emission scenario is considered to be with five boilers and one hot water heater operating at 100%.

The highest POI concentration when modelled with AERMOD was 119*ug/m*^{3} occurring at the Royal Building's fresh air intake, situated to the northwest of the exhaust system (Figure 8). The maximum ground level concentration in this scenario was 94*ug/m*^{3}, occurring on the north of the Centennial Building (Figure 9). The ASHRAE self-contamination model calculated that with winds from the west by northwest quadrant, acting on the Hot Water Heater Exhaust, which is the worst-case for self-contamination, the NO_X concentration at the nearest intake to the southeast, could be as high as 410*ug/m*^{3} (Figure 8 and Appendix A). These concentrations are within the recommended limit of 420*ug/m*^{3} (based on a one hour averaging time – 500*ug/m*^{3} based on a 1/2 hour averaging time).

The worst-case maximum aggregate NO_X concentrations, when exercising one emergency diesel generator in concert with operating the five boilers and one hot water heater at full capacity, were processed with AERMOD and the results are depicted in Figures 10 and 11. The highest POI concentration when modelled with AERMOD was 461*ug/m*^{3} occurring at private residences, to the north of the proposed Centennial Building (Figure 11), well within the recommended limit for short term, non-sensitive receptors. The maximum concentration at a sensitive receptor was 417*ug/m*^{3}, occurring at the Royal Building's fresh air intake, situated to the northwest of the exhaust system (Figure 10). This concentration is within the recommended, very conservative, limit.

Helicopters

Helicopters accessing a landing pad located at the north end of the roof of the Centennial Building, under take-off conditions, the maximum NO_X concentration anticipated is 409*ug/m*^{3} occurring at the north face of the proposed Interior Heart and Surgical Centre. It should be noted that; *i)* the proposed IHSC fresh air intakes are located as far as reasonably possible from the aforementioned north face of the building, and *ii)* winds required to carry helicopter exhaust toward the proposed IHSC are infrequent as indicated in the Annual Wind Rose for Kelowna, (Figure 5). None-the-less, exhaust concentrations realized at the proposed will vary with the helicopter's flight path, and may result in concentrations higher than those listed, on occasion. It would be reasonable to expect people at the pedestrian level and in the hospital will be subject to fumes from the helicopter from time to time, however, the predicted concentrations are within the recommended criteria.

6. CONCLUSIONS AND RECOMMENDATIONS

With regard to the Laboratory Fume Hood Exhausts, the worst-case concentration was predicted at 844ug/m^3 impacting the Royal Building's fresh air intake, situated to the northwest of the exhaust system (Figure 6). The proposed fume hood exhaust systems have been analysed for 421 chemicals (Table 2) commonly used in hospitals, universities, and research facilities, 385 of which have known exposure limits.

The results suggest that 280 of 385 volatile chemicals common to hospitals and universities, with known exposure limits, require no restrictions. This is based on the assumption that the spill is sufficient in quantity to cover the floor of the fume hood and that the resulting emission at the controlling Point of Impingement is within criterion. There were another 56 chemicals listed that could safely be used if a pan limited the spill area. Table 2 depicts these results.

With respect to aggregate NO_X, exercising generators individually, in conjunction with all the boilers and the hot water heater, meets the suggested guideline (420ug/m^3 – based on a one hour averaging time – 500ug/m^3 based on a 1/2 hour averaging time). Table 3 summarizes the expected annual NO_X production. It should be noted that this result remains valid when NO_X sources from the proposed Centennial Building are included in the aggregate NO_X analysis.

The EMS helicopter departing from the pad located at the north end of the roof of the Centennial Building was modelled operating at take-off power of 653 horsepower. The maximum NO_X concentration anticipated at the IHSC is 409ug/m^3 occurring at the north face of the building. It should be noted that; *i)* the proposed IHSC fresh air intakes are located as far as reasonably possible from the aforementioned north face of the building, and *ii)* winds required to carry helicopter exhaust toward the proposed IHSC are infrequent. None-the-less, exhaust concentrations realized at the proposed will vary with the helicopter's flight path, and may result in concentrations higher than those listed, on occasion. It would be reasonable to expect people at the pedestrian level and in the hospital will be subject to fumes from the helicopter from time to time, however, the predicted concentrations are within the recommended criteria.

We submit the Laboratory Fume Hood Exhausts, Boiler Exhausts, Hot Water Heater Exhausts and Emergency Diesel Generator Exhausts meet the suggested criteria, as detailed in the attached. We trust you will find everything in order and welcome your questions or comments.