28 June 2010
AMEC File: VE52003

VIA EMAIL AND POST

District of Maple Ridge
11995 Haney Place
Maple Ridge, BC
V2X 6A9

Attention: Steve Traviss

Dear Mr. Traviss,

Reference: Endotoxin Exposure Assessment

1.0 INTRODUCTION

Further to your request, AMEC Earth and Environmental, a division of AMEC Americas Limited (AMEC), conducted an exposure assessment of endotoxin for the District of Maple Ridge (Maple Ridge). The exposure assessment for endotoxin involved a site meeting to observe specific cleaning tasks relating to potential endotoxin exposure (inside the 225th Street Sewer Lift Station, Maple Ridge, BC) and a review of existing literature research.

The purpose of the endotoxin exposure assessment was to provide information to Maple Ridge of workers' exposure to endotoxin and if required, recommendations of controls to reduce potential exposures.

2.0 SCOPE OF SERVICES

The scope of services in this project included:

- Meeting with Maple Ridge on 31 May 2010 at the 225th Street Sewer Lift Station to observe cleaning tasks associated with potential endotoxin exposure (washing the inside well walls);
- Reviewing literature pertaining to endotoxin exposures and current exposure control guidelines (e.g., guidelines developed by the Health Council of The Netherlands) to assist in obtaining relevant data, especially for work tasks similar to washing sewer lift station walls/similar environments; and
- Preparing a written endotoxin exposure assessment relating to worker exposures at the 225th Street Sewer Lift Station.

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3.0 BACKGROUND

Endotoxin is a lipopolysaccharide (LPS) that forms the outer cell wall of gram-negative bacteria - bacteria can be classified as either gram-positive or gram-negative bacteria according to the biochemistry of the cell wall (*The Occupational Environment: Its Evaluation, Control and Management,* AIHA, 2003). Gram negative bacteria have much thinner cell walls bonded to lipoproteins in the outer membrane and it is the LPS in the outer membrane that are the active constituents of endotoxin (Bartlett, *et al*., 2004).

Health effects from inhaling endotoxin includes fatigue, mucosal irritation, malaise, cough, chest tightness and acute airflow obstruction – low level exposures may be associated with asthma and other symptoms resembling sick building syndrome (Bartlett, *et al*., 2004). Endotoxin is capable of triggering a strong inflammatory response in most mammals including humans and this inflammatory response is responsible for symptoms of ill health, and may result in permanent tissue damage in cases of high, or repeated, exposure (Bartlett, *et al*., 2004). High levels of exposure to endotoxin are capable of provoking a weak immunogenic reaction, producing fever (pyrogenic), shock, inducing weakness, diarrhea, inflammation, and intestinal hemorrhage (Bartlett, *et al*., 2004).

Gram-negative bacteria and accompanied endotoxin are ubiquitous in the environment; in sewage treatment plants, wastewater contains pathogenic gram-negative bacteria from humans and animals which can become aerosolized (Oppliger, *et al*., 2004)). Inhalation is thought to be the most important route of entotoxin exposure, e.g. after aerosol formation, although contact with raw sewage or sludge might also play a role (Spaan *et al*., 2008). An increased prevalence of airway, flu-like, gastrointestinal and neurological symptoms and joint pain has been observed in sewage workers and in several studies endotoxin exposure has been suggested as the most probable cause of these symptoms (Spaan *et al*., 2008). Work tasks that agitate wastewater, such as cleaning sewer lift station walls (with pressurized water sprays) can increase the levels of airborne endotoxin and the potential for worker exposure to endotoxin.

4.0 SEWER LIFT STATION OBSERVATIONS

During the site visit on 31 May 2010, a Maple Ridge worker was observed cleaning the walls of the wet well inside the 225th Street Sewer Lift Station. The sewer lift station contained stairs that led down (below grade) to a wet chamber and an adjacent wet well – a concrete walk-way platform was situated on top of the wet well and was approximately 5 metres in height above the bottom of the well. To perform the cleaning the worker stood on the walk-way and sprayed water with a pressurized water hose (approximately 100 psi and at a distance of 4 to 8 metres away) to remove the build-up of sewage material on the walls. It was made known to AMEC that the volume of sewage in the well varies and generally exists at a maximum of approximately 2 to 3 metres below the level of the walk-way; the sewage also originates from a mix of residential and commercial sources (mostly residential). Photographs of the cleaning task are presented in Appendix A Photographs.

Two high velocity, positive pressure fresh air ventilation systems were present inside the sewer lift station – one exhaust was located on the ceiling of the west side of the wet well (the fan was located outside at grade level) and the other exhaust was located in the wet chamber east of the wet well and on the ceiling below the stairs (the fan was located on the exterior roof of the sewer lift station). The general air current inside the wet well travelled from a west to east direction and exited out of the building through the open door at the top of the stairs. However, as air was exhausted in a vertical direction towards the floor, air entering the wet well was observed to circulate and mix, thereby creating a slight turbulence before travelling in a general direction from west to east and exiting out of the building. Although no measurements of air flow or velocity were conducted, the air current and direction of travel inside the wet well was observed by holding tissue paper in various spots and holding a smoke tube.
It was made known to AMEC that the worker responsible for cleaning the walls of the wet well inside the sewer lift station conducts the task approximately 2 hours every week. In addition to engineering controls (fresh air ventilation systems) and administrative controls (cleaning task occurs approximately two hours per week), the worker was observed to be wearing personal protective equipment (PPE) consisting of gloves and safety boots.

5.0 LITERATURE REVIEW

5.1 Exposure Limits

The common units used to describe endotoxin concentration, endotoxin units (EU), is equivalent to 0.1 nanograms (ng) of endotoxin (10 EU: 1 ng); EU's are standardized as the reaction of *Limulus* amoebocyte lysate to a reference *E. coli* endotoxin (Bartlett, *et al*., 2004).

Currently, no exposure limit for endotoxin exists in the British Columbia Occupational Health and Safety Regulation (OHSR), Part 5 Guidelines, Table of Exposure Limits for Chemical and Biological Substances (October 2009); globally however, a number of guidelines exist concerning endotoxin exposure. The current European exposure limit for endotoxin is 200 EU/m^3 while a proposed occupational exposure limit of 50 EU/m^3 recommended by the Health Council of The Netherlands (Smit *et al*., 2005) is being considered. Although a North American standard does not exist yet, a relative exposure limit has been suggested: "endotoxin in the working environment should be within 10 times the background level of endotoxin with observed health symptoms - in the absence of complaints, endotoxin exposure should not exceed 30 times the background concentration of endotoxin" (Bartlett, *et al*., 2004). With the absence of an established exposure limit in the BC OHSR, the more stringent and widely used endotoxin exposure limit of 50 EU/m^3 recommended by the Health Council of The Netherlands will be used for this exposure assessment.

5.2 Health Effects

In an attempt to assess possible endotoxin exposure risk for sewage operators, AMEC conducted a literature search via Medline for information on workers' exposures to endotoxin, related health effects and endotoxin exposures related to the sewage treatment industry; a total of fourteen literature reports were reviewed – see Appendix B Literature References for more information. A large study conducted over 15 years collected endotoxin exposure data from 470 sewage treatment workers (2,010 personal samples) and the geometric mean (GM) was determined to be 27 EU/m^3 (Spaan *et al.*, 2008). Likewise, several other studies in sewage treatment plants concluded that the geometric mean were below the 50 EU/m^3 exposure limit; Table 1 presents a summary of these findings.

Table 1 – Endotoxin Exposure Findings

Literature Source	Year of Study	Number of Workers Monitored	Number of Sewage Treatment Plants	Geometric Mean (EU/m^3)	Maximum Exposure (EU/m^3)
Spaan *et al.*,	2008	470	43	27	2135
Smit *et al.*,	2005	216	40	27	2093
Oppliger *et al.*,	2005	NA[1]	11	6	500
Bartlett *et al.*,	2004	4	1	4	50
Prazmo *et al.*,	2003	NA	12	20	52
Douwes *et al.*,	2001	11	2	10	143

[1]NA – not available

It has been shown that the highest values of endotoxin exposures measured at sewage treatment plants occur with agitation of wastewater (Thorn *et al.*, 2002). Oppliger *et al.*, 2005, determined a GM of 98 EU/m^3 and up to 500 EU/m^3 for tasks such as short term spray removal from basins, tank walls and grids. Similarly, Thorn *et al.*, 2002, also determined that the highest concentrations of endotoxins were during agitation tasks (repair work) – a maximum concentration of 270 EU/m^3 was reported; Smit *et al.*, 2005 also reported a maximum concentration of 2093 EU/m^3. It can be concluded that the highest endotoxin exposures are due to specific tasks such as cleaning and agitation of wastewater – task based measurements (such as debris removal) of 123 samples presented a GM of 64 EU/m^3 (Spaan *et al.*, 2008) and a daily maximum exposure of 50 EU/m^3 was reported by Bartlett *et al.*, 2004.

6.0 DISCUSSION

Although the current literature has presented low GM endotoxin exposures in several studies, task based measurements such as cleaning and repair work and in particular agitation of wastewater, has shown higher exposures than the recommended exposure limit of 50 EU/m^3. The specific task of cleaning the walls of the wet well at the 225th Street Sewer Lift Station is similar to the task-based measurements described in the literature (cleaning and agitation of wastewater); therefore, the potential for endotoxin exposures above the exposure limit of 50 EU/m^3 exists during this task and is in agreement with the findings from the report by Bartlett *et al.*, 2004. To eliminate or reduce workers' exposure, control measures (in the hierarchy of high to low order) such as substitution, engineering, administrative or PPE are recommended.

As substitution of the hazard is not possible, implementing engineering and administrative controls would be the most preferable before PPE. It is noted that engineering controls (the two fresh air ventilation systems located inside the sewer lift station) and administrative controls (the work is conducted for approximately two hours per week and not on a daily basis) are currently in place at the 225th Street Sewer Lift Station. However, as mentioned previously, the ideal airflow pattern inside the wet well is not optimal, as turbulence or mixing of air exists due to the conditions of the ventilation system (and therefore the potential of generating greater disturbance of airborne endotoxin during the cleaning is possible). Redesigning the fresh air ventilation system to an optimal flow and more laminar direction of travel out of the building (i.e., reduce the mixing of air) would improve the efficiency of the ventilation system in reducing worker exposures.

In addition, as the potential for exposure to endotoxin exists during the weekly cleaning task, PPE worn, such as a minimum of a half facepiece respirator with P100 cartridges would further reduce endotoxin exposures. PPE is recommended to further reduce exposures as inflammatory responses after inhalation of endotoxin has been documented (Thorn *et al.*, 1998) and endotoxin exposures of 250 EU/m^3 has been associated with an annual decline in forced expiratory volume during the first second (FEV_1) (Oppliger *et al.*, 2005). In the absence of worker exposure data from cleaning tasks at the 225th Street Sewer Lift Station, implementation of PPE is justified and consistent with conclusions in Oppliger et al., 2005, which stated that workers who were exposed to repeated short exposures should wear protective respirators as the range of concentrations measured (up to 500 EU/m^3) could influence worker's health.

7.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the current literature reviewed and the observations during the cleaning task the following conclusions and recommendations are provided:

- Several studies in sewage treatment plants concluded that the geometric mean for exposure to endotoxin during routine work was below the endotoxin exposure limit of 50 EU/m^3 recommended by the Health Council of The Netherlands.

- In contrast, task based measurements in the literature such as cleaning walls with a pressurized water hose in an indoor environment, have documented higher exposures than the recommended exposure limit of 50 EU/m^3; therefore, the potential for endotoxin exposures above the exposure limit of 50 EU/m^3 exists during the cleaning task at the 225th Street Sewer Lift Station.

- To eliminate or reduce workers' exposure, controls such as substitution, engineering, administrative or PPE (the 'hierarchy of controls') are recommended. A review of the engineering controls existing at the sewer lift station will provide information to improve the efficiency of the fresh air ventilation systems in reducing worker exposures.

- With the absence of worker exposure data from cleaning tasks at the 225th Street Sewer Lift Station and the documented influences on health from repeated short duration exposure to endotoxin, PPE is therefore recommended (such as a minimum half facepiece respirator with P100 cartridges). Furthermore, collecting air sampling data on worker exposures to endotoxin at the sewer lift station will confirm similar concentrations reported in the literature and determine the minimum types of PPE to be used based on the necessary respiratory protection factor and personal exposure concentration.

- Although air sampling will determine worker exposures to endotoxin during cleaning tasks at the sewer lift station, a single episode of sampling will provide limited information on workers' exposures. Multiple sampling episodes of the worker's weekly cleaning task would provide further information to accurately capture worst case exposures and inter-day exposure variation.

- It is noted that endotoxin exposures in this report only refers to the specific weekly cleaning task of washing the inside walls of the wet well at the 225th Street Sewer Lift Station.

8.0 CLOSURE

This submission has been prepared for the exclusive use of the District of Maple Ridge. No other warranty expressed or implied. Any use which a third party makes of this report, or any reliance on or decisions to be made based upon it, are the responsibility of the third parties. AMEC accepts no responsibility for the damages, if any, suffered by any third party as a result of decisions made or actions based on this report. A Statement of Limitations for this project is attached.

We trust this report meets your requirements. Should you have any questions or if we can be of any further assistance, please contact the undersigned at (604)294-3811.

Sincerely,

AMEC Earth & Environmental
a division of AMEC Americas Limited

Reviewed by:

Peter Bergholz, BSc
Occupational Hygienist

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Senior Occupational Hygienist

Appendices

Appendix A	Photographs
Appendix B	Literature References
Appendix C	Statement of Limitations

APPENDIX A

Photographs

Photograph 1. Worker washing the walls of the wet well – 225th Street Sewer Lift Station.

Photograph 2. Pressurized water hose for cleaning walls.

Photograph 3. Inside the wet well with fresh air ventilation system in ceiling.

Photograph 4. Fan located outside the sewer lift station.

APPENDIX B

Literature References

VE52003 - Reference Summary

1. Bartlett K, Van Netten C, Kirkham T (2004) *Environmental gases, bacteria, fungi, and endotoxin levels at the Saanich Peninsula Wastewater treatment plant*. University of British Columbia
2. Douwes *et al.*, (2001) *Work Related Symptoms in Sewage Treatment Workers.* Ann Agric Environ Med, 8: 39-45
3. Krajewski *et al.*, (2004) *Health Complaints from Workplace Exposure to Bioaerosols: a Questionnaire Study in Sewage Workers.* Ann Agric Environ Med, 11: 199-204
4. Laitinen *et al.*, (1994) *Workers' Exposure to Airborne Bacteria and Endotoxins at* Industrial Wastewater Treatment Plants. Am. Ind. Hyg. Assoc. J., 55 (11): 1055-1060
5. Lee *et al.*, (2006) *Indoor and Outdoor Air Quality Assessment of Four Wastewater Treatment Plants*. J Occ. Env. Hyg., 3: 36-43
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7. Prazmo *et al.*, (2003) *Exposure to Bioaerosols in a Municipal Sewage Treatment Plant*. Ann Agric Environ Med., 10: 241-248
8. Smit *et al.*, (2005) *Endotoxin Exposure and Symptoms in Wastewater Treatment Workers*. Am. J Ind. Med., 48: 30-39
9. Spaan *et al.*, (2008) *Endotoxin Exposure in Sewage Treatment Workers: Investigation of Exposure Variability and Comparison of Analytical Techniques*. Ann Agric Environ Med, 15: 251-261
10. Spaan *et al.*, (2008) *Variability in Endotoxin Exposure Levels and Consequences for Exposure Assessment*. Ann. Occup. Hygiene., Vol. 52, No. 5: 303-316
11. Stephenson *et al.*, (2004) *Side by Side Comparison of Three Sampling Methods for Aerosolized Endotoxin in a Wastewater Treatment Facility*. J Environ Health, 67(4):16-9
12. Thorn et al., (1998) *Inflammatory Response After Inhalation of Bacterial Endotoxin Assessed by the Induced Sputum Technique*. Thorax, 53: 1047-1052
13. Thorn *et al.*, (2002) *Measurement Strategies for the Determination of Airborne Bacterial Endotoxin in Sewage Treatment Plants*. Ann. Occup. Hygiene., Vol. 46, No. 6: 549-554
14. Visser *et al.,* (2006) *Influence of Different Cleaning Practices on Endotoxin Exposure at Sewage Treatment Plants.* Ann. Occup. Hygiene., Vol. 50, No. 7: 731-736
15. *The Occupational Environment: Its Evaluation, Control and Management,* American Industrial Hygiene Association, Second Edition (2003)

APPENDIX C

Statements of Limitations

Statement of Limitations

1. The work performed in this report was carried out in accordance with the Standard Terms and Conditions made part of our contract. The conclusions presented herein are based solely upon the scope of services and time and budgetary limitations described in our contract.
2. The report has been prepared in accordance with generally accepted environmental study and/or engineering practices. No other warranties, either expressed or implied, are made as to the professional services provided under the terms of our contract and included in this report.
3. The services performed and outlined in this report were based, in part, upon visual observations of the site and attendant structures. Our opinion cannot be extended to portions of the site, which were unavailable for direct observations, reasonably beyond the control of AMEC Earth & Environmental, a division of AMEC Americas Limited ('AMEC').
4. The objective of this report was to assess the health and safety conditions at the site, given the context of our contract, with respect to existing health and safety regulations within the applicable jurisdiction. Compliance of past owners with applicable local, provincial and federal government laws and regulations was not included in our contract for services.
5. The company practices and details described herein relies on information supplied by others, such as local, provincial and federal agencies as well as Site personnel. No attempt has been made to independently verify the accuracy of such information, unless specifically noted in our report.
6. Our observations relating to potential hazards and conditions at the Site are described in this report. No testing was performed.
7. The conclusions of this report are based, in part, on the information provided by others. The possibility remains that unexpected conditions may be encountered at the Site in locations not specifically investigated. Should such an event occur, AMEC must be notified in order that we may determine if modifications to our conclusions are necessary.
8. Any use which a third party makes of this report, or any reliance on or decisions to be made based on it, are the responsibility of such third parties. AMEC accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.