Particulate Matter and Sound Pressure Levels from TransLink 99 B-Line Diesel Bus Rapid Transit on West 10th Avenue at Blanca Street, Vancouver

August 28, 2012

by Eric Chris

Summary

At residences near the corner of Blanca Street and West 10th Avenue in Vancouver, the *particulate matter (PM) emissions from diesel buses (99 B-Line and N17) operated by TransLink reach 50 µg/m3, and exceed the Canadian standard of 30 µg/m3 for PM emissions by up to 67%.* Blackened tail pipes on diesel buses and visible soot emissions from diesel buses on the 99 B-Line route indicate that particulate filters, if installed, on the soot blowing diesel buses operated by TransLink are ineffective. *Sound pressure levels recorded for diesel buses operated by TransLink on West 10th Avenue greatly exceed the sound pressure level set by the WHO for residential areas at night by at least 362% and significantly exceed the sound pressure level set by APTA for a transit bus by 46%.* TransLink is not operating transit in accordance with national and international standards for noise and PM emissions.

Introduction

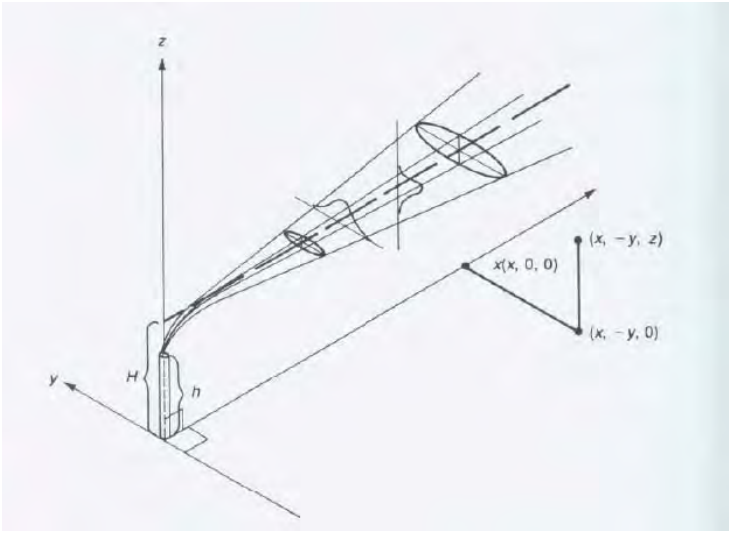
Conditions at the corner of Blanca Street and West 10th Avenue in Vancouver are unique. Diesel buses operate frequently every few minutes or seconds for almost 22 hours daily along West 10th Avenue where two diesel bus routes operate entirely underneath existing trolley bus lines. One diesel bus route is the 99 B-Line articulated diesel bus route operating until 2:20 am and the other diesel bus route is the late night N17 articulated diesel bus route operating until 3:36 am. TransLink continues to run 99 B-Line diesel buses on the N17 route after service ends on the 99 B-Line route.

On the 99 B-Line route, diesel buses pass very near residences every few seconds at peak hours and there are no sound barriers installed to mitigate noise levels and vibrations at residences. Located at the corner of Blanca Street and West 10th Avenue is a traffic light where diesel buses must often stop. When the diesel bus struggles to accelerate from the traffic light at the corner of Blanca Street and West 10th Avenue, it is at or near full engine load. At full load, the engine emits the greatest levels of PM and noise (sound pressure). The following picture shows the proximity of diesel buses to the condo units at the corner of Blanca Street and West 10th Avenue:

Dark plumes of diesel exhaust from the diesel buses pulling away from the traffic light at the corner of Blanca Street and West 10th Avenue are common. If particulate filters are installed on the 99 B-Line diesel buses operated by TransLink, they are not being maintained properly or are ineffective when they are crucial under full engine load. Blackened tail pipes on the 99 B-Line diesel buses operated by TransLink indicate that particulate filters are inadequate at capturing PM emissions.

Discussion

Fine PM emissions in the exhaust of diesel buses operating on West 10th Avenue rise due to the momentum and buoyancy of the hot exhaust gases. As the PM emissions rise, they disperse into two bell shaped patterns at right angles to the prevailing wind direction. This is indicated In the following figure showing the wind direction in the x-coordinate with the bell shaped dispersion occurring in the y-coordinate and z-coorindate planes:

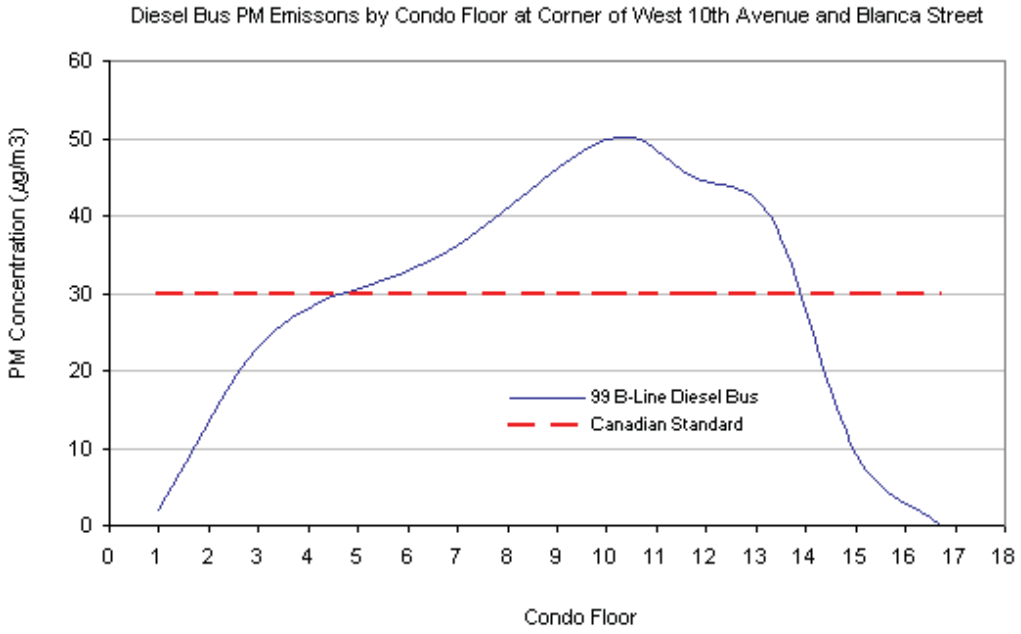


When someone walks down a street and is exposed to PM emissions from a diesel bus, exposure is brief and the PM emissions have been diluted by a large volume of air before the PM reaches the individual at ground level. In an office tower, air is exchanged by the heating and ventilation system, and clean air is brought into the office tower to mitigate pollution from diesel buses.

This is not the case for residents living in the condo units lacking a heating and ventilation system at the corner of Blanca Street and West 10th Avenue where the tall condo building acts as an obstacle to trap PM emissions. Fine PM emissions enter residences and linger to expose residents to elevated PM levels on a continuous basis. Relative to the exhaust stack of the 99 B-Line, condo residences are located 15 metres in the horizontal direction (x-coordinate in the previous figure) for 10 floors, extending approximately 33 metres, in the vertical direction (z-coordinate in the previous figure):

TransLink operates a significant number of old diesel buses (B8001 to B8021 manufactured in 1998) on the 99 B-Line route. Almost all of these diesel buses have a large 150 mm vertical exhaust stack which provides the ideal trajectory for the dispersion of PM emissions into the nearby residences at the corner of Blanca Street and West 10th Avenue:

Inside condo units on the 10th floor at the corner of Blanca Street and West 10th Avenue, the maximum PM emission level is 50 µg/m3 which exceeds the Canadian standard of 30 µg/m3 by 67%. In fact, the PM emissions from the diesel buses operated by TransLink exceed the Canadian standard for PM emissions from the 5th to 10th floor for condo units at the corner of Blanca Street and West 10th Avenue as shown in the following figure:



Example Calculation of PM Emission Level from 99 B-Line

Inputs

Exhaust flow rate for Detroit Diesel S50 engine used in New Flyer D60LF articulated buses, B8001 to B8021:

$V_e := 1920 \cdot ft^3 \cdot min^{-1}$ @ 2,100 rpm

Particulate matter emission rate for S50 Detroit Diesel engine (Detroit Diesel):

$Q := 0.05 \cdot \frac{gm}{hp \cdot hr} \cdot 320 \cdot hp = 0.00444 \cdot \frac{gm}{sec}$

EPA wind speed (see p. A1):

$u_w := 2 \cdot \frac{m}{sec}$

EPA dispersion parameters at residence (see p. A1):

$\sigma_y := 2.78 \cdot m \quad \sigma_z := 2.54 \cdot m$

Exhaust temperature (Detroit Diesel):

$T_s := (790 + 460) \cdot R = 694\,K$

Ambient temperature:

$T_a := 283 \cdot K$

Lateral distance from plume center:

$y := 0 \cdot m$

Exhaust stack height (New Flyer):

$h := 3.1 \cdot m$

Exhaust stack diameter (measured):

$d_s := 0.15 \cdot m$

EPA predicted plume height (see p. A1):

$H_e := 30.79 \cdot m$

Vertical distance of residence from ground:

$z := 30.79 \cdot m$

Canadian 24 hour standard for PM exposure:

$C_{PM} := 30 \cdot \mu g \cdot m^{-3}$

Results

Predicted PM concentration at residence based on Gaussian dispersion model:

$$C_e := \frac{Q}{2 \cdot \pi \cdot u_w \cdot \sigma_y \cdot \sigma_z} \cdot e^{\left(-\frac{1}{2} \cdot \frac{y^2}{\sigma_y^2}\right)} \cdot \left[e^{\left[-\frac{1}{2} \cdot \frac{(z - H_e)^2}{\sigma_z^2}\right]} + e^{\left[-\frac{1}{2} \cdot \frac{(z + H_e)^2}{\sigma_z^2}\right]} \right] = 50 \cdot \mu g \cdot m^{-3}$$

TransLink exceeds Canadian PM standard by the following percentage:

$$\frac{C_e - C_{PM}}{C_{PM}} = 67 \cdot \%$$

Example Calculation of Sound Pressure Level from 99 B-Line

Noise is expressed in decibels which is 20 times the logarithm of the sound pressure divided by the just audible sound pressure. Logarithms make big numbers seem small. For instance, the logarithm of one trillion is 12. Noise expressed in decibels is misleading. It does not give the true magnitude of the sound pressure resonating in the ear drum of an individual when a 99 B-Line diesel bus passes. This calculation gives the magnitude of the sound disturbance caused by the 99 B-Line in relation to the noise standard set by the American Public Transportation Association (APTA) and the noise guideline set by the World Health Organization (WHO).

Inputs

Audible sound pressure:

$$P_r := 20 \cdot \mu Pa$$

APTA sound pressure at 65 dB limit for bus at idle (see pp. A2a, A2b):

$$P_{APTA} := 35566 \cdot \mu Pa \qquad 20 \cdot \log\left(\frac{P_{APTA}}{P_r}\right) = 65 \text{ dB}$$

WHO sound pressure at 55 dB limit for residential area at night (see pp. B1a to B1e):

$$P_{WHO} := 11247 \cdot \mu Pa \qquad 20 \cdot \log\left(\frac{P_{WHO}}{P_r}\right) = 55 \text{ dB}$$

Recorded exterior noise in dB by TransLink diesel bus at idle (see pp. A2a, A2b)

$$\beta_x := 68.3$$

Results

Functional relationship of sound pressure (x) for diesel bus:

$$f(x) := 20 \cdot \log\left(\frac{x}{P_r}\right) - \beta_x$$

Sound pressure by diesel bus:

$$P_x := \text{root}(f(x), x) = 52003 \cdot \mu Pa$$

TransLink diesel bus exceeds APTA noise standard by:

$$\frac{P_x - P_{APTA}}{P_{APTA}} = 46 \cdot \%$$

TransLink diesel bus exceeds WHO noise guideline by:

$$\frac{P_x - P_{WHO}}{P_{WHO}} = 362 \cdot \%$$

Noise warning posted by City of Vancouver on West 10th Avenue near Blanca Street:

Typically, noise level is measured at a distance of three metres from the source. Noise level drops by six decibels when the distance from the source is doubled. Under acceleration, the recorded noise level (exterior) of a diesel bus operated by TransLink is 83.2 dB (see page A2b).

As a result, anyone living within 75 metres of a diesel bus at the corner of West 10th Avenue and Blanca Street is being subjected to a noise level exceeding the 55 dB noise level set by the WHO for noise in a residential area at night:

$$83.2 \cdot \text{dB} - 20 \log\left(\frac{75 \cdot \text{m}}{3 \cdot \text{m}}\right) \cdot \text{dB} = 55.2 \cdot \text{dB}$$

SCREEN.OUT

08/12/12
15:57:27

```
 ***  SCREEN3 MODEL RUN  ***
 *** VERSION DATED 96043 ***


SIMPLE TERRAIN INPUTS:
   SOURCE TYPE            =        POINT
   EMISSION RATE (G/S)    =      .444000E-02
   STACK HEIGHT (M)       =       3.1000
   STK INSIDE DIAM (M)    =        .1500
   STK EXIT VELOCITY (M/S)=      51.2770
   STK GAS EXIT TEMP (K)  =     694.0000
   AMBIENT AIR TEMP (K)   =     283.0000
   RECEPTOR HEIGHT (M)    =      30.7900
   URBAN/RURAL OPTION     =        URBAN
   BUILDING HEIGHT (M)    =        .0000
   MIN HORIZ BLDG DIM (M) =        .0000
   MAX HORIZ BLDG DIM (M) =        .0000

THE REGULATORY (DEFAULT) MIXING HEIGHT OPTION WAS SELECTED.
THE REGULATORY (DEFAULT) ANEMOMETER HEIGHT OF 10.0 METERS WAS ENTERED.

   STACK EXIT VELOCITY WAS CALCULATED FROM
   VOLUME FLOW RATE =   1920.0000     (ACFM)

BUOY. FLUX =    1.675 M**4/S**3;  MOM. FLUX =    6.031 M**4/S**2.

*** FULL METEOROLOGY ***

**********************************
*** SCREEN AUTOMATED DISTANCES ***
**********************************

*** TERRAIN HEIGHT OF    0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

  DIST     CONC              U10M   USTK  MIX HT   PLUME   SIGMA   SIGMA
   (M)   (UG/M**3)   STAB  (M/S)  (M/S)    (M)   HT (M)   Y (M)   Z (M)  DWASH
-------  ----------  ----  -----  -----  ------  ------  ------  ------  -----
     1.   419.2        5     2.0    2.0 10000.0   30.79     .92     .92    NO

**********************************
*** SCREEN DISCRETE DISTANCES ***
**********************************

*** TERRAIN HEIGHT OF    0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

  DIST     CONC              U10M   USTK  MIX HT   PLUME   SIGMA   SIGMA
   (M)   (UG/M**3)   STAB  (M/S)  (M/S)    (M)   HT (M)   Y (M)   Z (M)  DWASH
-------  ----------  ----  -----  -----  ------  ------  ------  ------  -----
    15.   49.94        5     2.0    2.0 10000.0   30.79    2.78    2.54    NO
    18.   41.11        5     2.0    2.0 10000.0   30.79    3.10    2.78    NO
    20.   36.54        5     2.0    2.0 10000.0   30.79    3.30    2.93    NO

     ***************************************
     *** SUMMARY OF SCREEN MODEL RESULTS ***
     ***************************************

************************************************
** REMEMBER TO INCLUDE BACKGROUND CONCENTRATIONS **
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Bus Technology & Alternative Fuels Demonstration Project

FINAL

Phase 1 - Test Program Report

October 19, 2006

Submitted to:

TransLink
Greater Vancouver Transportation Authority
1600-4720 Kingsway
Burnaby, BC V5H 4N2

Submitted by:

M.J. Bradley & Associates
1000 Elm Street, 2nd Floor
Manchester, NH 03101

5.1.2. Interior & Exterior Noise Test Results

Table 5.2 shows the average sound levels (dB) recorded for each test vehicle under each test condition. Where applicable, the standards included in the American Public Transportation Association (APTA) Standard Bus Procurement Guidelines are included for reference. These results are also summarized by tested technology in Figures 5.3 through 5.7. The error bars in these figures represent a 95% confidence interval for the average result, based on the actual variability from test run to test run.

The detailed noise test results for each bus are included at Appendix E.

	Interior								
	Driver			Mid-Coach			Rear		
	Idle	Accel	Cruise	Idle	Accel	Cruise	Idle	Accel	Cruise
APTA Standard	--	*75*	--	--	*83*	--	--	*83*	--
Diesel 7430	61.9	74.4	70.4	64.0	78.4	72.2	68.8	82.5	77.8
Diesel 7437	59.5	73.3	69.6	62.6	76.6	71.2	68.3	81.6	76.1
BioDiesel 7439	59.2	74.7	68.7	62.4	78.2	72.9	66.8	86.4	75.8
BioDiesel 7444	59.9	73.1	70.3	62.6	75.8	72.1	72.1	81.8	75.0
CNG 3292	59.2	71.9	67.5	62.5	73.6	70.8	66.5	82.4	73.6
CNG 3306	59.1	75.4	68.0	62.5	75.4	69.6	68.9	79.8	74.5
Hybrid 7244	58.0	71.5	66.4	58.8	79.1	66.5	64.2	79.0	69.3
Hybrid 7246	57.7	73.8	70.0	60.5	77.6	68.2	65.0	79.6	70.5
DPF 1001	61.2	72.1	66.6	63.0	75.2	67.7	72.0	81.3	75.0
DPF 1002	66.0	75.4	69.9	70.0	77.6	72.1	71.6	82.1	75.7

	Exterior		
	Accel	Decel	Idle
APTA Standard	*83*	--	*65*
Diesel 7430	78.5	69.0	63.7
Diesel 7437	81.1	73.8	64.5
BioDiesel 7439	83.2	69.9	63.6
BioDiesel 7444	81.4	71.7	68.3
CNG 3292	79.2	68.0	61.3
CNG 3306	81.0	66.4	62.5
Hybrid 7244	75.8	60.5	60.5
Hybrid 7246	82.6	75.0	61.7
DPF 1001	75.9	61.4	60.0
DPF 1002	75.0	61.1	59.4

Table 5.2 Average Noise Test Results (dB)

2012-03-20

To: Mr Ouzky, rapporteur environment EP

Cc: Mr Tatarella, Ms Merkies, Mr Krahmer, Ms Hassi.

Expert support for stricter vehicle noise emissions standards

Dear Mr Ouzky,

As independent experts on noise, from the fields of health and vehicle technologies respectively, we write to support an ambitious regulation to tighten the European standards for vehicle noise emissions. It should be stressed that a part of the vehicle fleet already fulfills the standard proposed by the European Commission.

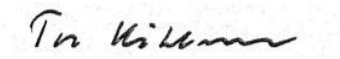
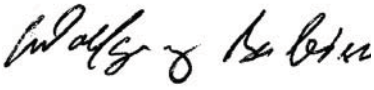
It is now the 20th anniversary of the last – small – improvement in standards, which unfortunately – set against the increase in traffic volume - has had little impact in reducing overall traffic noise levels. After this long period of very little progress in further traffic noise reductions, during which the health burden has increased, we support the initiative to tighten the European standards for vehicle noise emissions. An effective regulation will reduce the severe health impacts and the associated costs of road noise, but only if appropriate stringent limit values are provided for and set within a short time frame.

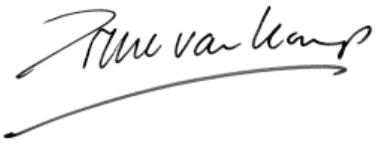
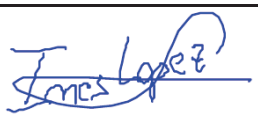
We are concerned that the alternative proposal by Germany will weaken and delay the badly needed reduction of traffic noise so much as to make it ineffective. A time delay of another 10 to 14 years leads to a shocking 30 years stand still, which comes on top of a period of little progress and rapidly increasing traffic

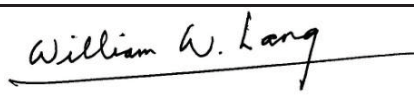
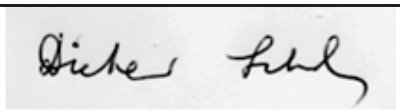
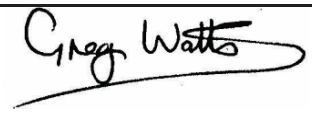
Road traffic noise contributes substantially to the burden of disease in the EU. The World Health Organisation's Night Noise Guidelines (2009) confirm that nighttime noise levels above 55 decibels (dB) are "increasingly dangerous for public health" and cause adverse health effects.[i] The noise maps for agglomerations and transport infrastructures made available by the Environmental Noise Directive and published on line in EEA's NOISE database, prove that in this small sample (17% of the population) 32 million people in the EU are exposed to levels over 55 dB at night and roughly an equivalent number to levels between 50 and 54 dB. Cautious extrapolations to the whole of the EU at least doubles this number, arriving at a total of over 100 million exposed to high levels of night noise. This illustrates the worrying extent of public exposure to noise. EEA also made available the health effects through the Good Practice Guide on health assessment from noise.[ii] A comprehensive Danish study published in 2011 has indicated the severity of the health burden of traffic noise.[iii] Furthermore, a report on the European Perspective on Environmental Burden of Disease covers the health effects of noise in detail.[iv]

With this – mostly new or updated – knowledge of EU-wide exposure to traffic noise, the health impacts and associated costs (several countries are investing heavily in abatement measures on the major infrastructure), enable better estimates of the benefits of noise reduction measures at the source than was possible to make 10 years ago.

In addition to benefits associated with health there are additional benefits associated with productivity and impacts on the ecosystem which although presently difficult to quantify are nevertheless recognized as important factors when assessing cost benefits from noise reduction[v][vi].

Name	Affiliation	Signature
Martin van den Berg (coordinator)	Temporary advisor to the WHO on noise and health; EEA expert panel on noise (EpON); Chairman EU-Working Group on Indicators and on Health and Socio-Economic aspects; Editor WHO Night Noise Guidelines	m.vdb@xs4all.nl 
Prof. Tor Kihlman (coordinator)	Prof. em. Applied Acoustics, Chalmers University of Technology, Sweden; Chair, CAETS Noise Control Technology Committee; Board member, International Institute of Noise Control Engineering (I-INCE); Former member EU Working group Health and Socio-economic assessment	tor.kihlman@chalmers.se 
Philip Abbott	Technical Director Acoustics, AECOM	
Dr. Wolfgang Babisch	Temporary advisor to the WHO on health effects of noise; International Commission on the Biological Effects of Noise (ICBEN), Member of Team 3 (Non-auditory Health Effects)	
Prof. Em. Birgitta Berglund	Institute of Environmental Medicine, Karolinska Iinstitute, Department of Psychology, Stockholm University; Temporary advisor to WHO; Author, editor WHO Guidelines for Community Noise; EU Noise Steering Group, chair of Dose/Effect WG; CEC Steering Committee on Urban Air, Indoor Environment and Human Exposure; President, International Commission on Biological	

	Effects of Noise (ICBEN); Member, Board for Energy Development, Swedish Council for Industrial and Technical Development; Expert, WHO WG aircraft noise and health	
Bernard Berry	Bernard F Berry. BSc, MSc, Hon FIOA Distinguished International Member: INCE-USA www.inceusa.org Director - Berry Environmental Ltd	
Mark Brink	Mark Brink, PD Dr. phil. ETH Zürich D-MTEC Public and Organizational Health	
Hans Boegli	Federal Office for the Environment FOEN Noise Abatement Section Air Traffic, Military, Health 3003 Berne	
Truls Gjestland	Senior Research Scientist, SINTEF, Norway; Temporary advisor to WHO; ICBEN – International Commission on Biological Effects of Noise	
Dr. Irene van Kamp	National Institute of Public Health and Environment, the Netherlands; Temporary advisor to WHO; ICBEN – International Commission on Biological Effects of Noise; Member of European Association for Public Health	
Prof.dr. Ines Lopez Arteaga	Visiting professor on Vibro-acoustics of Land Transportation Systems Marcus Wallenberg Laboratory for Sound and Vibration Research (MWL) KTH Royal Institute of Technology Stockholm, Sweden	

William W. Lang	Secretary, CAETS Noise Control Technology Committee; Vice-President I-INCE; Noise Control Foundation, USA	
Dr. Eng. Ulf Sandberg	Senior Research Scientist, Swedish National Road and Transport Research Institute (VTI); 2002-2008 Adj Prof in Tyre/Road Noise at Chalmers University of Technology	
Dr. Dietrich Schwela	Senior Research Associate, Stockholm Environment Institute, University of York; Co-chair, ICBEN Team 9; Former staff member of WHO.	
Prof. Stephen Stansfeld	Professor of Psychiatry; Chair, ICBEN; Coordinator, European Network on Noise and Health (ENNAH); Temporary advisor to WHO	
Prof. Greg Watts	Professor of Transportation Noise Bradford Centre for Sustainability Environments, School of Engineering, Design and Technology, University of Bradford	

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http://www.unece.org/trans/doc/2002/wp29grb/TRANS-WP29-GRB-36-inf_c1_sweden.pdf

[xi] See for example: www.cityhush.eu and Lercher, P., Sölder, M. (2009): *Exposure by motorbike noise in alpine residential areas – a case study in public health risk assessment,* presented at EuroNoise 2009, Oct 26-28 2009, Edinburgh, UK.