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NOISE CONTROL FOR A BETTER ENVIRONMENT

A combined cases simulation of environmental impacts of vehicle traffic noise and exhaust

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ABSTRACT

The prediction, assessment, and control of the environmental impacts of an ordinary motor traffic road are generally focused on a single factor, such as traffic noise only, or vehicle exhaust separately. In contrast to the usual researches, we use two case motor traffic roads information from the same terrain maps, as inputs to proprietary software, to predict vehicle noise and exhaust. A combined simulation is conducted for the environmental impacts of (1) traffic noise, using the Cadna A software, combined with (2) vehicle exhaust, using Cadna A-APL. The results are used in at least three applications to find the dominant impacts between noise and the air pollution. Firstly, the quantified findings can be used for overall management of the environmental impact of motor road traffic. Secondly, while an accurate site measurement of the vehicle exhaust is difficult due to the influences of meteorological conditions, a simulation has fewer such limitations. Thirdly, the influences of sound barriers and buildings with sound-insulating function on the exhaust diffusions can also be illustrated with Cadna-APL; sometimes, they are important to prioritize the impact control policy between motor traffic road noise and exhaust.

Keywords: Vehicle exhaust, traffic noise, Environmental impact assessment simulation, Case study
I-INCE Classification of Subject Number: 60

1. INTRODUCTION

Cadna A, an outdoor environmental noise calculation software developed by DataKustic, Germany, has powerful graphic functions and high computational efficiency. It is compatible with standards such as the ISO 9613, RLS-90, and Schall 03, and it is recommended by the Environmental Engineering Assessment Center of the China Environmental Protection Administration. Cadna A is suitable for the simulation of a three-dimensional sound field, since it has high calculation accuracy with practical parameter selection. It is well-recognized professionally in this field. The software has also passed the inspections by the relevant agencies of the German Ministry of

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Environmental Protection. It has been applied in the transportation sector in Germany and many other countries, with good reviews.

The atmospheric calculation module[1] of the Cadna A-APL software extends the calculation, assessment, and protection objectives of noise prediction to atmospheric pollution factors. It is compatible with the European Union Guidelines 1999/30/EC and 2000/69/EC. The simulation model is based on the AUSTAL2000 model developed by the German Ministry of Environmental Protection. The main features include: it can calculate the air pollution factors of road traffic; it can use the terrain model established by noise prediction calculation to draw maps; and it can input annual and multi-year meteorological statistical parameters to calculate the time emission process of pollutants from point sources, line sources, and surface sources.

Generally, the prediction, assessment, and control of traffic impacts are all focused on noise factor or vehicle exhaust emission factor. In this research, we used data from two motor vehicle roads in the same terrain map as inputs to the proprietary software, to predict vehicle noise and exhaust emissions. In addition, the Cadna A model was used to determine different types of impacts on different types of roads, and to provide knowledge for environmental impact management of road traffic. In general, environmental monitoring is restricted by complex meteorological conditions and non-accurate field monitoring results. The simulation method can overcome these limitations, and it can demonstrate the influence of acoustic facilities such as a noise barrier on the flow of vehicle exhaust emissions.

2. KEY POINTS OF SELECTION AND ASSESSMENT FOR CASE ROADS

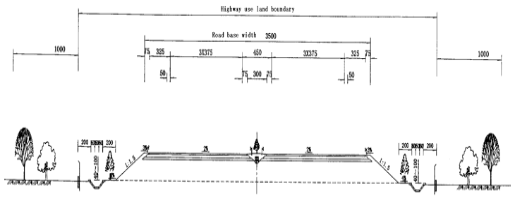
An expressway (Case E) and an urban arterial road (Case U) were selected for this research. Engineering parameters such as traffic volume and average speed are shown in Table 1. The layout of the road dimensions is shown in Figure 1. For E, the diffusion of vehicle exhaust emissions under the wind field parallel and perpendicular to the roads, and with and without sound barrier, was assessed together with noise attenuation. The assessment was similar for U, except that the presence of buildings on the roadside was considered as an assessment factor. For the noise impact prediction and its results can refer to Reference [2].

Table 1 - Simulation schedules*

Case No. Engineering prototype parameters	Expressway (E) Ordinary trans-provincial expressway	Urban Arterial road (U) Ring road
Number of lanes	6	8
Design ages	Year 2008~2030	Year 2006~2021
Design speed, km/h	120	80
Annual average traffic volume	38374pcu/d、25081v/h (67%P+24%M+9%H), Ratio of day & night=85%	Day time:1654 v/h (90%P+10%(H+M)) Night time: 584 v/h (80%P+10%(M+H))
Road width, m	35	80/（2×16）motor vehicle lanes +42 non-motorized parts
Subgrade height, m	4	0
Background noise level L_{day}/L_{night} dBA	49.0/43.4	49.2/42.5
Cross section	Figure 1- E	Figure 1- U

* P: Automobiles;
M: Middle vehicles;
H: Heavy trunks.

E



U

80.0 m = 5.0 m (sidewalk) + 6.0 m (non-motorized vehicle lane) + 8.0 m (green belt) + 16.0 m (motor vehicle lane) + 10.0 m (central reservation) + 16.0 m (motor vehicle lane) + 8.0 m (green belt) + 6.0 m (non-motor vehicle lane) + 5.0 (sidewalk)

Fig. 1 - Cross section of the road layouts

2.1 Assessment Metrics and Criteria

The Grade II criteria of the Chinese Ambient Air Quality Standard (GB 3095-2012) was utilized in this research. The assessment metrics and criteria are shown in Table 2.

Table 2 - Environmental air quality standards

Assessment metric	Unit g/km	Annual average concentration	Daily average concentration	Hourly average concentration
NO_x	μ g/m³	50	100	250
Pm_{10}	μ g/m³	70	150	-
NO_2	μ g/m³	40	80	200
SO_2	μ g/m³	60	150	500

2.2 Source strength determination

The engineering parameters and terrain information were input into the software to calculate the exhaust emissions strength of the vehicles on the researched road. See Table 3.

Table 3 - Sources emission estimating

Assessment metric	Unit	Expressway Example		Urban Arterial Road Example	
		Average vehicle flow at daytime	Average vehicle flow at nighttime	Average hourly vehicle flowrate at daytime	Average hourly vehicle flowrate at nighttime
NO_x	g/km	1349.7	475.9	416.7×2	147.2×2
Pm_{10}	g/km	72.5	25.6	Excluded from word count of this paper.	
NO_2	g/km	67.5	23.8		
SO_2	g/km	1.64	0.58		

2.3 Calculation Scheme

See Table 4.

Table 4 - Simulation schedules

Assessment factor	See Reference 1 for the studied road (Note: Based on annual average, conservative consideration of busier traffic values)				
	West wind 3m/s + South wind 3m/s + Noise barrier + No barrier	West wind 6m/s + South wind 6m/s + Noise barrier + No barrier	West wind 3m/s + South wind 3m/s + Noise barrier + No barrier	West wind 3m/s + south wind 3m/s + buildings + no buildings	West wind 6m/s + South wind 6m/s + Noise barrier + No barrier
NO_x	E	Excluded from word count of this paper.	U	E	Excluded from word count of this paper.
Pm_{10}	E		U	Excluded from word count of this paper.	
NO_2	E		U		
SO_2	E		U		

3. SIMULATION OF NOISE AND EXHAUST EMISSIONS WITH AND WITHOUT NOISE INSULATION

The E simulation results are shown in Table 5, and the U simulation results in Table 6. The atmospheric concentration and noise range of the color bars from Table 5 and 6 are shown in Table 7.

Table 7 - Numerical values of the color bars from Table 5 & 6

Contour belt	Noise	Air contour line
Legend: Color bar Value Range	> 35.0 dB > 40.0 dB > 45.0 dB > 50.0 dB > 55.0 dB > 60.0 dB > 65.0 dB > 70.0 dB > 75.0 dB > 80.0 dB > 85.0 dB	> 0.0 μg/m3 > 0.1 μg/m3 > 0.2 μg/m3 > 0.3 μg/m3 > 0.4 μg/m3 > 0.5 μg/m3 > 0.6 μg/m3 > 0.7 μg/m3 > 0.8 μg/m3 > 0.9 μg/m3 > 1.0 μg/m3

4. COMBINED ASSESSMENT OF ENVIRONMENTAL IMPACTS OF VEHICLE TRAFFIC NOISE AND EXHAUST EMISSIONS

4.1 Combined assessment of the roadside air and sound quality under 3m/s of wind field parallel + perpendicular to the direction of the E expressway

See Table 5:

(1) NO_x

① When the wind field is parallel to the road, NO_x emissions meet the roadside air quality standards. Also, when the wind field is perpendicular to the road, NO_x emissions meet the roadside air quality standard. However, because of the south wind, it was not possible to measure the NO_x concentration on the south side of the road.

② The presence of a barrier resulted in a higher NO_x concentration at the roadside, but the gas diffuses well at a distance. When there is no barrier, the gas diffusion contributes to lower concentration at the roadside, but the concentration is relatively high at a distance.

③ The distance at which the sound reached the standard limit to describe the noise impact was 348 m/385 m (L_{day}/L_{night} background 43.4 dBA). The noise impact range is greater than the air impact' s, which is consistent with the general perception.

④ Compared with the above average noise assessment, more attention should be paid to the impact of maximum concentration on the air quality assessment. Due to the limitations of the article length, details are not described in this paper.

(2) PM_{10}, NO_2, SO_2

The trends for PM_{10} and NO_2 are the same as the above NO_x, but their concentrations are lower. In special, the concentration of SO_2 is very low, there is only a very low concentration on the roadside, and it is not detected at a distance.

4.2 Combined assessment of the roadside air and sound quality under 3m/s of wind field parallel + perpendicular to the direction of the U urban arterial road

See Table 6:

(1) NO_x

① When the wind field is parallel to the road, NO_x emissions meet the roadside air quality standards. Also, when the wind field is perpendicular to the road, NO_x

emissions meet the roadside air quality standard. However, because of the south wind, it was not possible to measure the NO_x concentration on the south side of the road.

② The presence of a building nearby the road leads to a higher NO_x concentration at the roadside, but the gas diffuses well at a distance. When there is no building, the gas diffusion contributes to lower concentration at the roadside, but the concentration is relatively high at a distance.

③ The distance at which the sound reached the standard limit to describe the noise impact was 222 m/254 m (L_{day}/L_{night} background 42.5 dBA). The noise impact range is greater than the air impact' s, which is consistent with the general perception. However, when there are buildings on the roadside, the noise impact distance or range is reduced to 30 m, which is within the first row of the buildings. The noise blockage effect of buildings is significant.

④ Compared with the above average noise assessment, more attention should be paid to the impact of maximum concentration on the air quality assessment. Due to the limitation of the article length, details are not described in this paper.

(2) PM_{10}, NO_2, SO_2

The trends for PM_{10} and NO_2 are the same as the above NO_x, but their concentrations are lower. In special, the concentration of SO_2 is very low, there is only a very low concentration on the roadside, and it is not detected at a distance.

5. CONCLUSIONS AND DISCUSSION

The atmospheric calculation module-APL together with Cadna A software provided a combined assessment of the environmental air and noise impacts on the case roads. It demonstrates the function of impact prediction. In addition to that, it can be applied to the research and application of environmental impact assessment and planning due to its three-dimensional and dynamic simulation effect.

6. ACKNOWLEDGEMENTS

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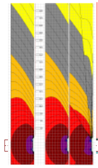
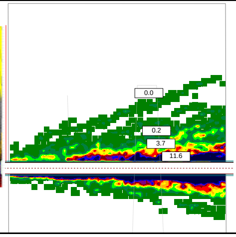
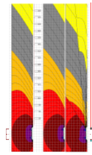
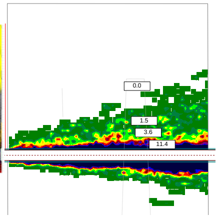
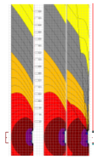
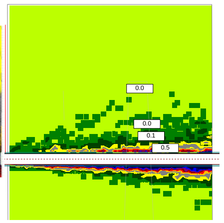
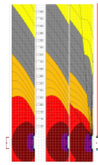
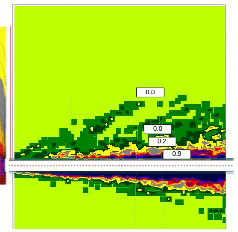
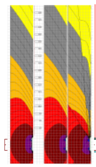
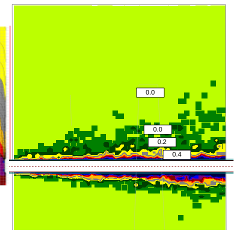
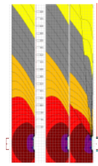
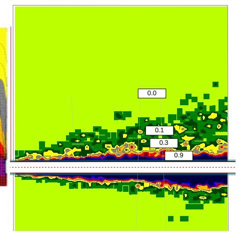
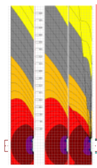
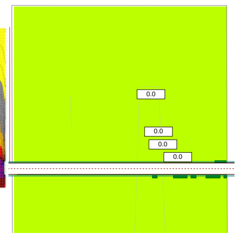
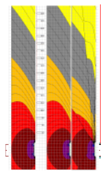
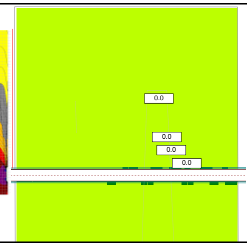
7. REFERENCES

1. Calculation of Air Pollutants, *Manual for CadnaA-Option APL,* 2nd Aug, (2010).

2. J. Zhang, M. Buret, S. Wu, et al., Buffer distances for surface roads and elevated highways correlated with pre-existing ambient noise, the 43th International Congress and Exposition on Noise Control Engineering, November 16-19, 2014 in Melbourne, *Proceedings of Internoise-2014,* D8b Session of Motor vehicle noise - policy and regulation: paper IDNo.812, (2014).

Table 5 - In both conditions of wind directions parallel + perpendicular to the H expressway, the roadside air quality of a case expressway is assessed with an exhaust diffusion map combined with the traffic noise map

Wind	Assess-ment Metric	Presence of a noise barrier (3.5 m high) on the side of the highway		No sound barrier on the side of the highway		Trend Assessment
		Vertical contour line of road cross-section noise (determined by nighttime average traffic flow, 10 m × 10 m grid, 1 dBA contour interval)	Plane contour line of air quality at 1.5 m hight (determined by average traffic flow during daytime)	Vertical contour line of road cross-section noise (determined by nighttime average traffic flow, 10 m × 10 m grid, 1 dBA contour interval)	Plane contour line of air quality at 1.5 m hight (determined by average traffic flow during daytime)	
3m/s West	NO_x					NO_x: 1.When the wind field is parallel to the road, NO_x emissions meet the roadside air quality standards. 2. The presence of a barrier resulted in a higher vehicle exhaust gas concentration at the roadside, but the gas diffuses well at a distance. When there is no barrier, the gas diffusion contributes to lower concentration at the roadside, but the concentration is relatively high at a distance. 3. The distance at which the sound reached the standard limit to describe the noise impact was 348 m/385 m (L_{day}/L_{night} background 43.4 dBA). The noise impact range is greater than the air impact' s, which is consistent with the general perception. 4. Compared with the average noise assessment, more attention should be paid to the impact of maximum concentration on the air quality assessment. Due to the limitations of the article length, details are not described in this paper.
3m/s West	PM_{10}					PM_{10}: The trend of PM_{10} is the same as the above NO_x, but its concentration is lower.
3m/s West	NO_2					The trend of NO_2 is the same as the above NO_x, but its concentrations is lower.
3m/s West	SO_2					The concentration of SO_2 is very low, there is only a very low concentration on the roadside, and it is not detected at a distance.

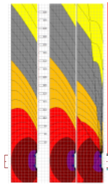
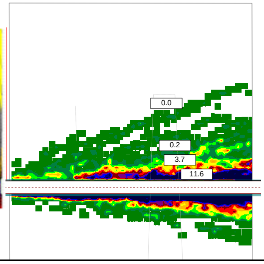
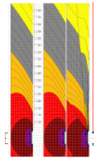
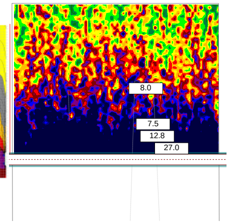
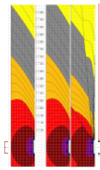
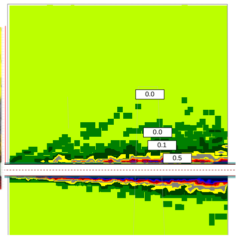
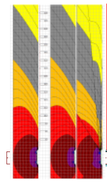
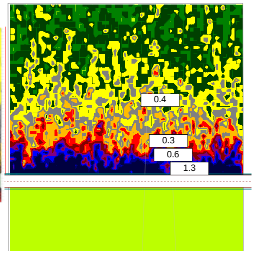
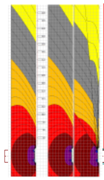
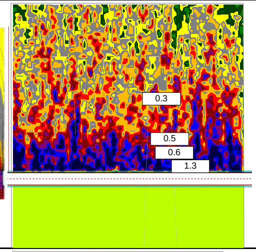
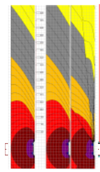
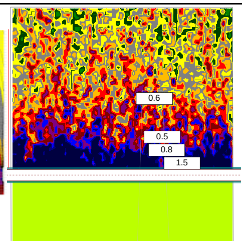
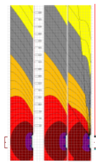
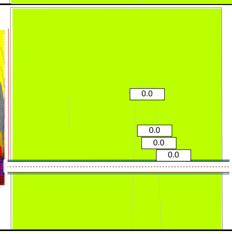
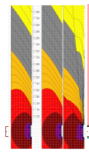
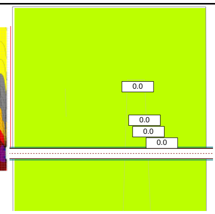
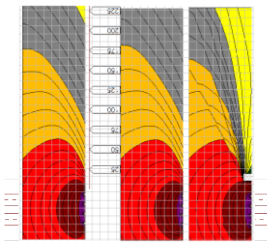
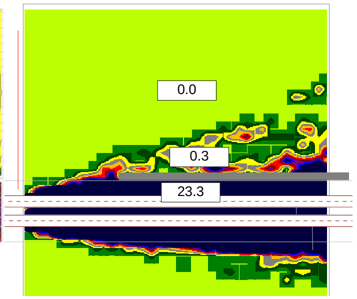
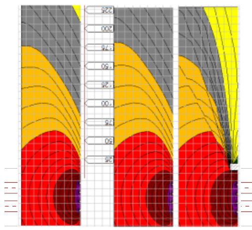
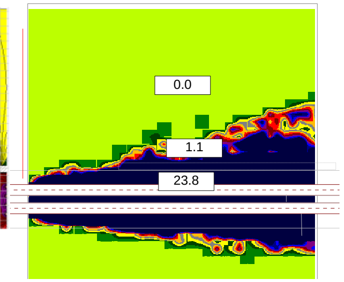
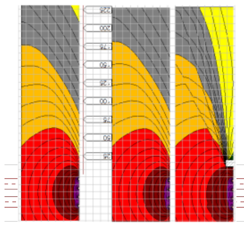
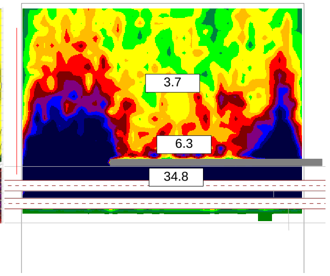
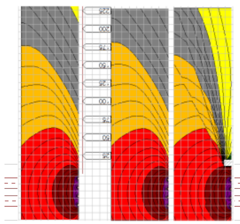
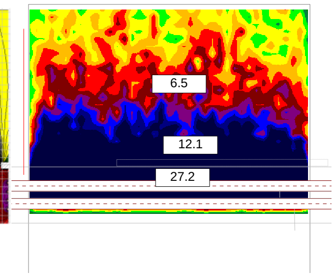
Wind	Assess-ment Metric	Presence of a noise barrier (3.5 m high) on the side of the highway		No sound barrier on the side of the highway		Trend Assessment
		Vertical contour line of road cross-section noise (determined by nighttime average traffic flow, 10 m × 10 m grid, 1 dBA contour interval)	Plane contour line of air quality at 1.5 m hight (determined by average traffic flow during daytime)	Vertical contour line of road cross-section noise (determined by nighttime average traffic flow, 10 m × 10 m grid, 1 dBA contour interval)	Plane contour line of air quality at 1.5 m hight (determined by average traffic flow during daytime)	
3m/s South	NO_x					NO_x:1. When the wind field is perpendicular to the road, NO_x emissions meet the roadside air quality standard. 2. Because of the south wind, the concentration on the south side of the road was not measured. 3. The presence of a barrier resulted in a higher vehicle exhaust gas concentration at the roadside, but the gas diffuses well at a distance. When there is no barrier, the gas diffusion contributes to lower concentration at the roadside, but the concentration is relatively high at a distance. 4. The distance at which the sound reached the standard limit to describe the noise impact was 348 m/385 m (L_{day}/L_{night} background 43.4 dBA). The noise impact range is greater than the air impact' s, which is consistent with general perception. 5. Compared with the average noise assessment, more attention should be paid to the impact of maximum concentration to assess the air quality. Due to the limitation of the article length, details are not described in this paper. PM_{10}:The trend of PM_{10} is the same as the above NO_x, but its concentration is lower.
3m/s South	PM_{10}					
3m/s South	NO_2					The trend of NO_2 is the same as the above NO_x, but its concentration is lower.
3m/s South	SO_2					The concentration of SO_2 is very low, there is only a very low concentration on the roadside, and it is not detected at a distance.

Table 6 - In the both conditions of wind directions parallel + perpendicular to the U road, roadside air quality of a case urban arterial road is assessed with the exhaust diffusion map combined with the traffic noise map

Wind	Assess-ment Metric	Presence of building on the road side along the main road in the urban center (the building height is 3.5 m)		No building on the road side along the main road in the urban center		Trend Assessment
		Vertical contour line of road cross-section noise (determined by nighttime average traffic flow, 10 m × 10 m grid, 1 dBA contour interval)	Plane contour line of air quality at 1.5 m (determined by average traffic flow during daytime)	Vertical contour line of road cross-section noise (determined by nighttime average traffic flow, 10 m × 10 m grid, 1 dBA contour interval)	Plane contour line of air quality at 1.5 m (determined by average traffic flow during daytime)	
3m/s West	NO_x					1. When the wind field is parallel to the road, NO_x emissions meet the roadside air quality standards. 2. The presence of a building nearby the road leads to a higher pollutant concentration at the roadside, but the gas diffuses well at a distance. When there is no building, the gas diffusion contributes to lower concentration at the roadside, but the concentration is relatively high at a distance. 3. The distance at which the sound reached the standard limit to describe the noise impact 222 m/254 m (L_{day}/L_{night} background 42.5 dBA). The noise impact range is greater than the air impact' s, , which is consistent with the general perception. However, when there are buildings on the roadside, the noise impact range is reduced to 30 m, which is within the first row of buildings. 4. Compared to the average noise assessment, more attention should be paid to the impact of maximum concentration to assess the air quality. Due to the limitation of the article length, details are not described in this paper.
3m/s South	NO_x					1. When the wind field is perpendicular to the road, NO_x emissions meet the roadside air quality standard. 2. Because of the south wind, the concentration on the south side of the road is not detected. 3. To compare the effect of buildings, the presence of a building makes the vehicles exhaust higher concentration of gas at the roadside, but the gas diffuses well at a distance; when there is no building, it is favorable for gas diffusion, but the concentration is relatively high at a distance 4. The distance at which the sound reached the standard limit to describe the noise impact is 222 m/254 m (L_{day}/L_{night} background 42.5 dBA). The noise impact range is greater than the air impact' s, which is consistent with general perception. However, when there are buildings on the roadside, the noise impact range is reduced to 30 m, which is within the first row of buildings. 5. Compared to the average noise assessment, more attention should be paid to the impact of maximum concentration on the air quality assessment. Due to the limitation of the article length, details are not described in this paper.
Legend		> 35.0 dB > 40.0 dB > 45.0 dB > 50.0 dB > 55.0 dB > 60.0 dB > 65.0 dB > 70.0 dB > 75.0 dB > 80.0 dB > 85.0 dB	> 0.0 µg/m3 > 1.0 µg/m3 > 2.0 µg/m3 > 3.0 µg/m3 > 4.0 µg/m3 > 5.0 µg/m3 > 6.0 µg/m3 > 7.0 µg/m3 > 8.0 µg/m3 > 9.0 µg/m3 > 10.0 µg/m3	> 35.0 dB > 40.0 dB > 45.0 dB > 50.0 dB > 55.0 dB > 60.0 dB > 65.0 dB > 70.0 dB > 75.0 dB > 80.0 dB > 85.0 dB	> 0.0 µg/m3 > 1.0 µg/m3 > 2.0 µg/m3 > 3.0 µg/m3 > 4.0 µg/m3 > 5.0 µg/m3 > 6.0 µg/m3 > 7.0 µg/m3 > 8.0 µg/m3 > 9.0 µg/m3 > 10.0 µg/m3	