SUPPLEMENTAL MATERIAL

Associations of short-term exposure to traffic-related air pollution with hospital admissions in London, U.K.

Evangelia Samoli[1], Richard W Atkisnon[2], Antonis Analitis[1], Gary W Fuller[3], David C Green[3], Ian Mudway [3], H Ross Anderson [2,3], Frank Kelly[3].

1. Department of Hygiene, Epidemiology and Medical Statistics, Medical School, University of Athens, 75 Mikras Asias Str, 115 27 Athens, Greece. 2. MRC-PHE Centre for Environment and Health, St George's, University of London, Cranmer Terrace, London, SW17 0RE U.K. 3. King's College Analytical & Environmental Sciences Division, King's College London, 4th Floor, Franklin-Wilkins Building, 150 Stamford Street, London SE1 9NH U.K.

*Address correspondence to: Evangelia Samoli, Department of Hygiene and Epidemiology, University of Athens Medical School, 75 Mikras Asias Street, 115 27 Athens, Greece Tel:++30-210-7462085, Fax:++30-210-7462205, e-mail: **esamoli@med.uoa.gr**

Annex 1. Selection of traffic-related pollution metrics

The use of indicator species to identify emissions from an air pollution source is well established in receptor analysis and source apportionment. Many studies have used enrichment factors of specific indicator species to identify and quantify sources[1] and indicator species are also used in source apportionment to attribute factors to source types. Viana et al.[2] reviewed PM source apportionment studies conducted across Europe and identified the pollutant species most frequently used in source attribution. These have been used to select indicators of different traffic pollution source mechanisms, along with source specific studies as summarized in Table 1.

Despite being strongly emitted from traffic sources an indicator species might also have other sources in the urban environment. The specificity of the each indicator species will therefore be different. The different transport sources, processes and indicator species are not represented individually in the London Atmospheric Emissions Inventory. We have therefore calculated a kerbside enrichment factor as an index of specificity for London for each tracer during the study period. This has been defined as:

Kerbside enrichment factor = ([Marylebone Road] – [North Kensington]) / [North Kensington]

Enrichment factors have been calculated separately for the warm and cool season to reflect potential differing seasonality between the traffic and non-traffic source types.

Table 1. Source indicators and their kerbside enrichment factors.

Source	Indicator	Background	Kerbside enrichment factor
Traffic - general	NOx	NOx, the sum of NO and NO_2, is found in greatest concentrations in London close to busy roads. Real-world measurements of exhaust from 72,000 vehicles show greatest NOx emissions arise from diesel and older (pre-EURO 3) petrol vehicles.[3] The London Atmospheric Emissions Inventory shows road transport to be the largest single NOx source in London at 47% of 2010 emissions followed by space heating (16%).[4]	4.6
Exhaust from petrol vehicles	CO	CO is emitted from incomplete fuel combustion. Real-world vehicle emissions measurements in London[5] shows exhaust CO between 1.9% for pre-euro petrol cars to 0.07% for Euro 4. By contrast all diesel vehicle types measured had emissions less than 0.07% and some as low as 0.01%.	1.4
Diesel exhaust	Black and elemental carbon	The black carbon measurement is a function of the light absorption of particles; which is strongly related to the carbon content of the aerosol. Elemental carbon defines the carbon concentration in particles that is not chemically bound.[6] Europe-wide these are mainly emitted from transport, especially diesel vehicles.[7] Viana et al.[2] list the use of black carbon as a tracer for vehicle exhaust in source apportionment studies. Measurements of	5.6 (for BC)

		real-world vehicle emissions in London using "smoke number" show that diesel vehicles are overwhelmingly the largest emitters with mean smoke numbers from light duty diesels being around 3.5 times greater than those from petrol.[5]	
Brake wear particles	Cu	Viana et al.[2] list the use of Cu as an indicator of traffic emissions from brake wear alongside Ba and Sb. The chemical composition of brake linings and brake dust vary according to product and application but due to its use as a high temperature lubricant Cu is generally the most abundant element in brake linings and is found in high abundance in brake dust.[8]	4.7
Tyre wear particles	Zn	Tyres are around 1% Zn by weight. It is used as an activator in the vulcanization process and is the only element in tyres that are present at significantly greater than crustal abundance.[8] Viana et al.[2] list the use of Zn as indicator of traffic emissions from tyre wear. Zn has also been used as an indicator of emissions from lubricating oil however traffic emissions are dominated (>90%) by tyre wear sources.[9] This was supported by Harrison et al.[9] who found negligible concentrations of sub-micron Zn in the roadside increment in London.	1.3
Mineral dust	Al	Viana et al.[2] list the use of Al, Si, Ca and Fe in PM$_{10}$ as indicators of crustal / mineral particles. Frank[10] used an equation using Si, Ca, Fe and Ti to apportion crustal material. However in urban settings Fe might also originate from vehicle wear sources for instance Harrison et al.[9] used Fe measured in the PM coarse as a marker for vehicle and soil dust in London. Of the remaining metallic elements measured in this study, Al and Ca occur in sufficient quantities to be used as tracers for mineral dusts. Given the identification of Ca in lubricating oil emissions from traffic in London,[11] Al was selected as the favored indicator species.	1.3

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Annex 2. Urban increment estimation

Source apportionment of several metrics was undertaken using the approach first proposed by Lenschow et al.[1] This approach assumes that the measured concentrations in urban areas consist of the sum of contributions from three different source areas, namely:

The regional background: This is the concentration of the pollutant present in air around the city. It is assumed to vary in time, but not space over the city and its surroundings. In the TRAFFIC study measurement sites to the west (Harwell, Oxfordshire), east (Detling, Kent) and, for CO only Egham in Surrey, were used to determine regional concentrations outside the London plume.

The urban background: This concentration is from the sum of all urban sources. The urban increment (urban – regional) is the concentration from urban sources. The urban increment for NOx, CO and BC were included in the analysis as specific tracers for urban traffic sources, as distinct from contributions from industry and more distant sources that determine the regional background. In this study the North Kensington measurement site was used.

The kerb / roadside: This is the concentration from a road source when measured very nearby. The contribution from the nearby road can be deduced from the difference between traffic and urban background monitoring sites. In this study the Marylebone Road measurement site was used to calculate kerbside enrichment factors.

References

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Annex 3. Supplemental description of the selected pollutants

Table 1. Distribution of the pollutants stratified by warm (April to September) and cool (October to March) period of the year.

	April to September				October to March			
Pollutant (μg/m^3, except CO mg/m^3)	**Mean**	**Median**	**IQR[a]**	**90th percentile**	**Mean**	**Median**	**IQR[a]**	**90th percentile**
NOx	37.4	31.1	20	63.1	72.9	59.7	55.0	139.0
NOx - Urban increment	28.0	21.8	17.1	49.6	56.6	43.9	41.2	136.3
CO	0.3	0.3	0.1	0.4	0.4	0.4	0.2	0.6
CO –Urban Increment	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2
EC	0.8	0.6	0.6	1.4	1.3	1.1	0.9	2.4
EC - Urban	0.6	0.5	0.3	1.1	0.9	0.7	0.6	1.8
BC	1.2	1.0	0.7	2.0	1.8	1.4	1.3	3.4
BC –Urban	0.8	0.6	0.4	1.4	1.1	0.9	0.9	2.1
Cu	0.0074	0.0063	0.01	0.142	0.0114	0.0087	0.01	0.0228
Zn	0.0093	0.0071	0.01	0.060	0.0150	0.0110	0.01	0.0318
Al	0.0765	0.0552	0.07	0.1555	0.0751	0.0567	0.06	0.1458
PM_{10}	15.2	13.1	8.0	24.0	21.5	18.0	12.5	38.0
$PM_{2.5}$	8.9	7.3	4.1	14.8	15.5	11.0	12.1	32.0
NO_2	28.9	26.1	14.5	45.2	43.5	43.0	22.9	62.9
SO_2	1.60	1.7	2.4	3.0	2.1	2.0	2.1	4.1
O_3	70.1	67.2	26.9	97.6	41.0	44.0	26.3	63.7

[a] IQR: Interquartile Range

Table 2. Annual correlations between pollutants.

Pollutant	**NOx**	**NOx- Urban**	**CO**	**CO- Urban**	**EC**	**EC- Urban**	**BC**	**BC- Urban**	**C**	**Zn**	**Al**	**PM_{10}**	**$PM_{2.5}$**	**NO_2**	**SO_2**
NOx	1														
NOx – Urban	0.98	1													
CO	0.83	0.81	1												
CO –Urban	0.35	0.41	0.60	1											
EC	0.91	0.90	0.74	0.37	1										
EC - Urban	0.78	0.83	0.62	0.45	0.92	1									
BC	0.90	0.88	0.77	0.36	0.92	0.78	1								
BC –Urban	0.81	0.83	0.66	0.35	0.86	0.85	0.92	1							
Cu	0.77	0.76	0.62	0.32	0.81	0.69	0.78	0.65	1						
Zn	0.68	0.63	0.57	0.13	0.68	0.45	0.68	0.45	0.74	1					
Al	0.36	0.33	0.26	0.00	0.40	0.28	0.40	0.26	0.49	0.55	1				
PM_{10}	0.65	0.57	0.57	0.04	0.53	0.32	0.60	0.38	0.56	0.71	0.65	1			
$PM_{2.5}$	0.65	0.57	0.58	0.05	0.54	0.33	0.61	0.39	0.56	0.71	0.55	0.95	1		
NO_2	0.90	0.87	0.74	0.23	0.83	0.69	0.80	0.72	0.71	0.66	0.44	0.66	0.66	1	
SO_2	0.55	0.51	0.42	0.08	0.46	0.24	0.48	0.32	0.40	0.47	0.37	0.51	0.49	0.52	1
O_3	-0.48	-0.45	-0.42	-0.13	-0.36	-0.23*	-0.39	-0.39	-0.27	-0.23	0.19	-0.19	-0.28	-0.40	-0.17

Annex 4. Percent change (and 95% confidence intervals (CIs)) in cardiovascular and respiratory hospital admissions associated with an interquartile range increase (in μg/m^3) in regulated pollutants following single day (lag 1 for cardiovascular and lag 2 for respiratory diagnoses) or weekly exposure (lags 0-6) in London, U.K. for 2011–12.

Pollutants	**CVD Admissions % (95% CI)**		**Respiratory Admissions % (95% CI)**		
	15-64 years	**65+ years**	**0-14 years**	**15-64 years**	**65+ years**
Single Day Exposure					
PM_{10}	0.17 (-0.86, 1.21)	-0.50 (-1.27, 0.28)	0.69 (-0.85, 2.25)	-0.67 (-1.69, 0.37)	-1.14 (-2.10, -0.16)
$PM_{2.5}$	0.19 (-0.73, 1.12)	-0.80 (-1.49, -0.10)	0.42 (-0.94, 1.81)	-0.80 (-1.72, 0.13)	-0.97 (-1.84, -0.09)
NO_2	1.00 (-0.87, 2.91)	-0.75 (-2.15, 0.68)	1.91 (-0.78, 4.67)	-1.14 (-2.94, 0.69)	-3.11 (-4.75, -1.44)
SO_2	0.79 (-0.72, 2.32)	-0.15 (-1.29, 1.00)	0.69 (-1.38, 2.81)	-0.90 (-2.38, 0.61)	-1.93 (-3.26, -0.57)
O_3	-0.12 (-2.01, 1.81)	1.58 (0.13, 3.05)	-1.64 (-4.35, 1.15)	3.23 (1.31, 5.19)	4.83 (3.01, 6.68)
Weekly Exposure					
PM_{10}	-0.76 (-2.32, 0.81)	-0.32 (-1.50, 0.87)	2.59 (-0.24, 5.50)	-0.61 (-2.17, 0.98)	-3.28 (-4.80, -1.73)
$PM_{2.5}$	-0.63 (-2.07, 0.83)	-0.66 (-1.74, 0.43)	2.21 (-0.33, 4.81)	-0.92 (-2.36, 0.54)	-3.03 (-4.43, -1.60)
NO_2	-1.52 (-4.47, 1.53)	-0.16 (-2.42, 2.16)	6.30 (1.07, 11.81)	-1.69 (-4.65, 1.35)	-7.16 (-9.89, -4.35)
SO_2	-1.32 (-4.07, 1.51)	-0.35 (-2.44, 1.79)	4.95 (0.54, 9.56)	-1.99 (-4.75, 0.87)	-3.21 (-5.77, -0.58)
O_3	0.66 (-2.22, 3.63)	1.95 (-0.23, 4.19)	-7.89 (-12.39, -3.16)	4.71 (1.66, 7.85)	8.84 (5.73, 12.04)

Annex 5. Results from multi pollutants' models. Percent change (and 95% confidence intervals (CIs)) in cardiovascular and respiratory hospital admissions associated with an interquartile range increase in traffic pollutants after single day exposure (lag 1 for cardiovascular and lag 2 for respiratory diagnoses) in London, U.K. for 2011–12. EC/BC and metals are also adjusted for PM mass.

Indicator/ Pollutant	**Controlling for**	**Cardiovascular Admissions % (95%CI)**		**Respiratory Admissions % (95%CI)**		
		15-64 years	**65+ years**	**0-14 years**	**15-64 years**	**65+ years**
General traffic						
NOx	O_3	1.05 (-0.27, 2.38)	0.24 (-0.76, 1.25)	0.74 (-1.01, 2.52)	0.12 (-1.14, 1.40)	-0.59 (-1.74, 0.57)
	SO_2	0.74 (-0.65, 2.16)	-0.38 (-1.44, 0.69)	0.96 (-0.85, 2.80)	-0.62 (-1.99, 0.77)	-1.42 (-2.66, -0.16)
	$PM_{2.5}$	1.22 (-0.26, 2.73)	0.54 (-0.59, 1.69)	0.98 (-0.88, 2.88)	-0.31 (-1.73, 1.13)	-1.65 (-2.92, -0.36)
NOx Urban	O_3	1.07 (-0.13, 2.29)	0.36 (-0.56, 1.28)	0.82 (-0.75, 2.41)	0.22 (-0.93, 1.39)	-0.47 (-1.53, 0.59)
	SO_2	0.77 (-0.48, 2.05)	-0.14 (-1.10, 0.83)	0.94 (-0.68, 2.58)	-0.42 (-1.65, 0.84)	-1.12 (-2.25, 0.02)
	$PM_{2.5}$	1.12 (-0.17, 2.41)	0.53 (-0.45, 1.52)	0.97 (-0.64, 2.61)	-0.17 (-1.40, 1.08)	-1.27 (-2.38, -0.14)
	EC Urban	-2.02 (-4.79, 0.84)	0.91 (-1.33, 3.20)	-0.24 (-4.03, 3.70)	-2.78 (-5.58, 0.10)	-2.12 (-4.68, 0.52)
Petrol vehicle exhaust						
CO	O_3	1.86 (0.29, 3.46)	-0.22 (-1.42, 0.98)	0.79 (-1.39, 3.01)	-0.37 (-1.93, 1.22)	-0.85 (-2.28, 0.61)
	SO_2	1.70 (0.05, 3.39)	-0.62 (-1.88, 0.65)	0.70 (-1.54, 3.00)	-1.12 (-2.77, 0.56)	-1.69 (-3.20, -0.15)

	$PM_{2.5}$	2.09 (0.31, 3.91)	0.19 (-1.17, 1.56)	0.95 (-1.40, 3.35)	-0.61 (-2.37, 1.17)	-1.80 (-3.38, -0.20)
CO Urban	*O_3*	0.96 (-0.07, 2.00)	-0.07 (-0.85, 0.72)	0.94 (-0.44, 2.35)	0.37 (-0.67, 1.41)	-0.32 (-1.25, 0.62)
	SO_2	1.02 (-0.03, 2.07)	-0.20 (-1.00, 0.60)	0.81 (-0.60, 2.24)	0.17 (-0.88, 1.23)	-0.48 (-1.43, 0.49)
	$PM_{2.5}$	0.96 (-0.07, 1.99)	-0.06 (-0.84, 0.72)	0.91 (-0.47, 2.31)	0.29 (-0.74, 1.32)	-0.49 (-1.42, 0.46)
	EC Urban	0.43 (-0.87, 1.75)	0.02 (-0.99, 1.03)	0.38 (-1.38, 2.17)	0.26 (-1.04, 1.59)	-0.60 (-1.77, 0.58)
Diesel vehicle exhaust						
EC	*NOx*	4.15 (0.88, 7.53)	0.54 (-1.91, 3.05)	-0.42 (-4.87, 4.24)	0.13 (-3.03, 3.39)	1.16 (-1.85, 4.27)
	CO	0.90 (-1.05, 2.90)	0.38 (-1.11, 1.90)	0.79 (-1.82, 3.47)	0.32 (-1.62, 2.30)	-0.17 (-1.96, 1.65)
EC Urban	*NOx*	2.49 (0.57, 4.45)	0.05 (-1.42, 1.55)	1.65 (-1.08, 4.45)	2.09 (0.17, 4.06)	1.63 (-0.15, 3.45)
	CO	1.00 (-0.37, 2.38)	0.21 (-0.84, 1.28)	0.97 (-0.87, 2.85)	0.73 (-0.63, 2.12)	0.72 (-0.53, 1.99)
BC	*NOx*	3.32 (-0.22, 6.98)	0.33 (-2.31, 3.03)	-1.32 (-6.18, 3.79)	-0.60 (-4.01, 2.92)	2.90 (-0.45, 6.37)
	CO	0.40 (-1.74, 2.59)	0.74 (-0.91, 2.41)	0.68 (-2.14, 3.59)	0.65 (-1.51, 2.86)	-0.01 (-2.02, 2.03)
BC Urban	*NOx*	0.55 (-1.66, 2.82)	-0.63 (-2.31, 1.08)	0.59 (-2.48, 3.76)	0.28 (-1.91, 2.52)	1.85 (-0.19, 3.94)
	CO	-0.21 (-1.74, 1.35)	0.00 (-1.18, 1.19)	0.64 (-1.40, 2.71)	0.76 (-0.78, 2.32)	0.79 (-0.60, 2.21)
Vehicle Non-exhaust						
Cu	*NOx*	1.37 (-0.56, 3.34)	0.03 (-1.45, 1.53)	-1.40 (-3.97, 1.25)	-1.55 (-3.45, 0.38)	-1.07 (-2.84, 0.74)
	CO	0.80 (-0.85, 2.47)	0.15 (-1.11, 1.42)	-0.27 (-2.47, 1.99)	-1.16 (-2.80, 0.51)	-1.31 (-2.82, 0.23)

ZN	*NOx*	-0.27 (-1.73, 1.22)	0.17 (-0.96, 1.31)	-1.85 (-3.85, 0.20)	-0.44 (-1.94, 1.09)	-0.14 (-1.51, 1.24)
	CO	-0.38 (-1.76, 1.03)	0.21 (-0.85, 1.28)	-1.16 (-3.05, 0.77)	-0.18 (-1.6, 1.26)	-0.40 (-1.69, 0.91)
Al	*NOx*	0.55 (-1.08, 2.21)	-1.13 (-2.37, 0.12)	-0.39 (-2.84, 2.11)	0.79 (-0.89, 2.50)	1.62 (0.06, 3.21)
	CO	0.39 (-1.22, 2.03)	-1.13 (-2.35, 0.10)	0.20 (-2.22, 2.68)	0.86 (-0.79, 2.55)	1.45 (-0.09, 3.01)

Annex 6. Percent change (and 95% confidence intervals (CIs)) in hospital admissions by age group and season associated with season-specific interquartile range (IQR) increase in traffic-related pollutants after single day exposure (lag 1 for cardiovascular (A) and lag 2 for respiratory (B) diagnoses) in London, U.K. for 2011–12. EC/BC and metals are adjusted for PM mass.

(A) Cardiovascular Admissions

Indicator/Pollutants	**15-64 years % (95% CI)**		**65+ years % (95% CI)**	
	April-September	**October-March**	**April-September**	**October-March**
General traffic				
NOx	0.87 (-0.96, 2.73)	0.53 (-1.09, 2.17)	-0.59 (-1.94, 0.78)	0.07 (-1.24, 1.40)
NOx – Urban	1.12 (-0.62, 2.89)	0.41 (-0.99, 1.84)	-0.40 (-1.69, 0.90)	0.13 (-1.01, 1.29)
Petrol vehicle exhaust				
CO	0.95 (-1.08, 3.02)	0.96 (-0.67, 2.61)	-0.63 (-2.14, 0.90)	-0.07 (-1.39, 1.27)
CO –Urban	0.82 (-0.69, 2.36)	0.31 (-1.20, 1.84)	-0.22 (-1.34, 0.92)	0.02 (-1.21, 1.26)
Diesel vehicle exhaust				
EC	2.41 (-0.03, 4.90)	0.56 (-1.30, 2.46)	-0.66 (-2.47, 1.18)	0.00 (-1.51, 1.54)
EC - Urban	1.23 (-0.16, 2.63)	0.33 (-1.25, 1.94)	-0.28 (-1.33, 0.78)	-0.21 (-1.53, 1.13)
BC	3.22 (0.75, 5.74)	0.85 (-1.37, 3.11)	-0.10 (-1.91, 1.74)	0.66 (-1.14, 2.49)
BC –Urban	1.92 (0.08, 3.80)	0.68 (-1.32, 2.73)	0.04 (-1.34, 1.44)	-0.19 (-1.78, 1.43)

Vehicle Non-exhaust				
Cu	1.33 (-0.99, 3.70)	1.51 (-0.66, 3.73)	-0.28 (-1.97, 1.45)	-0.32 (-2.13, 1.51)
Zn	0.77 (-1.30, 2.87)	0.07 (-2.17, 2.37)	0.06 (-1.44, 1.58)	0.14 (-1.76, 2.07)
Al	-0.06 (-3.13, 3.11)	0.23 (-1.85, 2.36)	-0.37 (-2.65, 1.97)	-2.12 (-3.84, -0.38)

(B) Respiratory Admissions

	0-14 years % (95%CI)		**15-64 years % (95%CI)**		**65+ years % (95%CI)**	
	April-September	**October-March**	**April-September**	**October-March**	**April-September**	**October-March**
General traffic						
NOx	1.14 (-2.26, 4.67)	2.40 (0.09, 4.76)	0.47 (-1.40, 2.38)	-0.65 (-2.30, 1.02)	0.57 (-0.93, 2.08)	-2.09 (-3.75, -0.39)
NOx – Urban	1.41 (-1.89, 4.81)	2.14 (0.14, 4.17)	0.40 (-1.41, 2.23)	-0.32 (-1.75, 1.13)	0.46 (-0.98, 1.92)	-1.60 (-3.06, -0.12)
Petrol vehicle exhaust						
CO	0.52 (-3.18, 4.36)	1.62 (-0.82, 4.12)	0.33 (-1.71, 2.42)	-0.20 (-1.93, 1.55)	1.19 (-0.44, 2.85)	-1.13 (-2.89, 0.67)
CO –Urban	0.24 (-2.49, 3.05)	0.84 (-1.43, 3.16)	-0.37 (-1.87, 1.16)	1.41 (-0.19, 3.03)	-0.31 (-1.52, 0.90)	0.33 (-1.32, 2.01)
Diesel vehicle exhaust						
EC	5.67 (0.92, 10.64)	0.93 (-1.80, 3.73)	0.58 (-1.94, 3.16)	0.39 (-1.50, 2.31)	-0.57 (-2.58, 1.49)	-0.93 (-2.87, 1.05)
EC - Urban	3.81 (1.02, 6.68)	2.10 (-0.19, 4.44)	0.52 (-0.98, 2.05)	-0.31 (-1.81, 1.22)	0.05 (-1.16, 1.27)	-0.76 (-2.42, 0.92)
BC	2.48 (-2.15, 7.33)	1.86 (-1.23, 5.04)	0.41 (-2.09, 2.97)	0.66 (-1.62, 3.00)	-0.51 (-2.48, 1.50)	-1.16 (-3.48, 1.21)
BC –Urban	1.04 (-2.42, 4.63)	2.89 (0.04, 5.83)	-0.18 (-2.06, 1.75)	0.99 (-1.05, 3.07)	-0.47 (-1.91, 0.98)	-0.27 (-2.35, 1.86)

Vehicle Non-exhaust						
Cu	1.54 (-2.92, 6.22)	-1.53 (-4.65, 1.70)	-1.31 (-3.72, 1.17)	-0.76 (-3.13, 1.66)	-1.01 (-2.91, 0.92)	-2.26 (-4.64, 0.18)
Zn	1.55 (-2.21, 5.45)	-3.99 (-7.30, -0.56)	0.48 (-1.56, 2.57)	-0.64 (-3.18, 1.97)	-0.21 (-1.80, 1.41)	-1.48 (-4.05, 1.16)
Al	4.39 (-1.17, 10.26)	-2.06 (-5.46, 1.45)	-0.14 (-3.12, 2.94)	-0.90 (-3.34, 1.60)	1.25 (-1.08, 3.63)	-0.30 (-2.80, 2.27)