Supporting Information

Urinary Metabolites of Polycyclic Aromatic Hydrocarbons and their Association with Lipid Peroxidation: A Biomarker-Based Study between Los Angeles and Beijing

Yan Lin,[1,2] Xinghua Qiu,[2*] Nu Yu[1], Qiaoyun Yang[2], Jesus Araujo[3] and Yifang Zhu[1*]

1. Department of Environmental Health Sciences, Jonathan and Karin Fielding School of Public Health, University of California, Los Angeles, Los Angeles, California 90095, United States
2. State Key Joint Laboratory for Environmental Simulation and Pollution Control, College of Environmental Sciences and Engineering, and Center for Environment and Health, Peking University, Beijing 100871, P. R. China
3. Division of Cardiology, Department of Medicine, School of Medicine, University of California, Los Angeles, Los Angeles, California 90095, United States

* Corresponding Authors: Yifang Zhu: yifang@ucla.edu

Xinghua Qiu: xhqiu@pku.edu.cn

Contents of this file

Table S1. Information of OH-PAHs standards, the monitored ions of methylated OH-PAHs in GC-MS (EI) and the method detection limits of OH-PAHs

Compound	Abbreviation	Ions monitored	Detection Limits (pg mL^{-1})	Purity	Source
1-hydroxynaphthalene	1-OH-NAP	158, 159	14.9	98%	Dr. Ehrenstrofer[a]
2-hydroxynaphthalene	2-OH-NAP	158, 159	13.6	99%	Dr. Ehrenstrofer
2-hydroxybiphenyl	2-OH-BP	184, 185	13.0	97.7%	AccuStandard[b]
3-hydroxybiphenyl	3-OH-BP	184, 185	8.6	100%	AccuStandard
4-hydroxybiphenyl	4-OH-BP	184, 185	18.2	100%	AccuStandard
2,2’-dihydroxybiphenyl	2,2’-DOH-BP	214, 215	11.9	100%	AccuStandard
3,4-dihydroxybiphenyl	3,4-DOH-BP	214, 215	12.3	100%	AccuStandard
4,4’-dihydroxybiphenyl	4,4’-DOH-BP	214, 215	9.7	100%	AccuStandard
2-hydroxydibenzofuran	2-OH-DBF	198, 199	10.8	98.3%	Chiron AS[c]
2-hydroxyfluorene	2-OH-FLU	196, 197	7.5	98%	Aldrich[d]
3-hydroxyfluorene	3-OH-FLU	196, 197	12.3	N.A.[f]	Aldrich
1-hydroxyphenanthrene	1-OH-PHE	208, 209	8.8	99%	Dr. Ehrenstrofer
2-hydroxyphenanthrene	2-OH-PHE	208, 209	17.0	99%	Dr. Ehrenstrofer
3-hydroxyphenanthrene	3-OH-PHE	208, 209	12.8	99%	Dr. Ehrenstrofer
4-hydroxyphenanthrene	4-OH-PHE	208, 209	9.9	99.6%	Dr. Ehrenstrofer
1-hydroxypyrene	1-OH-PYR	217, 218	14.3	100%	AccuStandard
(SS) $^{13}C_6$-3-hydroxyphenanthrene	$^{13}C_6$-3-OH-PHE	214, 215		≥95%	CIL[e]
(IS) d_{10}-anthracene	d_{10}-ANT	188, 189		99.2%	AccuStandard
(IS) d_{10}-pyrene	d_{10}-PYR	212, 213		99.1%	AccuStandard

[a.] Augsburg, Germany; [b.]New Haven, CT, USA; [c.]Trondheim, Norway; [d.] St. Louis, MO, USA; [e.]Andover, MA, USA[f.] Notavailable.

Table S2. The influence of individual characteristic and physical activities on urinary OH-PAHs based on multivariate regression model with step-wise approach

Pollutants[a]	Gender	Age	BMI	City	CD[b]	BD[c]	BI[d]	BFI[e]	DD[f]	HD[g]	PD[h]	ED[i]
1-OH-NAP	0.6	0.61	0.15	**<0.001**	0.89	0.29	0.21	0.39	0.24	0.61	0.07	0.43
2-OH-NAP	**<0.001**	0.14	0.76	0.89	0.36	0.05	0.23	0.75	0.98	0.67	**<0.05**	**<0.01**
2-OH-BP	**<0.05**	**<0.05**	**<0.05**	0.11	0.51	0.93	0.34	0.91	**<0.05**	0.34	0.28	**<0.05**
4-OH-BP	0.24	0.8	0.11	**<0.001**	0.84	0.1	0.34	0.18	0.82	0.98	0.48	0.46
4,4'-DOH-BP	0.83	0.77	**<0.05**	**<0.001**	0.84	0.25	0.3	0.24	0.85	0.59	0.09	**<0.05**
2-OH-DBF	0.24	0.62	**<0.001**	**<0.001**	0.34	0.15	0.48	0.22	0.92	0.44	0.76	0.08
2-OH-FLU	0.37	0.86	**<0.001**	**<0.001**	0.54	0.22	0.39	0.34	0.95	0.74	0.68	0.11
3-OH-FLU	0.84	1	**<0.001**	**<0.001**	0.48	0.26	0.25	0.31	0.51	0.37	0.14	**<0.05**
1-OH-PHE	0.99	**<0.05**	**<0.001**	**<0.001**	0.73	0.05	0.15	0.8	0.94	0.78	0.6	0.23
2-OH-PHE	0.09	0.78	**<0.05**	**<0.001**	0.82	0.32	0.66	0.53	0.69	0.81	0.43	0.38
4-OH-PHE	0.36	0.7	0.99	**<0.001**	0.21	0.38	0.42	0.69	0.3	0.79	0.69	0.23
1-OH-PYR	0.48	0.33	0.26	**<0.001**	0.58	0.27	0.51	**<0.05**	0.55	0.46	0.95	0.23
ΣOH-NAPs	**<0.05**	0.34	0.4	0.11	0.86	0.22	0.24	0.85	0.34	0.07	0.41	**<0.05**
ΣOH-BPs	0.54	0.09	**<0.01**	**<0.001**	0.9	0.27	0.7	0.41	0.09	0.11	0.64	**<0.01**
ΣOH-FLUs	0.85	0.14	**<0.001**	**<0.001**	0.13	**<0.05**	0.07	0.28	0.66	0.41	0.32	0.09
ΣOH-PHEs	0.84	**<0.05**	**<0.01**	**<0.001**	0.18	**<0.05**	**<0.05**	0.43	0.64	0.56	0.75	0.32
Σ_8OH-PAHs	**<0.05**	0.45	0.44	**<0.01**	0.68	0.12	0.5	0.38	0.39	0.61	0.32	0.15
Σ_{12}OH-PAHs	**<0.05**	0.25	0.21	**<0.001**	0.73	0.14	0.59	0.29	0.28	0.35	0.38	**<0.05**

[a.] Data was log-transformed before the analysis; [b.] CD – Cooking duration (h); [c.] BT – Barbecue duration (h); [d.] BI – Barbecue intake (pound); [e.] BFI – Baked food intake (pound); [f.] DD – Driving duration (h); [g.] HT – Duration near heavy traffic(h); [h.] PD – Duration in public traffic transportation (h); [i.] ED – Duration in environmental tobacco smoke (h).

Table S3. Comparison between the physical activities in Los Angeles and Beijing

	In Los Angeles (n=57)	In Beijing (n=47)	*p*-value[a]
Cooking Duration(h)	0.86±0.99[b]	0.00±0.02	**<0.01**
Barbecue Duration (h)	0.16±0.52	0.00±0.00	**<0.05**
Barbecue intake (pound)	0.23±0.48	0.26±0.59	0.73
Baked food intake (pound)	0.54±0.78	0.66±0.56	**<0.05**
Driving Duration (h)	0.67±1.14	0.16±0.67	**<0.01**
Duration near heavy traffic	0.62±0.99	4.03±3.49	**<0.01**
Duration in public transportation (h)	0.58±1.21	3.00±4.18	**<0.01**
Duration in environmental tobacco smoke (h)	0.02±0.09	1.49±2.39	**<0.01**

a. Mann-Whitney U-test, two-tailed

b. Mean±standard deviation

Table S4 Descriptive statistics of biomarkers urine samples in Beijing (BJ) and Los Angeles before (LA_1) and after the trip(LA_2)

Biomarker	Median (IQR[a])			*p*-value[b]			Beijing/LA
	In LA_1(n=30)	In BJ(n=47)	In LA_2(n=27)	LA_1 vs. BJ	LA_2 vs. BJ	LA_1 vs. LA_2	Ratio(95%CI;*p*-value)[c]
Exposure biomarker (ng/mL)							
1-hydroxynaphthalene	0.86 (0.15, 1.81)	2.37 (0.95, 4.40)	0.51 (0.16, 1.09)	<0.001	<0.001	0.51	4.1 (2.3-7.3; <0.001)
2-hydroxynaphthalene	1.92 (0.78, 5.69)	5.20 (2.08, 6.46)	2.57 (0.80, 5.52)	<0.05	<0.05	0.79	1.7 (1.1-2.6; <0.05)
∑hydroxynaphthalenes	3.47 (1.08, 8.53)	6.95 (3.78, 13.1)	2.95 (0.89, 7.30)	<0.01	<0.01	1.00	2.1 (1.3-3.2; <0.01)
2-hydroxybiphenyl	0.44 (0.28, 0.66)	0.53 (0.39, 1.22)	0.64 (0.46, 0.94)	<0.05	0.84	<0.05	1.7 (1.1-2.5; <0.05)
4-hydroxybiphenyl	0.24 (0.13, 0.39)	1.65 (0.88, 3.32)	0.25 (0.09, 0.67)	<0.001	<0.001	0.73	5.8 (3.8-8.7; <0.001)
4,4'-dihydroxybiphenyl	0.27 (0.12, 0.56)	1.44 (0.65, 2.43)	0.41 (0.07, 0.70)	<0.001	<0.001	0.61	4.2 (2.7-6.7;<0.001)
∑hydroxybiphenyls	1.04 (0.55, 1.72)	3.77 (2.17, 6.75)	1.34 (0.74, 2.98)	<0.001	<0.001	0.14	3.6 (2.4-5.2; <0.001)
2-hydroxydibenzofuran	0.18 (0.10, 0.37)	2.19 (1.33, 4.53)	0.30 (0.12, 0.58)	<0.001	<0.001	0.31	9.5 (6.5-13.7; <0.001)
2-hydroxyfluorene	0.14 (0.09, 0.29)	1.75 (0.80, 2.97)	0.26 (0.09, 0.43)	<0.001	<0.001	0.39	9.0 (6.1-13.3; <0.001)
3-hydroxyfluorene	0.06 (0.04, 0.09)	0.57 (0.33, 1.08)	0.07 (0.02, 0.15)	<0.001	<0.001	0.64	8.6 (5.6-13.2; <0.001)
∑hydroxyfluorenes	0.21 (0.13, 0.40)	2.24 (1.12, 4.02)	0.28 (0.11, 0.58)	<0.001	<0.001	0.41	8.8 (6.0-13.0; <0.001)
1-hydroxyphenanthrene	0.08 (0.05, 0.24)	0.70 (0.30, 1.09)	0.11 (0.05, 0.23)	<0.001	<0.001	0.97	6.1 (4.0-9.3; <0.001)
2-hydroxyphenanthrene	0.05 (0.03, 0.11)	0.35 (0.21, 0.56)	0.07 (0.03, 0.10)	<0.001	<0.001	0.74	5.5(3.9-7.7; <0.001)
4-hydroxyphenanthrene	0.04 (0.01, 0.08)	0.18 (0.07, 0.29)	0.05 (0.02, 0.10)	<0.001	<0.001	0.53	4.2 (2.7-6.6; <0.001)
∑hydroxyphenanthrenes	0.19 (0.10, 0.47)	1.26 (0.49, 2.04)	0.28 (0.09, 0.49)	<0.001	<0.001	0.82	5.4 (3.7-7.9; <0.001)
1-hydroxypyrene	0.06 (0.03, 0.13)	0.51 (0.16, 0.94)	0.09 (0.04, 0.18)	<0.001	<0.001	0.52	5.2 (3.3-8.2; <0.001)
$\sum_8$hydroxylated PAHs[d]	4.05 (1.27, 8.76)	11.6 (5.89, 20.9)	3.43 (1.20, 8.27)	<0.001	<0.001	0.89	2.8(1.8-4.2; <0.001)
$\sum_{12}$hydroxylated PAHs[e]	5.51 (2.17, 10.4)	18.1 (10.3, 33.7)	6.58 (2.04, 11.1)	<0.001	<0.001	0.51	3.2 (2.2-4.7; <0.001)
Effect biomarker (ng/mL)							
malondialdehyde	27.9 (14.3, 52.3)	49.4 (20.2, 92.4)	36.1 (16.1, 62.8)	<0.05	0.25	0.24	1.5 (1.0-2.0; <0.05)

[a.] IQR: interquartile range; [b.] Mann-Whitney test; [c.] Calculated by multivariate linear regression models with enter approach, adjusted by age, gender and BMI;

[d.] Sum of OH-NAPs, OH-FLUs, OH-PHEs, and 1-OH-PYR; [e.] Sum of OH-PAHs, OH-BPs, and 2-OH-DBF

Table S5. Pearson correlation among different OH-PAHs and metabolite ratios (data was log-transformed)

	ΣOH-BPs	2-OH-DBF	ΣOH-FLUs	ΣOH-PHEs	1-OH-PYR	1-/2-OH-NAP	1+2-/4-OHPHE
ΣOH-NAPs	0.56**	0.52**	0.57**	0.58**	0.58**	-0.13	-0.01
ΣOH-BPs		0.77**	0.76**	0.77**	0.68**	0.20*	0.11
2-OH-DBF			0.97**	0.91**	0.83**	0.33**	0.19*
ΣOH-FLUs				0.93**	0.86**	0.34**	0.22*
ΣOH-PHEs					0.86**	0.30**	0.15
1-OH-PYR						0.26**	0.14
1-/2-OH-NAP							0.11

**: p<0.01; *:p<0.05

Table S6. Summary of the studies cited to investigate the relationship between naphthalene exposure and 1-/2-OH-NAP ratio

No.	Exposure characteristic	Population description	Sample size	Male/ Female	Smokers/Non-smokers	ΣOH-NAPs (μg/g creatinine)	1-/2-OH -NAP	Ref.
Study1	Biomass burning	Cooking women (pre-intervention)	47	0/47	0/47	34.2	1.30	15
		Cooking women (post-intervention)	47	0/47	0/47	20.3	0.97	15
Study2	Biomass burning	Cooking women (pre-intervention)	57	0/57	0/57	39.0	1.04	16
		Cooking women (post-intervention)	57	0/57	0/57	19.6	0.96	16
Study3	Coking processes	Tar distillation operators	69	N/A[a]	56/13	1220	2.62	17
		Naphthalene oil distillation workers	33	N/A	33/0	1079	1.84	17
		Unexposed workers	36	25/11	28/8	15.8	1.70	17
Study4	Bitumen vapor	bitumen-exposed workers(pre+post shift)	112	112/0	0/112	4.38	0.77	18
		Roadside construction workers(pre+post shift)	240	240/0	0/240	5.82	0.60	18
Study5	Ambient environment	Healthy people visiting a certain hospital	273	273/0	140/133	5.60	0.55	1
Study6	Coking processes	Works in distillation department	29	29/0	N/A	2204	1.75	19
		Sorting department gas fitting operators	11	11/0	N/A	677	1.89	19
Study7	Aluminum plant	Resident within 1km from the plant (Sep. 14, 2005)	65	N/A	0/65	4.65	0.92	20
		Resident within 1km from the plant (Sep. 21, 2005)	68	N/A	0/68	4.05	0.62	20
		Resident within 1km from the plant (May 23+24, 2006)	109	N/A	0/109	4.22	0.40	20
		Resident within 1km from the plant (May 30+31, 2006)	111	N/A	0/111	3.81	0.31	20

Table S6. Summary of the studies cited to investigate the relationship between naphthalene exposure and 1-/2-OH-NAP ratio (continued)

		Resident living more than 11km from the plant (Sep. 14, 2005)	62	N/A	0/62	3.14	0.80	[20]
		Resident living more than 11km from the plant (Sep. 21, 2005)	66	N/A	0/66	4.31	0.57	[20]
		Resident living more than 11km from the plant (May 23+24, 2006)	106	N/A	0/106	4.20	0.46	[20]
		Resident living more than 11km from the plant (May 30+31, 2006)	112	N/A	0/112	4.38	0.50	[20]
Study8	Coking processes	Workers at adjacement workplaces of coken ovens	118	118/0	0/118	12.8	1.23	[21]
		Workers at bottom of coken ovens	169	169/0	0/169	16.9	1.41	[21]
		Workers at side of coken ovens	82	82/0	0/82	25.1	1.15	[21]
		Workers at top of coken ovens	20	20/0	0/20	45.6	1.32	[21]
Study9	Creosote impregnation plant	Residence living at 50-360 m downwind from the plant(morning+evening)	57	N/A	0/57	3.15	1.08	[22]
		Residence living at 0.75-1.1 km upwind from the plant(morning+evening)	51	N/A	0/51	5.23	1.28	[22]
Study10	Traffic emission	Schoolchildren near a road	64	38/26	0/64	6.81	0.41	[23]
Study11	Brick kiln	Brick kiln workers	46	46/0	0/46	6.60	2.39	[24]
		Non-exposed group	34	34/0	0/46	1.66	0.97	[24]
Study12	Jet fuel	Workers with low exposure(pre+post shift)	172	N/A	0/172	2.95	0.41	[25]
		Workers with high exposure(pre+post shift)	141	N/A	0/141	4.98	0.57	[25]

[a.] not available

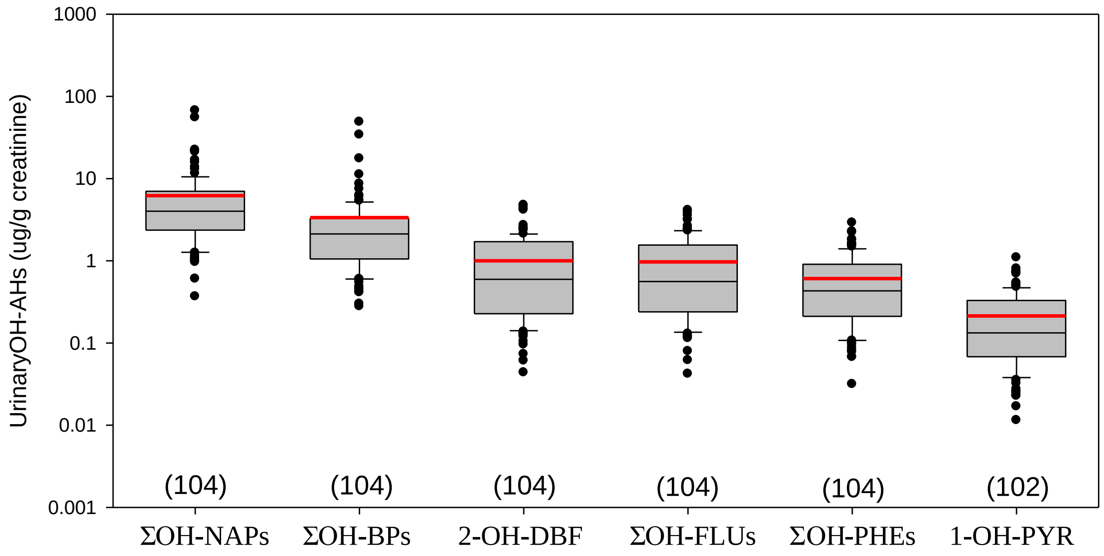

Figure S1. Concentration of grouped urinary OH-PAHs. The *solid horizontal line* represents the median, and the *red horizontal line* represents the mean. The *box* represents the 25th–75th percentiles, and the *whiskers* represent the 10th–90th percentiles. *Numbers in parentheses* are the number of detections.

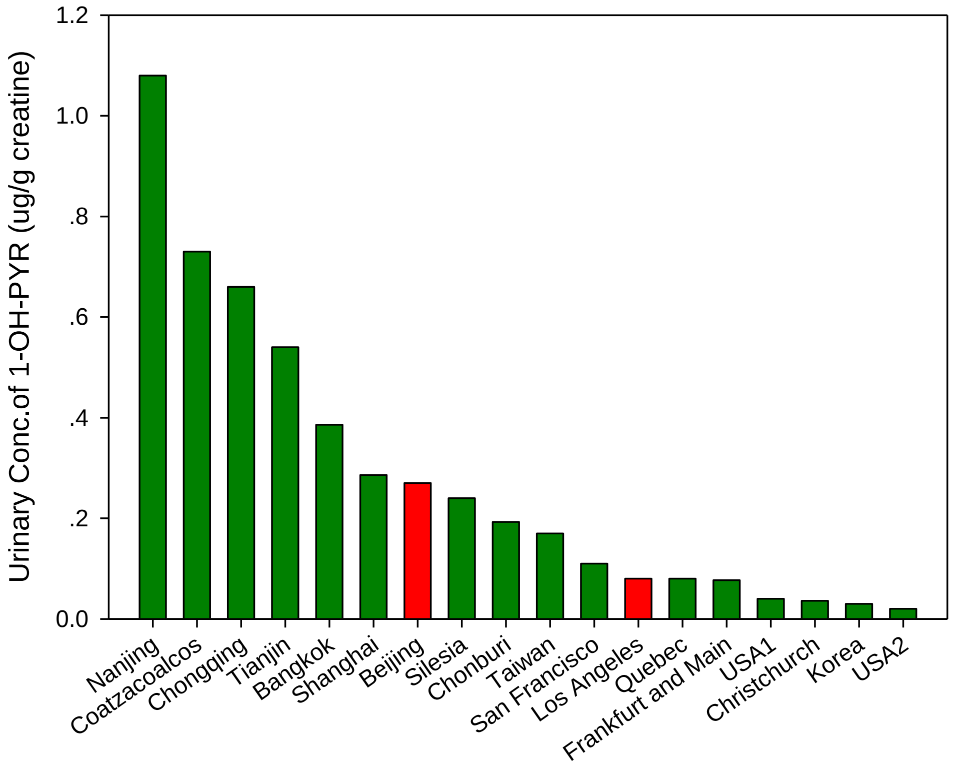

Figure S2. Concentration of urinary 1-OH-PYR in the population around world. Red bars are results from this study. Nanjing: 273 male adults;[1]Coatzacoalcos: 82 school children;[2]Chongqing: 343 male adult;[3]Tianjin: 116 adults in rural sites;[4] Bangkok: 105 schoolchildren;[5]Shanghai: 343 female adults;[6]Silesia: 108 non-smokers;[7]Chonburi: 61 schoolchildren;[5]Taiwan: 93 indoor officers;[8] San Francisco: 76 non-smokers;[7]Quebec:140 adults;[9]Frankfurt and Main: 289 non-smokers with age>20;[10] USA1: 1309 people with age>20;[11] Korea: 129 male university students;[12] Christchurch: 89 male students;[13] USA2: 1625 people with age>20.[14]

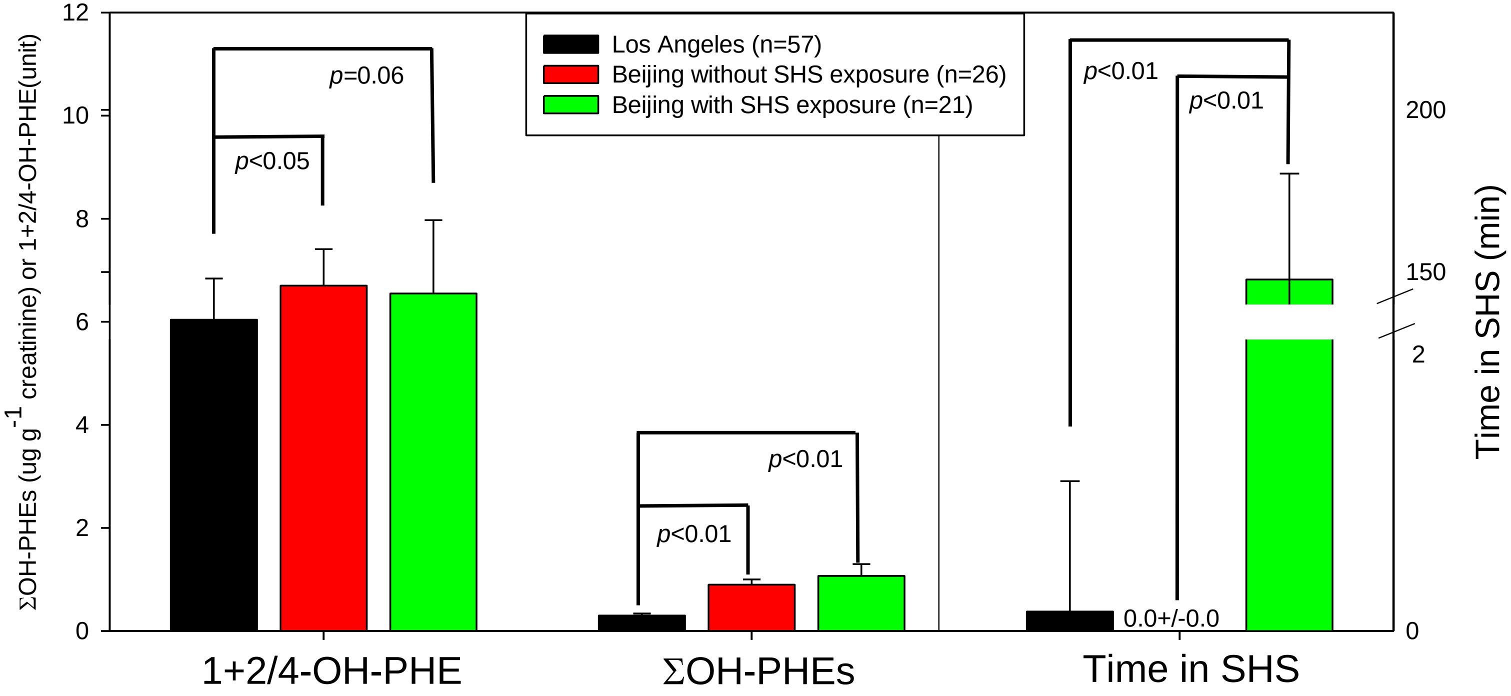

Figure S3. Comparison in 1+2/4-PHEs, ∑OH-PHEs and time in secondhand smokes (SHS) among population in Los Angeles, in Beijing without SHS exposure and in Beijing with SHS. Error bar indicates the standard error. *p*-value is calculated by Mann-Whitney U-test.

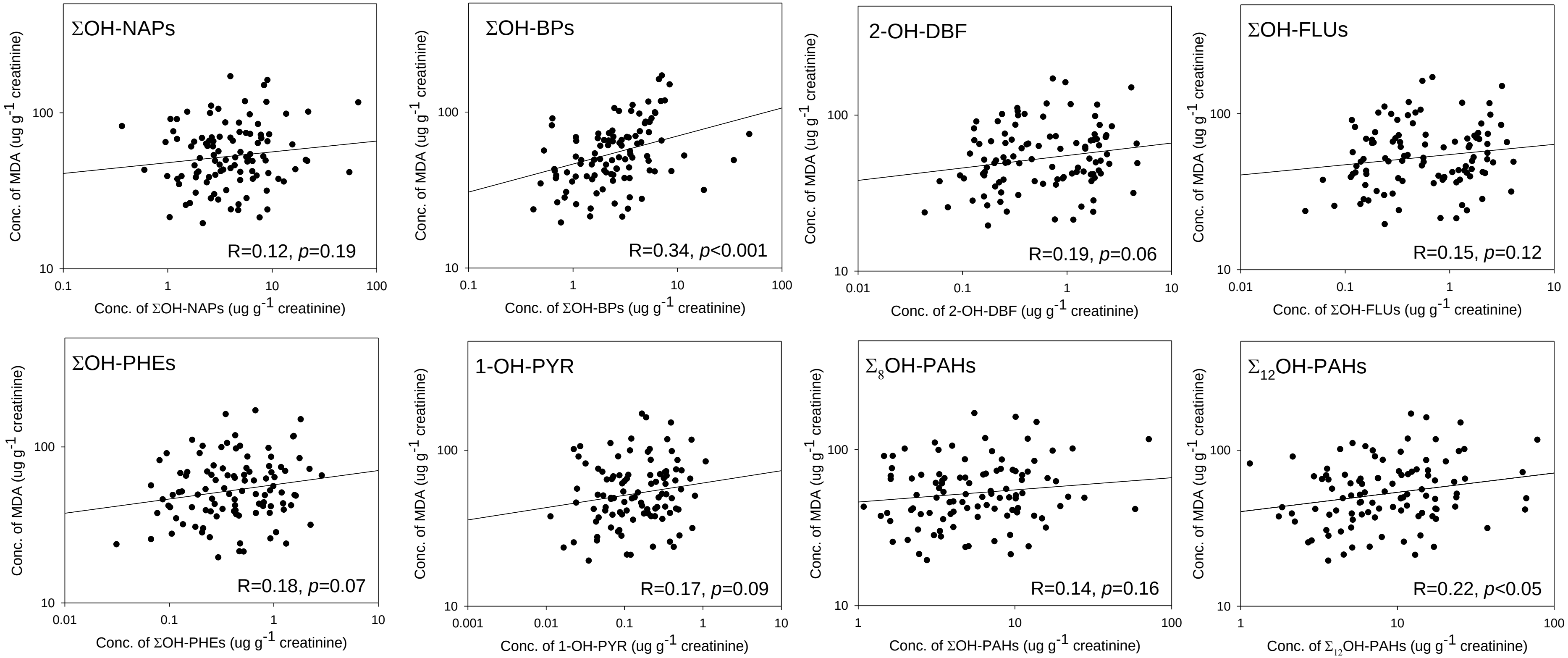

Figure S4. Correlation between MDA and OH-PAHs in both cities. *Σ_8OH-PAHs* sum of ΣOH-NAPs, ΣOH-FLUs, ΣOH-PHEs, 1-OH-PYR; *Σ_{12}OH-PAHs* sum of Σ_8OH-PAHs, ΣOH-BPs and 2-OH-DBF.

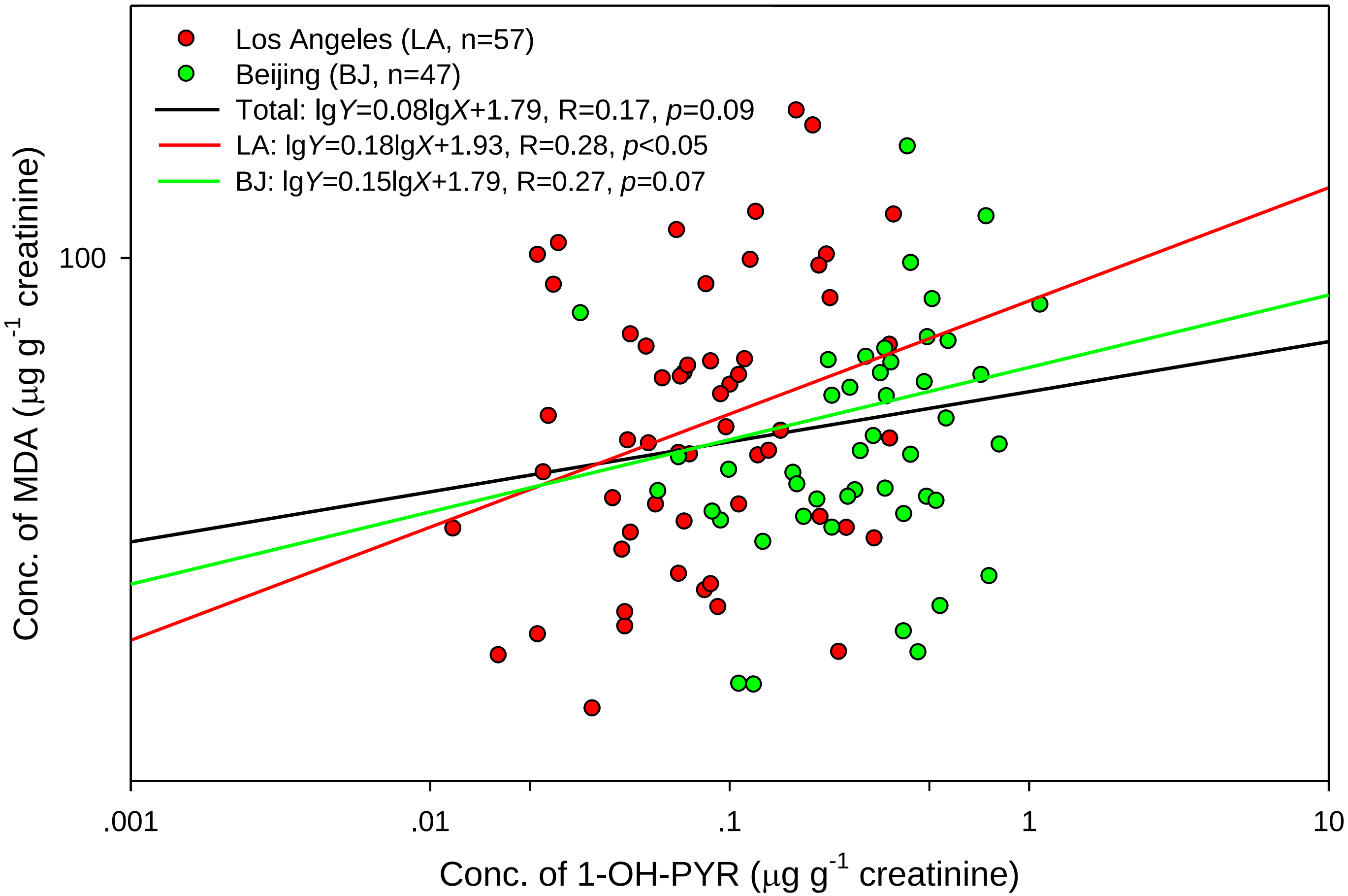

Figure S5. Correlation between MDA and 1-OH-PYR in Los Angeles and Beijing

References:

(1). Xia, Y.; Zhu, P.; Han, Y.; Lu, C.; Wang, S.; Gu, A.; Fu, G.; Zhao, R.; Song, L.; Wang, X., Urinary metabolites of polycyclic aromatic hydrocarbons in relation to idiopathic male infertility. *Hum. Reprod.***2009,***24*, (5), 1067--1074.

(2). Sánchez-Guerra, M.; Pelallo-Martínez, N.; Díaz-Barriga, F.; Rothenberg, S. J.; Hernández-Cadena, L.; Faugeron, S.; Oropeza-Hernández, L. F.; Guaderrama-Díaz, M.; Quintanilla-Vega, B., Environmental polycyclic aromatic hydrocarbon (PAH) exposure and DNA damage in Mexican children. *Mutation Research/Genetic Toxicology and Environmental Mutagenesis***2012,***742*, (1), 66-71.

(3). Han, X.; Zhou, N.; Cui, Z.; Ma, M.; Li, L.; Cai, M.; Li, Y.; Lin, H.; Li, Y.; Ao, L.; Others, Association between urinary polycyclic aromatic hydrocarbon metabolites and sperm DNA damage: a population study in Chongqing, China. *Environ. Health Persp.***2011,***119*, (5), 652.

(4). Yang, Q. Y.; Qiu, X. H.; Li, R.; Ma, J.; Li, K. Q.; Li, G., Polycyclic aromatic hydrocarbon (PAH) exposure and oxidative stress for a rural population from the North China Plain. *Environ. Sci. Pollut. R.***2015,***22*, (3), 1760-1769.

(5). Ruchirawat, M.; Settachan, D.; Navasumrit, P.; Tuntawiroon, J.; Autrup, H., Assessment of potential cancer risk in children exposed to urban air pollution in Bangkok, Thailand. *Toxicol. Lett.***2007,***168*, (3), 200-209.

(6). hofmann, J. N.; Liao, L. M.; Strickland, P. T.; Shu, X.; Yang, G.; Ji, B.; Li, H.; Rothman, N.; Kamangar, F.; Gao, Y.; Others, Polycyclic aromatic hydrocarbons: determinants of urinary 1-hydroxypyrene glucuronide concentration and risk of colorectal cancer in the Shanghai Women's Health Study. *Bmc Cancer***2013,***13*, (1), 282.

(7). St. Helen, G.; Goniewicz, M. L.; Dempsey, D.; Wilson, M.; Jacob III, P.; Benowitz, N. L., Exposure and Kinetics of Polycyclic Aromatic Hydrocarbons (PAHs) in Cigarette Smokers. *Chem. Res. Toxicol.***2012,***25*, (4), 952--964.

(8). Huang, H. B.; Lai, C. H.; Chen, G. W.; Lin, Y. Y.; Jaakkola, J.; Liou, S. H.; Wang, S. L., Traffic-Related Air Pollution and DNA Damage: A Longitudinal Study in Taiwanese Traffic Conductors. *PLOS ONE***2012,***7*, (e374125).

(9). Viau, C.; Vyskočil, A.; Martel, L., Background urinary 1-hydroxypyrene levels in non-occupationally exposed individuals in the Province of Québec, Canada, and comparison with its excretion in workers exposed to PAH mixtures. *Sci. Total Environ.***1995,***163*, (1–3), 191-194.

(10). Heudorf, U.; Angerer, J., Internal exposure to PAHs of children and adults living in homes with parquet flooring containing high levels of PAHs in the parquet glue. *Int. Arch. Occ. Env. Hea.***2001,***74*, (2), 91-101.

(11). Grainger, J.; Huang, W.; Patterson Jr., D. G.; Turner, W. E.; Pirkle, J.; Caudill, S. P.; Wang, R. Y.; Needham, L. L.; Sampson, E. J., Reference range levels of polycyclic aromatic hydrocarbons in the US population by measurement of urinary monohydroxy metabolites. *Environ. Res.***2006,***100*, (3), 394-423.

(12). Kim, H.; Cho, S. H.; Kang, J. W.; Kim, Y. D.; Nan, H. M.; Lee, C. H.; Lee, H.; Kawamoto, T., Urinary 1-hydroxypyrene and 2-naphthol concentrations in male

Koreans. *Int. Arch. Occ. Env. Hea.***2000,***74*, (1), 59-62.
(13). Cavanagh, J. E.; Brown, L.; Trought, K.; Kingham, S.; Epton, M. J., Elevated concentrations of 1-hydroxypyrene in schoolchildren during winter in Christchurch, New Zealand. *Sci. Total Environ.***2007,***374*, (1), 51-59.
(14). Li, Z.; Sandau, C. D.; Romanoff, L. C.; Caudill, S. P.; Sjodin, A.; Needham, L. L.; Patterson Jr, D. G., Concentration and profile of 22 urinary polycyclic aromatic hydrocarbon metabolites in the US population. *Environ. Res.***2008,***107*, (3), 320--331.
(15). Riojas-Rodriguez, H.; Schilmann, A.; Marron-Mares, A. T.; Masera, O.; Li, Z.; Romanoff, L.; Sj O Din, A.; Rojas-Bracho, L.; Needham, L. L.; Romieu, I., Impact of the improved patsari biomass stove on urinary polycyclic aromatic hydrocarbon biomarkers and carbon monoxide exposures in rural mexican women. *Environ. Health Persp.***2011,***119*, (9), 1301.
(16). Li, Z.; Sj O Din, A.; Romanoff, L. C.; horton, K.; Fitzgerald, C. L.; Eppler, A.; Aguilar-Villalobos, M.; Naeher, L. P., Evaluation of exposure reduction to indoor air pollution in stove intervention projects in Peru by urinary biomonitoring of polycyclic aromatic hydrocarbon metabolites. *Environ. Int.***2011,***37*, (7), 1157--1163.
(17). Bieniek, G.; Others, Urinary naphthols as an indicator of exposure to naphthalene. *Scandinavian journal of work, environment \& health***1997,***23*, (6), 414--420.
(18). Pesch, B.; Spickenheuer, A.; Kendzia, B.; Schindler, B. K.; Welge, P.; Marczynski, B.; Rihs, H.; Raulf-Heimsoth, M.; Angerer, J.; Brüning, T., Urinary metabolites of polycyclic aromatic hydrocarbons in workers exposed to vapours and aerosols of bitumen. *Arch. Toxicol.***2011,***85*, (1 Supplement), 29-39.
(19). Bieniek, G., Aromatic and polycyclic hydrocarbons in air and their urinary metabolites in coke plant workers. *Am. J. Ind. Med.***1998,***34*, (5), 445-454.
(20). Bouchard, M.; Normandin, L.; Gagnon, F.; Viau, C.; Dumas, P.; Gaudreau, E. R.; Tremblay, C., Repeated measures of validated and novel biomarkers of exposure to polycyclic aromatic hydrocarbons in individuals living near an aluminum plant in Quebec, Canada. *Journal of Toxicology and Environmental Health, Part A***2009,***72*, (23), 1534--1549.
(21). Kuang, D.; Zhang, W.; Deng, Q.; Zhang, X.; Huang, K.; Guan, L.; Hu, D.; Wu, T.; Guo, H., Dose-response relationships of polycyclic aromatic hydrocarbons exposure and oxidative damage to DNA and lipid in coke oven workers. *Environ. Sci. Technol.***2013,***47*, (13), 7446--7456.
(22). Bouchard, M. E. L.; Pinsonneault, L.; Tremblay, C.; Weber, J., Biological monitoring of environmental exposure to polycyclic aromatic hydrocarbons in subjects living in the vicinity of a creosote impregnation plant. *Int. Arch. Occ. Env. Hea.***2001,***74*, (7), 505--513.
(23). Barraza-Villarreal, A.; Escamilla-Nuñez, M. C.; Schilmann, A.; Hernandez-Cadena, L.; Li, Z.; Romanoff, L.; Sjödin, A.; Del Río-Navarro, B. E.; Díaz-Sanchez, D.; Díaz-Barriga, F., Lung Function, Airway Inflammation, and Polycyclic Aromatic Hydrocarbons Exposure in Mexican Schoolchildren: A Pilot Study. *J. Occup. Environ. Med.***2014,***56*, (4), 415-419.
(24). Kamal, A.; Malik, R. N.; Martellini, T.; Cincinelli, A., PAH exposure

biomarkers are associated with clinico-chemical changes in the brick kiln workers in Pakistan. *Sci. Total Environ.***2014,***490*, 521-527.
(25). Rodrigues, E. G.; Smith, K.; Maule, A. L.; Sjodin, A.; Li, Z.; Romanoff, L.; Kelsey, K.; Proctor, S.; McClean, M. D., Urinary Polycyclic Aromatic Hydrocarbon (ho-PAH) Metabolite Concentrations and the Effect of GST Polymorphisms Among US Air Force Personnel Exposed to Jet Fuel. *J. Occup. Environ. Med.***2014,***56*, (5), 465-471.