

# Urinary arsenic, heavy metals, phthalates, pesticides, polyaromatic hydrocarbons but not parabens, polyfluorinated compounds are associated with self-rated health: USA NHANES, 2011–2012

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**Abstract** Links between environmental chemicals and human health have emerged, but the effects on self-rated health were less studied. Therefore, it was aimed to study the relationships of different sets of urinary environmental chemicals and the self-rated health in a national and population-based study in recent years. Data was retrieved from the US National Health and Nutrition Examination Surveys, 2011–2012, including demographics, serum measurements, lifestyle factors, self-rated health (with two grouping approaches) and urinary environmental chemical concentrations. *T* test and survey-weighted logistic regression modeling were performed. Among American adults aged 12–80 ( $n=6833$ ), 5892 people had reported their general health condition. Two thousand three hundred sixty-nine (40.2 %) people reported their general health condition as excellent or very good while 3523 (59.8 %) reported good, fair, or poor. People who reported their general health condition as good, fair, or poor had higher levels of urinary arsenic, heavy metals (including cadmium, cobalt, manganese, molybdenum, lead, antimony, strontium, tungsten and uranium), phthalates, pesticides and polyaromatic hydrocarbons but lower levels of benzophenone-3 and triclosan. There were no associations with urinary parabens, perchlorate, nitrate, thiocyanate or polyfluorinated compounds. However, only urinary cadmium, benzophenone-3, triclosan, and 2-hydroxynaphthalene remained significant when comparing

between “good to excellent” and “poor to fair.” This is the first time observing risk associations of urinary arsenic, heavy metal, phthalate, pesticide, and hydrocarbon concentrations and self-rated health in people aged 12–80, although the causality cannot be established. Further elimination of these environmental chemicals in humans might need to be considered in health and environmental policies.

**Keywords** Chemicals · Environmental health · Risk factor · Self-rated health

## Introduction

Links between environmental chemicals and human health including hypertension, cardiovascular diseases, food allergy, lung diseases, cancer and vision, remembering condition, hearing and balancing impairments and even emotional needs in American adults have emerged (Shiue 2013a, b, c, 2014a, b, 2015a, b), but the effects on self-rated health, an important risk predictor for human health conditions including both physical and mental domains (Mavaddat et al. 2014; Euteneuer 2014; Quon and McGrath 2014), have not been studied. In this context, therefore, the present study was aimed to examine the relationships of different sets of urinary environmental chemical concentrations and self-rated health in a national and population-based setting.

## Methods

### Study sample

As described elsewhere (Centers for Disease Control and Prevention CDC 2012), the US National Health and Nutrition

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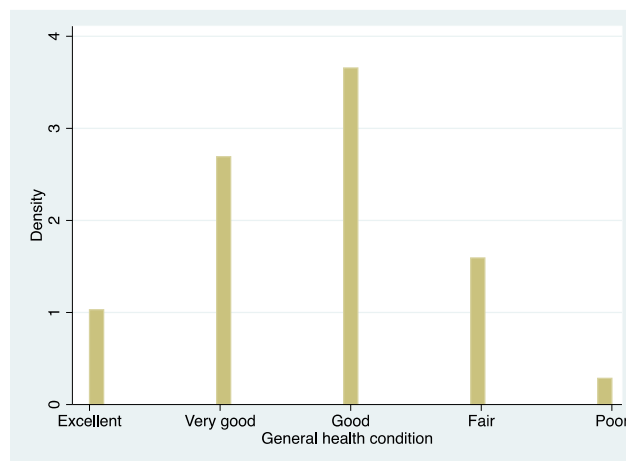
Examination Surveys (NHANES) has been a national, population-based, multi-year, cross-sectional study since the 1980s. The study sample is representative of the civilian, noninstitutionalized US population. Information on demographics, serum measurements, lifestyle factors, self-rated health and urinary environmental chemical concentrations was obtained by household interview. In the current analysis, the 2011–2012 cohort as the most recent study cohort with the available information mentioned above was selected for statistical analysis. Informed consents were obtained from participants by the NHANES researchers.

**Biomonitoring**

Urines were only collected in a subsample, being one third of the whole cohort (still representative), to measure environmental chemical concentrations in urines among people aged 6 and above. Urine specimens were processed, stored under appropriate frozen (−20 °C) conditions, and shipped to the Division of Environmental Health Laboratory Sciences, National Center for Environmental Health, Centers for Disease Control and Prevention for analysis. According to the NHANES website (more details via: [http://wwwn.cdc.gov/nchs/nhanes/2011-2012/PERNT\\_G.htm](http://wwwn.cdc.gov/nchs/nhanes/2011-2012/PERNT_G.htm)), ion chromatography coupled with electrospray tandem mass spectrometry was used to detect and measure the amount. Chromatographic separation is achieved using an IonPac AS16 column with sodium hydroxide as the eluent. The eluent from the column is ionized using an electrospray interface to generate and transmit negative ions into the mass spectrometer. Comparison of relative response factors (ratio of native analyte to stable-isotope-labeled internal standard) with known standard concentrations yields individual analyte concentrations. For statistical analysis purpose in the present study, urinary environmental chemical concentrations were all log transformed since they were highly skewed to one side.

**Statistical analysis**

People aged 12–80 were included in the current statistical analysis because self-rated health was asked in such age group (for more details please refer to: [http://wwwn.cdc.gov/nchs/nhanes/2011-2012/HSQ\\_G.htm](http://wwwn.cdc.gov/nchs/nhanes/2011-2012/HSQ_G.htm)). Associations of different sets of urinary environmental chemical concentrations and self-rated health (question: Would you say your health in general is...? Answer: excellent, very good, good, fair, or poor) were examined separately by *t* test and survey-weighted logistic regression modeling to present odds ratios (OR) and 95 % confidence intervals (more details via: [http://www.cdc.gov/Nchs/tutorials/environmental/orientation/sample\\_design/index.htm](http://www.cdc.gov/Nchs/tutorials/environmental/orientation/sample_design/index.htm)), with *P*<0.05 considered statistically significant (Fig. 1). Self-rated health was treated as binary. There were



**Fig. 1** Distribution of self-rated health condition

two grouping approaches employed. In the first instance, being excellent and very good were grouped together (reference group) while being good, fair, and poor were grouped together. In the second instance, being excellent, very good, and good were grouped together (reference group) while being fair and poor were grouped together. Results following different grouping strategies were shown accordingly. Covariates including urinary creatinine, age, sex, ratio of family income to poverty (proxy of socioeconomic status), body mass index (BMI), serum cotinine (biomarker of smoking status), alcohol habit and physical activity level were adjusted.

In addition, upon significant associations presented in the results, a subsequent analysis was initiated by treating the outcome variable as continuous. Survey-weighted general linear regression modeling was carried out to present betas (B) with 95 % confidence interval (CI). Statistical software STATA version 13.0 (STATA, College Station, TX, USA) was used to perform all the analyses. Since the present study is employing secondary data analyses without personal information identified, no further ethics approval was required.

**Results**

Among American adults aged 12–80 (*n*=6833), 5892 people had reported their general health condition. 2369 (40.2 %) people reported their general health condition as excellent or very good while 3523 (59.8 %) reported good, fair or poor (see Table 1). People who reported their general health condition good, fair or poor had higher levels of urinary arsenic, heavy metals (including cadmium, cobalt, manganese, molybdenum, lead, antimony, strontium, tungsten and uranium), phthalates, pesticides and polyaromatic hydrocarbons but lower levels of benzophenone-3 and triclosan. There were no associations with urinary parabens, perchlorate, nitrate, thiocyanate or polyfluorinated compounds. However, only cadmium (OR 1.28, 95 % CI 1.09–1.50, *P*=0.004),

**Table 1** Associations between urinary environmental chemical concentrations and self-rated health ( $n=5892$ , 12–80 years)

	Very good, excellent ( $n=2369$ , 40.2 %)	Good, fair, poor ( $n=3523$ , 59.8 %)	OR (95 % CI) <sup>a</sup>	<i>P</i> value
Arsenic ( $\mu\text{g/L}$ )	Mean (SD)	Mean (SD)		
Total arsenic	18.3 (54.7)	20.5 (61.5)	1.22 (1.12–1.33)	<0.001
(continuous; presented by beta)			0.04 (0.01–0.08)	0.014
Arsenous	0.5 (0.3)	0.6 (1.7)	1.51 (0.94–2.43)	0.085
Arsenic acid	0.6 (0.2)	0.7 (1.1)	1.03 (0.36–2.96)	0.950
Arsenobetaine	11.0 (51.9)	11.8 (53.8)	1.05 (0.95–1.16)	0.321
Arsenocholine	0.3 (0.7)	0.3 (0.5)	1.27 (0.70–2.30)	0.410
Dimethylarsonic	5.4 (6.0)	6.2 (9.1)	1.40 (1.21–1.63)	<0.001
(continuous; presented by beta)			0.07 (0.02–0.12)	0.006
Monomethylarsonic	0.9 (0.5)	0.9 (1.9)	1.59 (0.92–2.74)	0.093
Trimethylarsine	0.2 (0.2)	0.2 (2.0)	0.49 (0.26–0.93)	0.031
(continuous; presented by beta)			−0.14 (−0.029–0.002)	0.052
Heavy metals ( $\mu\text{g/L}$ )				
Barium	1.7 (1.6)	1.9 (3.4)	1.08 (0.94–1.25)	0.257
Cadmium	0.2 (0.3)	0.4 (0.6)	1.41 (1.20–1.66)	<0.001
(continuous; presented by beta)			0.13 (0.08–0.19)	<0.001
Cobalt	0.5 (0.6)	0.5 (1.1)	1.24 (1.07–1.45)	0.009
(continuous; presented by beta)			0.05 (−0.02–0.11)	0.137
Cesium	4.7 (3.1)	4.8 (2.9)	1.19 (0.93–1.51)	0.158
Manganese	0.2 (0.2)	0.2 (0.6)	1.32 (1.05–1.67)	0.021
(continuous; presented by beta)			0.002 (−0.08–0.08)	0.968
Molybdenum	54.2 (51.3)	56.7 (51.7)	1.27 (1.03–1.55)	0.025
(continuous; presented by beta)			0.06 (−0.01–0.14)	0.071
Lead	0.5 (0.4)	0.7 (1.4)	1.51 (1.26–1.81)	<0.001
(continuous; presented by beta)			0.10 (0.02–0.18)	0.015
Antimony	0.1 (0.1)	0.1 (0.1)	1.41 (1.16–1.70)	0.001
(continuous; presented by beta)			0.09 (0.03–0.16)	0.007
Strontium	120.8 (145.3)	120.9 (102.2)	1.19 (1.01–1.39)	0.036
(continuous; presented by beta)			−0.01 (−0.06–0.04)	0.671
Thallium	0.2 (0.1)	0.2 (0.1)	1.15 (0.92–1.45)	0.205
Tin	1.3 (3.2)	1.5 (3.4)	1.11 (0.92–1.33)	0.268
Tungsten	0.1 (0.3)	0.2 (1.0)	1.22 (1.00–1.49)	0.046
(continuous; presented by beta)			0.03 (−0.05–0.10)	0.440
Uranium	0.01 (0.02)	0.01 (0.07)	1.37 (1.12–1.68)	0.005
(continuous; presented by beta)			0.09 (0.003–0.17)	0.044
Phthalates (ng/mL)				
Mono(carboxyoctyl)	60.6 (136.4)	48.1 (99.1)	1.00 (0.90–1.10)	0.944
Mono(carboxynonyl)	4.5 (10.7)	5.3 (22.8)	1.12 (1.00–1.26)	0.053
(continuous; presented by beta)			0.03 (−0.04–0.09)	0.436
Mono-2-ethyl-5-carboxypentyl	23.4 (39.8)	26.9 (71.2)	1.29 (1.13–1.49)	0.001
(continuous; presented by beta)			0.08 (0.02–0.14)	0.008
Mono-n-butyl	21.1 (96.3)	22.5 (58.6)	1.14 (1.02–1.27)	0.027
(continuous; presented by beta)			0.05 (0.01–0.09)	0.018
Mono-(3-carboxypropyl)	13.5 (73.4)	14.0 (100.6)	1.05 (0.96–1.15)	0.233
Mono-ethyl	216.2 (1233.1)	187.1 (559.5)	1.13 (1.01–1.27)	0.040
Mono-(2-ethyl-5-hydroxyhexyl)	16.4 (34.5)	18.6 (59.6)	1.20 (1.06–1.36)	0.008
Mono-(2-ethyl)-hexyl	3.3 (6.4)	3.3 (8.9)	1.12 (0.94–1.33)	0.194
Mono-isobutyl	12.0 (27.3)	13.0 (16.6)	1.21 (1.06–1.38)	0.007

**Table 1** (continued)

	Very good, excellent ( <i>n</i> =2369, 40.2 %)	Good, fair, poor ( <i>n</i> =3523, 59.8 %)	OR (95 % CI) <sup>a</sup>	<i>P</i> value
(continuous; presented by beta)			0.06 (0.01–0.11)	0.016
Mono- <i>n</i> -methyl	3.2 (7.5)	4.4 (25.2)	1.05 (0.94–1.17)	0.397
Mono-isononyl	6.2 (19.7)	3.6 (10.0)	0.96 (0.86–1.07)	0.422
Mono-(2-ethyl-5-oxohexyl)	10.0 (19.4)	11.4 (29.7)	1.22 (1.06–1.40)	0.007
(continuous; presented by beta)			0.06 (0.01–0.12)	0.024
Mono-benzyl	10.0 (20.8)	10.9 (18.6)	1.22 (1.12–1.32)	<0.001
(continuous; presented by beta)			0.07 (0.03–0.11)	0.004
Cyclohexane-1,2-dicarboxylic acid monohydroxy isononyl ester	0.6 (6.2)	0.5 (1.6)	1.19 (0.72–1.96)	0.478
Pesticides (ng/L)			0.05 (–0.08–0.18)	0.405
Urinary 2,5-dichlorophenol	87.2 (596.4)	193.2 (1372.5)	1.10 (1.01–1.19)	0.023
(continuous; presented by beta)			0.03 (0.05–0.06)	0.024
Urinary 2,4-dichlorophenol	2.9 (18.4)	5.8 (37.9)	1.13 (1.00–1.27)	0.044
(continuous; presented by beta)			0.04 (–0.01–0.08)	0.089
Perchlorate (ng/mL)	4.6 (6.2)	4.4 (6.1)	1.04 (0.84–1.29)	0.705
Nitrate (ng/mL)	55903.1 (49952.9)	57798.0 (61626.2)	1.12 (0.86–1.46)	0.372
Thiocyanate (ng/mL)	1708.2 (2334.9)	2182.1 (3442.3)	1.13 (0.95–1.35)	0.158
Phenols (ng/mL)				
Benzophenone-3	388.8 (1996.2)	216.5 (1272.8)	0.89 (0.82–0.97)	0.008
(continuous; presented by beta)			–0.04 (–0.07–0.02)	0.001
Bisphenol A	2.9 (7.6)	3.3 (7.7)	1.12 (0.95–1.33)	0.171
Triclosan	98.5 (281.0)	92.2 (275.6)	0.93 (0.89–0.98)	0.011
(continuous; presented by beta)			–0.04 (–0.06–0.02)	0.002
Polyaromatic hydrocarbons (ng/L)				
2-Hydroxyfluorene	427.1 (696.8)	643.5 (1128.4)	1.32 (1.14–1.53)	0.001
(continuous; presented by beta)			0.10 (0.04–0.15)	0.002
3-Hydroxyfluorene	206.9 (408.5)	318.0 (649.5)	1.24 (1.06–1.44)	0.009
(continuous; presented by beta)			0.07 (0.02–0.13)	0.012
9-Hydroxyfluorene	405.4 (554.0)	574.0 (1190.7)	1.20 (1.02–1.41)	0.032
(continuous; presented by beta)			0.06 (0.003–0.13)	0.042
1-Hydroxyphenanthrene	178.2 (202.4)	207.9 (313.0)	1.20 (1.00–1.44)	0.047
(continuous; presented by beta)			0.05 (–0.01–0.12)	0.117
2-Hydroxyphenanthrene	91.9 (118.1)	113.8 (165.2)	1.31 (1.11–1.54)	0.003
(continuous; presented by beta)			0.09 (0.02–0.16)	0.013
3-Hydroxyphenanthrene	106.5 (156.9)	131.4 (261.7)	1.23 (1.07–1.42)	0.007
(continuous; presented by beta)			0.06 (0.005–0.11)	0.035
1-Hydroxypyrene	183.0 (264.6)	222.3 (351.4)	1.24 (1.08–1.42)	0.005
(continuous; presented by beta)			0.07 (0.01–0.13)	0.033
1-Hydroxynaphthalene (1-naphthol)	13372.9 (194622.0)	46121.8 (713677.6)	1.07 (0.94–1.23)	0.284
2-Hydroxynaphthalene (2-naphthol)	7019.0 (9756.8)	10122.4 (13871.8)	1.35 (1.17–1.56)	<0.001
(continuous; presented by beta)			0.11 (0.06–0.15)	<0.001
4-Hydroxyphenanthrene	31.3 (38.5)	36.4 (53.2)	1.11 (0.92–1.34)	0.260

<sup>a</sup> Adjusted for age, sex, body mass index, ratio of family income to poverty, serum cotinine (smoking status), alcohol status, physical activity level and urinary creatinine

benzophenone-3 (OR 0.89, 95 % CI 0.82–0.96, *P*=0.007), triclosan (OR 0.87, 95 % CI 0.80–0.96, *P*=0.007) and 2-hydroxynaphthalene (OR 1.18, 95 % CI 1.00–1.40, *P*=

0.050) remained significant risk effects on self-rated health when comparing between “good to excellent” and “poor to fair” (data not shown).

## Discussion

There are strengths in designing this study. First, this study was conducted in a large and nationally representative human sample with mixed socioeconomic status. Second, this is the first time examining the risk associations of urinary arsenic, heavy metals, phthalates, pesticides, phenols, polyaromatic hydrocarbons, parabens, perchlorate, nitrate, thiocyanate and polyfluorinated compounds and self-rated health in both adolescents and adults aged 12–80. Therefore, no previous studies from literature with the same or similar topics could be compared and discussed here. However, there are also some limitations that cannot be ignored. First, there could still be other emerging chemicals from the living environments that we might not yet know and would need future research to further identify and examine. Second, the causality cannot be established in the present study due to the cross-sectional study design in nature. Therefore, future studies with a longitudinal or experimental study design to confirm or refute the current observations and, if at all, to understand the persisting risk effects along the life course from those mentioned above environmental chemicals would be suggested.

## Conclusion

In sum, American adults who reported their general health condition good, fair or poor had higher levels of urinary arsenic, heavy metals (including cadmium, cobalt, manganese, molybdenum, lead, antimony, strontium, tungsten and uranium), phthalates, pesticides and polyaromatic hydrocarbons but lower levels of benzophenone-3 and triclosan, compared to those reported their health conditions excellent or very good. There were no associations with urinary parabens, perchlorate, nitrate, thiocyanate or polyfluorinated compounds. Further elimination of these environmental chemicals in humans might need to be considered in future health and environmental policies.

**Conflict of interest** None.

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