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FOCUSED REVIEW

Human Biological Monitoring of Mercury Through Hair Samples in China

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Abstract
Mercury (Hg) is a global pollutant that affects environmental and human health. Considering the high toxicity of Hg, it is required to assess the exposure of Hg in human body for appropriate risk management. In this review paper, we summarized data obtained through regional and small-scaled human biomonitoring (HBM) program for Hg in hair samples in China, which can deliver scientific data to make decisions on environmental health policy. Besides, the major conclusions got from this study and perspectives for future works through these HBM program in China were presented. To better understand the current situation of hair Hg levels in China, a well-coordinated and designed national HBM program is urgently needed considering the requirements of the Minamata Convention on Mercury for effectiveness evaluation.

Keywords Mercury · Hair samples · China · Human biomonitoring

Introduction

Human health is significantly impacted by the environment. It was estimated recently by World Health Organization (WHO) that 12.6 million people died due to living or working in contaminated environment in 2012 (Joas et al. 2017; Prüss-Ustün et al. 2017). Mercury (Hg) is a global pollutant that affects environmental and human health (Li et al. 2018). Three different forms of Hg exist in the environment: elemental Hg (Hg^0), inorganic Hg (Hg^+ and Hg^{2+}), and organic (such as methyl, ethyl, and phenyl) mercury. It can cause neurological, hepatic, renal, immunological, cardiovascular, reproductive and genetic damage to animals and human beings (Li et al. 2018). The most adverse impact of Hg exposure is Minamata Disease, which is due to the prenatal or postnatal exposure to methylmercury (MeHg) in adults and children (Clarkson et al. 2003).

Hg is present in the environment through natural events like volcanic eruptions or anthropogenic activities like metal mining and smelting, and coal-burning. Due to its long-distance travel nature, Hg is ubiquitous and can be found in water, air, and soil. Besides, it can also be found in consumer goods (including some medicines), and food products and people may be exposed to Hg through ingestion, inhalation, and dermal contact (Li et al. 2018).

Considering the high toxicity of Hg, it is required to assess the exposure of Hg in human body for appropriate risk management. Assessment of population exposure to Hg can be achieved through two methodological approaches: (a) environmental monitoring, i.e. analysis of Hg in environmental media and calculation of human exposure according to their intake and (b) measurement of Hg in human body fluids and tissues such as hair, blood, urine or breast milk, i.e. human monitoring (Černá et al. 2017). The assessment of exposure to Hg in human body through environmental monitoring is based on algorithms and/or modeling and concentrations of Hg in environmental media such as water, food, air or products. However, building exposure models requires making many assumptions which introduces uncertainties in exposure estimates (Zidek et al. 2017). On the other hand, human biological monitoring (HBM) provides

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measures of internal exposure and/or effect, integrating all sources and routes of uptake of Hg by direct measurements of biological specimens while environmental monitoring are helpful to identify the contamination sources (Zhang et al. 2017). HBM allows for direct and a more precise assessment of risk of Hg exposure in people, considering individual variability in exposure and kinetics (e.g. absorption, distribution, metabolism and excretion).

National HBM program can provide profiles of chemical exposure like Hg and their temporal trends that are representative at country level. Study designs of such national HBM programs often include data collection of multiple factors from participants such as age, gender, living environment (e.g., urban vs. rural), socioeconomic status (SES), lifestyle habits (e.g., smoking), etc. Countries such as USA, Canada, Germany, France, Belgium, and South Korea, etc have established cross-sectional nationwide HBM surveys and programs to monitor and track the chemicals including Hg and their concentrations within their respective general populations (Choi et al. 2017a). For example, in USA, hundreds of chemicals including Hg have been measured from the general public through National Health and Nutrition Examination Survey (NHANES) (CDC 2015; Yin et al. 2016). In Canada, Canadian Health Measure Survey (CHMS) has been conducted for three cycles since 2007 (Health Canada 2015; Lye et al. 2013). In Korea, the Korean National Environmental Health Survey (KoNEHS) and Environmental Exposure and Health Survey in Children and adolescents (KOrEHS-C) were implemented (Choi et al. 2017b; Park et al. 2016). A more detailed description about these national HBM has been summarized by Choi et al. (2017a).

China is a large producer, emitter and user of Hg (Chai et al. 2011; Feng 2005; Hui et al. 2017; Jiang et al. 2006), therefore, the impact of Hg to the Chinese people is required to be evaluated. Besides, since China has signed and ratified the *Minamata Convention on Mercury* coordinated by United Nations Environment Program (UNEP), it is also required to evaluate the effectiveness of the implementation of the Convention and the check of the compliance with this international agreement (UNEP 2013). To the best of our knowledge, there is still no nationwide HBM program implemented in China to date although the investigation of dietary exposure to different chemicals including Hg has been conducted five times through total diet study (Wu et al. 2018). Total diet study was recommended by WHO as a useful tool for exposure assessment of chemicals and nutritional factors through dietary intake, which can be considered as an environmental monitoring method. However, numerous regional or small-scaled HBM program for Hg have been conducted through different funding sources in China. In this review, we will summarize the data obtained through regional and small-scaled HBM program for Hg in hair samples in China, which can deliver useful scientific data to inform environmental health policy decision. Besides, the major conclusions got from these studies and perspectives for future works through these HBM program in China will also be presented.

Human Biological Monitoring of Hg in Hair Samples in China

We searched for information on HBM studies conducted in the Chinese population, excluding studies in occupational settings. Relevant sources were a literature review by PubMed search using key words: mercury; hair; China. Besides, since many works regarding the HBM of Hg was reported in Chinese, we also searched the Chinese literature databases including China Knowledge Resource Integrated Database (KNS), China Science Periodical Database (CSPD), and China Science and Technology Journal Database (CSTJ) using the same key words.

Human hair is a well-established and widely used matrix for measuring Hg exposure of an individual. Comparing to blood and urine, hair has several advantages as it is collected through a non-invasive manner, and contains higher Hg concentrations. Although concerns were raised on the suitability of hair as an appropriate matrix for judging Hg exposure in occupational exposed population like Hg miners, chloralkali workers, or small-scale artisanal gold miners, it is a good indicator for general public for assessment of Hg exposure (Li et al. 2008, 2011). The growth rate of hair (1 cm per month) and the tendency of toxins such as Hg to accumulate in hair make it possible to estimate long-term exposure. In addition, tracing the dynamic changes along hair growing direction provides an insight into average exposure on timescale ranging from weeks to months. Therefore, human hair was used as a biomarker in many Hg exposure studies.

The Hg levels in hair samples of Chinese people are summarized in Table 1 and Fig. 1 (which represents the mean value of respective regions from Table 1). As can be seen in Table 1 and Fig. 1, among the 34 provinces/regions in China, twenty-four provinces/regions have hair mercury data available in the general public. Besides, the time interval covers 40 years of studies (from 1977 to 2017).

As can be seen from Table 1 and Fig. 1, reports on hair Hg levels in 24 provinces, special administrative regions and autonomous regions in China are summarized, which includes inland cities, coastal cities, suburbs, riverside and lakeside cities (Li et al. 2018). It can be seen that the hair levels of Hg in the general public are generally below 1 mg/kg, which is the US EPA recommended reference level for human beings although Chengdu, Harbin and Taiyuan see hair Hg levels over 1 mg/kg. Among the reported inland residents (with samples size over 10, 000), about

Table 1 Hg levels in hair samples in general Chinese population (mg/kg)

Region	Population	Sample size	Average	Median	Range	References
Anhui	Residents	110	0.48 ± 0.90	0.19	0.01–6.14	Niu et al. (2016)
Beijing	Mother–baby pair	27	0.59 ± 0.23 (mothers) 0.66 ± 0.31 (babies)			Feng et al. (1994)
	Mother–baby pair	60	0.36 (GM, mothers)			Zhang et al. (2005)
	Urban residents	120	0.46		0.17–1.63	Yin et al. (1980)
	Suburban residents	133	0.35		0.08–1.66	Yin et al. (1980)
Fujian	Residents	211		1.80	0.04–9.58	Chen et al. (1993)
	Mother–baby pair	48	0.68 ± 0.53 (mothers) 0.56 ± 0.30 (babies)		0.13–2.81 0.09–1.34	Yang (2011)
Guangdong	Zhanjiang fishermen	78	1.80 ± 0.93			Tian (2011)
	Zhanjiang residents	50	0.63 ± 0.18			Tian (2011)
	Guangzhou residents	72	0.78 ± 0.22			Tian (2011)
	Zhuhai residents	52	0.57 ± 0.19			Tian (2011)
	Shenzhen residents	13	0.71 ± 0.15			Tian (2011)
Guizhou	Guiyang residents	209			ND–3.50	Yang and Chen (1987)
Hainan	Coastal children	94	0.80 ± 0.65		0.06–4.20	Liu et al. (2014)
	Coastal adults	83	1.02 ± 0.92		0.18–4.81	Liu et al. (2014)
Hebei	Shijiazhuang residents (20–50 years)	324	0.46 (GM)		ND–3.00	Wu et al. (1982)
	Qinhuangdao fishermen	100	1.91			Yin et al. (1981)
	Qinhuangdao farmers	100	0.43			Yin et al. (1981)
Henan	Residents (4.5–64 years)	154		0.41	ND–4.90	Chen and Wang (1978)
	Kaifeng and Jiaozuo residents	101	0.19 ± 0.17 (GM)		0.07–1.42	Niu et al. (2012)
	Lingbao farmers around gold smelting area	47	1.05			Ba et al. (1996)
	Lingbao farmers at control areas	40	0.51			Ba et al. (1996)
Heilongjiang	Haerbin residents	362	1.69		0.11–36.40	Feng et al. (1998)
Hubei	Huangshi Residents (15–60 years)	834		0.53	0.02–2.70	Li and Zhou (1993)
Hong Kong	Female	35	1.57			Dickman et al. (1998)
	Male	166	3.97			Dickman et al. (1998)
	Vegetarians	16	0.38 ± 0.49			Dickman et al. (1998)
	Fertile (17–72 years)	94	3.33			Dickman et al. (1999)
	Male subfertile (17–72 years)	117	4.23			Dickman et al. (1999)
	Vegetarians (22–61 years)	45	1.21 ± 0.49			Dickman et al. (1999)
Jilin	Changchun residents	839	0.45(GM)			Department of Hygiene of Jilin Medical University et al. (1977)
	Changchun children (0–10 years)	81	0.77 ± 0.49			Department of Hygiene of Jilin Medical University et al. (1977)
	Changchun residents	140	0.45		0.09–10.46	Li et al. (2006)
Jiangsu	Suzhou children (1–12 years)	60	0.85 (GM)		0.14–3.75	Zhang (2003)
	Suzhou adults (23–68 years)	60	0.95		0.42–9.45	Zhang (2003)
	Wujiang neonates	2321	0.24 (GM)			Song et al. (2013)
	Wujiang pregnant women	303	0.49 ± 0.002			Cai et al. (2014)
	Wujiang mother-infant pair	213	0.61 ± 0.39 (mothers) 0.29 ± 0.18 (infants)		0.10–2.20 0.03–0.85	Guo et al. (2013)
	Lianyungang fishermen	100	2.88			Yin et al. (1981)
	Lianyungang farmers	100	0.44			Yin et al. (1981)

Table 1 (continued)

Region	Population	Sample size	Average	Median	Range	References
Liaoning	Shenyang mother–child pair	58	0.71 ± 0.28 (children) 0.68 ± 0.28 (mothers)		0.10–1.58 0.10–1.60	Dong et al. (2002)
	Dalian residents	174	0.46 ± 0.28 (GM)		0.04–6.62	Niu et al. (2014)
	Jinzhou fishermen	100	3.3 (GM)			Yin et al. (1981)
	Jinzhou farmers	100	0.29			Yin et al. (1981)
Inner Mongolia	Hohhot residents (15–60 years)	417		0.52	0.02–2.70	Liu and Li (1991)
	Baotou residents	207		0.35	0.1–1.13	Kang et al. (1994)
Ningxia	Qingtongxia fishermen	13	6.73		1.55–16.9	Zhang et al. (1988)
	Xiji residents	13	0.22		ND–1.45	Zhang et al. (1988)
Qinghai	Qinghai lake fishermen (23–58 years)	74	1.59 ± 0.65	1.88	0.31–4.55	Xu and Mo (1981)
	Xining residents	543	0.41 ± 0.42	0.26	ND–2.10	Xu and Mo (1981)
Shandong	Qingdao	103	0.13 (GM)		0.02–4.24	Zhang (2009)
		40	0.47		0.09–12.19	
		40	0.30		0.09–0.86	
		40	0.80		0.12–28.75	
	Qingdao fishermen	100	2.30			Yin et al. (1981)
	Qingdao farmers	100	0.47			Yin et al. (1981)
	Jining fishermen	101	1.04 ± 1.05	0.81	0.03–6.70	Feng and Han (1988)
	Jining farmers	92	0.17 ± 0.22	0.12	0.01–1.08	Feng and Han (1988)
Shanxi	Taiyuan residents	143		0.2	ND–0.66	Cao (2002)
	Taiyuan adults	503	1.05	0.81	ND–6.20	Department of Environmental Hygiene (1980)
	Taiyuan children	164	1.15	0.79	ND–5.40	Department of Environmental Hygiene (1980)
Shanghai	Residents (0–92 years)	492	0.53	0.42	0.04–9.73	Song (2010)
	Preschool children	1982	0.29			Yan et al. (2017)
Sichuan	Chengdu residents	238	1.42 ± 1.57	1.34		Wang and Zhang (1981)
	Luzhou mother–baby pair	123	0.10 ± 0.07 (mothers) 0.20 ± 0.16 (babies)			Chen et al. (2004)
Taiwan	Women (31.3 ± 10.7 years)	263	1.73 ± 2.12		0.02–16.34	Chien et al. (2010)
Tianjin	Tanggu fishermen	100	1.54			Yin et al. (1981)
	Tanggu farmers	100	0.79			Yin et al. (1981)
Zhejiang	Ningbo residents	262	1.18 ± 0.62		0.22–5.79	Song et al. (2007)
	Hangzhou residents	357		1.43	ND–7.2	Shao (1977)
	Hangzhou farmers	143		1.10	ND–2.5	Shao (1977)
	Hangzhou fishermen	48			0.9–15.2	Shao (1977)
	Zhoushan mothers	405	1.25 (GM)			Gao et al. (2007)
	Zhoushan pregnant women	3109	1.27	1.09	0.04–17.19	Wang et al. (2010)

GM geometric mean, *ND* not detected

17% is over 1 mg/kg. When considering the levels of Hg in hair samples in coastal/riverside city residents (with samples size over 10,000, too), most of them are over 1 mg/kg like people in Zhejiang, Ningxia, and Hong Kong, which could be ascribed to the fish consumption in these people. When comparing the hair Hg levels with other Asian countries, it can be seen that it is in a relatively low levels of hair Hg in China (Li et al. 2018). This may be ascribed to the low consumption of fishes and other marine foods in China. Besides, the Hg levels in fishes in China are generally low because fishes consumed in China are mostly from aquaculture and the fishes have very short food chain, thus the chances of bioaccumulation of high levels of Hg, especially MeHg are rare (Liu et al. 2018; Xu and Wang 2017).

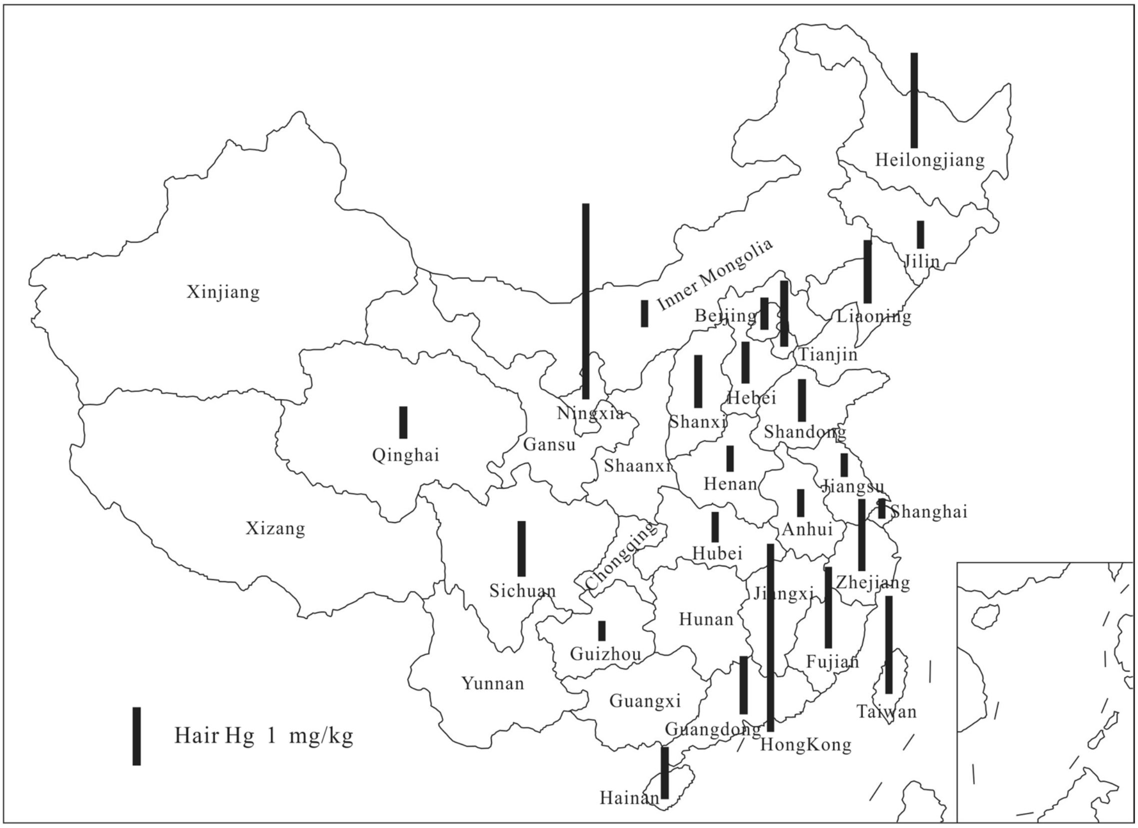

Fig. 1 Hg levels in hair samples from general population in different regions in China, in which the data is the mean value of respective regions from Table 1

Conclusions and Perspectives

In all, the hair levels of Hg in the general population were generally below 1 mg/kg, which is the US EPA recommended reference level for human beings. However, it should also be noticed that the levels of Hg in hair samples in some coastal and lakeside cities exceeded the reference level of 1 mg/kg, which may be ascribed to frequent consumption of fishes and other aquacultural foods.

There is still no nationwide HBM program implemented in China to date. To better understand the current situation of Hg levels in China, a well-coordinated and designed national HBM program is urgently necessary considering the requirements of the Minamata Convention on Mercury for effectiveness evaluation.

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References

Ba Y, Zhang Y, Cui L, Cheng X, Yang J, Liu H, Yang J, Qin J (1996) Using urinary and hair mercury levels as human biomorning index in mercury contaminated areas (in Chinese). J Chin Health Lab Technol 6:268–270

Cai S, Lv H, Su H, Guo J (2014) Research on the relationship between hair mercury and teh frequency of fish-eating in pregant women in Wujiang (in Chinese with English abstract). Chin Foreign Med Res 12:91–92

Cao M (2002) The normal hair mercury level in 143 Taiyuan residents (in Chinese). J Pract Med Technol 9:841–841

CDC (2015) Fourth National Report on Human Exposure to Environmental Chemicals, Updated Tables. National Center for Environmental Health, Division of Laboratory Sciences, Centers for Disease Control Prevention, Atlanta

Černá M, Puklová V, Hanzlíková L, Sochorová L, Kubínová R (2017) 25 years of HBM in the Czech Republic. Int J Hyg Environ Health 220:3–5. https://doi.org/10.1016/j.ijheh.2016.08.004

Chai Z, Stemshorn B, Hao J, Jiang G, Hu J, Feng X, Lan H, Sun Y, Larssen T, Lahl U, den Herder K, Chin C, Baird S (2011) Special policy study on mercury management in China. The China Council for International Cooperation on Environment and Development, Beijing

Chen B, Wang Y (1978) The investigation on normal hair mercury levels (in Chinese). Henan Sci Technol:24–28

Chen Y, Wang Z, Shi M (1993) Analysis of hair mercury levels in 211 samples in Fujian (in Chinese). Fujian Environ 10:15–16

Chen Z, Zhang Q, Gan Z, Li L (2004) Analysis of the content of Hg in hair of preganant and parturient women and neonates in Luzhou City (in Chinese with English abstract). J Luzhou Med College 27:119–120

Chien L, Gao CS, Lin HH (2010) Hair mercury concentration and fish consumption: risk and perceptions of risk among women of childbearing age. Environ Res 110:123–129

Choi J, Knudsen LE, Mizrak S, Joas A (2017a) Identification of exposure to environmental chemicals in children and older adults using human biomonitoring data sorted by age: Results from a literature review. Int J Hyg Environ Health 220:282–298. https://doi.org/10.1016/j.ijheh.2016.12.006

Choi W, Kim S, Baek Y-W, Choi K, Lee K, Kim S, Yu SD, Choi K (2017b) Exposure to environmental chemicals among Korean adults-updates from the second Korean National Environmental Health Survey (2012–2014). Int J Hyg Environ Health 220:29–35. https://doi.org/10.1016/j.ijheh.2016.10.002

Clarkson TW, Magos L, Myers GJ (2003) The toxicology of mercury—current exposures and clinical manifestations. N Engl J Med 349:1731–1737. https://doi.org/10.1056/NEJMra022471

Department of Environmental Hygiene (1980) The normal hair mercury level in 667 Taiyuan residents (in Chinese). J Shanxi Med Univ 8:46–46

Department of Hygiene of Jilin Medical University, Changchun Envionmetal Protection Monitoring Station, Fuyu Sanitation and antiepidemic Station (1977) The normal value of mercury in 839 residents hair samples from Changchun (in Chinese). J Hyg Res:265–267

Dickman MD, Leung CK, Leong MK (1998) Hong Kong male subfertility links to mercury in human hair and fish. Sci Total Environ 214:165–174. https://doi.org/10.1016/s0048-9697(98)00062-x

Dickman MD, Leung KMC, Koo LCL (1999) Mercury in human hair and fish: is there a Hong Kong male subfertility connection? Mar Pollut Bull 39:352–356. https://doi.org/10.1016/S0025-326X(98)00204-5

Dong Y, Bai J, Cui Q, Li B, Li L (2002) The mercury level in children from industrial area of Shenyang city (in Chinese). Chin J Child Health Care 10:279–280

Feng X (2005) Mercury pollution in China—an overview. In: Pirrone N, Mahaffey KR (eds) Dynamics of mercury pollution on regional and global scales: atmospheric processes and human exposures around the World. Springer, Boston, pp 657–678. https://doi.org/10.1007/0-387-24494-8_27

Feng X, Han Y (1988) Investigation of hair mercury levels in fishermen from Nansihu Lake (in Chinese). J Environ Health 5:35–36

Feng W, Qian Q, Chai Z (1994) Study on the correlation between mercury contents in hair of lying-in women and their new-born babies by INAA (in Chinese). Nucl Technol 17:182–185

Feng Q, Suzuki Y, Hisashige A (1998) Hair mercury levels of residents in China, Indonesia, and Japan. Arch Environ Health 53:36–43

Gao Y, Yan C-H, Tian Y, Wang Y, Xie H-F, Zhou X, Yu X-D, Yu X-G, Tong S, Zhou Q-X, Shen X-M (2007) Prenatal exposure to mercury and neurobehavioral development of neonates in Zhoushan City, China. Environ Res 105:390–399. https://doi.org/10.1016/j.envres.2007.05.015

Guo B-Q, Cai S-Z, Guo J-L, Xu J, Wu W, Li H, Zhou X, Kim D-S, Yan C-H, Lü H-D (2013) Levels of prenatal mercury exposure and their relationships to neonatal anthropometry in Wujiang City, China. Environ Pollut 182:184–189. https://doi.org/10.1016/j.envpol.2013.07.023

Health Canada (2015) Results of the Canadian health measures survey cycle (2012–2013)

Hui M, Wu Q, Wang S, Liang S, Zhang L, Wang F, Lenzen M, Wang Y, Xu L, Lin Z, Yang H, Lin Y, Larssen T, Xu M, Hao J (2017) Mercury flows in China and global drivers. Environ Sci Technol 51:222–231. https://doi.org/10.1021/acs.est.6b04094

Jiang G-B, Shi J-B, Feng X-B (2006) Mercury pollution in China: an overview of the past and current sources of the toxic metal. Environ Sci Technol 40:3673–3678. https://doi.org/10.1021/es062707c

Joas A, Schwedler G, Choi J, Kolossa-Gehring M (2017) Human biomonitoring: science and policy for a healthy future, April 17–19, 2016, Berlin, Germany. Int J Hyg Environ Health 220:299–304. https://doi.org/10.1016/j.ijheh.2017.01.013

Kang H, Yang Z, He Y (1994) The normal hair mercury level in Kun district, Baotou city (in Chinese). J Baotou Med 18:44–45

Li G, Zhou F (1993) Study on the normal hair mercury levels in Huangshi city (in Chinese). Chin Envion Sci Technol:40–41

Li Z, Wang Q, Luo Y (2006) Exposure of the urban population to mercury in Changchun city, Northeast China. Environ Geochem Health 28:61–66. https://doi.org/10.1007/s10653-005-9012-2

Li Y-F, Chen C, Li B, Wang J, Gao Y, Zhao Y, Chai Z (2008) Scalp hair as a biomarker in environmental and occupational mercury exposed populations: suitable or not? Environ Res 107:39–44

Li P, Feng X, Qiu G, Wan Q (2011) Hair can be a good biomarker of occupational exposure to mercury vapor: simulated experiments and field data analysis. Sci Total Environ 409:4484–4488. https://doi.org/10.1016/j.scitotenv.2011.06.045

Li Y-F, Shang L, Zhao J, Hu H, Wang W (2018) Environmental bioinorganic chemistry of mercury. Science Press, Beijing

Liu H, Li P (1991) The normal hair mercury level in Hohhot (in Chinese). Chin J Ind Hyg Occup Dis 9:40–41

Liu JL, Xu XR, Yu S, Cheng H, Peng JX, Hong YG, Feng XB (2014) Mercury contamination in fish and human hair from Hainan Island, South China Sea: implication for human exposure. Environ Res 135:42–47

Liu M, Chen L, He Y, Baumann Z, Mason RP, Shen H, Yu C, Zhang W, Zhang Q, Wang X (2018) Impacts of farmed fish consumption and food trade on methylmercury exposure in China. Environ Int 120:333–344. https://doi.org/10.1016/j.envint.2018.08.017

Lye E, Legrand M, Clarke J, Probert A (2013) Blood total mercury concentrations in the Canadian population: Canadian Health Measures Survey Cycle 1, 2007–2009. Can J Public Health 104:e246–e251. https://doi.org/10.17269/cjph.104.3772

Niu X, Zhang Y, Zhou J (2012) Comparison of mercury levels of general residents in coastal and inland areas (in Chinese). Environ Chem 31:1942–1947

Niu X, Sun Q, Guo M, Zhou J, Zhang Y (2014) Mercury exposure for general residents in Dalian urban area (in Chinese with English abstract). Asian J Ecotoxicol 9:940–949

Niu Z, Wang Y, Liu G (2016) Investigation on hair mercury concentration of people in 8 typical regions of Anhui Province and its influence factors (in Chinese with English abstract). Environ Chem 35:533–539

Park C, Hwang M, Kim H, Ryu S, Lee K, Choi K, Paek D (2016) Early snapshot on exposure to environmental chemicals among Korean adults—results of the first Korean National Environmental Health Survey (2009–2011). Int J Hyg Environ Health 219:398–404. https://doi.org/10.1016/j.ijheh.2016.04.001

Prüss-Ustün A, Wolf J, Corvalán C, Neville T, Bos R, Neira M (2017) Diseases due to unhealthy environments: an updated estimate of the global burden of disease attributable to environmental determinants of health. J Public Health (Oxf) 39:464–475. https://doi.org/10.1093/pubmed/fdw085

Shao Y (1977) The normal hair mercury levels in 500 samples from urban and suburb area of Hangzhou. J Hyg Res:395–401

Song L (2010) Human hair mercury levels in the residents living in Shanghai and the environmental influecing factors (in Chinese with English abstract). East China Normal University

Song Y, Yang J, Li J, Cheng J, Wang W (2007) Investigation of the mercury contents in the hair of 262 Ningbo residents (in Chinese with English abstract). Occup Health 23:282–283

Song G, Lv H, Guo J, Chen M, Su H (2013) Analysis and evaluation to mercury content in cord blood and fetal hair of 2316 neonates (in Chinese). Lab Med Clin 10:1208–1209

Tian W (2011) Human exposure level and risk assessment of total mercury and methylmercury in the Pearl River Delta (in Chinese). Jinan University

UNEP (2013) Minamata convention on mercury. United Nations Environment Programme, Geneve

Wang J, Zhang Y (1981) Study on the normal hair mercury level in Chengdu (in Chinese). Chin J Environ Eng:52–55

Wang H, Wu J, Zhou Q, Ying T, Shen Z (2010) Survey on maternal mercury exposure and its association with neonate in Zhoushan islands (in Chinese with English abstract). Chin Prev Med 11:1081–1084

Wu S, Gu T, Hu X, Gao Y, Gao S (1982) Analysis of mercury in 324 hair samples from Shijiazhuang residents (in Chinese). J Hebei Med Univ 3:205–206

Wu Y, Zhao Y, Li J (2018) The fifth China total diet study. Science Press, Beijing

Xu L, Mo Y (1981) Normal mercury level in 543 hair samples from Qinghai (in Chinese). Qinghai Med J:26–28

Xu X, Wang W-X (2017) Mercury exposure and source tracking in distinct marine-caged fish farm in southern China. Environ Pollut 220:1138–1146. https://doi.org/10.1016/j.envpol.2016.11.021

Yan J, Gao ZY, Wang J, Yan CH (2017) Hair mercury levels and their relationship with seafood consumption among preschool children in Shanghai. Biomed Environ Sci 30:220–223. https://doi.org/10.3967/bes2017.030

Yang S (2011) Clinic investigation on mercury in maternity and newborn and their corelation (in Chinese). J Fujian Med Univ 45:427–429

Yang H, Chen X (1987) Analysis of mercury in 209 hair samples from Guiyang, Guizhou, China (in Chinese). Ind Health Occup Dis 13:226–227

Yin C, Guo H, Jin Y, Li W, Liu J, Zhang H (1980) Hair mercury (total mercury and methylmercury) levels in Beijing Residents (in Chinese). J Hyg Res:56–59

Yin C, Guo H, Li W, Zhang S (1981) Mercury investigation in hair samples from fishermen and farms in five provinces around Bohai Sea and Yellow Sea (in Chinese). J Hyg Res:12–14

Yin L, Yu K, Lin S, Song X, Yu X (2016) Associations of blood mercury, inorganic mercury, methyl mercury and bisphenol A with dental surface restorations in the U.S. population, NHANES 2003–2004 and 2010–2012. Ecotoxicol Environ Saf 134:213–225. https://doi.org/10.1016/j.ecoenv.2016.09.001

Zhang Y (2003) Investigation of the accumulation of Pb, Cd and Hg and their health effects in Suizhou residents (in Chinese). Suzhou University

Zhang L (2009) Study on the human hair mercury levels in the residents living in the different function regions in Qingdao and influence factors (in Chinese with English abstract). J Saf Environ 9:95–97

Zhang P, Chen G, Zhang B (1988) Investigation on the mercury contamination in Qingtongxia reservior and its impact on fish, poultry and human hair mercury levels (in Chinese). J Environ Health:31–32

Zhang W, Ren A, Yang Z, Pei L, Hao L, Xie Q, Jiang Y, Wei Y, Li Z (2005) Correlation studies of trace elements in mother's hair, venous blood and cord blood (in Chinese with English abstact). Chin J Reprod Health 16:209–212

Zhang X, Cui X, Lin C, Ma J, Liu X, Zhu Y (2017) Reference levels and relationships of nine elements in first-spot morning urine and 24-h urine from 210 Chinese children. Int J Hyg Environ Health 220:227–234. https://doi.org/10.1016/j.ijheh.2016.10.013

Zidek A, Macey K, MacKinnon L, Patel M, Poddalgoda D, Zhang Y (2017) A review of human biomonitoring data used in regulatory risk assessment under Canada's Chemicals Management Program. Int J Hyg Environ Health 220:167–178. https://doi.org/10.1016/j.ijheh.2016.10.007