# Mercury Pollution and Health Risks in Chinese Fish and Rice

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July. 25. 2024

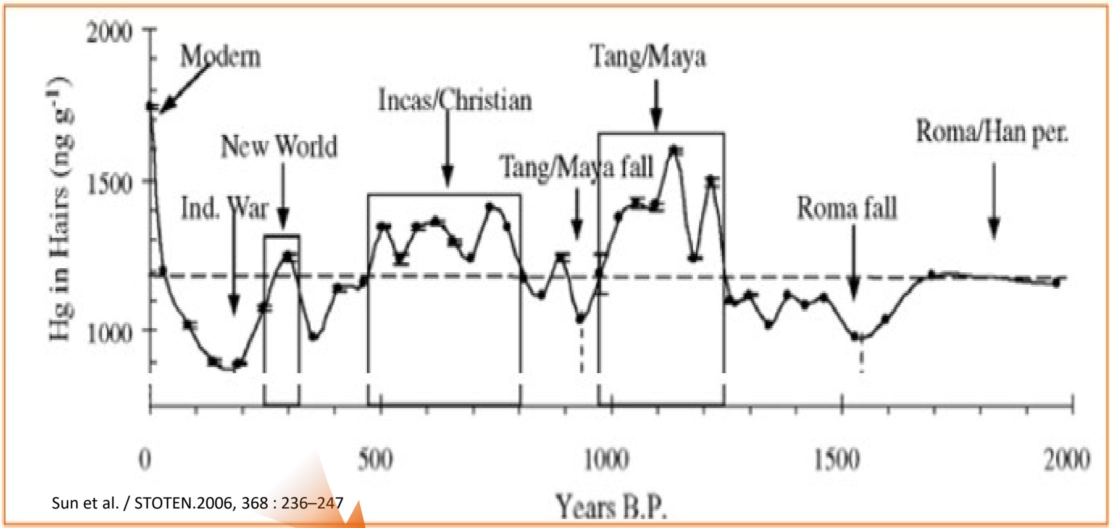
# The past and present lives of Hg

*Ancient alchemy (mercury):*
*—— the predecessor of modern science*

Let’ s take a trip down memory lane and look at the past and present of mercury:

*——Believe it or not, back in the day, mercury was considered a real treasure! The legendary elixir of immortality that Qin Shihuang, the first Emperor of China, was obsessed with?*
*It was mostly made from cinnabar, which is used to refine mercury.*

Elixir of immortality（cinnabar.： HgS--Hg+S）




Sun et al. / STOTEN.2006, 368 : 236–247



It’ s pretty fascinating how Hg, has been intertwined with thousands of years of Chinese culture.

*———Throughout history, we’ ve seen that the use of Hg ramped up during times of social progress. You could even say that ancient alchemy, which heavily relied on mercury, was the forerunner of modern chemistry.*

# The past and present lives of mercury

*Hg has extremely important pharmacological effects in Chinese medicine*

*It's definitely worth mentioning that mercury has played a significant role in Chinese medicine:*

- ✓ It was documented in one of the most important ancient Chinese herbal texts, the "Shennong Materia Medica Classic."
- ✓ t has crucial pharmacological effects, especially in Chinese and Tibetan medicine.


Important ancient Chinese herbal medicine, "Shennong Materia Medica Classic"


Now, this is a pretty controversial and sensitive topic, and it really needs more research from experts in medicine and toxicology!

# The past and present lives of mercury

**"beneficial/non-toxic" ------ "toxic" ------"limited use"**

*these days we all know that*

*——**Mercury is a toxic non essential element,** and the toxicity of different forms of mercury varies greatly.*

*——**Methyl mercury is the most toxic,** 100 times stronger than inorganic mercury.*

***——the most famous case is the Minamata disease***

*Minamata disease, 1956 ( Photo: Eugene Smith)*

- *No beneficial biological function but can bio-accumulate in tissues*
- *Possible effects are nerve damages, birth defects, cancer …*

# The past and present lives of mercury

SCIENTIFIC REPORTS

www.nature.com/scientificreports

OPEN

SUBJECT AREAS: POLLUTION REMEDIATION, GEOCHEMISTRY, ATMOSPHERIC CHEMISTRY, ENVIRONMENTAL MONITORING

Atmospheric mercury inputs in montane soils increase with elevation: evidence from mercury isotope signatures

Hua Zhang[1,2*], Run-sheng Yin[3*], Xin-bin Feng[1], Jonas Sommar[1], Christopher W. N. Anderson[4], Atindra Sapkota[1], Xue-wu Fu[1] & Thorjørn Larssen[2]

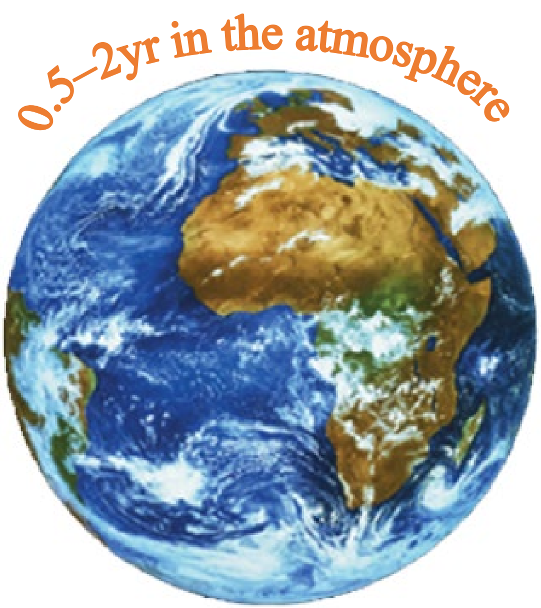
*——Because of its unique physical and chemical properties, we've noticed that*

**Mercury pollution is getting worse in high-altitude mountain environments. And it's not just near human pollution sources; even remote areas are affected.**

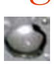
——In these environments, mercury levels in ecosystems—like in fish and birds—are way above international safety limits. We call this phenomenon the **"Mountain Cold-Trapping Effect of Mercury."**

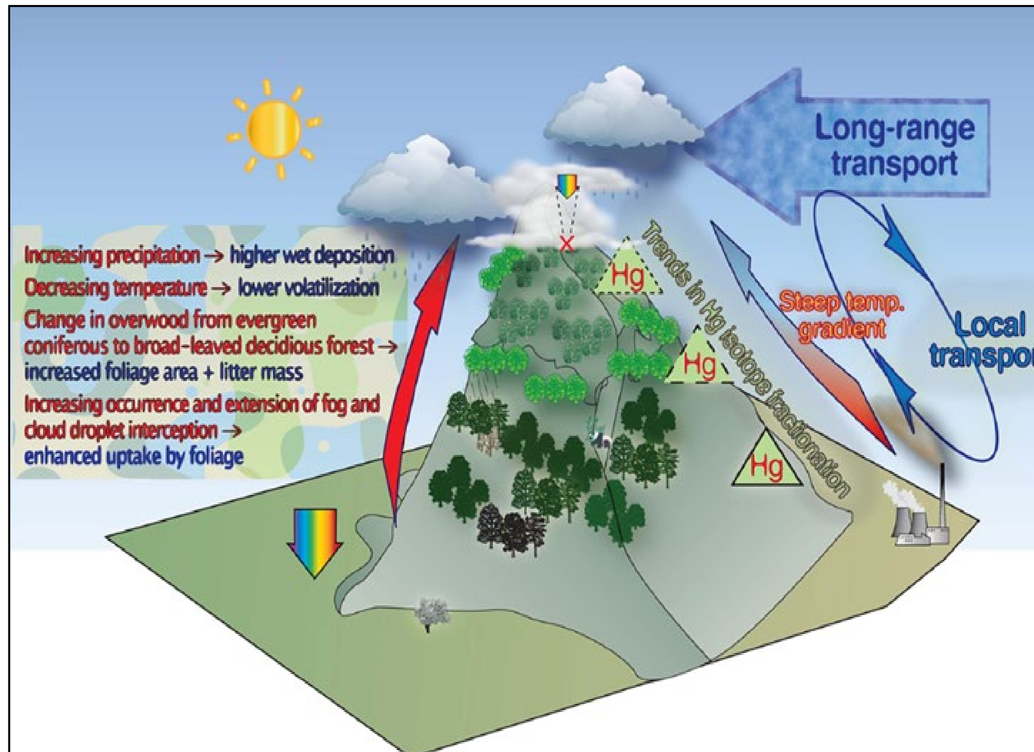
*Mercury: A global pollutant*

*—— Long-range transport through atmosphere*




$Hg^0$






**"Mountain Cold-Trapping Effect of Mercury"**

*Zhang H.,* et al., 2013, ***Sci Rep.***

This study caught the eye of the science community. For example, the Journal of Integrated Environmental Assessment and Management **covered it with the headline**, "**Not Just for Seafood: Mercury Pollution in Montane Ecosystems**."

# IEAM Blog

Official blog for the journal Integrated Environmental Assessment and Management: Timely news, discussions, and thoughts

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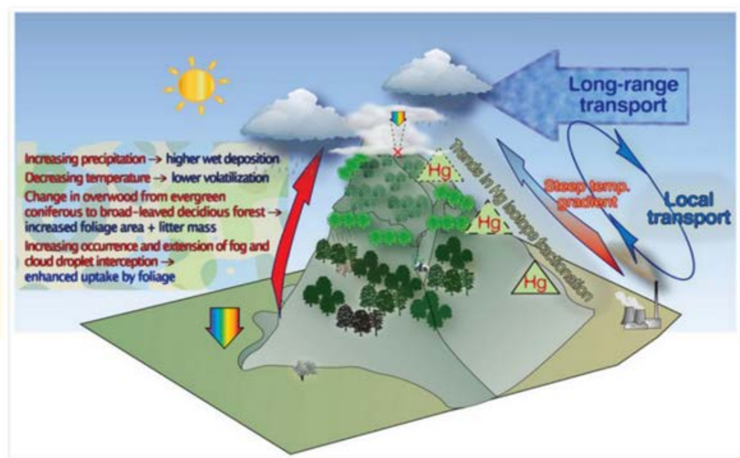
## Not Just for Seafood: Mercury Pollution in Montane Ecosystems

By Roberta Attanasio, *IEAM* Blog Editor

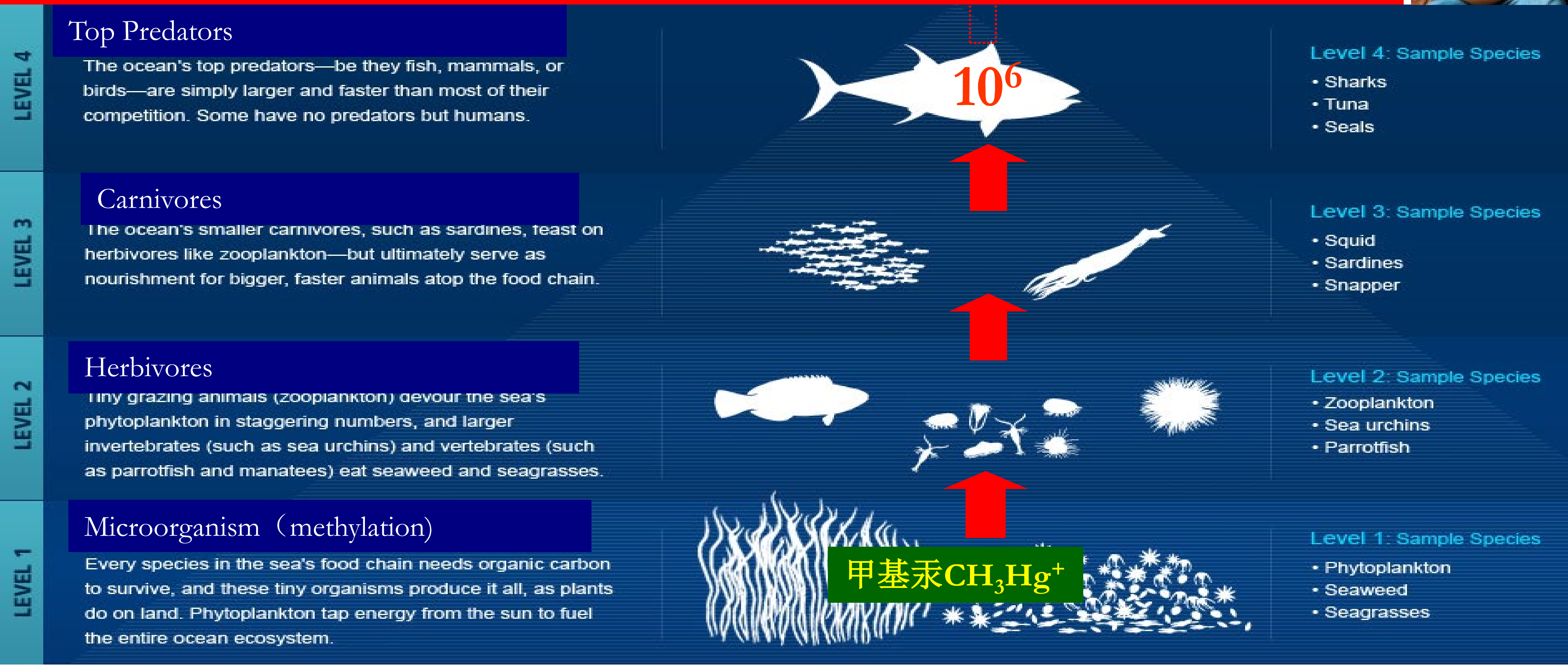
Hua Zhang and collaborators examined topsoil samples along an elevational gradient transect on Mt. Leigong in subtropical southwestern China. The results of the study derived from the atmosphere distinctly increases with altitude. The authors provide potential mechanisms for this so-called altitudinal magnification effect or "mountain trapping effect" (see figure below, from Zhang et al. 2013, *Scientific Reports*




*Potential mechanisms for mercury magnification in montane soils, by Hua Zhang and Jonas Sommar, licensed under* ______

*Because of the way mercury accumulates and amplifies up the food chain, it's widely accepted that*

- ✓ **Eating fish and other aquatic products is the main way humans are exposed to methylmercury.**
- ✓ **The mercury content in fish has always been a hot topic globally!**




**We all know that countries in Europe and North America have made significant strides in reducing atmospheric mercury emissions over the past few decades.**

# ——So what is the trend of Hg pollution in Europe and the US?

**Overall, mercury pollution has either declined or remained stable.**

**However, in some regions,**

**it initially decreased but began to increase again after 2010.**

Environmental Science & Technology



Article

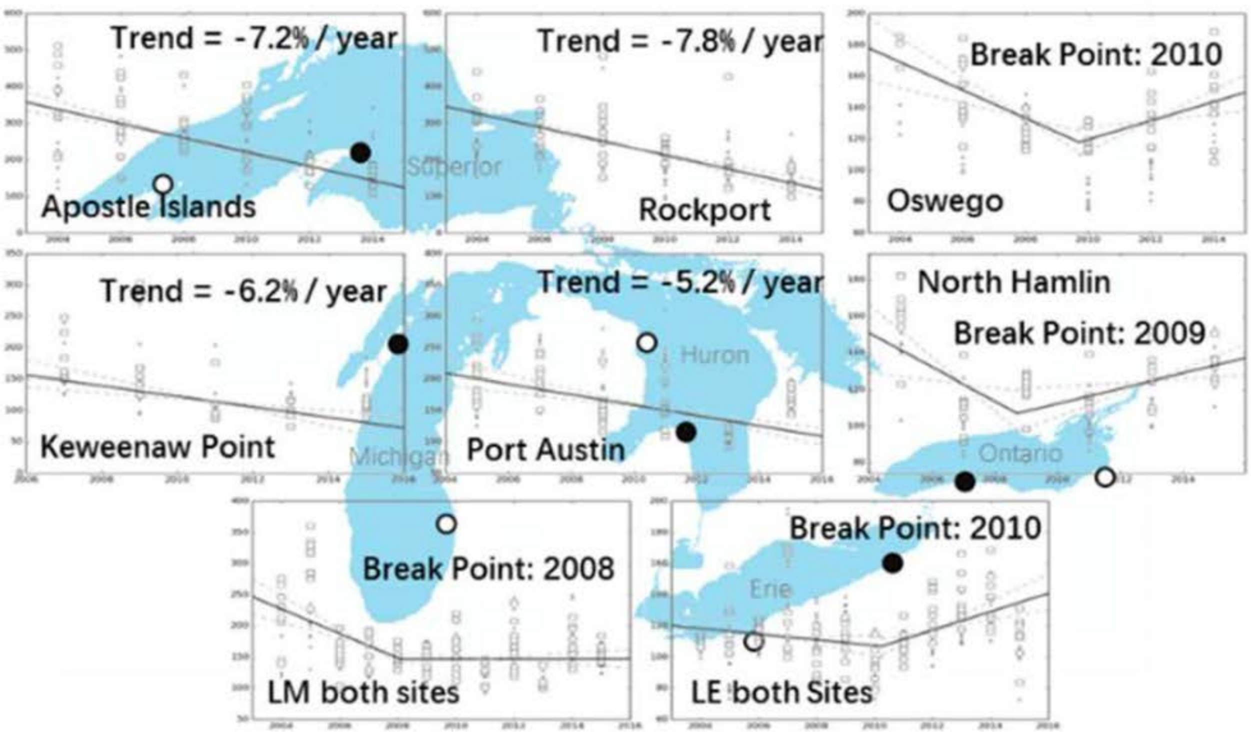
**Mercury temporal trends in top predator fish of the Laurentian Great Lakes from 2004 to 2015: are concentrations still decreasing?**

Chuanlong Zhou, Mark D. Cohen, Bernard S. Crimmins, Hao Zhou, Timothy A. Johnson, Philip K. Hopke, and Thomas M. Holsen

*Environ. Sci. Technol.*, **Just Accepted Manuscript** • Publication Date (Web): 05 Jun 2017



**Canada** **11 yrs**



# According to another two studies analyzing 40 years' and 35 years' worth of data

Canada — 40 yrs

Article
pubs.acs.org/est

**Fish Mercury Levels Appear to Be Increasing Lately: A Report from 40 Years of Monitoring in the Province of Ontario, Canada**

Nilima Gandhi,[†] Rex W. K. Tang,[‡] Satyendra P. Bhavsar,*[†,‡,§] and George B. Arhonditsis[†,‡]

US — 35 yrs

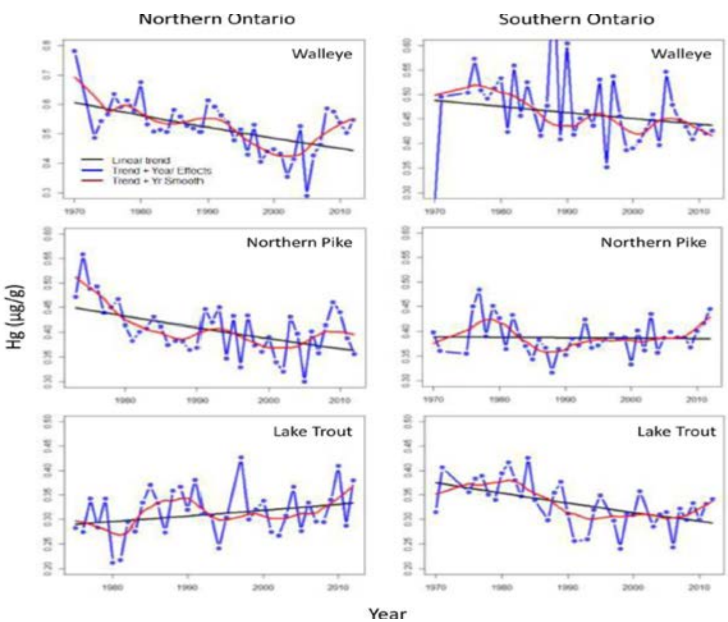
Environ Monit Assess (2011) 175:175–191
DOI 10.1007/s10661-010-1504-6

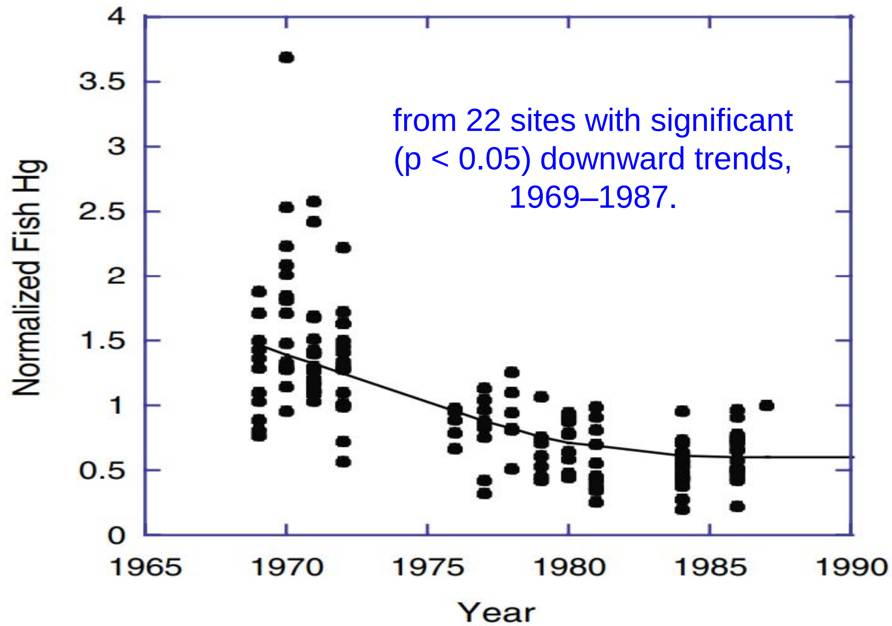
**Mercury trends in fish from rivers and lakes in the United States, 1969–2005**

Ann T. Chalmers · Denise M. Argue · David A. Gay · Mark E. Brigham · Christopher J. Schmitt · David L. Lorenz

## In most cases, the temperature is decreasing,

## while in some areas it remains stable or increases.




*N. Gandhi et al Env. Sci. Tech. 48, 5404–5414 (2014).*

*Ann T. et al., Env Monit Assess 2011 175: 175-191*

# According to a study analyzing 60 years' data

## Overall, either declined or remained stable

Article

Cite This: *Environ. Sci. Technol.* 2019, 53, 1834−1843

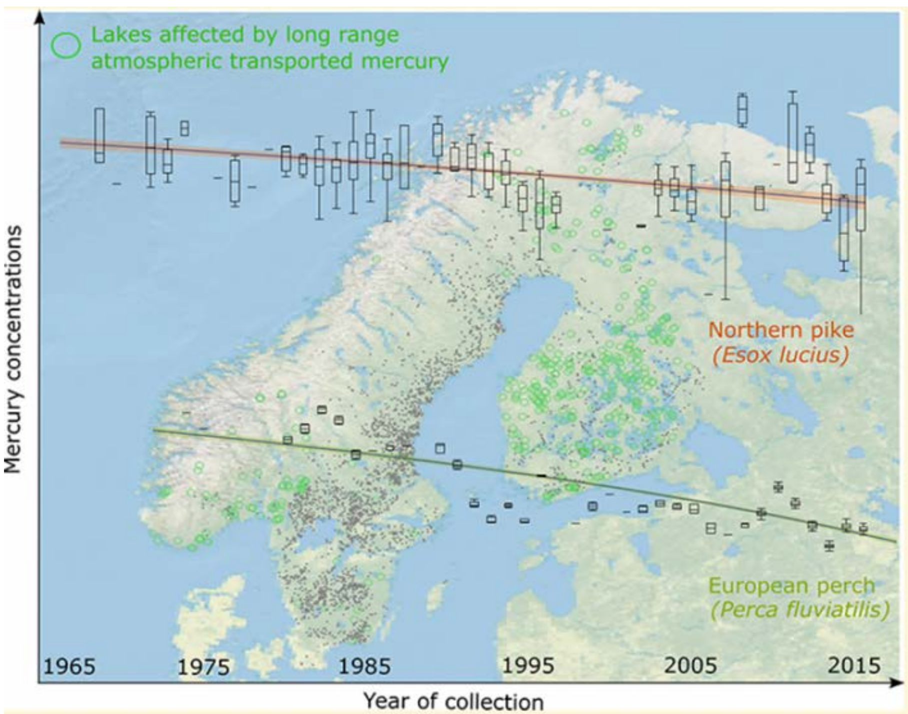
pubs.acs.org/est

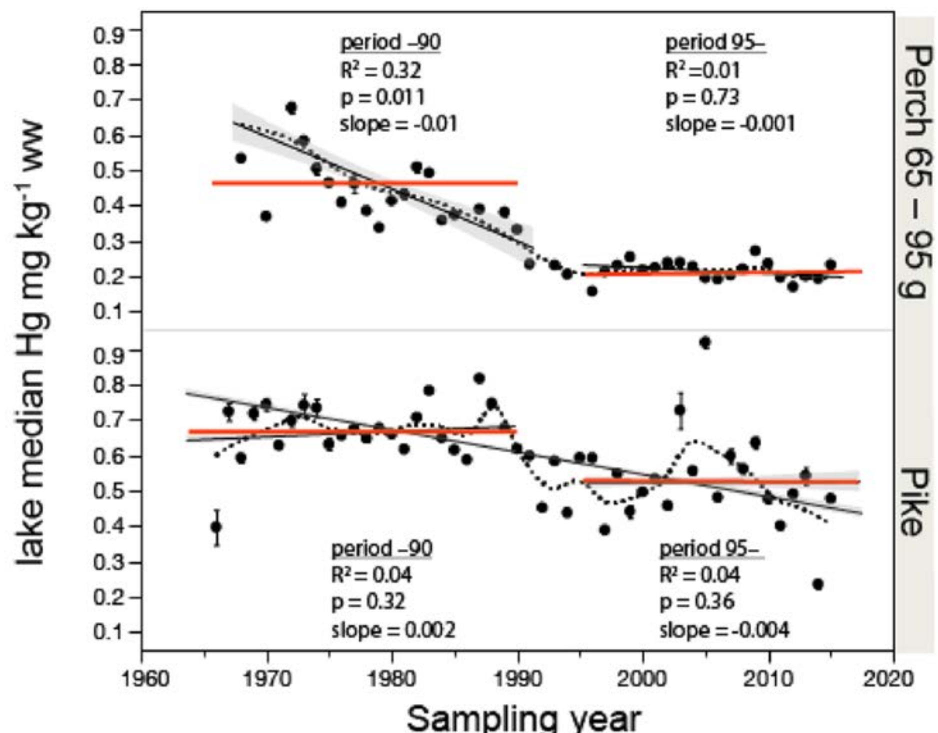
**Norway et al.,**

**60 yrs**

### Improved Environmental Status: 50 Years of Declining Fish Mercury Levels in Boreal and Subarctic Fennoscandia

Hans Fredrik Veiteberg Braaten,[*,†] Staffan Åkerblom,[‡] Kimmo K. Kahilainen,[§,∥] Martti Rask,[⊥] Jussi Vuorenmaa,[#] Jaakko Mannio,[#] Tommi Malinen,[∥] Espen Lydersen,[¶] Amanda E. Poste,[†] Per-Arne Amundsen,[□] Nicholas Kashulin,[■] Tatiana Kashulina,[■] Petr Terentyev,[■] Guttorm Christensen,[○] and Heleen A. de Wit[†]



And one more study of **37 yrs data:**

## the Hg concentrations in Canadian Great Lakes fish have generally declined from mid-1970s to 2007

*Environ. Sci. Technol.* **2010**, *44*, 3273–3279

**Changes in Mercury Levels in Great Lakes Fish Between 1970s and 2007**

37 yrs

SATYENDRA P. BHAVSAR,*,† SARAH B. GEWURTZ,†,‡ DARYL J. MCGOLDRICK,§ MICHAEL J. KEIR,§ AND SEAN M. BACKUS§

Overall, either declined or remained stable

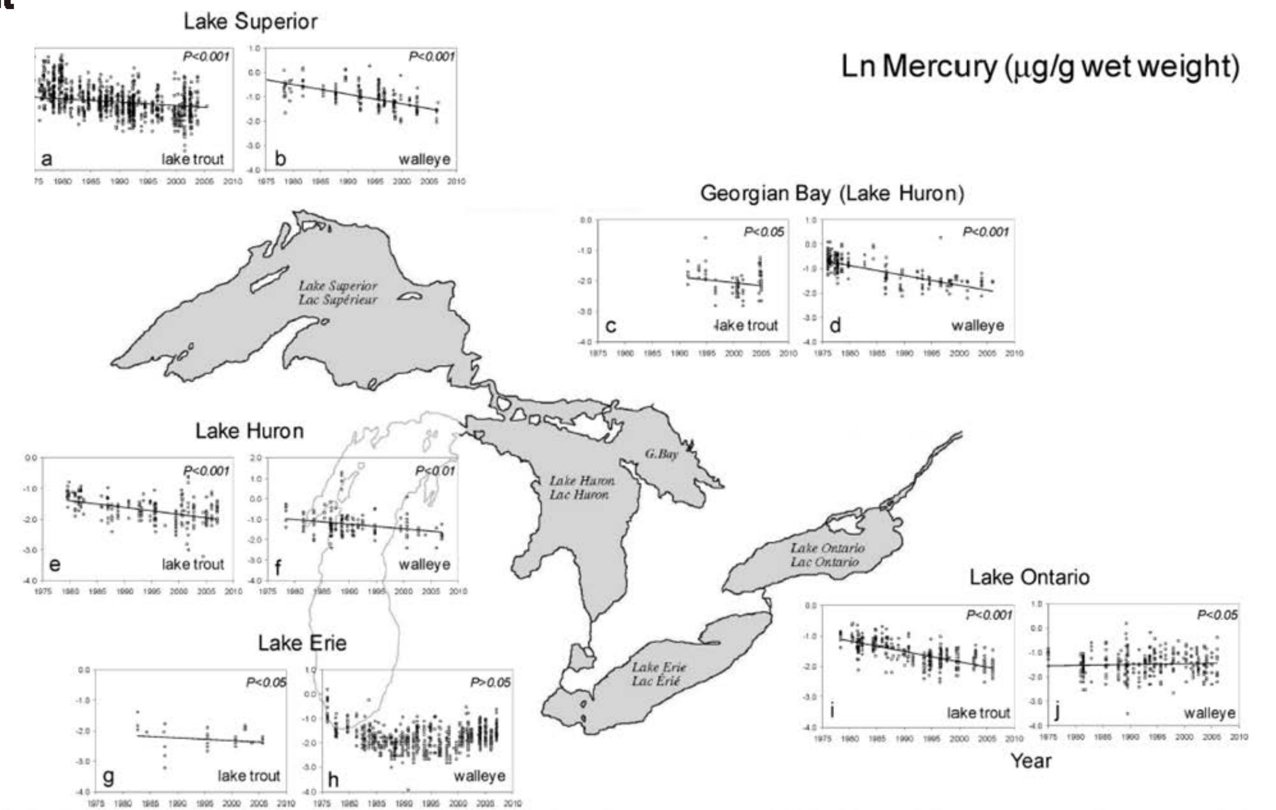
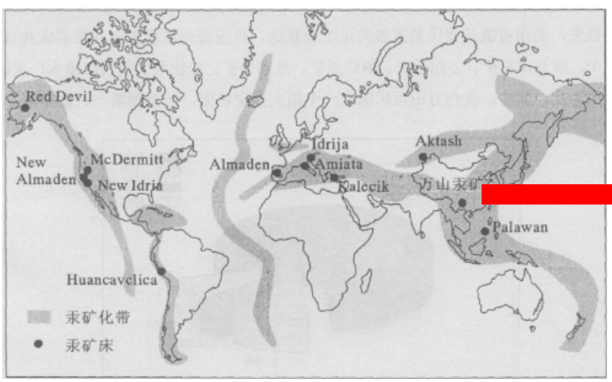



**FIGURE 2.** Temporal trends of mercury (natural log-transformed, µg/g ww) in OMOE skinless fillets. (a, c, e, g, i) 55−65 cm lake trout, and (b, d, f, h, j) 45−55 cm walleye collected from Lakes Superior (a-b), Georgian Bay (c,d), Huron (e,f), Erie (g,h), and Ontario (i,j) between 1973 and 2007. *P*-value is for statistical significance.

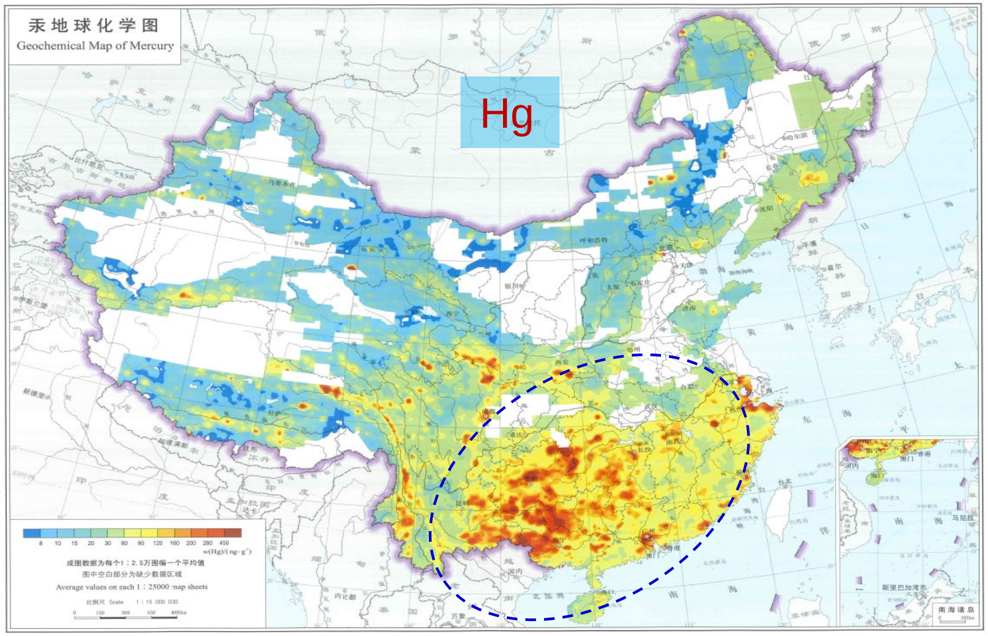
In the past 30 years, China has become the **world's largest producer, consumer, and emitter of mercury**. It's also the **biggest producer and consumer of commercial fish**

## ——This has led to growing public concern about the potential mercury pollution in fish.

China sits on the Pacific Rim's mercury mineralization zone, which means that the weathering of rocks leads to high levels of mercury in the soil




Global Hg Mineralization Zones and Distribution of Hg Deposits




Mercury Geochemical Map of China

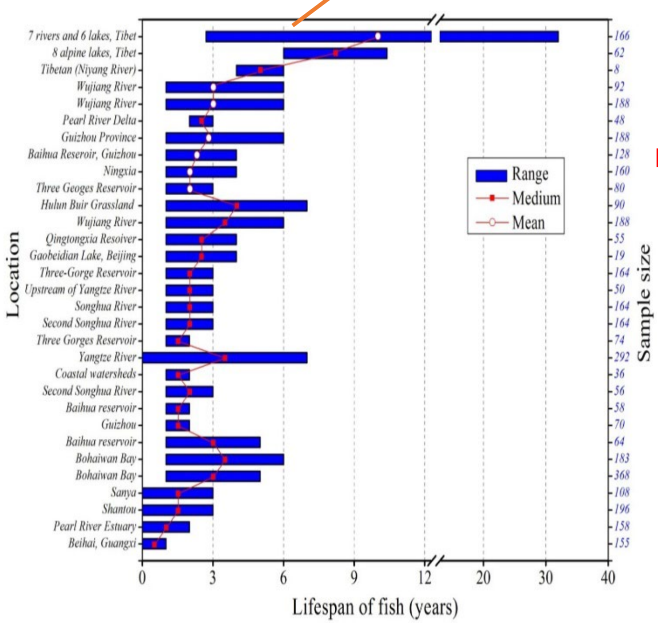
Environmental mercury pollution in China is influenced by the regional geological and geochemical factors.

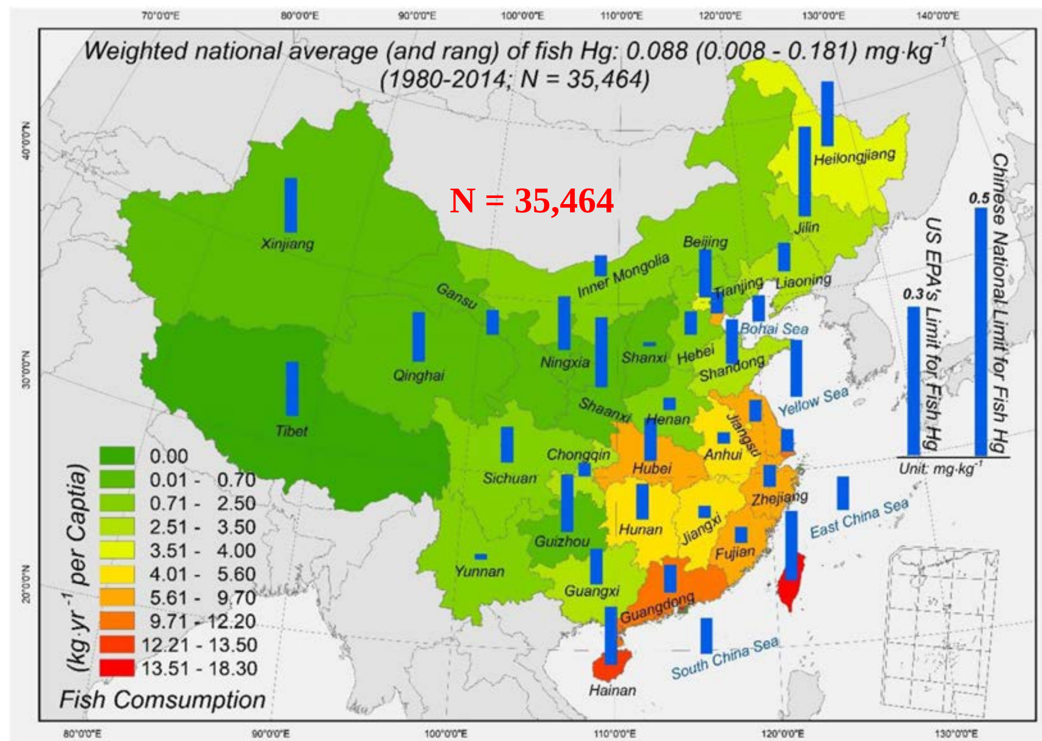
**So, the big question is: Are Chinese residents at risk of methyl mercury exposure from eating fish?**

# We've got 40 years of data analysis and research to back this up.

——Chinese fish, it turns out, have pretty short lifespans—just 1 to 3 years. They make it to our tables before they have a chance to accumulate significant levels of mercury.

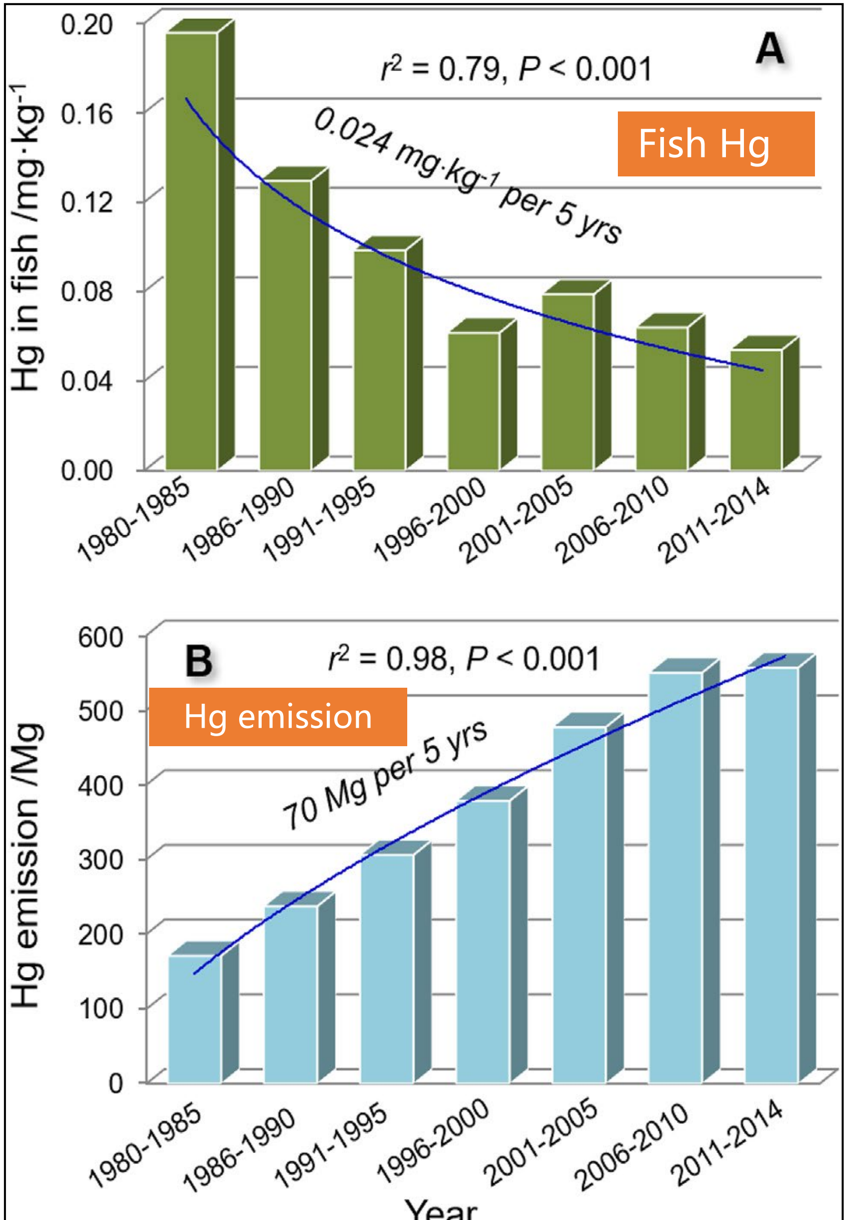
Exception of Xinjiang, Tibet, Qinghai(Religious beliefs, do not eat fish, wild)

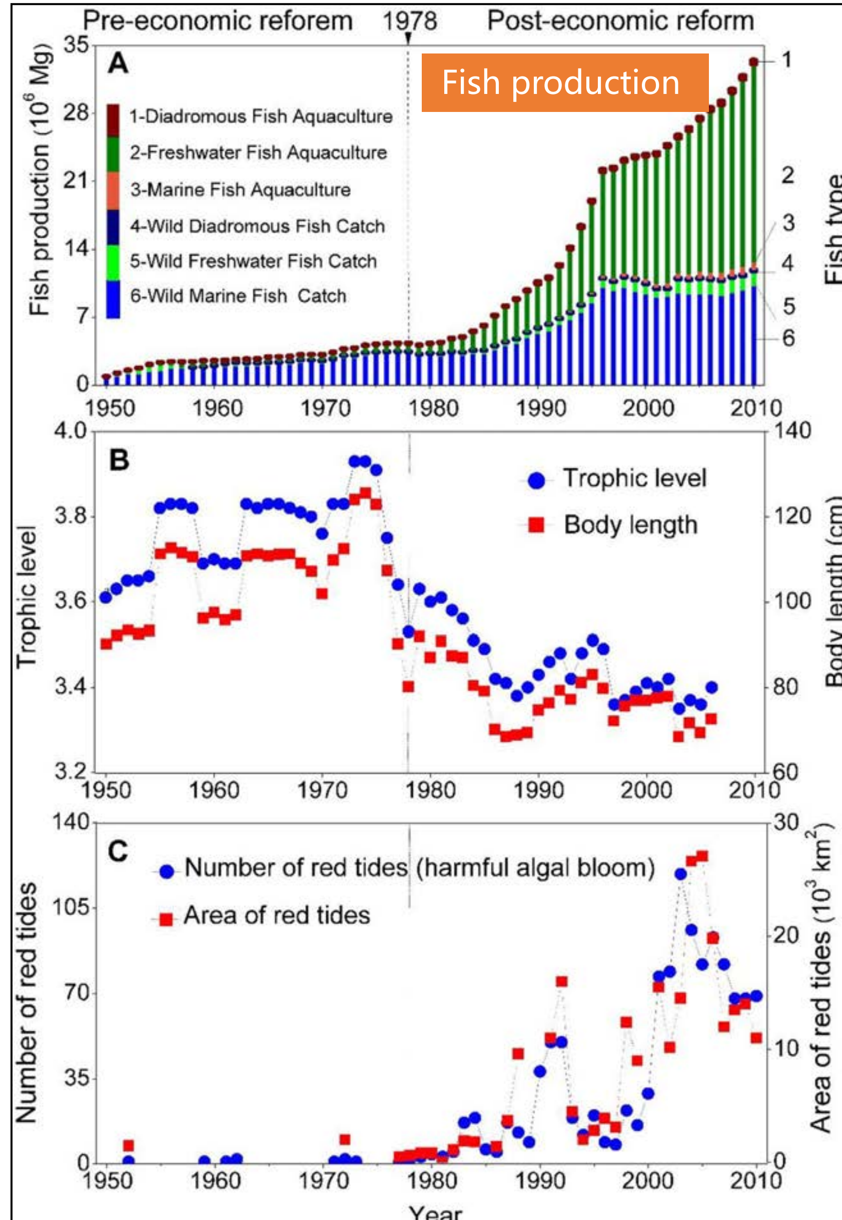



**Distribution of mercury content in fish in China**

*Zhang H, Feng X.B.*, et al., ***Eco-Environment & Health***, *2022*




*Zhang H, Feng X.B., , et al., Eco-Environment & Health, 2022*

# We've seen a **downward trend** in both total mercury (THg) and methyl mercury (MeHg) levels in aquatic foods in China.


Environmental Pollution 312 (2022) 120026

Contents lists available at ScienceDirect

Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

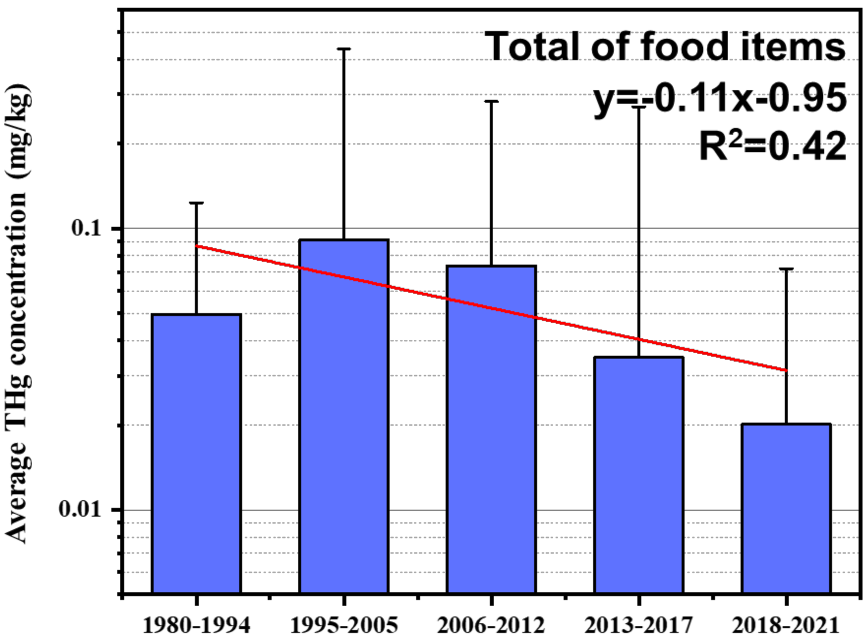
ELSEVIER

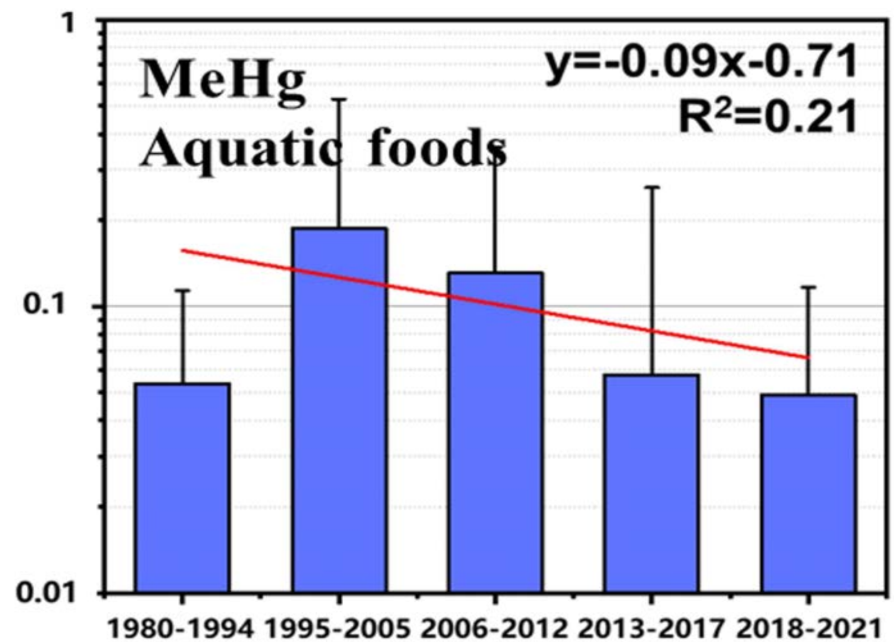
Risk assessment of mercury through dietary exposure in China☆

Ying Qing[a,1], Yongzhen Li[b,1], Jiaqi Yang[c], Shichun Li[a], Kaixin Gu[a], Yunxia Bao[a], Yuhao Zhan[a], Kai He[a], Xiaoying Wang[a], Yanfei Li[d,*]

This is based on a Very large number of

**295,688 food samples!**




**Temporal variations in Hg concentrations from 1980 to 2021 in China**

*Qing Y, et al., Environmental Pollution. 2022*

**even though China's atmospheric mercury emissions have been on the rise over the past 30 years,**
**——the amount of fish people are eating—both freshwater and marine—has actually gone down. Overall, the mercury levels in the country are pretty low.**


Eco-Environment & Health 1 (2022) 46–52

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journal homepage: www.journals.elsevier.com/eco-environment-and-health

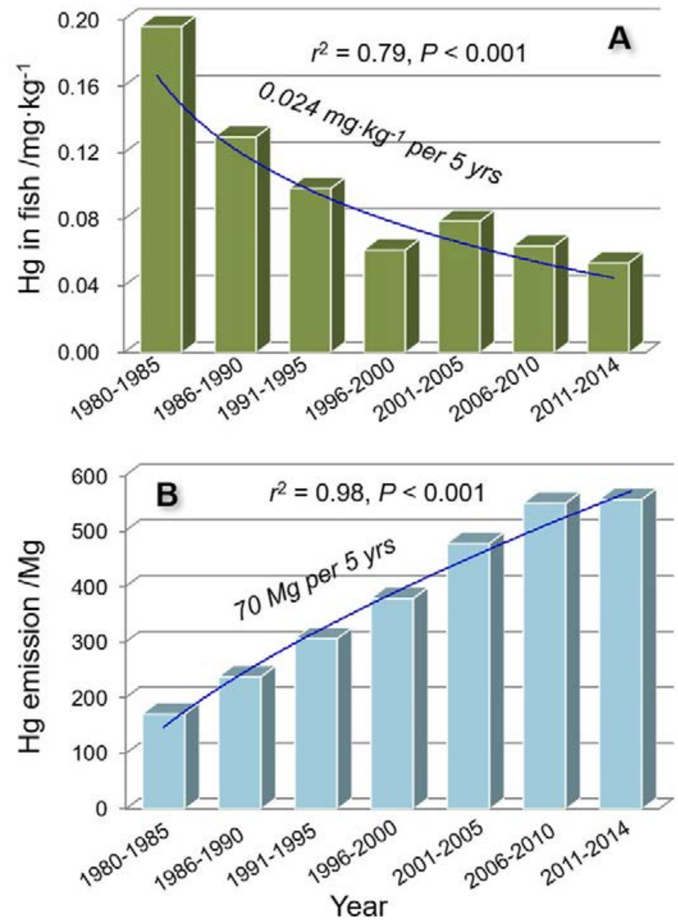
ELSEVIER

Original Research Article

Decreasing mercury levels in consumer fish over the three decades of increasing mercury emissions in China

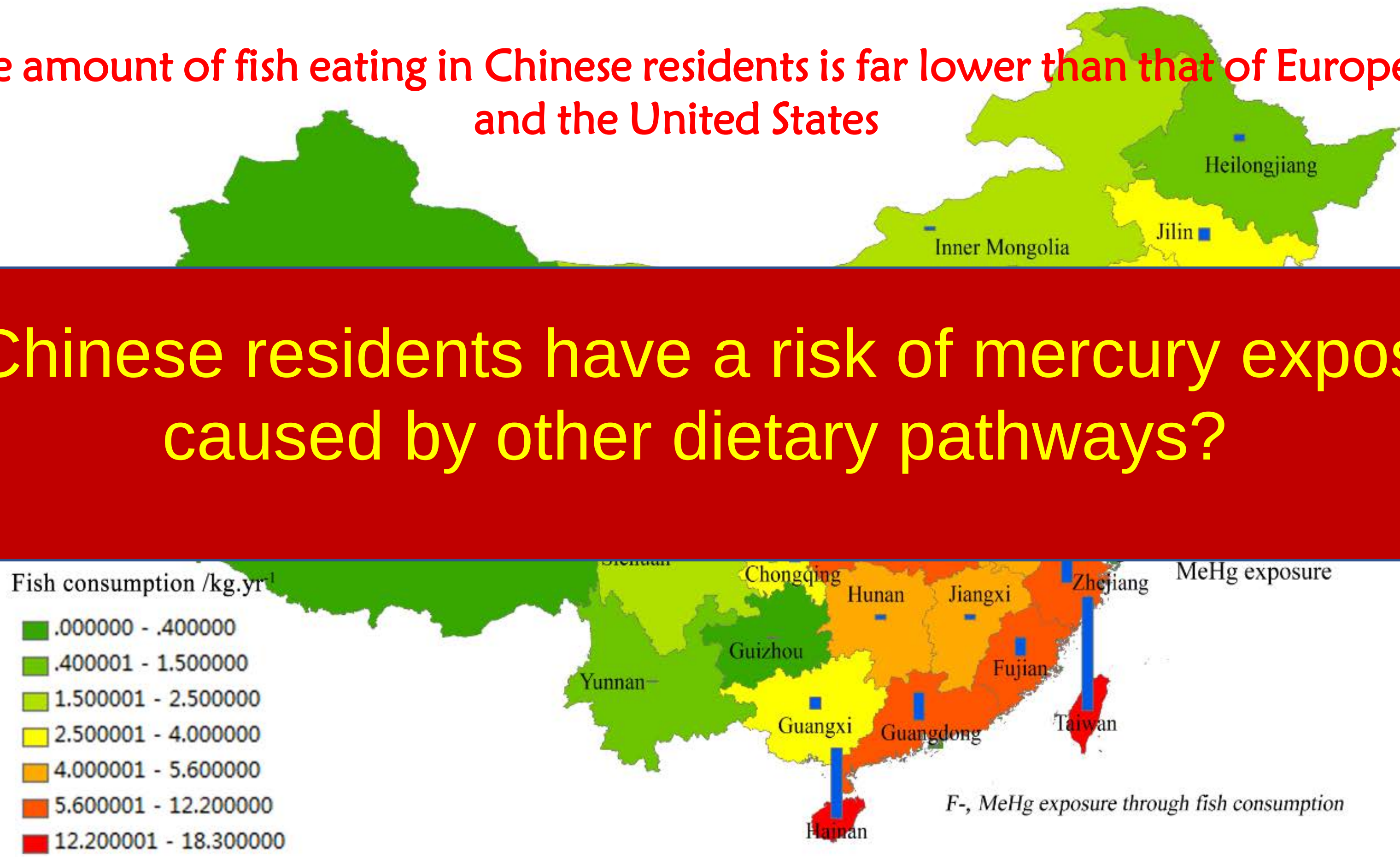
Hua Zhang[a,b,*], Wen-Xiong Wang[c], Che-Jen Lin[d], Xin-Bin Feng[a], Jian-Bo Shi[e,f], Gui-Bin Jiang[e], Thorjørn Larssen[b]





# Chinese residents' mercury exposure levels caused by eating fish

The amount of fish eating in Chinese residents is far lower than that of Europe and the United States



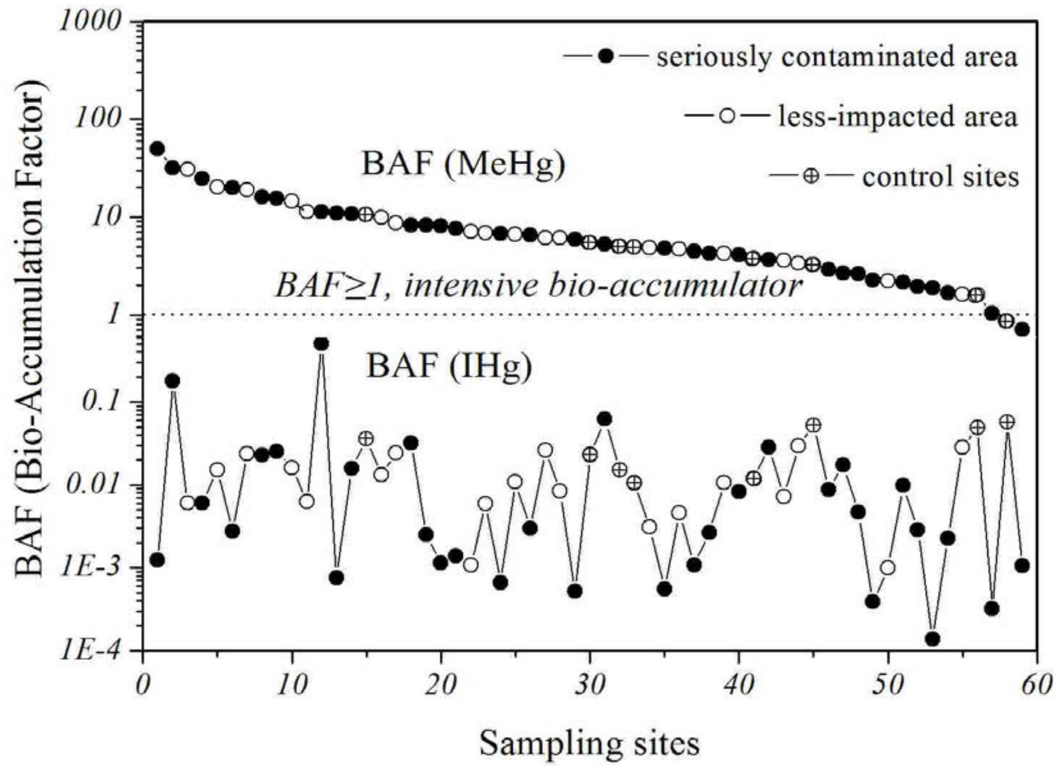

**Do Chinese residents have a risk of mercury exposure caused by other dietary pathways?**

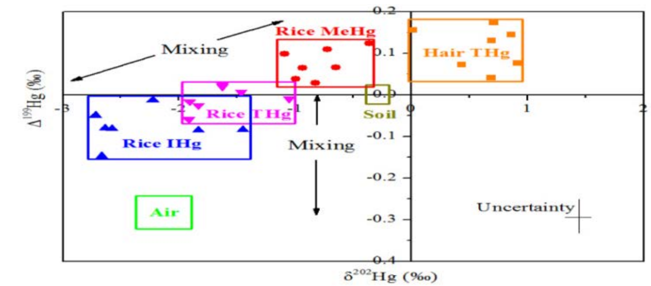
*Zhang H, Feng X.B.,* *et al., "Consultation Report on the Implementation of the National Minamata Convention in China", 2018*

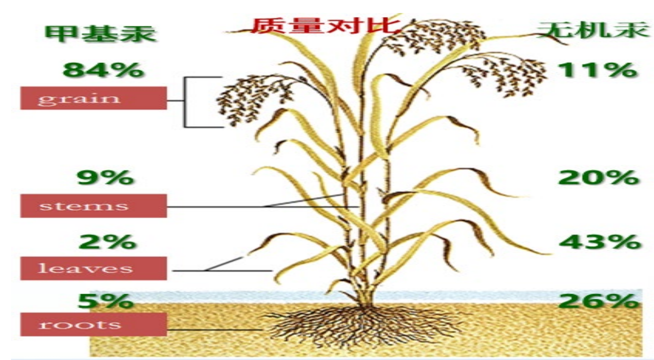
# Our research in the mercury mining area found that rice is the most toxic methylmercury enriched plant

*——Isotope tracing research shows that inorganic Hg in rice from Hg mining areas:*

*root absorption (40% -60%)+leaf absorption (30-45%)*

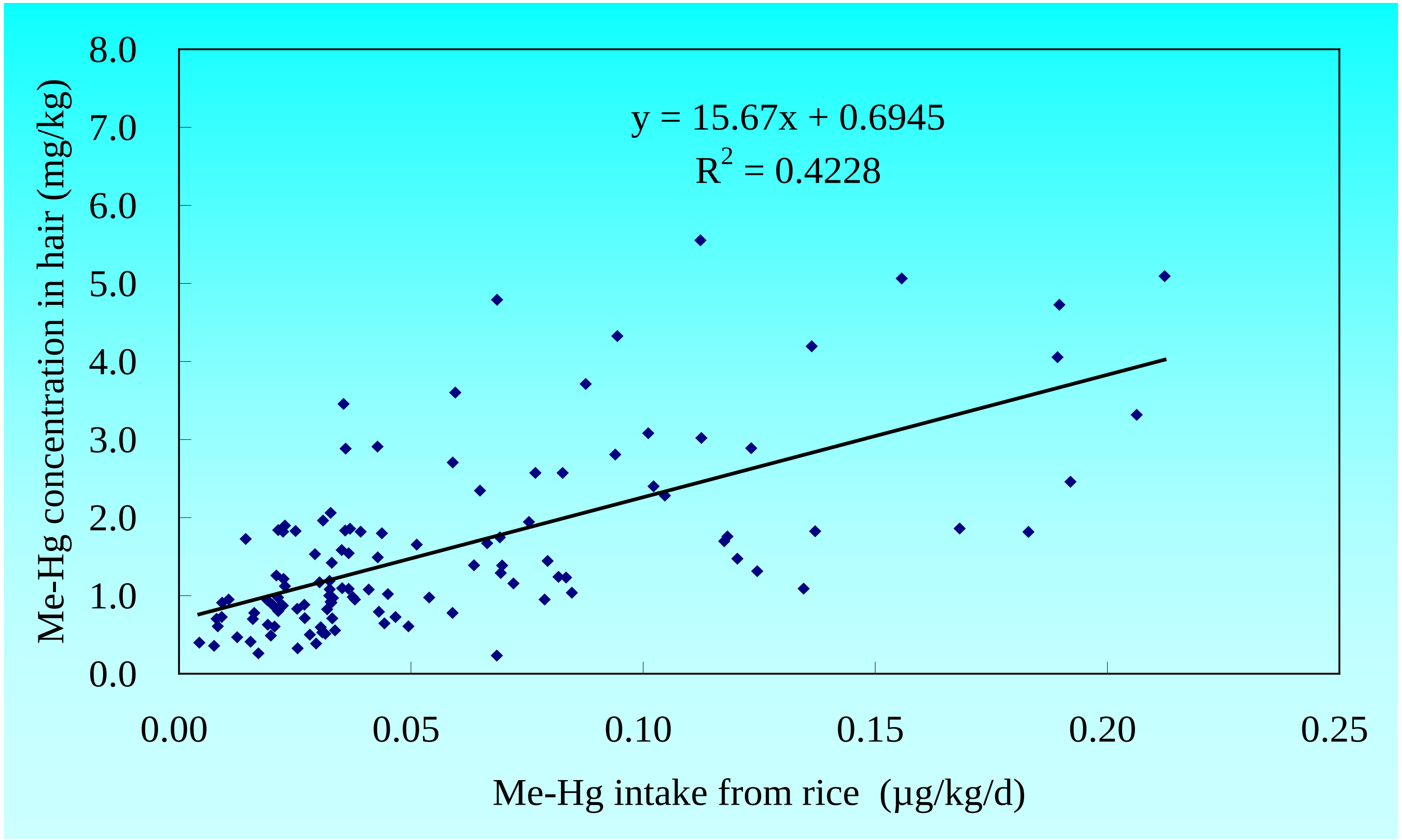


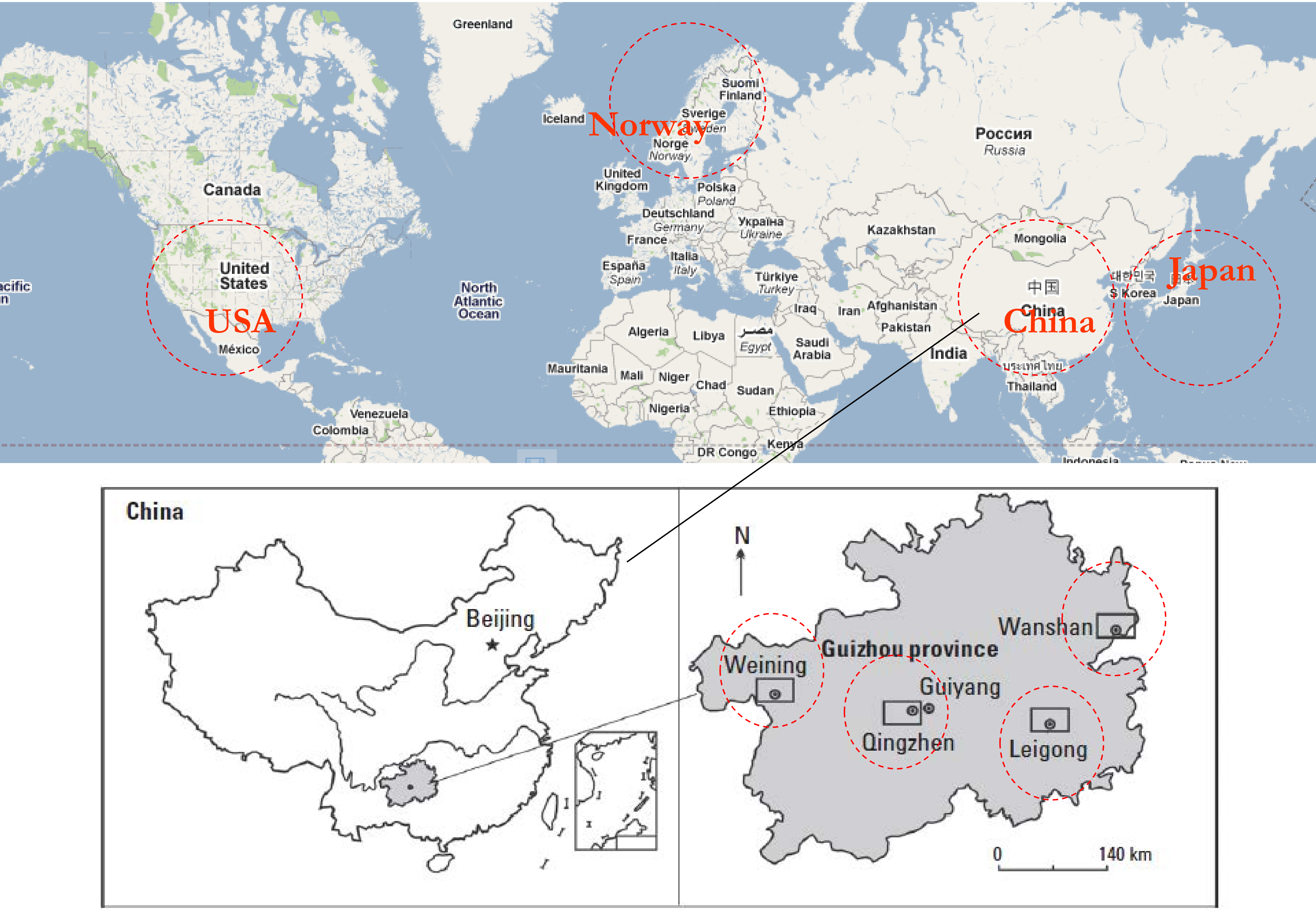

*Zhang et al., ES&T，2010*

*The main human exposure to Me-Hg via food consumption is not restricted to fish,* ***but in some cases in mining areas of China to frequent rice meals***




Correlation between MeHg in hair and MeHg intake from rice eating

*Feng X. et al., Environ Sci & Technol, 2008. 42, 326-332.*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Mali
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Chad
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Ethiopia
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Colombia
Kenya
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China
Beijing
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Guizhou province
Weining
Wanshan
Guiyang
Qingzhen
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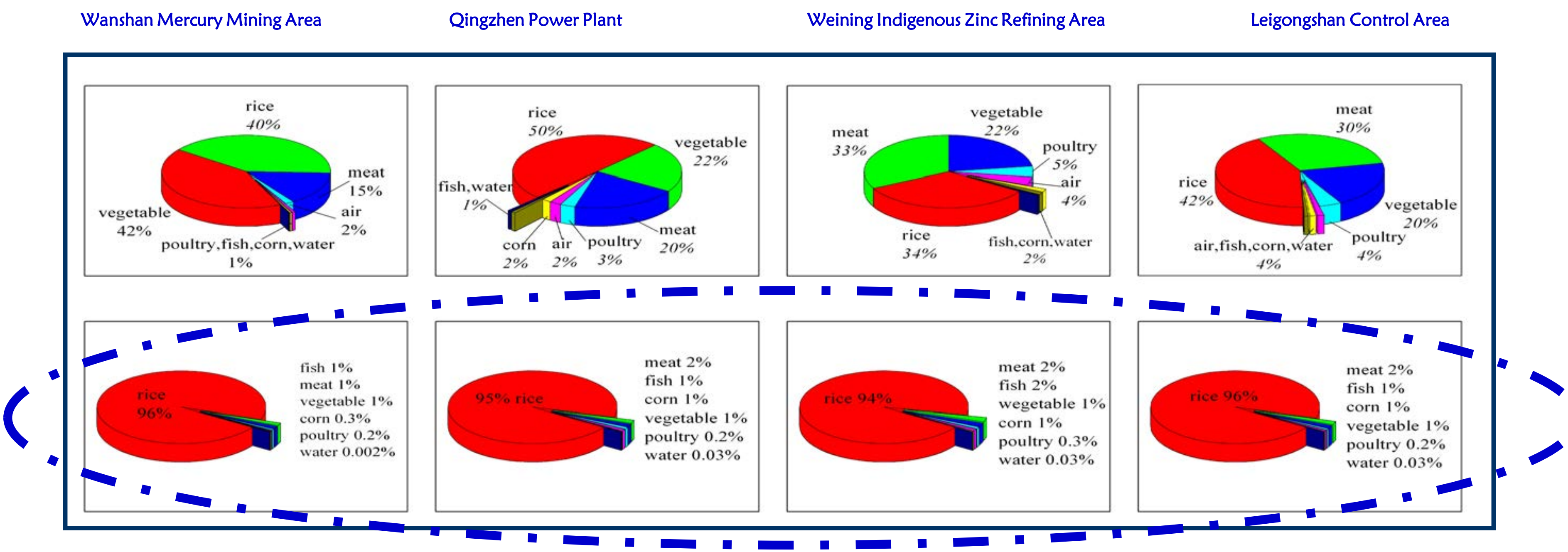
140 km

# Revealed that 90% of inland residents in China are exposed to methyl-Hg through rice



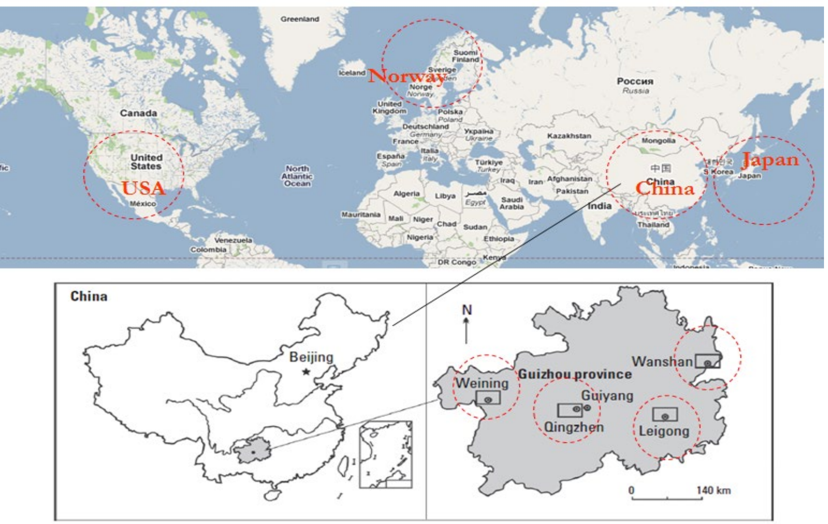

**Analysis of Exposure Pathways of Total Hg and Methyl-Hg in Typical Regions of Guizhou Province**

**(The upper row is total mercury, and the lower row is methyl mercury)**

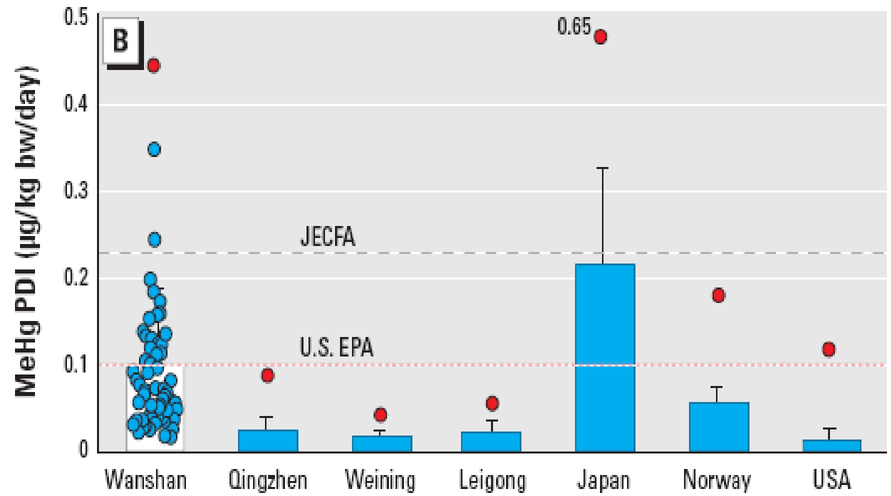
*Zhang H, Feng X.B., et al., Environ. Health Perspect. 2010*

# Comparison between "Chinese Hg Capital" and other countries

exposure level of methyl Hg in Hg mining area in China is lower than that of Japan




Study Area Distribution Map




Comparison of Methylmercury Exposure Levels in Guizhou Province China with Foreign Countries

*Zhang H et al., Environ. Health Perspect. 2010*

# Mercury surprise: Rice can be risky

Millions in China are at risk, and potentially elsewhere as well

## Janet Raloff
***Science News***

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### Mercury surprise: Rice can be risky

Millions in China are at risk, and potentially elsewhere as well

By Janet Raloff
APRIL 16, 2010 AT 5:10 PM

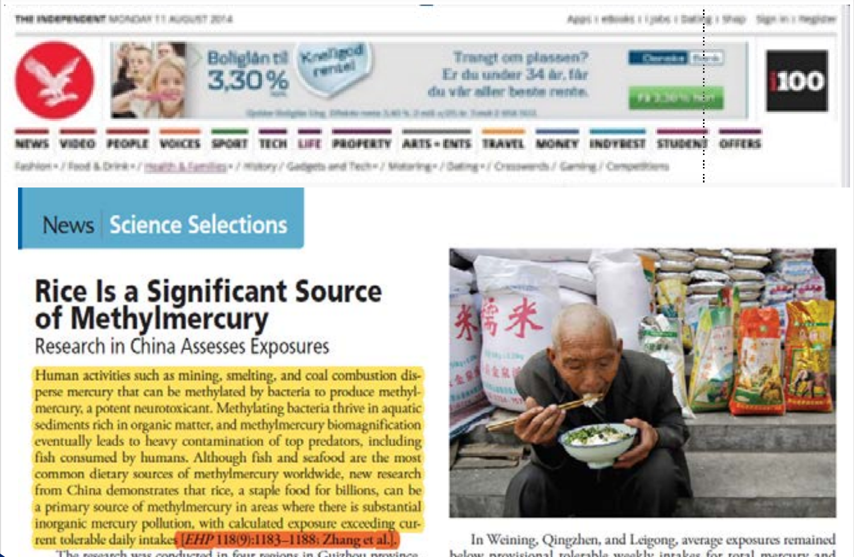
Ask toxicologists how best to avoid mercury poisoning and they'll almost certainly advise against eating too much of the wrong types of fish. (Never mind that there's considerable confusion about what the wrong types are.) But a new study out of China shows that for millions of people at risk of eating toxic amounts of mercury-laced food, fish isn't the problem. Rice is.

And that's bad news because in their part of the world rice is the dietary staple

A team of Chinese and Norwegian researchers investigated dietary mercury contamination in rural, inland China — a region were few people eat fish. They focused on Guizhou province, which they describe as the "mercury capital of China." The area is home to 12 large mercury-mining and smelting operations, not to mention other heavy coal-powered industry. All of these industrial operations belch out tons of air- and water pollution laced with substantial quantities of mercury.

Hua Zhang and Xinbing Feng of the Chinese Academy of Sciences' Graduate University in Beijing and their coauthors measured mercury in the air, water and in all major foods from local markets. Then they modeled likely ingestion rates of these foods for residents of various communities across the province. These included a village located inside a nature preserve, a region downwind of a major coal plant, people living near a defunct zinc smelter and a community whose air was polluted by mercury-mining operations.

## Julia R. Barrett
***The Independent***



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### Rice Is a Significant Source of Methylmercury
Research in China Assesses Exposures

Human activities such as mining, smelting, and coal combustion disperse mercury that can be methylated by bacteria to produce methylmercury, a potent neurotoxicant. Methylating bacteria thrive in aquatic sediments rich in organic matter, and methylmercury biomagnification eventually leads to heavy contamination of top predators, including fish consumed by humans. Although fish and seafood are the most common dietary sources of methylmercury worldwide, new research from China demonstrates that rice, a staple food for billions, can be a primary source of methylmercury in areas where there is substantial inorganic mercury pollution, with calculated exposure exceeding current tolerable daily intakes [EHP 118(9):1183–1188; Zhang et al.].

The research was conducted in four regions in Guizhou province, an area of inland China with rich deposits ...

In Weining, Qingzhen, and Leigong, average exposures remained below provisional tolerable weekly intakes for total mercury and


国际著名汞专家渥太华大学
**Alexandre POULAIN教授**在国际会议报告上介绍我们的成果

## Just like with fish, China is the largest producer and consumer of rice in the world.

So, what's the deal with mercury levels in Chinese rice?

# Two studies from 15 and 27 provinces in China both shown very low Hg in rice

Environment International 126 (2019) 406–412
Contents lists available at ScienceDirect
Environment International
journal homepage: www.elsevier.com/locate/envint

Mercury contents in rice and potential health risks across China

Huifang Zhao[a,b], Haiyu Yan[a], Leiming Zhang[c], Guangyi Sun[a], Ping Li[a,*], Xinbin Feng[a,*]

Zhao et al., 2019

N=507

THg: 4.74 (1.06–22.7) ppb
MeHg: 0.682 (0.03–8.71) ppb

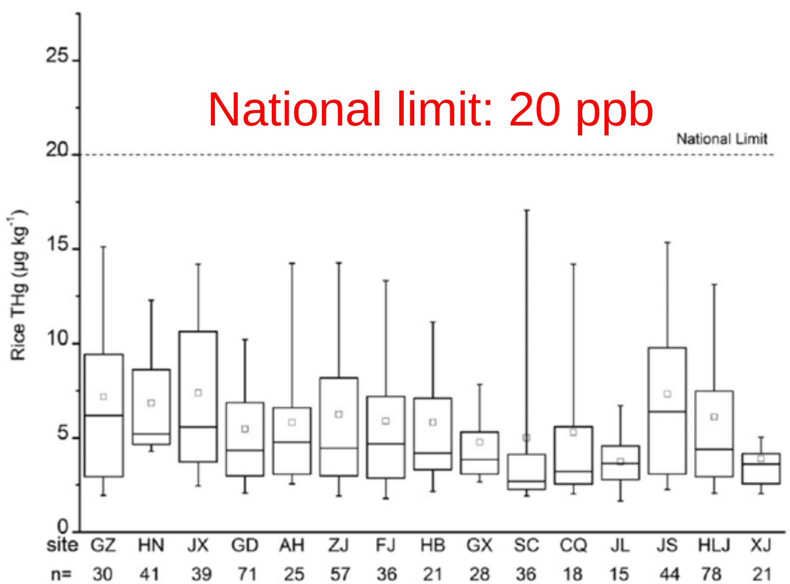


**Fig. 2.** Comparison of THg concentrations in rice samples collected from different provinces in China.

Environmental Pollution 258 (2020) 113706
Contents lists available at ScienceDirect
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Methylmercury and inorganic mercury in Chinese commercial rice: Implications for overestimated human exposure and health risk☆

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N=767

THg: 3.97 ± 2.33 ppb
MeHg: 1.37 ± 1.18 ppb

**Table 1**
THg, MeHg, and IHg variation in rice samples of this study.

| Country of origin | Provinces | Number of brands (n) | THg (μg/kg) (mean ± SE) | Range | MeHg (μg/kg) (mean ± SE) | Range | IHg (μg/kg) | Range |
|---|---|---|---|---|---|---|---|---|
| China | Heilongjiang | 68 | 4.04 ± 1.73 | 1.28–7.94 | 1.18 ± 0.500 | 0.317–2.89 | 2.86 ± 1.67 | 0.402–6.39 |
| | Jilin | 30 | 3.27 ± 0.900 | 1.96–5.14 | 1.37 ± 0.643 | 0.585–2.92 | 1.90 ± 0.648 | 1.17–3.62 |
| | Liaoning | 20 | 3.97 ± 1.11 | 2.25–6.24 | 1.04 ± 0.352 | 0.501–1.80 | 2.76 ± 1.01 | 1.72–5.00 |
| | Hebei | 6 | 5.13 ± 3.83 | 2.34–12.7 | 1.12 ± 0.0530 | 0.629–1.88 | 4.01 ± 4.00 | 1.34–12.0 |
| | Shandong | 15 | 5.27 ± 2.32 | 1.61–8.42 | 0.891 ± 0.254 | 0.467–1.28 | 4.38 ± 2.17 | 1.09–7.88 |
| | Shanxi | 5 | 1.66 ± 0.655 | 1.08–2.77 | 1.02 ± 0.384 | 0.495–1.44 | 0.635 ± 0.435 | 0.261–1.33 |
| | Shaanxi | 5 | 3.04 ± 1.26 | 0.970–4.32 | 1.21 ± 0.677 | 0.484–2.29 | 1.84 ± 1.10 | 0.486–3.06 |
| | Tianjin | 5 | 2.70 ± 0.593 | 2.33–3.75 | 0.739 ± 0.496 | 0.383–1.61 | 1.96 ± 0.173 | 1.73–2.13 |
| | Ningxia | 20 | 3.62 ± 0.946 | 1.59–5.94 | 1.36 ± 0.459 | 0.823–2.96 | 2.26 ± 1.08 | 0.663–4.69 |
| | Gansu | 3 | 3.058 ± 0.702 | 2.257–3.49 | 1.07 ± 0.0680 | 0.736–2.20 | 1.43 ± 0.123 | 1.29–1.52 |
| | Xinjiang | 20 | 2.72 ± 1.92 | 1.29–10.6 | 0.601 ± 0.270 | 0.169–1.50 | 2.12 ± 1.95 | 0.544–10.9 |
| | Inner Mongolia | 20 | 4.03 ± 1.49 | 2.12–8.29 | 2.11 ± 1.46 | 0.727–4.39 | 1.92 ± 0.447 | 0.959–2.46 |
| | Jiangsu | 36 | 1.56 ± 1.92 | 1.04–8.19 | 1.31 ± 0.869 | 0.0200–3.31 | 3.25 ± 1.86 | 0.250–7.46 |
| | Anhui | 35 | 3.56 ± 1.52 | 1.07–7.54 | 1.23 ± 0.549 | 0.536–3.20 | 2.32 ± 1.36 | 0.539–6.65 |
| | Zhejiang | 19 | 5.24 ± 4.71 | 1.38–23.3 | 1.16 ± 0.582 | 0.635–2.90 | 4.11 ± 4.28 | 0.399–20.4 |
| | Hunan | 53 | 4.17 ± 1.82 | 1.36–9.55 | 1.70 ± 1.17 | 0.435–6.80 | 2.48 ± 1.36 | 0.0730–6.90 |
| | Hubei | 35 | 5.14 ± 2.53 | 1.12–13.1 | 1.99 ± 1.09 | 0.648–5.62 | 3.16 ± 2.44 | 0.386–11.6 |
| | Jiangxi | 41 | 3.93 ± 2.09 | 1.01–8.59 | 1.31 ± 0.717 | 0.0430–3.82 | 2.62 ± 1.89 | 0.124–7.21 |
| | Henan | 21 | 3.86 ± 2.43 | 1.11–10.1 | 1.45 ± 0.804 | 0.541–4.11 | 2.42 ± 1.89 | 0.0320–7.02 |
| | Shanghai | 10 | 6.09 ± 1.93 | 1.61–8.71 | 1.41 ± 0.554 | 0.467–1.28 | 4.68 ± 1.61 | 1.09–7.88 |
| | Guangdong | 43 | 3.62 ± 1.91 | 0.638–12.0 | 1.40 ± 0.0730 | 0.150–5.38 | 2.22 ± 1.09 | 0.0120–6.69 |
| | Guangxi | 38 | 4.24 ± 3.13 | 1.89–20.4 | 2.14 ± 2.35 | 0.595–15.0 | 2.10 ± 1.14 | 0.617–6.45 |
| | Fujian | 20 | 3.11 ± 1.45 | 2.10–31.7 | 0.890 ± 0.428 | 0.375–19.0 | 2.18 ± 1.34 | 1.36–12.7 |
| | Hainan | 17 | 3.25 ± 2.16 | 0.769–6.98 | 0.898 ± 0.755 | 0.0470–2.45 | 2.35 ± 1.48 | 0.722–4.93 |
| | Taiwan | 14 | 4.72 ± 1.77 | 1.98–8.56 | 0.923 ± 0.280 | 0.508–1.59 | 3.80 ± 1.71 | 1.48–7.77 |
| | Yunnan | 27 | 4.37 ± 2.26 | 1.33–10.4 | 1.89 ± 1.40 | 0.0270–6.21 | 2.47 ± 1.18 | 0.278–5.63 |
| | Guizhou | 25 | 4.94 ± 1.81 | 1.65–7.86 | 1.52 ± 1.06 | 0.0830–4.95 | 3.42 ± 1.45 | 1.04–6.33 |
| | Sichuan | 39 | 3.01 ± 1.27 | 0.883–6.11 | 1.11 ± 0.588 | 0.178–2.93 | 1.90 ± 1.09 | 0.155–5.19 |
| | Chongqing | 19 | 2.56 ± 1.24 | 0.808–5.63 | 0.912 ± 0.453 | 0.298–1.99 | 1.65 ± 1.16 | 0.650–4.65 |
| Total Chinese domestic | | 709 | 4.03 ± 2.37 | 0.638–31.7 | 1.40 ± 1.21 | 0.0200–18.6 | 2.63 ± 1.80 | 0.0123–20.4 |
| Cambodia | | 8 | 3.92 ± 1.02 | 1.79–5.02 | 1.56 ± 0.580 | 1.11–2.86 | 2.36 ± 0.850 | 0.422–3.26 |
| India | | 7 | 1.88 ± 0.180 | 1.73–2.16 | 0.680 ± 0.163 | 0.423–0.889 | 1.20 ± 0.194 | 1.01–1.57 |
| Laos | | 6 | 5.26 ± 2.36 | 2.99–8.90 | 1.57 ± 0.863 | 1.04–3.29 | 3.68 ± 1.78 | 1.93–6.24 |
| Pakistan | | 5 | 2.33 ± 0.455 | 1.63–2.85 | 0.738 ± 0.261 | 0.338–0.988 | 1.587 ± 0.230 | 1.29–1.86 |
| Spain | | 2 | 2.30 ± 0.00900 | 2.29–2.30 | 0.680 ± 0.207 | 0.534–0.827 | 1.62 ± 0.199 | 1.48–1.76 |
| Italy | | 3 | 4.29 ± 0.200 | 4.09–4.49 | 1.90 ± 0.600 | 1.40–2.57 | 2.39 ± 0.796 | 1.52–3.09 |
| Japan | | 6 | 3.74 ± 1.36 | 1.88–6.02 | 1.21 ± 0.749 | 0.409–2.29 | 2.53 ± 0.846 | 1.47–3.73 |
| Russia | | 7 | 2.59 ± 1.14 | 1.48–4.67 | 0.584 ± 0.360 | 0.184–1.10 | 2.01 ± 0.866 | 1.30–3.72 |
| Vietnam | | 7 | 2.03 ± 0.780 | 1.12–3.09 | 0.662 ± 0.241 | 0.383-0.948 | 1.37 ± 0.699 | 0.197–2.22 |
| Thailand | | 8 | 3.44 ± 1.59 | 1.74–5.81 | 0.820 ± 0.491 | 0.0690–1.47 | 2.62 ± 1.22 | 1.21–4.35 |
| Total imported | | 58 | 3.82 ± 1.56 | 1.12–8.90 | 1.02 ± 0.639 | 0.0690–3.29 | 2.17 ± 1.13 | 0.197–6.24 |
| Total average | | 767 | 3.97 ± 2.33 | 0.638–31.7 | 1.37 ± 1.18 | 0.0200–19.0 | 2.60 ± 1.14 | 0.0120–20.4 |

# Globally, rice samples also shown very low Hg concentrations

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**Table 1**
Comparison of THg and MeHg (ng/g) in rice from worldwide markets or non-polluted sites.

| Rice origin | Sampling site | Sample size | THg (ng/g) | Range (ng/g) | MeHg (ng/g) | Range (ng/g) | MeHg% (MeHg/THg) % | Reference |
|---|---|---|---|---|---|---|---|---|
| Bangladesh | Barishal, Commilla, Rajshahi, Dhaka, Jessore, Chittagong | 172 | 2.48 ± 1.41 | 0.42 14.4 | 0.83 ± 0.6 | 0.026 7.47 | 33% ± 11% (5.66% 66.3%) | This study |
| China | 15 provinces | 23 | 5.70 | 1 13 | 4.70 | 1.90 10.5 | No | Shi et al., (2005) |
| China | 7 provinces, south China | 284 | 10.1 | 0.860 47.2 | 2.47 | 0.130 18.2 | 35.8% (1.70% 96.7%) | Li et al., (2012) |
| China | 20 provinces | 712 | 5.80 | 0.0200 31.0 | No | No | No | Qian et al., (2010) |
| China | 29 provinces | 709 | 4.03 ± 2.37 | 0.638 31.7 | 1.40 ± 1.21 | 0.0200 18.6 | 36.3% (5 98%) | Xu et al. (2020b) |
| Cambodia | | 8 | 3.92 ± 1.02 | 1.79 5.02 | 1.56 ± 0.580 | 1.11 2.86 | 41.8 ± 16.6% (29.5 76.4%) | |
| India | | 7 | 1.88 ± 0.180 | 1.73 2.16 | 0.680 ± 0.163 | 0.423 0.889 | 36.1 ± 7.99% (24.2 42.8%) | |
| Laos | | 6 | 5.26 ± 2.36 | 2.99 8.90 | 1.57 ± 0.863 | 1.04 3.29 | 30.6 ± 7.67% (16.3 37.0%) | |
| Pakistan | | 5 | 2.33 ± 0.455 | 1.63 2.85 | 0.738 ± 0.261 | 0.338 0.988 | 30.9 ± 6.80% (20.7 36.2%) | |
| Spain | | 2 | 2.30 ± 0.00900 | 2.29 2.30 | 0.680 ± 0.207 | 0.534 0.827 | 29.6 ± 8.91% (23.3 35.9%) | |
| Italy | | 3 | 4.29 ± 0.200 | 4.09 4.49 | 1.90 ± 0.600 | 1.40 2.57 | 44.8 ± 16.2% (31.1 62.8%) | |
| Japan | | 6 | 3.74 ± 1.36 | 1.88 6.02 | 1.21 ± 0.749 | 0.409 2.29 | 30.9 ± 12.3% (11.2 43.1%) | |
| Russia | | 7 | 2.59 ± 1.14 | 1.48 4.67 | 0.584 ± 0.360 | 0.184 1.10 | 21.4 ± 8.02% (12.4 35.9%) | |
| Vietnam | | 7 | 2.03 ± 0.780 | 1.12 3.09 | 0.662 ± 0.241 | 0.383 0.948 | 36.0 ± 20.7% (24.3 82.3%) | |
| Thailand | | 8 | 3.44 ± 1.59 | 1.74 5.81 | 0.820 ± 0.491 | 0.0690 1.47 | 23.1 ± 10.2% (3.8 36.6%) | |
| Brazil | Brazil | 23 | 2.30 | 0.300 10.4 | No | No | No | Batista et al., (2012) |
| Sri Lanka | Sri Lanka | 163 | 1.73 ± 0.89 | 0.21 6.13 | 0.51 ± 0.37 | 0.03 3.81 | 38.1 ± 18% (0.7 100%) | Xu et al. (2020a) |
| Cambodia | Kampong, Cambodia | 6 | 8.14 | 6.16 11.7 | 1.44 | 1.17 1.96 | No | Cheng et al., (2013) |
| Cambodia | Kandal, Cambodia | 6 | 10.2 | 5.91 15.1 | 2.34 | 0.480 5.23 | No | Cheng et al., (2013) |
| Spain | Palma de Mallorca, Spain | 12 | 4.48 | 2.15 7.25 | No | No | No | da Silva et al., (2013) |
| Madagascar | Madagascar | 51 | 1.10 | 0.360 3.40 | 0.120 | 0.0150 1.10 | 13 43% | Rothenberg et al., (2015) |
| China, Egypt, France, Germany, India, Italy, Pakistan, Sri Lanka, Thailand, USA | Kuwait | 18 | 6.40 ± 2.40 | 4.00 14.00 | No | No | No | Jallad, (2015) |
| Around world | Britain, Germany, Switzerland | 87 | 3.04 ± 2.70 | 0.530 11.1 | 1.91 ± 1.07 | 0.110 6.45 | 71.0 ± 26.0% (6 100%) | Brombach et al., (2017) |
| No | Beijing, Qingdao, Nanjing, Wuhan, San Jose, New York, Chicago, Miami | 79 | 3.82 ± 2.83 | 1.47 15.9 | 2.29 ± 2.46 | 0.570 13.9 | 57.0% (16.0 96.0%) | Cui et al., (2017) |

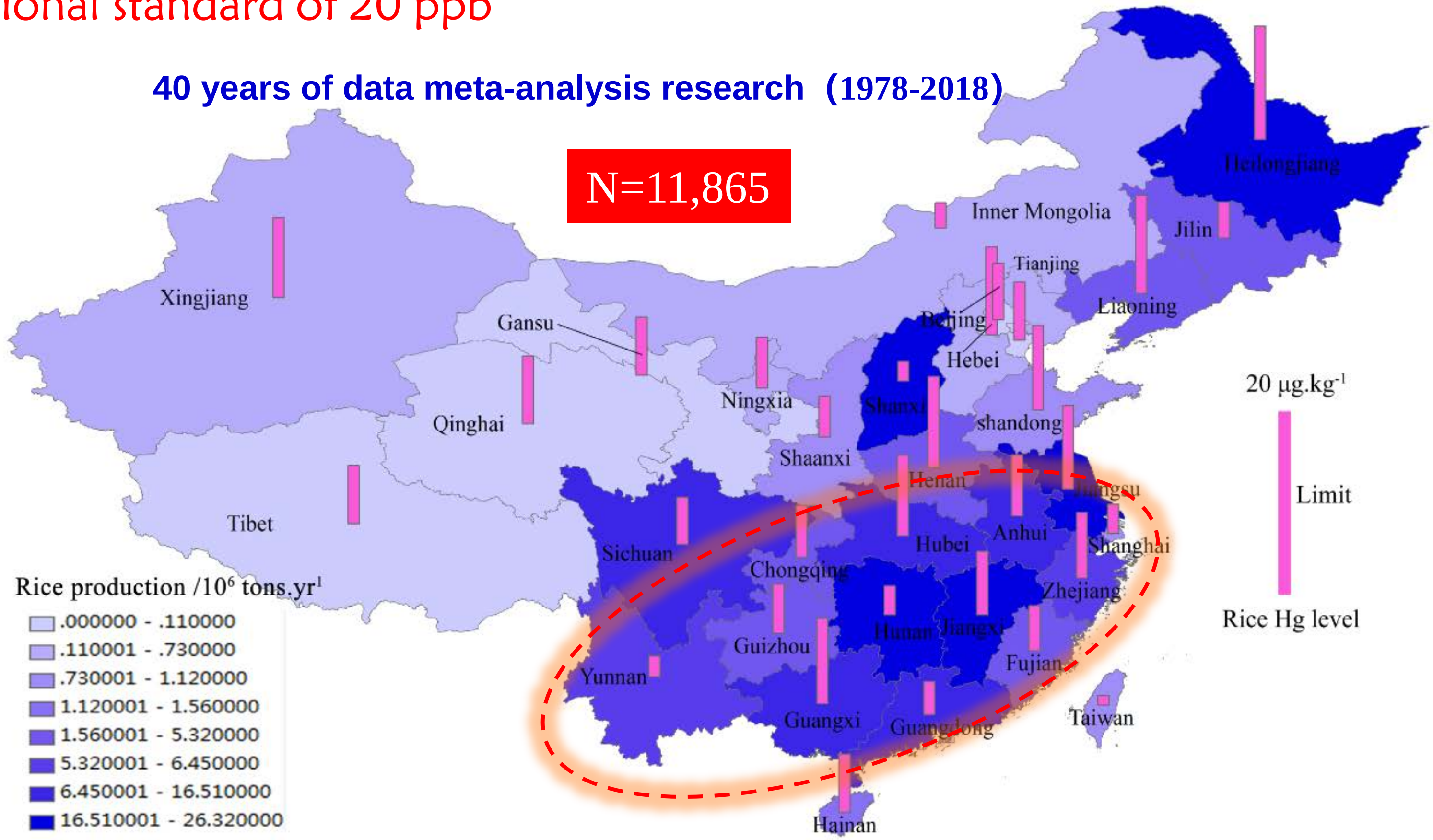
standard limit: 20 ppb

# Hg content distribution in Chinese rice

The mercury content in the main rice producing areas is generally lower than the national standard of 20 ppb

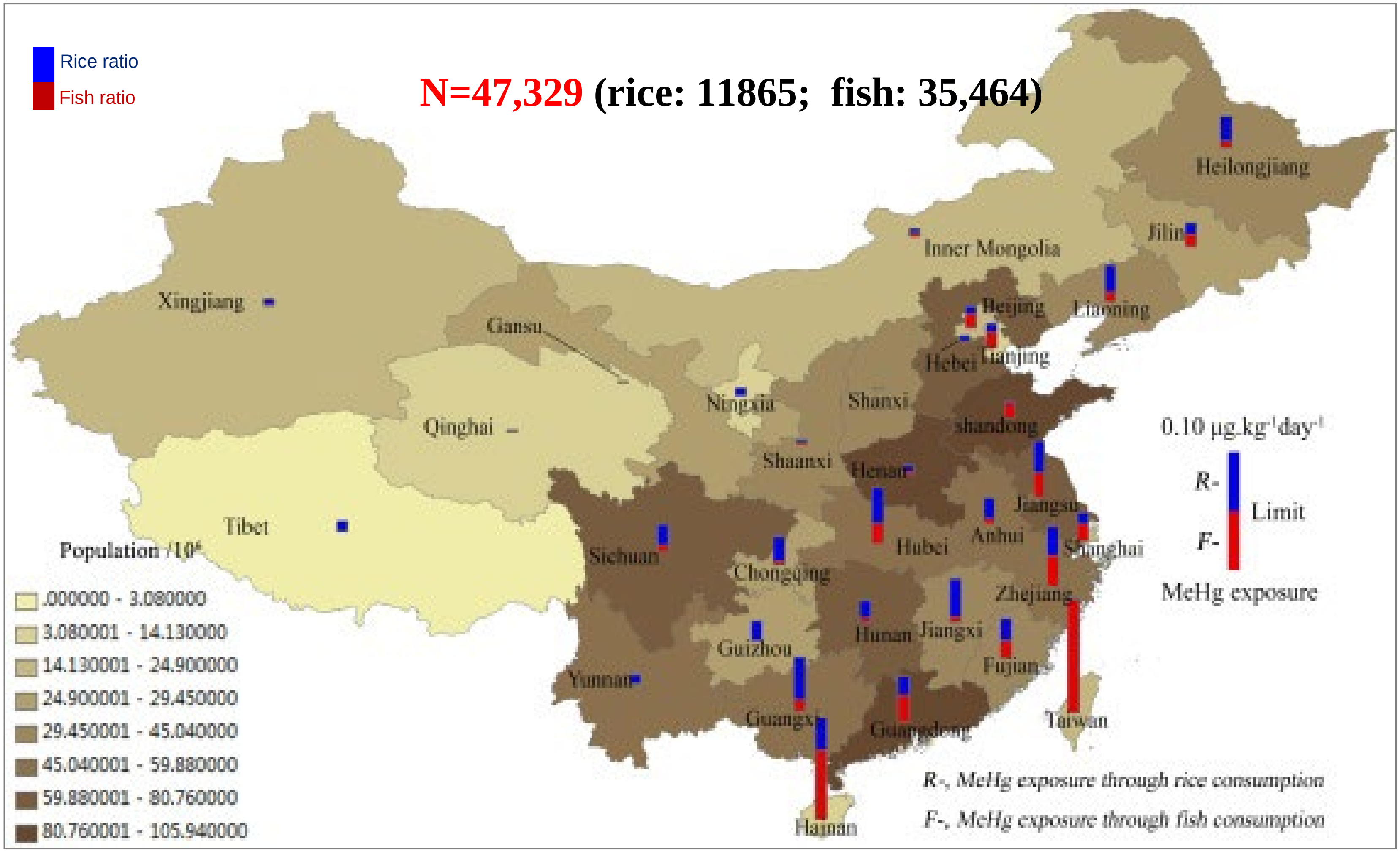
**40 years of data meta-analysis research (1978-2018)**

N=11,865




*Zhang H.*, et al., "Consultation Report on the Implementation of the National Minamata Convention in China", 2018

The overall exposure level of methyl-Hg among residents in China is relatively low, and residents in coastal and inland areas (mining areas) may have a higher risk, especially those who are sensitive to infants and young children.

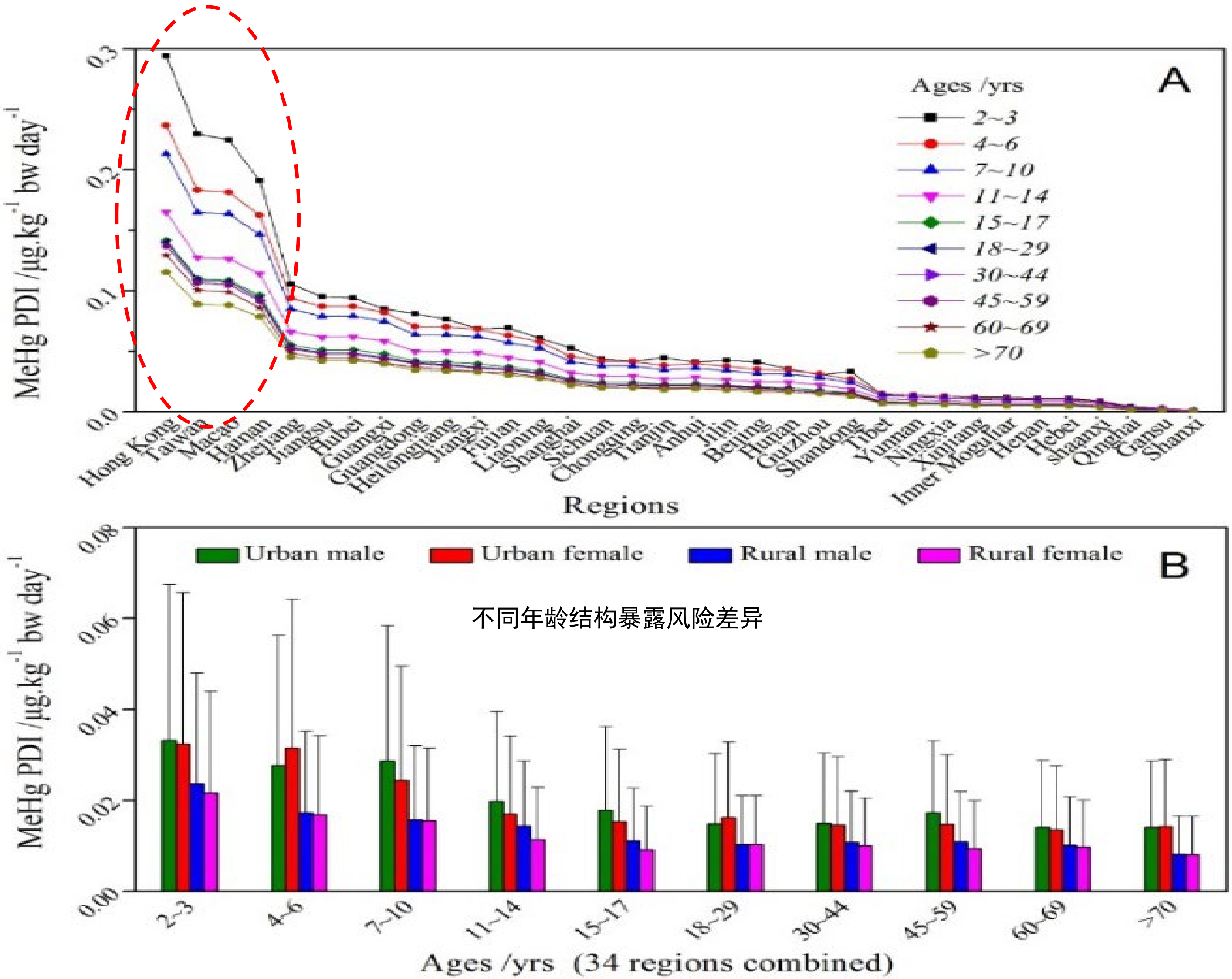



**Health risk and pathways of human methylmercury exposure in China**

*Zhang H. et al., "Consultation Report on the Implementation of the National Minamata Convention in China", 2018*

# The younger the age, the greater the risk of exposure to methylmercury.

——Due to differences in dietary structure, males are higher than females, and urban areas are higher than rural areas.




*Zhang H.* et al., "Consultation Report on the Implementation of the National Minamata Convention in China", 2018

## The current standard limits is based on the following assumptions (which is not rigorous)

—— *"During pregnancy, the exposure of methyl -based mercury during pregnancy has a direct correlation with the nerve development of the subsequent stage"*

**The above theory cannot explain the phenomenon that "increased the increase in the consumption of maternal fish (that is, the exposure of methyl -based mercury) will bring obvious benefits to children's development"**

| Study Location | Exposure Outcomes | Results Support | Do Not Support | Results Conflict |
|---|---|---|---|---|
| Minamata | Harm++ | ✓ | | |
| Iraq | Harm++ | ✓ | | |
| New Zealand | Harm | ✓ | | |
| Faroe Islands | Harm | ✓ | | |
| Seychelle Islands | No harm | | ✓ | |
| United Kingdom | Benefited | | ✓ | ✓ |
| United States | Benefited | | ✓ | ✓ |
| Denmark | Benefited | | ✓ | ✓ |

Epidemiological survey research results based on traditional concepts and theoretical assumptions

*Zhang H. et al., 2014. Environ. Sci. & Technol.* 48(2): 1206-1212.

# We have proposed a new BRV method

Environmental Science & Technology

Article

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**New Insights into Traditional Health Risk Assessments of Mercury Exposure: Implications of Selenium**

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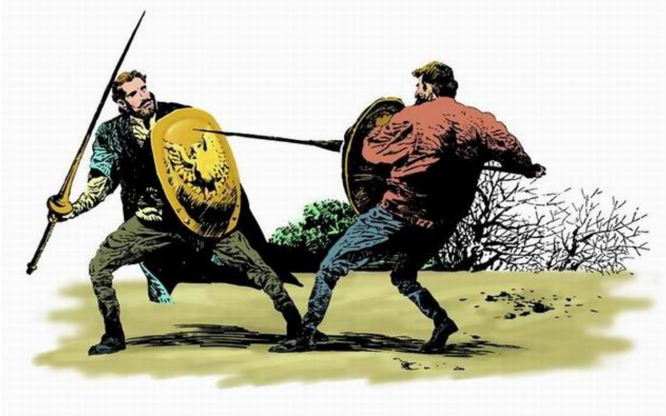
$$BRV = PDI_{Se} - \Delta_{Se} - PDI_{Hg} \quad (1)$$

$$PDI = \Sigma(C^{i} \times IR^{i})/bw \quad (2)$$

$$BRR = (PDI_{Se} - \Delta_{Se})/PDI_{Hg} \quad (3)$$



**——The risk assessment of mercury exposure or selenium exposure should be considered comprehensive consideration of mercury selenium interaction, to avoid providing the public with misleading policy suggestions**

***Zhang H.*** *et al., 2014.* ***Environ. Sci. & Technol.*** 48(2): 1206-1212.

## The BRV method can be expanded to other heavy metals

$$BRV = PDI_{Se} - \Delta_{Se} - PDI_{Hg}$$

$$BRV = PDI_{Se} - \Delta_{Se} - \sum PDI_{HMs}$$

$$PDI_{Cd} + PDI_{Hg} + PDI_{iAs}$$

# The above BRV method is widely cited not only by peers in selenium-mercury exposure risk research

uncertainty around the assessment. Also, selenium (Se) is thought to provide a buffer against the toxicity of MeHg. Zhang et al. (2014) proposed a new criterion for Se/Hg exposure assessment to help reducing the uncertainty around Hg absolute assessment. However, recent studies reported that more information is needed to provide a strong scientific

2016). For instance, the benefit-risk value (BRV) takes into account the possible toxicity of Se, with a threshold set at a probable daily intake (PDI) of 72 nmol/kg body weight (bw)/day (400 µg/day for a 70 kg individual) (Zhang et al., 2014; FAO and WHO, 2001). The BRV also considers that a minimum Se daily intake (10 nmol/kg bw/day) is necessary

The benefit-risk value (BRV; nmol/kg body weight (bw)/day) developed by Zhang et al. (2014) was calculated according to Eqs. (1) and (2):

$$BRV_{Hg} = PDI_{Se} - MI_{Se} - PDI_{Hg} \quad (1)$$

$$PDI_{TE} = \sum (C_{TEi} \times IR_i)/bw \quad (2)$$

consumption of fish (Donaldson et al., 2010; Speedy, 2003; Chan et al., 1999). Considering a meal as 250 g of fresh flesh, this IR would mean that about one meal would be consumed every 4 days. BRV results are interpreted as beneficial if they ranged from 0 to 72 nmol/kg bw/day (Zhang et al., 2014). $BRV_{Hg}$ under 0 nmol/kg bw/day represented a molar Hg excess over Se and a BRV above 72 nmol/kg bw/day represents

studies (Castoldi et al., 2008).

The study of Zhang et al. (2014) reported a $BRV_{Hg}$ of 9 ± 21 (± SD) nmol/kg bw/d in China, which is lower than our estimate for Canadians (26 ± 6 (± SD) nmol/kg bw/d). Given that the Chinese population eats more rice (600 g/day) and less meat (84 g/day), their Se intake is likely lower than the one of North Americans. In fact, more than 50% of the Chinese Hg and Se intake comes from eating rice (Zhang et al., 2014). Only one other study to our knowledge has calculated the BRV but did not estimate the daily Se intake (Melgar et al., 2019). More risk

Selenium Health Benefit Value ($HBV_{Se}$).

Otherwise, considering both elements, Zhang et al. (2014) presented another risk assessment proposal, the Benefit-Risk Value (BRV), this criterion relates this two elements and attempts to reflect either the excess of Hg or the surplus of Se, in which case can be assessed with respect to the Se adequate intake.

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*2.2.5. Benefit-risk value (BRV) and related percentage of Se AI*

Benefit-risk value (BRV) criterion, proposed by Zhang et al. (2014), assesses the combined exposure of MeHg and Se and it was applied for the consumption of tuna in Spain:

$$BRV = PDISe - \Delta Se - PDIHg$$

# This approach has also caught on with researchers studying selenium-arsenic, selenium-mercury, selenium-lead, and even the combined risk of exposure to selenium and multiple heavy metals.

*2.2.6. New proposal of BRV including iAs and related percentage of Se AI*

The new proposal consists in adding to the aforementioned criterion the loss of Se bioavailability due to the iAs intakes, maintaining the interpretation of the results as Zhang et al. (2014) have described previously taken only Hg as element that decrease Se bioavailability into account.

$$BRV = PDISe - \Delta Se - (PDIHg + PDIiAs)$$

2014). Ahn et al. (2018) do not provided data on Se. However, this fisherman with the reported tuna intake rate could have exceeded by far the allowable upper Se intake level of 400 μg/day (WHO/FAO, 2004). Thus, positive $HBV_{Se}$ proper of tuna did not prevent fisherman from suffering the harmful effects caused by Hg and perhaps by Se.

Therefore, positive $HBV_{Se}$ are by themselves insufficient to establish safe intakes; since total amounts of Se and Hg should also be taken into account, and even synergistic effects from certain levels cannot be ruled out (Bjørklund et al., 2017b)

*3.7. Beneficial Risk Value (BRV) criterion and related percentage of Se AI*

Based on current knowledge about Se-Hg interactions, the physiology/toxicology of Se and the toxicology of Hg, in this work, a new criterion (BRV) proposed by Zhang et al. (2014) to assess the exposure to Hg and the intake has been applied. According to this BRV criterion, it is taken into account both that the formation of Hg-Se complexes reduces

icit of Se necessary to cover by other foodstuffs.

Zhang et al. (2014) point out that in diets with Se excess (uncommon), co-exposure to moderate amounts of Hg might reduce Se toxicity, due to the formation of complexes with Hg.

To date, the international scientific community has not reached a consensus on both the minimum requirement and the toxicity threshold value of Se (EFSA, 2014; Vinceti et al., 2017a; WHO/FAO, 2004).

Zhang presented this criterion (BRV) applying as ∇Se the threshold value for Se poisoning set by the Chinese Nutrition Society in 1990 of 800 μg/day for adults. However, other international agencies establish the range of levels between 300 and 400 μg/day as unsafe threshold value. Likewise, minimal requirement values recommended by agencies vary from 30 to 70 μg/day in adults (EFSA, 2014). Therefore, whenever this BRV criterion is applied, the Se reference values employed should be indicated.

*3.8. New BRV criterion including iAs and related percentage of Se AI*

criterion integrating the four elements.

As Zhang et al. (2014) pointed out with the first BRV criterion, until this approach is endorsed by consistent clinical trials in humans, its application should be restricted to the scientific domain. This criterion might be as well a suggestion to design research studies considering this group as a single factor.

integrated analysis for MeHg and n-3 LCPUFA that evaluated the net effect of fish consumption on a species-by-species basis. Zhang et al.[33] proposed a new criterion for assessing MeHg exposure and Se intake based on Se−Hg interactions and the physiology and toxicology of Se. In general, the interaction between MeHg and micronutrients is unknown. Such interactions

attributed to a low soil Se concentration. Instead, we believe the high concentration of Hg in the atmosphere is inhibiting Se uptake from soil. Zhang et al.[24] proposed a new criterion for Se and Hg exposure assessment, based on their understanding of the interaction between Se and Hg; the physiology and toxicology of Se; and the toxicology of Hg. According to Zhang et al., daily dietary Se intake can have an important mitigating

MeHg is then accumulated by rice plants, and concentrated in rice grain. Zhang et al.[24] showed that chemically reactive Hg in soil will readily precipitate Se as a stable and insoluble Hg−Se complex in the rhizopshere or on the root surface of rice plants. We therefore propose that the lack of Se uptake by rice plants

sponse where an insufficient intake, as well as excess of Se can produce adverse health outcomes (Rayman, 2012). This is the reason that Se is also considered as a toxicant at high dose causing skin diseases known as selenosis but no adverse effects have been seen in exposures up to 853 μg/day (Zhang et al., 2014). The BEs associated with protection against selenosis range from 400 to 480 μg/L in whole blood and 180–

high Se exposure were observed in this population (Lemire et al., 2012). A new indicator, the molar ratio of Hg and Se, has been proposed and tested to quantify the toxicity of Hg in the traditional diet (Zhang et al., 2014).

The Canadian Inuit's unique contaminant exposure profiles are the

levels for the study populations were within a safe-level range.

Zhang et al. (2014a, 2014b) proposed a new criterion for Se/Hg exposure assessment, which is based on Se-Hg interactions and considers not only the toxicological consequences of Hg exposure but also the benefits and/or adverse effects of Se intake. The benefit-risk ratio (BRR) indicates health benefits if $1 < BRR < 1 + \nabla Se/PDI_{Hg}$, or it

# Summary & Perspectives

环境健康诊断与修复

Dr. E&H Diagnosis and Remediation of Environment & Health

## Dr. E&H Cross-team

- *In general, the mercury content in China's rice and fish is lower than the standard limits, so the risk of mercury exposure for most residents is pretty low.*
- *However, in certain areas like mercury mining regions and near chemical plants, some people—especially sensitive groups like infants and pregnant women—might face higher risks of mercury exposure.*
- *Due to differences in diet, coastal residents are at a higher risk compared to those living inland. Similarly, people in cities and towns face higher risks than those in rural areas, and men are generally at a higher risk than women.*
- *We need more research on mercury exposure standards, especially considering the unique aspects of edible fish and rice. Plus, we should take into account the protective effects of selenium and other nutrients.*

**Thank you!**

**Prof. Hua ZHANG,**
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