Total mercury and methyl-mercury in paddy soil and rice around Wanshan Hg mining area, Guizhou Province, China—Is rice an intensive bio-accumulator for methyl-mercury from paddy soil?

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Total mercury and methyl-mercury in paddy soil and rice around Wanshan Hg mining area, Guizhou Province, China—Is rice an intensive bio-accumulator for methyl-mercury from paddy soil?

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Abstract:

Total mercury (THg) and methyl-mercury (Me-Hg) were determined in paddy soil and rice samples collected from five valleys around the Wanshan mercury (Hg) mining area in China, covering more than 700 kilometers, to evaluate mercury (Hg) bio-accumulation in rice. The geometric mean of THg and Me-Hg in rice samples was 44 (7.3-510) µg/kg and 6.6 (1.2-44) µg/kg, respectively. The corresponding geometric mean of THg and Me-Hg in the paddy soil samples was 5.3 (0.20-310) mg/kg and 1.2 (0.14-12) µg/kg. Elevated levels in paddy soil and rice reflected serious Hg pollution due to the long history of large-scale and artisanal Hg mining activities. Generally, both THg and Me-Hg concentrations in paddy soil decreased with distance from the mine tailings in all valleys, suggesting river-transport of Hg species. Rice/soil concentration ratios (CRs) for THg ranged from 0.00017 to 0.53 (geometric mean=0.0083) and for Me-Hg from 0.71 to 50 (geometric mean = 5.6), respectively. Hence, the CRs for Me-Hg were on average more than 600 times higher than THg (maximum=25 000 times). This indicated that rice (the edible part) is an intensive bio-accumulator of Me-Hg from paddy soil unlike THg, which may be trapped by the roots. Me-Hg concentration in rice was positively related to Me-Hg concentration in paddy soil (R=0.45, P<0.01, log-transformed), which suggested that Me-Hg in paddy soil may be the source of Me-Hg in rice.

Key words: rice, methyl-mercury, bio-accumulator, paddy soil, Wanshan Hg mine
Introduction

Mercury (Hg) is a global and extremely toxic pollutant (1). Organic compounds of Hg, such as methyl-mercury (Me-Hg), are of the greatest concern for human health due to their high toxicity. Under appropriate conditions such as reducing environments, Me-Hg can be generated from inorganic Hg in environments by micro-organisms (2-4). Me-Hg has a strong ability of bioaccumulate in the aquatic food chain, resulting in fish tissue concentrations more than $10^6$ higher than ambient water Hg concentrations. (5).

China is rich in Hg and Hg reserves rank third in the world (6). From the perspective of the global plate tectonics, Guizhou Province is situated in the largest Circum-Pacific Mercuriferous Belt (7). Therefore, Guizhou is one of the world's most important Hg production centers. To date, at least 12 large and super-large Hg mines have been discovered in the province. The Wanshan Hg mine is the third largest in the world. Hg mining in Wanshan started more than 2000 years ago, although the most intensive mining period was the last half of the 20th century (7). Mining ceased in 2001, but left large quantities of mining wastes, including calcine smelting residues (calcines) in the area. Between 1949 and early 1990s, approximately 130 million tons of calcines had been dispersed into the adjacent ecosystem (8). Relatively high concentrations of both THg (up to 1120 µg/kg) and Me-Hg (up to 174 µg/kg) have been reported in rice samples collected from the most contaminated region in the Wanshan Hg mining area, Guizhou province, China (9). Me-Hg exposure by rice intake for residents in the Wanshan area was reported by Feng et al. (6), and the authors reported Me-Hg concentrations in human hair were positively correlated with Me-Hg intake through rice consumption ($R^2=0.42, P<0.001$).
One of the major questions associated with Hg pollution in the Wanshan area concerns dispersion and transport of Hg and Me-Hg from mining sites to paddy soil, conversion of inorganic Hg to Me-Hg, and accumulation of Me-Hg by rice plant. Several previous studies in the region have focused on contaminated sites very close to the mine tailings; however, a comprehensive survey of the Hg concentrations in river water, paddy soil and rice in the region was not previously carried out. The purpose of this study was 1) to develop a systematic mapping of Hg contamination levels in the rice-paddy systems in all five valleys of the region around the Wanshan Hg mining area; and 2) to compare the biogeochemical behaviors of inorganic Hg and MeHg in soil-rice plants systems.

**Materials and Methods**

**Study area.** The Wanshan terrain is karstic, with elevations ranging from 205 to 1149 m above sea level. The region has a sub-tropical humid climate characterized by abundant precipitation and mild temperatures. The annual average rainfall is 1200-1400 mm and the annual mean temperature is 17°C.

There are five major river valleys in the study area and all are included in the present study, including Gouxi River (GX) (artisanal Hg smelting valley) and four non-artisanal Hg smelting valleys: Aozhai River (AZ), Xiaxi River (XX), Gaolouping River (GL), and Huangdao River (HD). The rivers are between 22 and 34 km long from upstream to where they join with two larger rivers; Jinjiang River to the north and Wushui River to the south (Fig. 1). Most Hg mines and smelters are situated in the upstream part of the river, while the rice paddies are located downstream of the calcine piles.

All five rivers valleys in the survey have significant remains of Hg mines and smelters.
Since the bedrock in the area is limestone, smelting residues are mainly calcines. The calcines are typically located very close to or even in the rivers, together with large quantities of waste rocks and discarded low-grade ores. In the valley of GX River, small scale artisanal smelting was still ongoing at the time of sampling, mainly using previously mined low grade ore. A large number (around 50) of very simple furnaces were observed along the banks of the upper parts of the river. More detailed information on the local environmental setting is available elsewhere (6, 7, 9-11).

Almost all of rice paddies in Wanshan are located along the rivers valleys, and are mainly irrigated by river water contaminated by Hg from mine tailings if available rainfall or spring water from mountain or other tributaries are insufficient.

**Sample collection and preparation.** Sampling locations were shown in Fig. 1. Riparian paddy soil and rice samples were collected from 59 locations along the five rivers around the Wanshan Hg mine in August 2007.

Rice samples (the edible portion) were collected from paddy fields during the harvest period, and soil samples were collected from the rice roots (20-30 cm depth). At each sampling site, a composite sample was composed of 5 sub-samples (i.e., quincunx) collected within an area of about 3-5 m² in one field. All rice and soil samples were stored in sealed polyethylene bags to avoid cross contamination.

In the laboratory, rice grain samples were freeze-dried, then processed by first removing the hull from the seeds, and then the seeds were crushed and ground by a grinder. All precautions were taken in order to avoid any cross-contamination during the process. Two sub-samples of rice were ground, the first was discarded and the second powdered sample
was subsequently sealed in a polyethylene bag and stored in a refrigerator. The grinder was thoroughly cleaned after each sample. Wet soil samples were directly mixed by the grinder after removing bigger particles (e.g. stones and plant residues), then sealed in polyethylene bags and frozen until analysis. Before measurement, two partitions were taken from each wet soil sample, one for determination of Hg, and the other was dried under 45 °C to calculate the water content ratio.

**Analytical method.** For T-Hg analysis, soil samples were digested in a water bath (95 °C) using a fresh mixture of HCl and HNO\(_3\) (1:3, v/v), whereas rice samples were digested with a mixture of HNO\(_3\) and H\(_2\)SO\(_4\) (4:1, v/v). T-Hg for soil samples was measured using cold vapor atomic absorption spectrometry (CVAAS), while THg for rice samples was determined using dual-stage gold amalgamation method and cold vapor atomic fluorescence spectrometry (CVAFS) detection following method 1631 (12).

For Me-Hg analysis, rice samples were prepared using KOH-methanol/solvent extraction, while soil samples were prepared using CuSO\(_4\)-methanol/solvent extraction. For both, Me-Hg was determined using aqueous ethylation, purge, trap and GC-CVAFS detection (13, 14) following method 1630 (15).

Soil pH was measured using a pH electrode and the solid: water ratio was 1:2.5 (16). Organic matter (OM) contents of soil samples was determined using the potassium dichromate volumetric method coupled with water heating (17).

Quality control system consists of method blanks, blank spikes, matrix spikes, certified reference material and blind duplicates. Limits of determination for THg were 0.01 µg/kg (CVAFS) in rice samples and 0.01 mg/kg (CVAAS) in soil samples, respectively. For Me-Hg,
limits of determination were 0.003 µg/kg in both rice and soil samples. The average THg concentration of the soil standard (GBW07405) and rice standard (GBW10010) was 0.30 ± 0.01 mg/kg (n = 8) and 5.4 ± 0.4 µg/kg (n=8), which is comparable with the certified concentration of 0.29 ± 0.04 mg/kg and 5.3 ± 0.5 µg/kg, respectively. The percentage of recoveries on spiked samples ranged from 83 to 110% for Me-Hg in rice samples, together with soil samples. The relative percentage difference was lower than 8 % for T-Hg and Me-Hg in rice and soil duplicate samples.

Results and discussion

Hg levels in paddy soil. THg concentrations in rice paddy soil ranged from 0.21 to 310 mg/kg (geometric mean = 5.3 mg/kg). The highest concentration was observed in a rice paddy located just under a large pile of mine tailings in GL (site D12), and was clearly influenced by discharge from the tailings. For 68% (40 out of 59) of the soil samples, THg concentrations exceeded the Chinese national standard limit for soils (1.5 mg/kg) (18), showing widespread contamination to soils from mining and smelting activities.

THg concentrations in paddy soils in sites isolated from Hg mine tailings (located at least 20 km from Wanshan and irrigated with uncontaminated spring water) (SI Figs. S1-S5) were 0.22-1.6 mg/kg, which was somewhat higher than THg concentrations reported for uncontaminated soils worldwide (0.01-0.5 mg/kg) (19). Higher concentrations may be expected due to elevated concentrations in the bedrock in the area or/ and atmospheric Hg deposition (7).

Me-Hg levels in paddy soil ranged from 0.14-12 µg/kg (geometric mean =1.2 µg/kg). The highest value was found at a site in AZ (B15), which was located near large quantities of
abandoned gangue piles. The THg concentration in this sample was 25 mg/kg, which was also considered elevated.

Generally, both THg and Me-Hg concentrations in paddy soil decreased with distance from the mine tailings in all valleys (Fig. 2a, Fig. 2c and SI Figs. S1-S5), suggesting river-transport of Hg species. The correlation between soil Me-Hg concentration and distances from pollution source \((R=-0.27, P<0.05, \text{log-transformed})\) was weak compared to that of soil THg and distances \((R=-0.64, P<0.01, \text{log-transformed})\), showing that factors affecting Me-Hg concentrations were more complicated than that of THg concentrations.

**Relationship between Hg in paddy soil and in river water.** THg concentration in paddy soil samples was significantly correlated with THg concentration in river water samples in all valleys \((R=0.67, P<0.01, \text{log-transformed})\) (Fig. 3a), suggesting that irrigation with Hg-contaminated river water is the main Hg contamination source to the paddy field. The correlation between river water Me-Hg levels and rice paddy soil Me-Hg levels was weak \((P>0.05)\) (Fig. 3c), showing that Hg methylation in the paddy soil is more important than riverine Me-Hg transport. Correlation between soil pH or OM (organic matter) and soil Hg levels (THg and Me-Hg) was also weak (Fig. S6, Supporting Information), which may imply that OM and pH were not key factors explaining the variations in Hg or Me-Hg concentrations.

**Relationship between THg and Me-Hg in paddy soil.** A significantly positive relationship \((R=0.62, P<0.05, \text{log-transformed})\) between THg and Me-Hg concentrations in paddy soil samples was observed in GX artisanal Hg smelting valley (Fig. 4a). For the other four non-artisanal Hg smelting valleys, the correlation was weak \((P>0.05, R=0.26-0.46)\), which suggested that Me-Hg concentrations in the soils were driven by factors other than the THg concentration in these four valleys. The stronger correlation observed in GX may reflect
higher bioavailability of THg from ongoing artisanal Hg smelting activities. Recent research
indicates that newly deposited Hg may be more bioavailable for Hg methylation in boreal
wetlands systems (21, 22), and our result indicates this may be the case for rice paddy soils as
well.

Despite weak correlations between THg and Me-Hg in the soil samples in the four
non-artisanal Hg smelting valleys, the percentage of Me-Hg as THg (%Me-Hg) showed a
significant negative correlation with THg in soil in all five valleys (R=-0.81 to -0.94, P<0.01,
log-transformed) (Fig. 4c). A similar negative correlation was also observed in water samples
collected from the five rivers in two sampling periods around Wanshan Hg mine (Zhang et al.
in prep.). The negative relationship between %Me-Hg and THg in an aqueous environment
may be explained by Schaefer et al. (23), who suggested in Hg-contaminated water the
amount of Me-Hg that accumulates is limited by high rates of reductive de-methylation by Hg
resistant bacteria, whereas in low THg water microbial communities are not adapted to Hg,
and so the concentration of bioavailable Hg may be insufficient to induce the expression of
mercury-resistance (mer) operons that regulate reductive demethylation. In the present study,
both paddy soil Me-Hg concentration and %Me-Hg (geometric mean= 1.17 µg/kg and
0.023%, respectively) (table S1) were relatively lower than rice Me-Hg concentration and
%Me-Hg (geometric mean=6.59 µg/kg and 40%, respectively) (table S2). Similar to the
aqueous environment, the relatively low Me-Hg and %Me-Hg in paddy soil may be also
attributed to elevated THg levels and high rates of reductive de-methylation by Hg resistant
bacteria, but this mechanism deserves further research.

**Hg levels in rice.** THg concentrations in rice samples ranged from 7.3 to 508 µg/kg
(geometric mean = 44 µg/kg). Approximately 71% (42 out of 59) of the selected sampling
sites contained rice with THg concentration that exceeded 20 µg/kg, the national limit for
foodstuff other than fish (Chinese National Standard Agency, 24). It should however be noted
here that the recommended value is based on international dose response relationships established for Hg in fish, where most Hg occurs as Me-Hg, and that the Chinese value for THg in other food sources may not be sufficiently protective.

The Me-Hg concentration in rice samples ranged from 1.2 to 44 µg/kg (geometric mean = 6.6 µg/kg). These results are comparable to previous reports from Wanshan Hg mining area, China (up to 27.6 µg/kg, Feng et al., (6); 174 µg/kg, Qiu et al., (9) and 144 µg/kg, Horvat et al., (25)) and Wuchan Hg mining area, China (reached 18 µg/kg, Qiu et al., (26)). In our data set 6.8 % (4 out of 59) of the sampling sites had Me-Hg concentrations above 20 µg/kg, the Chinese national limit for THg, which clearly indicated a health risk for residents. Moreover, Me-Hg constituted a large proportion of THg in rice, with median of 18% and maximum of 40%. This shows that rice has a high ability to accumulate Me-Hg. The primary Me-Hg exposure pathway is through consumption of fish and marine mammals (27-29). However, the present study indicated that inhabitants in the Wanshan Hg mining area may be faced with the threat of Me-Hg exposure by consumption of rice (6).

THg and Me-Hg concentration in rice samples were generally linked to Hg levels in paddy soil or river water samples, and decreased with distance from the mine tailings in all valleys (Fig. 2b, Fig. 2d and SI Figs. S1-S5).

The geometric mean of THg values in rice samples in GX was 199 µg/kg, significant higher than values observed in the other four valleys (23-33 µg/kg) (Table S2). One-Way-ANOVA analyses (SPSS 13.0) indicated that THg in rice samples in GX artisanal Hg smelting valley were significantly higher than values measured in the four non-artisanal Hg smelting valleys (P<0.01) (assuming 5 groups (valleys)). The corresponding values for paddy soil THg (5.4 µg/kg) in GX artisanal Hg smelting valley, however, were not higher than
other four non-artisanal Hg smelting valleys (3.4-18 µg/kg) (ANOVA, P>0.05)) (Table S1). Interestingly, a site (A21) located about 2 km away from the GX artisanal Hg smelting valley, but without direct influence of the Hg contaminated stream water, also had elevated concentrations of THg and Me-Hg (154 µg/kg and 6.7 µg/kg, respectively) in rice, but very low soil THg concentration (0.29 mg/kg) and moderately low Me-Hg concentration (0.60 µg/kg). At this site the main Hg pathway is probably through atmospheric deposition. The high THg concentration in rice in GX may be partly explained by Hg uptake direct from the atmosphere through leaf surfaces.

This result confirmed that rice grown in GX artisanal Hg smelting valley was more heavily affected by Hg emissions from large quantities of artisanal Hg mining and smelting activities compared to other four non-artisanal Hg smelting valleys. A previous study indicated that a large amount of Hg vapor was released to the ambient air during the artisanal smelting process (30).

**Relationship between Hg in rice and soil.** Significant positive correlations between THg concentration in rice and soil were observed in XX valley and AZ valley (R=0.57 and 0.81, P<0.01, log-transformed) (Fig. 3b), suggested that THg in paddy soils could serve as an important source of THg in rice. However, poor correlations in other three valleys (combined table of Fig. 3b) indicated other parameters controlled THg in rice. Soil properties, such as redox conditions, and whether THg is complexed with soil organic matter, or bound to sulfides and silicates may also be important. Rice properties also need to be considered. Genotypic variation, for instance, may affect rice grain accumulation of Hg (31). In addition, uptake of gaseous Hg from the atmosphere by leaf surface may be important at some places.
A significant positive correlation between rice (the edible portion) Me-Hg concentration and soil Me-Hg concentration was observed in GL valley (R=0.65, P<0.05, log-transformed) (Fig. 3d). However, a weak correlation in other four valleys (combined Table of Fig. 3d), suggested Me-Hg accumulation from the soil to the rice grain was a complicated process. Understanding the mechanism of Me-Hg translocation in the rice plant between root, shoot, leaf, and grain deserves further research.

**Relationship between THg and Me-Hg in rice.** Though a positive correlation between THg in rice and Me-Hg in rice was observed (R=71, P<0.05, log-transformed) (Fig. 4b), it does not necessarily imply that Me-Hg in rice is methylated from inorganic Hg in the rice. The correlation may be just a reflection of the correlation between external uptake of THg and Me-Hg, e.g., THg may be absorbed from ambient gaseous Hg through leaf surface while Me-Hg was mainly uptake from Me-Hg in paddy soil by root as discussed above.

Like soil samples, a negative correlation between THg and %Me-Hg was also observed in rice (R=-0.60, P<0.01) (Fig. 4d) and probably reflected the fact that inorganic Hg and Me-Hg uptake in rice have different accumulation mechanisms. It should be noted here that such an inverse correlation between THg and %Me-Hg may be common in severely Hg-contaminated environment compartments, such as water, paddy soil and plant (rice).

**Rice/soil concentration ratios (CRs).** The results for T-Hg and Me-Hg in paddy soil samples and rice samples from the five valleys around Wanshan Hg mine are summarized in Table S1 and Table S2, respectively. Corresponding rice/soil concentration ratios (CRs) for THg and Me-Hg are shown in Table 1.
The geometric mean of THg concentrations in rice (0.044 mg/kg) is much lower than that in corresponding paddy soil (5.3 mg/kg) in all five valleys. The geometric mean of Me-Hg concentrations in rice (6.6 µg/kg), conversely, is much higher than that of Me-Hg concentrations in corresponding paddy soil (1.2 µg/kg). Rice/soil concentration ratios (CRs) for THg range from 0.00017 to 0.53 (geometric mean = 0.0083) and for Me-Hg from 0.71 to 50 (geometric mean = 5.6) (Table 1), respectively. Hence, the CR for Me-Hg is on an average of 675 times that of THg (Fig. 5). The CR for THg is similar to levels reported for other plants, usually being lower than 0.5 (33). This may indicate that rice may have a similar barrier (iron plaque) on the root surface, which blocks Hg uptake through the root system like other plants (34). Me-Hg, however, seems to be easily taken up in the rice plant; almost all samples (97%) have CR higher than 1 (Fig. 5b). Plants with CR closes to 1 are usually classified as intensive bio-accumulators (35). Other studies have found that organic Hg (e.g. Me-Hg) can be translocated within plants more easily than inorganic Hg (36, 37).

As shown in Fig. 5a and Fig. 5b, CRs for both THg and Me-Hg were inversely related to the soil Hg concentrations (R=-0.67 and 0.59, P<0.01), indicating that THg concentration (or Me-Hg concentration) in paddy soil was an important factor controlling the THg (or Me-Hg) to accumulate in the rice grain.

THg in rice samples in the whole GX artisanal Hg smelting valley, as mentioned above, were significantly higher than values for the other four non-artisanal Hg smelting valleys, however, no significant difference was observed for THg in corresponding paddy soils between different valleys. Therefore, the mean values of concentration ratios (CRs) for THg in GX valley were also higher than in other four valleys (Table 1) (ANOVA, P<0.05,
assuming 5 groups).

The abnormally high THg levels in rice samples in GX artisanal Hg smelting valley may be attributed to assimilation of gaseous Hg through the leaves. Atmospheric gaseous Hg levels in GX valley are expected to be higher than in the other valleys due to ongoing Hg smelting activities. TGM (total gaseous mercury) concentration in the Wanshan area has been reported in the range 90 to 2000 ng/m$^3$ (7). Uptake of Hg through both through roots and leaf surfaces has been previously suggested by Lindberg et al. (38), and this may be an important mechanism for THg in rice in Wanshan.

Acknowledgments

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Supporting Information

Table S1 and Table S2: Summarizations of THg, Me-Hg and %Me-Hg in paddy soil and rice samples in Wanshan area.

Figure S1 to Figure S5: Comparison of THg and Me-Hg in rice samples, paddy soil samples and river water samples with the increased distance along river from Hg mine tailings in the 5 valleys.

Figure S6: Relationships between PH (or organic matter) and THg (or Me-Hg) in paddy soil samples.

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Table 1. Rice to soil concentration ratios (CRs) for THg and Me-Hg along different rivers around Wanshan Hg mine.

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<th>XX</th>
<th>GLP</th>
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<td>0.00037</td>
<td>0.00017</td>
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<td>min</td>
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<td>1.04</td>
<td>1.58</td>
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<td>min</td>
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<td>4.67&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.84</td>
<td>5.09&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.35&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.62&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>log-normal</td>
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<sup>a</sup> Geometric Mean.
Figure 1. Map of sampling locations in Wanshan Hg mining area in Guizhou Province, China.

Figure 2. Relationship between Hg (or Me-Hg) concentrations in paddy soil samples (or rice samples) and distances along the river from Hg mine tailings in Wanshan Hg mining area.
(a) Relationship between THg concentrations in paddy soil samples and distances along the river from Hg mine tailings in Wanshan Hg mining area;
(b) Relationship between THg concentrations in rice samples and distances along the river from Hg mine tailings in Wanshan Hg mining area;
(c) Relationship between Me-Hg concentrations in paddy soil samples and distances along the river from Hg mine tailings in Wanshan Hg mining area;
(d) Relationship between Me-Hg concentrations in rice samples and distances along the river from Hg mine tailings in Wanshan Hg mining area.

Figure 3. Relationship between THg (or Me-Hg) concentrations in stream water samples and in riparian paddy soil samples as well as between THg (or Me-Hg) concentrations in rice samples and in paddy soil samples collected in Wanshan Hg mining area.
(a) Relationship between THg concentrations in riparian paddy soil samples and in stream water samples;
(b) Relationship between THg concentrations in rice samples and in paddy soil samples (* river water data were cited from another paper, Zhang et al., in prep.);
(c) Relationship between Me-Hg in paddy soil samples and in stream water samples;
(d) Relationship between Me-Hg concentrations in rice samples and in paddy soil samples.

Figure 4. Relationship between THg concentrations and Me-Hg concentrations (or %Me-Hg) in paddy soil samples (or in rice samples) collected in Wanshan Hg mining area.
(a) Relationship between concentration of THg and Me-Hg in paddy soil samples;
(b) Relationship between concentration of THg and Me-Hg in rice samples;
(c) Relationship between THg concentrations and ratio of Me-Hg to THg (%Me-Hg) in paddy soil samples;
(d) Relationship between THg concentrations and ratio of Me-Hg to THg (%Me-Hg) in rice samples.

Figure 5. Relationship between rice to soil concentrations ratios (CRs) for THg and soil THg concentrations as well as between CRs for Me-Hg and soil Me-Hg in Wanshan Hg mining area.
(a) Relationship between soil THg concentrations and CRs for THg;
(b) Relationship between soil Me-Hg concentrations and CRs for Me-Hg.
Fig. 1
Figure 2

(a) THg in rice paddies (μg/kg) vs. Distance from Hg mine tailing (km)

(b) THg in rice (μg/kg) vs. Distance from Hg mine tailing (km)

(c) MeHg in rice paddies (ng/g) vs. Distance from Hg mine tailing (km)

(d) MeHg in rice (ng/g) vs. Distance from Hg mine tailing (km)
Figure 3
Figure 4

(a) $R^2 = 0.18$, $P < 0.01$

(b) $R^2 = 0.50$, $P < 0.01$

(c) $R^2 = 0.75$, $P < 0.01$

(d) $R^2 = 0.36$, $P < 0.01$
Figure 5
Total mercury and methyl-mercury in paddy soil and rice around Wanshan Hg mining area, Guizhou Province, China —— Is rice an intensive bio-accumulator for methyl-mercury from paddy soil?

Table S1. Concentration of THg (mg/kg) and Me-Hg (µg/kg) (dry weight) in paddy soil along rivers around Wanshan Hg mine.

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<tr>
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\(^a\) Geometric mean  
\(^b\) Median
Table S2. Concentration of THg (ug/kg) and Me-Hg µg/kg) (dry weight) and ratio of Me-Hg to THg (%Me-Hg) in rice along rivers around Wanshan Hg mine.

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</table>

\(^a\) Geometric Mean.  
\(^b\) Median
Figure S1
Figure S2
Figure S3

Three graphs showing the distribution of THg and MeHg in rice, paddy soil, and stream water as a function of distance from Hg mine tailing (km). The graphs illustrate the concentration of THg and MeHg along the Xiaxi River.
Figure S4
Figure S5
Figure S6