

Total mercury in rice plant (*Oryza sativa*) collected from Sekinchan, Selangor, Malaysia and associated health risks

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Abstract

Consumption of mercury-contaminated rice could pose a potential health risk to humans. In this study, total mercury (THg) concentrations in various parts (roots, stems, leaves, and grains) of rice plant (*Oryza sativa*) collected from Sekinchan, Selangor, Malaysia were analysed for risk assessment. The THg concentrations in collected samples were analysed by Direct Mercury Analyzer (DMA-80). The mean concentrations found in plant parts were as follows: root, 47.01±0.42 µg/kg; stem, 6.43±1.77 µg/kg; leaf, 26.25±4.71 µg/kg; grain, 2.64±0.42 µg/kg. THg distribution in rice plants was roots > leaves > stems and grains. The mean THg concentration in grain (2.64±0.42 µg/kg) was below the maximum permitted proportion stipulated by Malaysian Food Regulation 1985 (50.0 µg/kg). The estimated weekly intake (EWI) of THg through rice was 0.07±0.01 µg/kg bw/week for 60 kg adult, below the provisional tolerable weekly intakes (PTWI) as suggested by JECFA indicating unlikely to cause impairment of public health due to consumption of rice planted in this region. However, periodical monitoring of mercury pollution in Selangor area is crucial because mercury contamination in crops could jeopardize food safety and security.

1. Introduction

Mercury (Hg) contamination in agricultural crops has been regarded as an environmental problem affecting food safety and risking human health (Zhao *et al.*, 2019). The understanding of Hg pollution status in an agricultural crop is essentially important as its health status is closely related to productivity, food safety, and human and ecosystem health (Aziz *et al.*, 2015). Hg is a highly toxic pollutant that is capable to bioaccumulate and biomagnify across multiple trophic levels (Jan *et al.*, 2015). The long-term ingestion of Hg contaminated rice as staple food could lead to the chronic neurotoxicity effects (Jackson, 2018). As population keep expanding, the increment of anthropogenic activities in mining, smelting and coal combustion has released Hg into the atmosphere, terrestrial and aquatic systems (Streets *et al.*, 2019). Mercury can be transported globally (Kocman *et al.*, 2017) and its distribution has been reported widely (Pacyna *et al.*, 2010).

To date, Asia has become the main source of Hg emission, with east and southeast Asia countries contributed about 40% of the global total Hg. Malaysia,

among one of the developing countries in these regions, also faced mercury pollution (Habuer *et al.*, 2016). Recent global anthropogenic Hg emissions estimated Malaysia released 6.13 tonnes, ranked at Top 5 among Southeast Asia countries (UNEP, 2018). Over the past decades, biomonitoring of Hg contamination was mainly focused on fish and seafood (Abeyasinghe *et al.*, 2017), which have been successful in creating awareness, especially pregnant women in the selection of seafood-based dietary (Bloomington *et al.*, 2010). In Malaysia, most of the Hg monitoring studies focused on river water, sediment, and fish and shellfish (Hajeb *et al.*, 2012; Praveena *et al.*, 2013; Looi *et al.*, 2015). In recent year, Hg is also detected in tropical fruits such as papaya and mango (Praveena *et al.*, 2013). However, little attention was paid on crop plant such as rice (*Oryza sativa* L).

Plants can absorb Hg that is deposited on the leaf surface. It can also uptake Hg from water and soil via roots (Li *et al.*, 2017). In comparison to other crop plants, rice is known with greater ability to accumulate MeHg (Qiu *et al.*, 2008). In Malaysia, the paddy plantation supplies 71% of rice to support the local

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market requirement (Ismail and Ngadiman, 2017). However, to date, there is no study investigating the Hg pollution status in Malaysian soil-rice system. Since rice is the staple food for most of the world including Malaysia, it is important to assess the health risk due to exposure of Hg via rice consumption. It is imperative to fill in this gap of knowledge to provide baseline data on Hg pollution status in rice plant for food safety and health risk assessment. The aims of this study are to (i) determine the THg concentration in various parts (roots, stems, leaves, and grains) of rice plant (*Oryza sativa*) collected from Sekinchan, Selangor, Malaysia, and (ii) preliminary assess the potential human health risk associated with THg exposure based on the maximum permitted proportion stipulated by Malaysian Food Regulation 1985 and estimated weekly intake (EWI).

2. Materials and methods

2.1 Sampling sites

Sekinchan, Selangor is well-known for its paddy plantation activities in Malaysia. Rice plants were collected randomly from five sampling sites in May 2019 (Table 1).

2.2 Sampling and analytical procedure

Rice plants were collected in triplicate and the collected samples were kept in the acid-washed ziplock polyethylene bags and transported to the laboratory at 4°C for sample preparation and analysis. In the laboratory, the rice plants were homogenised according to sampling sites and rinsed with deionised water before divided the rice plants to its parts (i.e., root, stem, leaf, and grain). Subsequently, plant parts were oven-dried at 50°C until a constant weight was achieved, followed by grinding, manual husk separation, and sieved through 1 mm mesh sieve (Juen et al., 2014). About 0.2 g of prepared samples were weighted and introduced in direct mercury analyser (DMA-80, Milestone, CT, USA) for THg determination. The limit of detection (LOD) and limit of quantification (LOQ) for THg analysis were 0.01 and 0.04 ng, respectively.

2.3 Quality assurance and quality control (QA/QC)

Homogenized and triplicate (n=3) samples were collected from each sampling sites to address the variability due to sampling activities. Besides, triplicate readings and relative standard deviation were taken to ensure representative results. Method and standard blanks were used to account for background correction. The analytical method was verified using by the analysis of standard reference material (NIST-SRM 1568b: Rice Flour). The average THg recovery for SRM 1568b was 83.4%.

2.4 THg weekly intake for Malaysian

The calculation of the estimated weekly intake (EWI) for THg was based on the average rice consumption for residents in Malaysia at 87.64 kg/capita/year (OECD-FAO, 2019). This is equivalent to 1.68 kg/capita/week. The EWI for THg of an adult weighing 60 kg was estimated as follow:

$$\text{THg EWI } (\mu\text{g/kg}) = [\text{rice consumption (kg/week)} \times \text{rice THg concentration } (\mu\text{g/kg}) / 60 \text{ kg}] \quad (1)$$

The EWI was compared with provisional tolerable weekly intakes (PTWI) as suggested by the Joint FAO/WHO Expert Committee on Food Additives (JECFA).

2.5 Statistical analysis

Data collected were analysed using IBM SPSS Statistics 23 software. One-way analysis of variance (ANOVA) was used to determine whether there was a significant difference between various parts of the rice plant.

3. Results and discussion

3.1 THg in rice plant

The THg concentration in rice plant parts was below the maximum permitted proportion set by Malaysian Food Regulation 1985 (Ministry of Health Malaysia, 2006), except for roots from sampling sites P1 and P2 (Table 2). The higher concentration in roots indicating the uneven spatial distribution of mercury in soil (Huang et al., 2019), atmosphere, and groundwater

Table 1. The description of sampling sites from Sekinchan, Selangor

No	Abbreviation	GPS	Site Description
1	P1	3°31'21.06"N 101° 6'53.46"E	Paddy field near a temporary paddy storage area
2	P2	3°30'2.94"N 101° 7'32.52"E	Paddy field beside the river water intake point
3	P3	3°30'3.18"N 101° 7'32.82"E	Paddy field beside the river water intake point, separated by a short walkway from P2
4	P4	3°30'22.32"N 101° 8'1.68"E	Paddy field beside the river water intake point
5	P5	3°31'10.62"N 101° 8'0.90"E	Paddy field near paddy processing plant

contamination caused by nearby active landfills. This study found that the THg differed significantly in the parts of rice plants ($p < 0.05$) except for stems and grains. The mean THg concentration in various parts of rice plant in descending order: root ($47.01 \pm 0.42 \mu\text{g/kg}$) > leaf ($26.25 \pm 4.71 \mu\text{g/kg}$) > stem ($6.43 \pm 1.77 \mu\text{g/kg}$) and grain ($2.64 \pm 0.42 \mu\text{g/kg}$) (Figure 1). The THg distributions in rice plant parts are similar to those reported in by Pang *et al.* (2019) but inconsistent with the THg distributions in rice plant (leaf > root > stem > grain) cultivated in Xinyang city, China, which has low background soil THg level (Tang *et al.*, 2017). Previous studies suggested that Hg concentrations in rice root were correlated with Hg concentrations in soil (Meng *et al.*, 2014; Tang *et al.*, 2017). Thus, the relatively high THg concentration in root compared to other rice plant parts ($p < 0.05$) indicating THg might originate from the soil. In addition to bioaccumulation pathway, the plant is also capable to absorb atmospheric mercury via leaf and stem (Pang *et al.*, 2019).

Table 2. Total mercury (THg) concentrations ($\mu\text{g/kg}$) of rice plant parts compared with maximum permitted proportion as stipulated by Malaysian Food Regulation 1985

Sampling site	Plant parts	Mean	Standard Deviation
P1	Root	70.88	6.83
	Stem	9.48	0.7
	Leaves	34.02	2.56
	Grain	2.25	0.2
P2	Root	52.86	3.45
	Stem	5.01	0.58
	Leaves	27.41	2.35
	Grain	3.04	0.13
P3	Root	37.16	2.91
	Stem	6.3	0.36
	Leaves	23.51	0.59
	Grain	2.29	0.19
P4	Root	41.5	2.59
	Stem	5.78	1.25
	Leaves	22.82	0.51
	Grain	2.47	0.08
P5	Root	32.67	1.63
	Stem	5.6	0.31
	Leaves	23.47	1.08
	Grain	3.15	0.15
Maximum permitted proportion ^a		50	

^aMalaysian Food Regulation 1985 (Regulation 38, Fourteenth Schedule)

3.2 Estimated weekly intake

The estimated weekly intake (EWI) of THg from the consumption of rice by an adult of 60 kg was $0.07 \pm 0.01 \mu\text{g/kg}$ body weight. The EWI was remarkably below the provisional tolerable weekly intake (PTWI) of $4 \mu\text{g/kg}$ body weight as suggested by Joint FAO/WHO Expert

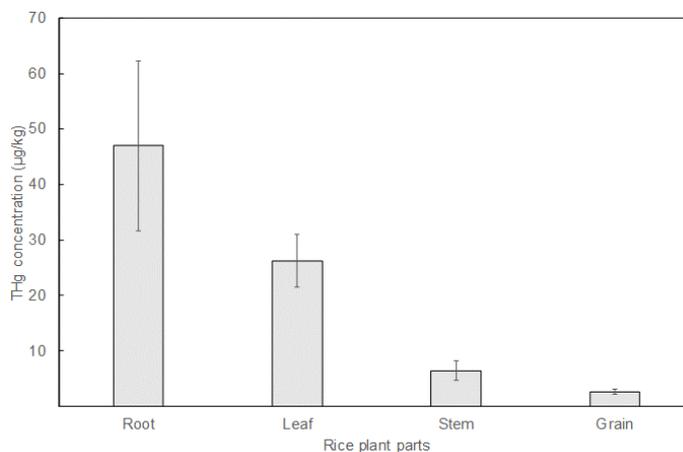


Figure 1. Total mercury (THg) concentrations ($\mu\text{g/kg}$) of rice plant parts collected from Sekinchan, Selangor

Committee on Food Additives (JECFA, 2011), suggesting that the exposure of THg due to consumption of rice grown in sampling sites would unlikely to cause public health implication. Even though the EWIs from this study were far below the PTWI issued by the JECFA, future monitoring studies emphasis on assessing the 'true' health effects of THg exposure in the local rice-consumption population, especially on pregnant women and children which are the vulnerable groups are needed. A detailed social study that takes demographic parameters such as gender, age, occupational, and educational status into account should be incorporated in the abovementioned monitoring study.

4. Conclusion

In general, the THg concentrations were higher in the root of the rice plant, followed by leaf, stem, and grain. Notably, the concentrations of THg in rice grains were below the maximum permitted proportion set by Malaysian Food Regulation 1985 and PTWI recommended by JECFA. Although the rice grain has a relatively low level of THg, it is clearly shown that rice can accumulate THg. Therefore, periodic monitoring and assessing the health risk associated with mercury exposure, especially concerning the most toxic methylmercury, should be carried out in order to safeguard food security.

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