Arsenic in cooked rice in Bangladesh

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In Bangladesh, rice is boiled with an excessive amount of water, and the water remaining after cooking will be discarded. We did an on-site experiment to assess the effect of this cooking method on the amount of arsenic retained in cooked rice. The concentration of arsenic in cooked rice was higher than that in raw rice and absorbed water combined, suggesting a chelating effect by rice grains, or concentration of arsenic because of water evaporation during cooking, or both. The method of cooking and water used can affect the amount of arsenic in cooked rice, which will have implications for the assessment of the health risks of arsenic.

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Establishment of a dose-response relation for chronic effects of arsenic exposure is becoming an important task in many Asian and Latin-American countries, where contamination of tube-well water by geologically-derived arsenic poses a serious threat to health. However, estimation of arsenic exposure is difficult. The total concentration of arsenic in drinking water is generally used as an exposure index; however, this method does not include exposure through sources other than water. As a result, the intake of arsenic could be underestimated, which would lead to an overestimation of risk.1

In an arsenic-contaminated area of northwestern Bangladesh2, the residents depend heavily on rice for their caloric intake (about 70% of total), suggesting that rice is an important dietary source of arsenic. In our study area, and presumably many areas in Bangladesh and west Bengal, rice is usually cooked with a substantial amount of water, which is sometimes contaminated with arsenic. Water that is not absorbed during cooking is discarded by inverting the cooking pan.1 Thus, the actual amount of arsenic in cooked rice could be either increased, by chelation of arsenic in water by binding on rice grains, or decreased if water-soluble arsenic is released from rice into the water to be discarded.

We did an on-site experiment to assess arsenic loss and fixation during rice cooking. We asked two people to cook rice in their usual way, in their own fireplaces. 500 g of raw rice (International Rice Research Institute variety 20) purchased at a local market was boiled in a type of aluminium pot usually used in the area, with water from nearby tube-wells. The cooks decided how much water to use and provided five samples of cooked rice. We measured total arsenic concentrations of the dry raw rice, wet cooked rice, tube-well water, and discarded water (two per sample of each) with an atomic absorption spectrophotometer equipped with a hydride generation system (AAS-HG) (Model Z4100 [Perkin Elmer, Norwalk, CT, USA]) after digesting the samples with a mixture of nitric acid, perchloric acid, and sulphuric acid. We analysed certified reference materials (National Institute of Environmental Studies, Tsukuba, Japan, number 18) to ensure the accuracy of the assay.2 The coefficient of variation for the replicates by AAS-HG was less than 4%.

The table shows total concentrations of arsenic in the samples tested. The amount of cooking water and the water content of cooked rice were consistent between samples (69–75% of the total weight). The weight ratio of added water to raw rice ranged between 3:2/1 to 4:0/1, which is much higher than the typical ratio of 1:3/1 used in Japan.4 Since an adult Bangladeshi man consumes an average 1500 g of cooked rice per day,5 which contains at least 1 L of drinking water, water intake through cooked rice would add substantially to the amount of arsenic ingested.

Also noteworthy is that the amount of arsenic in the raw rice was more than four-fold that of raw Japanese white rice, which contained only 40 ng/g. Therefore, 1500 g of cooked rice, which corresponds to roughly 435 g of raw rice, could provide an additional, substantial burden of arsenic. Results from our calculations suggest that cooked rice could be an important source of arsenic if it is boiled in arsenic-contaminated water.

| Water added (g) | Cooked rice (g) | Water absorbed (g) | Arsenic concentration (ng/g) | Water* arsenic | Discarded water | Cooked rice: predicted† | Cooked rice: measured‡ | Retained arsenic
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<td>1724</td>
<td>1224</td>
<td>173</td>
<td>372</td>
<td>392</td>
<td>314</td>
<td>359 (14%)</td>
<td>61%</td>
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<tr>
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<td>1610</td>
<td>1110</td>
<td>173</td>
<td>372</td>
<td>361</td>
<td>310</td>
<td>345 (11%)</td>
<td>60%</td>
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<td>1688</td>
<td>1188</td>
<td>173</td>
<td>372</td>
<td>391</td>
<td>313</td>
<td>377 (20%)</td>
<td>59%</td>
</tr>
<tr>
<td>4 2556</td>
<td>1632</td>
<td>1132</td>
<td>173</td>
<td>223</td>
<td>254</td>
<td>208</td>
<td>228 (10%)</td>
<td>57%</td>
</tr>
<tr>
<td>5 2604</td>
<td>1970</td>
<td>1470</td>
<td>173</td>
<td>223</td>
<td>390</td>
<td>210</td>
<td>284 (35%)</td>
<td>84%</td>
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*a Water was obtained from two nearby tube-wells, samples 1–3, and samples 4 and 5 were from the same tube-well, respectively. *Predicted concentration=concentration of arsenic in raw rice/weight of rice+concentration of arsenic in water/weight of water/weight of cooked rice. †Proportion increase from predicted concentrations.

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The amount of arsenic in the cooked rice was 10–35% higher than we had predicted (table) suggesting that arsenic in the water is chelated by rice grains, or that arsenic becomes concentrated during the cooking process, because of evaporation.

The largest increase of arsenic (35%) was in the only sample (number 5) cooked with a light lid made of aluminium, rather than ceramic. The ratio of arsenic in the discarded water to that in the initial water was highest in this sample, suggesting that more water evaporated from this sample than from the others. This finding, although from one sample, suggests that evaporation affects the concentration of arsenic in cooked rice. Furthermore, it would raise concerns about the amount of arsenic retained in curry, the most popular dish in the studied localities, which is cooked with a large amount of water and simmered for a long time.

Our results suggest that rice prepared with arsenic-contaminated water might be an important source of arsenic, and that the cooking process could affect the amount of this element in cooked rice. Although the cooking method used for our samples is typical in this locality, a drawback of this study is small sample size; hence, a large-scale study is required to validate our findings. Finally, we should note that a dose-response association between arsenic exposure and any health effects might overestimate the health risk of arsenic if the intake of this element from sources other than drinking water is not included.

Contributors
M Bae did chemical analyses. C Watanabe supervised fieldwork and did statistical analyses. T Inaoka, M Sekiyama, N Sudo, and M H Bokul did fieldwork. R Ohtsuka supervised and did the field survey. All authors assisted in writing of the report.

Conflict of interest statement
None declared.

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Effect of sunlight and season on serotonin turnover in the brain

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Although the effectiveness of phototherapy and specific-serotonin-uptake-blocking drugs strongly suggests that serotonin has a role in the development of seasonal depression, concentrations of serotonin, dopamine, and norepinephrine metabolites are normal in the cerebrospinal fluid (CSF) of patients with seasonal affective disorder.1 Tryptophan depletion, which inhibits serotonin synthesis, reverses the antidepressant effect of bright light therapy.2 The amounts of serotonin and its metabolites in CSF are, at best, an imprecise indicator of brain serotonergic neuronal activity. Serotonin in lumbar CSF is probably derived from the terminals of descending projections from the spinal cord, and not from the brain.3 Concentrations in plasma of serotonin and its major metabolite, 5-hydroxyindole acetic acid (5-HIAA), are also misleading, since most serotonin in plasma is derived from the gut, and less than 10% of the 5-HIAA in plasma comes from the brain.4

To overcome these difficulties, we developed a technique in which percutaneously placed catheters were positioned high in an internal jugular vein to directly sample venous blood from the brain, allowing us to measure overflow of neurotransmitters and metabolites into the internal jugular venous effluent. With this method, differences between concentrations of neurotransmitters in the arteries and in the veins can be extrapolated to estimate the amounts produced in the brain. We assessed seasonal variation in overflow of monoamines (serotonin, norepinephrine, and dopamine) from the brain in healthy male volunteers, and investigated the effect of sunlight on these neurotransmitters. Additionally, we measured the seasonal variation in the rate of whole body production of 5-HIAA, hepatosplanchnic and skeletal muscle 5-HIAA overflow, and 5-HIAA concentration in arterial plasma, to investigate whether any seasonal effect on brain serotonin overflow was synchronous with change in extracerebral synthesis and release of serotonin.

101 men, aged 18–79 years, were recruited by local advertisement from the general community and underwent a comprehensive clinical and physical examination to screen for any previously undiagnosed medical conditions before enrolment. Exclusion criteria included a history of major illness (including depression), cardiovascular disease, current medication, and previous psychiatric therapy. The experimental procedure conformed to the guidelines of the National Health and Medical Research...