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Rice versus Drinking Water: Estimating the Primary Source of Arsenic in the U.S. Diet

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Arsenic compounds are often naturally present in water and food.[1,2] A new study estimates Americans' inorganic arsenic exposures from drinking water and rice—a food that may contain arsenic—and concludes that rice consumption may account for as much inorganic arsenic exposure as drinking water in some U.S. populations.[1]

At high levels, long-term exposures to inorganic forms of arsenic are strongly linked to cancer[3] and have been associated to a lesser extent with diabetes, lung disease, and cardiovascular disease.[4] Arsenic in drinking water is almost exclusively inorganic arsenic; consequently, national and international guidelines have established drinking water exposure limits. Drinking water remains a priority in terms of reducing exposure to arsenic, with organizations including the World Health Organization and the U.S. Environmental Protection Agency (EPA) setting a limit of 10 μg/L for drinking water.[1,2,5]

Arsenic concentrations in foods are highly variable, and regulatory limits have not yet been established.[2,6,7] Because the structure of a food can hinder the accessibility of arsenic for uptake and absorption, a person's internal dose is not necessarily equal to the total amount of arsenic contained in the food that is eaten.[8] Rice, which accumulates more arsenic than other staple foods, has been estimated to contribute approximately 20% of dietary arsenic exposure on average,[9] but the quantities of arsenic in rice can vary as a function of the specific variety as well as the growing conditions and environment where it is raised.[8]

In the new study, the researchers incorporated data on arsenic levels in drinking water and rice in the United States into the Stochastic Human Exposure and Dose Simulation (SHEDS) model,[10] which was developed by the EPA to estimate people's everyday chemical exposures. Data on the arsenic content of drinking water were drawn from the Second Six-Year Study, a survey of 49,473 U.S. public water utilities serving approximately 230 million people. Dietary data came from the What We Eat in America survey, which is the dietary component of the National Health and Nutrition Examination Survey (NHANES).

Additional data incorporated into the SHEDS model were based on 54 samples of various rice types (e.g., long-grain, brown, parboiled) collected from U.S. mills by the researchers. This diverse sampling reflected arsenic variance in the rice supply chain.

Cooked samples of rice underwent dilute nitric acid extraction to liberate the total arsenic content, as well as an *in vitro* assay that mimics the digestive process. Processed samples were analyzed for arsenic content and identification of specific organic and inorganic compounds.

The SHEDS model output allowed the researchers to estimate that inorganic arsenic exposures attributable to drinking water and rice consumption averaged 4.2 and 1.4 μg/day, respectively. They were also able to identify groups that might have higher-than-average arsenic exposures from rice, including the grouped subpopulation "Tribal, Asian, and Pacific" (2.8 μg/day).[1]

Despite an estimated higher average intake of arsenic from drinking water compared with rice, about two-thirds of the drinking water samples had concentrations below the detection limit. This suggests that most people will not have greater arsenic exposure from drinking water compared with rice, says Rosalind Schoof, principal at Ramboll Environ, an environmental and health consulting firm.

Schoof, who was not associated with the study, points to the use of extensive up-to-date data and thorough rice sampling and analysis as valuable strengths of this study. She also highlights the *in vitro* bioaccessibility surveys and the in-depth speciation of the arsenic compounds as strengths, saying, "This study will facilitate assessing arsenic exposures and more accurately estimating inorganic exposures."

Limitations to the study were primarily associated with the source data. For example, the dietary data, although extensive, captured only what people ate on two days about a week apart, which prevented accurate assessment of exposures at the extreme ends of consumption.

"As you go out on the tails of the statistical distribution of rice consumption rates, this two-day survey starts to become unreliable," says study coauthor Jack Creed, a research chemist at the EPA's National Exposure Research Laboratory. For example, if a person ate a lot of rice on one of their survey days, their rice consumption would appear to be high, even if they usually did not eat much rice. This is especially worth noting, given that adverse health effects of arsenic result from long-term exposure.

Creed notes that more information is needed on what people are actually eating, especially long-term rice consumption in subpopulations such as very young children and specific ethnic groups. "That's what it is going to take to get to estimate the exposures that you'd like to better evaluate," he says. NHANES recently started collecting more detailed information about Asian subpopulations with very different diets (including Chinese Americans, Indian Americans, and a composite group made up of Filipino, Vietnamese, Korean, and Japanese Americans) so that they can be more accurately assessed.[11]

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Rice has the potential to accumulate arsenic from soil and irrigation water, but the form of the arsenic plays an important role in its uptake. Arsenite is chemically similar to silicon, and arsenate is an analog for phosphate. Silica and phosphate transporters in rice plants can move arsenite and arsenate, respectively, into the plant and distribute arsenic to the edible grain. Arsenite and arsenate are both inorganic forms of arsenic, which are more toxic than organic forms. © Claudine Van Massenhove/Shutterstock.

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