Cancer Risk Assessment for Arsenic Exposure through Oyster Consumption

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Risk is assessed on the basis of assumptions, but this practice might not be well received by the general public. To avoid miscommunication, the assumptions should be stated clearly in reporting the results. Recently, a report on an assessment of the cancer risk associated with consumption of oysters caused a panic among consumers in Taiwan and produced significant effects on related industries. A group of researchers measured the arsenic content in oysters in the Taiwan area and conducted a cancer risk assessment accordingly. The results, published in a research article in an international journal, included a lifetime cancer risk estimate of $5.10/10^{-4}$ as calculated based on the assumption that a person consumes oysters with the highest arsenic level (19.3 mg/g dry weight) at the highest rate (139 g/day) for 30 years. A national newspaper in Taiwan translated part of the article and published results that focused on the finding that this estimate was more than 500 times higher than what would be considered acceptable by the U.S. Environmental Protection Agency. As a result, most consumers stopped purchasing oysters, and the related industries suffered substantial losses. The newspaper's omission of the key assumptions in the risk assessment and the extreme assumptions made in the risk assessment led to this tragedy. This event demonstrated the importance of careful communication of risk assessment results. ***Key words:*** **arsenic, cancer, oyster, risk assessment.** ***Environ Health Perspect*** **110:123–124 (2002). [Online 10 January 2002]**
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Risk assessments are conducted on the basis of assumptions. In reporting results, assumptions should be clearly stated and their validity should be examined carefully to prevent confusion and unnecessary adverse impacts on society. A recent incident triggered by an assessment of the cancer risk associated with oysters in Taiwan demonstrated how damaging miscommunication can be. A group of researchers who participated in the Asia/Pacific Mussel Watch (APMW) project, a part of the efforts of the International Mussel Watch Committee (IMC), measured contents of metals and pesticides in seafood in the Taiwan area from 1991 to 1998 (*1*). They obtained samples of oysters (*Crassostrea gigas*) from 12 culture areas and found high levels of arsenic. On the basis of those measurements and the results of a food questionnaire survey on residents of Taipei, the researchers estimated that the lifetime cancer risk associated with the arsenic in oysters might be as high as 5.10×10^{-4} (*2,3*), more than 500 times higher, according to Han et al. (*4*), than what would be considered acceptable by the U.S. Environmental Protection Agency (EPA).

A few months after the latest report was published, a newspaper in Taiwan translated part of the report and put the information under the eye-catching headline "British Scientific Journals Revealed Taiwanese Oyster Is Associated with a Cancer Risk 500 Times that of the U.S. Standard" (*5,6*). As a result, most consumers stopped purchasing oysters, and the price and sale of oysters slumped (*7,8*). Because oysters are the most popular shellfish in Taiwan, related industries suffered substantial losses, and many people's livings were affected (*7,8*). Being seriously blamed by the industries and local governments, the researchers appeared on the mass media and emphasized that the estimate was calculated on the basis of extreme values, which was not clearly stated in the newspaper article (*6,9*). In addition, many high-profile figures, including the prime minister, swallowed raw oysters in front of the mass media to express their support for the safe quality of oysters (*7,8*). However, most people still hesitated to eat oysters, and the suspicion of a conspiracy to sabotage Taiwan's economy, which was generally believed to be groundless, triggered an investigation by government agencies (*10,11*).

The newspaper's omission of the key assumptions in the risk assessment led to this debacle. As the researchers pointed out, the newspaper article did not provide details on how the risk estimate was derived (*9*). In fact, the risk estimate was calculated for consuming oysters with 19.3 μg/g dry weight of arsenic at the rate of 139 g/day for 30 years. Only one of the 662 respondents in the questionnaire survey reported consuming oysters at this rate, and only 6 (0.7%) reported rates > 60 g/day (*2*) (Table 1). The level of 19.3 μg/g dry weight was measured in oysters obtained from the Machu Islands area (*2,4*), which is about 200 miles away from the Taiwan island and very close to mainland China. A substantial portion of the oysters on the markets of Machu Island are actually from mainland China, and oysters raised in this area are unlikely to appear in the markets of Taiwan (*11,12*).

Therefore, even if the value of 139 g/day was not an outlier or error, only a few dozen residents of Machu Island might be exposed to arsenic from oysters at the highest rate (*13*), and it is doubtful that any of them would consume oysters at that rate for 30 years (*9*). The highest level measured in Taiwan (17.1 μg/g dry weight) was in oysters from the Taishi area, which supplies < 1% of the oysters in Taiwan. Most oysters in Taiwan come from the Putai area (*14*), which had the lowest arsenic level in oysters (4.86 μg/g dry weight) observed in the study (*4*). Because most of the above information was not provided in the original newspaper article (*6*), readers were given a false impression that most Taiwanese were consuming oysters with high levels of arsenic.

The scientific articles also failed to provide some information that might have reduced such a degree of unnecessary panic. The "cancer risk" predicted by the U.S. EPA model is for skin cancer, which is not fatal in most cases (*15*), and there are assumptions and uncertainties in the model itself (*15–17*). In fact, a meta-analysis showed that this model might overestimate risk estimates for exposure levels < 0.27 ppm (*18*). When the assumptions that the arsenic level measured by dry weight is five times that measured by wet weight and that each person consumes 2 L of water a day (*2,4*) are applied, the maximum daily dose of 139 g of oyster with 19.3 μg/g dry weight of arsenic is similar to being exposed to 0.268 ppm of arsenic in drinking water. Therefore, all the arsenic exposure levels covered by the risk assessment were within the range in which the U.S. EPA model might overestimate risk.

Most of the arsenic in seafood is in organic forms, which are much less toxic than the inorganic forms, and which are generally believed to be noncarcinogenic (*19*). Therefore, the cancer risk assessment was based on the level of inorganic arsenic (*2,4*). The researchers did not measure the proportions of arsenic species in the seafood,

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but assumed that 10% of the arsenic in oysters is in inorganic forms, according to a report by Edmonds and Francesconi (*20*). The estimate of 10%, however, was for seafood in general, and the only oyster data in that report were on *Crassostrea gigas* from Japan, in which only 1.4% of the arsenic was inorganic—about one-seventh of the value used in the risk assessment (*20*). A study on another kind of oyster (*Crassostrea angulata*) from Spain showed the proportion of inorganic arsenic as 4% (*21*). Although such data are limited, the estimate of 10% is likely to be an overestimation.

In addition to the highest estimate, the researchers also reported risk estimates for "typically exposed individuals" ($17.1–68.0 \times 10^{-6}$) (*4*), but the consumption rate used (18.6 g/day) was, in fact, the 91st percentile value (*2*), which cannot be applied to more than 90% of the population. Although the median would be a more appropriate choice to represent the "typically exposed," 90.9% of the respondents were put into the lowest exposure group, < 18.6 g/day. Therefore, the authors should report statistics on further divisions of this group to identify the median level. All the above factors lead to a possible overestimation of the risk.

Furthermore, in the study, 15–20 oysters of similar size were sampled from each location at the same time (*22*). Although thorough quality control and quality assurance measures were taken (*2,4*), the possible variation of arsenic contents in oysters over time was not evaluated, which added to the uncertainties in the risk estimates. Likewise, the food questionnaire survey was a one-time study conducted in Taipei, and even if the results did not change over time, which is quite doubtful, it is not likely to be representative of the whole Taiwan area. The decision to warn the public to refrain from a widely consumed food item should be based on a more thorough investigation (*2*).

In the study by Edmonds and Francesconi (*20*), the *Crassostrea gigas* from Japan had a mean total (organic and inorganic combined) arsenic of 21 µg/g dry weight (converted from 4.2 mg/kg dry weight), which is even higher than the highest mean level (19.3 µg/g) observed among the 12 areas in Taiwan. The *Crassostrea angulata* from Spain had a mean total arsenic of 12.20 µg/g dry weight (converted from 2.44 mg/kg dry weight) (*22*), higher than the 10.8 µg/g estimated mean level in Taiwan (*2*). In fact, when the actual market shares are taken into account, the mean total arsenic in oysters in Taiwan should be close to 7 µg/g. Therefore, the arsenic level in oysters in Taiwan is not higher, and may even be lower, than those around the world. In other words, if the same approach were applied to other risk assessments, similar incidents could happen in many other countries.

With the improvement of measurement instruments and techniques, it is not surprising that trace amounts of many toxic substances can be detected in most food items. Therefore, to evaluate the relevance of a specific route of exposure in real life, it is important to know the total exposure from different routes. For example, in adults in North America, the daily arsenic intake from food alone is generally > 20 µg (*23*), which may constitute a substantial portion (> 10%) of the total arsenic exposure in populations where the levels of arsenic in the water are < 100 µg/L (intake < 100 µg/L × 2 L/day = 200 µg/day). Researchers should be very cautious in using the data to conduct risk assessments, and the mass media should also be careful and professional in disseminating the information. This tragic incident demonstrates that to avoid confusion and unnecessary panic among the public, assumptions should be clearly stated and real-life situations should be taken into account when conducting the risk assessment and reporting the risk estimates.

Table 1. Assumptions that led to the maximum lifetime cancer risk from arsenic in oysters in Taiwan.

Assumptions	Facts
Oysters in Taiwan contain 19.3 µg/g dry weight of arsenic	1. The level of 19.3 µg/g dry weight was measured in oysters obtained from the Machu Islands area, which is about 200 miles away from Taiwan island 2. A substantial portion of the oysters on the markets of Machu Island are actually from mainland China, and oysters raised in this area are unlikely to appear in the market on Taiwan 3. Most oysters in Taiwan come from the Putai area, which had the lowest arsenic level in oysters (4.86 µg/g dry weight) observed in the study by Han et al. (*22*)
Oysters were consumed at the rate of 139 g/day	Only 1 of the 662 respondents in the questionnaire survey reported consuming 139 g of oysters per day, and only 6 (0.7%) reported rates > 60 g/day
Consumption rate remains constant for 30 years	Few people consume oysters at such a high rate for such a long time
Of the arsenic in oysters, 10% is in inorganic forms	A study found that only 1.4% of the arsenic in *Crassostrea gigas* from Japan was inorganic

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