Heavy Metals in Seafoods and Potential Risks on Human Health: A Case Study from Singapore

Elena G. Koroleva, Moscow State Lomonosov University, Russia
Igor A. Korolev, Moscow State Lomonosov University, Russia
Andrew G. Shitov, Moscow State Lomonosov University, Russia

Abstract: The level of a variety of heavy metals were measured in the different seafood types consumed in Singapore. Heavy metal concentrations ranged BLD-14.18 mg/g ww for As, BLD-0.50 mg/g ww for Cd, BLD-25.53 mg/g ww for Cu, BLD-0.58 mg/g ww for Hg, BLD-1.21 mg/g ww for Pb amongst the seafood types. The mean daily intake of heavy metals from seafood was calculated for the general population of Singapore. Daily intakes are below the oral RfD set by the US FDA, except for As. Daily intake for As exceeded the conservative cancer benchmark concentrations set by the US EPA, meaning that a significant number of people are potentially at risk in Singapore over a lifetime of seafood consumption.

Keywords: heavy metal, risk assessment, seafood.

1. Introduction

Seafood consumption is a rich source of vitamins, minerals and omega-3 polyunsaturated fatty acids that have a wide range of beneficial effects to human health. Seafood is recognized as a major source of heavy metals and POPs. Episodes of acute food poisoning have been reported following consumption of seafood contaminated with pollutants such as mercury (Gochfeld, 2003). Chronic exposure to heavy metals may also result in health hazards (De Wit, 2002).

Seafood consumption in Singapore averaged 46.3±36.9 and 49.9 ±40.0 g/day for women and men respectively in 1998 (Ministry of Health, Singapore, 2001) which is comparable to typical seafood consumption rates in Taiwan (Chien et al.,2003), but more than twice the intake in San Francisco, USA (Greenfield et al., 2000). Most seafood consumed in Singapore is imported – principally from Asia (e.g. prawns from Thailand), but also from Europe (e.g. salmon from Norway) and the Americas (e.g. scallops from U.S.)

In this study, the level of a variety of heavy metals (i.e. As, Cd, Cu, Pb, Hg) were measured in the seafood types consumed in Singapore.
2. Materials and methods

Sample collection and preparation
Twenty types of seafood samples (shark and tuna steak; shark fin; canned tuna; fillet of cod, stingray, silver pomfret, selar, kuning, conger eel, greasy grouper, sea bass, song fish, salmon; squid ring; grey and giant tiger prawn; flower crab, green mussel, scallop) were collected from local supermarkets in 2002-2003. The selection of the seafood types was based on supermarket sales figures and represent typical consumption patterns in Singapore. Samples were purchased in their common packaging, and in the laboratory, the edible portions of the samples were homogenized in a stainless steel blender prior to analysis.

Heavy metal analysis
All Teflon and glassware used for sample analysis was washed in 2% HNO₃ and rinsed with deionised water to remove any contaminants prior to use. Approximately 2 g of homogenized wet tissue for each seafood type was accurately weighed in a PTFE vessel containing 10 mL of concentrated HNO₃. The mixture was then digested in a MarsX microwave oven using the following program: ramp to 115°C in 10 min, hold for 10 min. Samples were analyzed by ICP-MS Elan 6100 (Perkin-Elmer, Wellesley, MA, USA) for As, Cd, Cr, Cu, Hg, Pb and Zn. Procedural blanks were analysed after every six samples. Two certified standard reference materials, SRM 2976 green mussel (NIST, Gaithersburg, MD, USA) and DORM-2 dogfish muscle (NRC, Ottawa, Canada) were analysed to validate the complete analytical method.

Risk assessment calculations
A mean daily intake for seafood of 48.1 g/day was used in dietary exposure calculations, together with an average body weight of 60 kg. The estimate mean daily intake of contaminants from seafood was calculated as the mean daily intake of seafood multiplied by the mean concentration of contaminants in the twenty seafood types (Bayen et al., 2005). Using the methodology specified by the US Environmental Protection Agency, mean lifespan concentration of contaminants was calculated according to two hypotheses: 'nondetect samples are equal to zero' i.e. contaminant values below the limit of analytical detection are ascribed a value of zero; and 'nondetect samples are equal to half of the limit of detection' i.e. contaminant values below the limit of analytical detection are ascribed a value of 50% of the limit of analytical detection. The second hypothesis tends to overestimate the concentration, and therefore the intake, if the
samples are truly free of contamination.

Statistics
All statistical data analyses were performed using XSTAT 6.19 software. Principal component analysis was also used in this study.

3. Results
Concentrations of heavy metals in mug/g wet weight (ww) of As, Cd, Cu and Hg in the seafood samples analysed are present in Table 1. Limits of detection for heavy metals in seafood were as follow: 0.05 mug/g ww for As, 0.11 mug/g ww for Cd, 0.30 mug/g ww for Cu, 0.02 mug/g ww for Hg, and 0.18 mug/g ww for Pb. Lead was detected in only five types of seafood, ranging from 0.19 to 1.21 mug/g ww, with the peak concentration present in salmon fillets. Average concentration of heavy metals in seafood as well as their relative occurrence between seafood types reported in Table 1.

Table 1: Mean level, occurrence and mean intake of heavy metals from seafood for a 60 kg person in Singapore.

<table>
<thead>
<tr>
<th>metal</th>
<th>Mean level (range)¹ in mug/g ww</th>
<th>Occurrence amongst the seafood types</th>
<th>Mean daily intake (mug/kg body weight/day) no detect=0</th>
<th>Mean daily intake (mug/kg body weight/day) no detect = 0.5 DL</th>
</tr>
</thead>
<tbody>
<tr>
<td>As</td>
<td>3.88 (BLD-14.18)</td>
<td>95%</td>
<td>3.1</td>
<td>3.1</td>
</tr>
<tr>
<td>Cd</td>
<td>0.13 (BLD-0.50)</td>
<td>30%</td>
<td>0.08</td>
<td>0.11</td>
</tr>
<tr>
<td>Cu</td>
<td>2.73 (BLD-25.53)</td>
<td>95%</td>
<td>2.2</td>
<td>2.2</td>
</tr>
<tr>
<td>Hg</td>
<td>0.09 (BLD-0.58)</td>
<td>45%</td>
<td>0.07</td>
<td>0.07</td>
</tr>
<tr>
<td>Pb</td>
<td>0.22 (BLD-1.21)</td>
<td>25%</td>
<td>0.12</td>
<td>0.18</td>
</tr>
</tbody>
</table>

¹Mean concentration (range between brackets) amongst the various types of seafood for the hypothesis “No detect=0.5 detection limit”.

4. Discussion
To undertake risk assessment linked with the consumption of food, the first
step is to compare the levels with the maximum residue limits. Samples were higher than respective MRLs in three cases relative to Singapore standards: the As standard of 1 ppm was exceeded in 70% seafood types; the Cd standard of 0.2 ppm for seafood other than mollusks was exceeded in selar and kuning fishes, as well as grey prawn; and the Hg standard of 0.5 ppm was exceeded in conger eel. US standards for similar elements are higher and were not exceeded.

Data comparison with consumption studies conducted elsewhere shows that mean daily intake of contaminants from seafood in Singapore corresponds to the lower range of what is reported for Pb, Cd, Cr from the whole diet in Italy, but exceeded the upper range in the case of Hg (Alberti-Finanza et al., 2003). Mean daily intake of Cd and Pb from seafood in Singapore corresponds to 90% and 70% of the total intake from a whole diet in Bangkok, Thailand (Zhang et al., 1999).

The 'oral reference dose' (Oral PfD) is an estimate of the daily exposure of a person to a contaminant that is likely to be without appreciable risk of a deleterious noncarcinogenic effect during a lifetime (US EPA; http://www.epa.gov/iris/). Daily intakes of heavy metals from seafood are below the oral RfD, except for As, although our study did not characterize the species of As present. If it is assumed that 2% of the total As in fish and shellfish is in the inorganic form (Li et al., 2003), the intake of inorganic As from seafood would be below the oral RfD.

The 'cancer benchmark concentration' represent the exposure concentration at which a lifetime cancer risk equates to one case in one million persons. The level is defined as a public health protective concentration in the Congressional House Report to the Food Quality Protection Act of 1996 in the USA. Cancer benchmark concentrations were exceeded for As. The 'cancer hazard ratio' is the ratio of the mean daily intake for a specific contaminant relative to the cancer benchmark concentration. The cancer hazard ratio of seafood consumption was equal to 3109 for As. Once again, it is important to note that the cancer benchmark for As is based on the inorganic form of As. However, using a value of 2% of the total As as its inorganic in fish and shellfish still results in the cancer hazard ratio greater than one, meaning that, according to Dougherty et al., (2000), a significant number of people are potentially at risk in Singapore over a lifetime of seafood consumption. It is worth mentioning that these calculations are derived from raw tissue analysis and more information is required on the effect of seafood cooking in Singapore on the final load of contaminants ingested. It is also important to consider that the standard deviation for available seafood consumption data in Singapore is large, and significant levels of variability are likely to exist between ethnic subgroups of the population.
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References


