A survey of cadmium in Pacific oysters (*Crassostrea gigas*) and its implication to the shellfish industry and human health

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Background

- Cadmium sources
  - Natural and anthropogenic
- Human exposure
  - Smoking and food
- Human health impacts
- The PTWI
  - 7 µg Cd/kg of body weight from all sources, or about 60 µg Cd/p/d for a 60 kg person
Problem Identification

• Hong Kong and British Columbia
  – 60% of samples over 2 ppm, mean 2.63 ppm
• Hong Kong and Hood Canal, WA
  – Oysters ranged from 1.2-4.9 ppm, mean 2.9 ppm
• Codex Alimentarius Commission
  – Deliberation of 1-ppm ML for molluscan shellfish
• International community
  – EU - 1 ppm ML, HK - 2 ppm ML
Cd in Hood Canal oysters, 2003

Replicate composite samples at 3 Hood Canal beaches

2.2 ppm
USDA funded study

- $450,000 2004-2006
- Integrated Research Education and Extension Competitive Grants Program - National Integrated Food Safety Initiative
- $3,000 - Graduate Women In Science
Project Partners

- Oregon State University – Seafoods Laboratory
- California Sea Grant – UC Davis
- Pacific Shellfish Institute
- Integral Consulting
  - Hong Kong University of Science & Tech.
- University of Alaska
Research Goals

- To evaluate the spatial distribution of cadmium in west coast Pacific oysters
- To identify factors that may influence cadmium concentrations
- To evaluate the impact of cadmium enrichment on the shellfish industry and human health
Sampling Methods

Flag transect

Collect 60 oysters
Sampling Methods

Collect local water  Set up assembly line
Sampling Methods

Remove fouling  Scrub oysters  Rinse oysters
Sampling Methods

Place into bags

Ship to AmTest
Laboratory Analysis
Spatial Distribution

Of the 92 oyster composites...

- Cd concentrations ranged from 0.44-2.5 ppm
- Mean and standard dev. – 1.24 ± 0.57 ppm
- Weak trend observed with concentrations increasing in a northward and seaward direction
Cadmium Concentrations in Pacific Oysters

Cadmium (μg/g)

CD
- 0.47 - 1.00
- 1.01 - 2.00
- 2.01 - 3.00

Miles
Cd concentrations from 5 regions

56% of composites exceeded 1 ppm, 17% exceeded 2 ppm
Possible Explanations for Spatial Distribution

• Large scale forces
  – Geology
  – Ocean currents
  – Coastal upwelling

• Localized forces
  – Rainfall
  – Flushing patterns
Potential Sources & Factors Influencing Cd concentrations

- Seasonal sampling at 5 geographic locations (SPS, HC, NHC, NPS, CE)
  - Oyster tissue
  - Sediments (metals, grain size, TOC)
  - Water (total & dissolved metals, TSS, plankton)
  - Physical parameters (temperature, salinity)
Sampling Methods
Temperature & Salinity

- WDOE - Marine water quality monitoring searchable database
  - 1990-2000
  - Surface (.5-2.5m) and depth (9-11m)
  - January, April, July and October
  - 5 DOE stations in close proximity to study sampling sites
Cd concentrations (ppm) in sediments from 5 locations
Water Results

- Total Cd ranged from .00005 mg/l (Hamma Hamma) to .00035 mg/l (Thorndyke)
- Dissolved Cd was < .0005 mg/l at all stations
- TSS ranged from 10-15 mg/l at all stations with exception of Willapa Bay at 100 mg/l.
Cd accumulation increased with increasing temperature, particularly at 20°C, in 5 species of marine bivalves. (Hung 1982, Jackim et al. 1977)
Seawater Salinity

Hamma Hamma

Seasonal salinities at surface and depth

5 geographic locations

January surface salinities

A decrease in salinity from 30 ppt to 20 ppt increased Cd uptake in 4 species of marine bivalves by as much as 24-400%.

(Jackim et al. 1977)
Oyster Tissue Weight

- Weak negative relationship between tissue weights and Cd concentrations ($rs=-.30$, $p=.004$)
- Tissue dilution theory!
Seasonal Implications

High Cd - Jan

Decrease in weight with utilization of glycogen stores

Low Cd - Aug

Increase in weight with feeding and gamete production

(Boyden and Phillips 1981, Harrison 1979)
Growth Rates

- The faster the growth rate, the shorter the amount of time spent on the oyster bed
- Hood Canal vs. south Puget Sound
- Growth rate experiment
Conclusions

- Certain shellfish growing areas may be more suitable than others in terms of Cd enrichment.
- Tissue Cd levels do not appear to be directly related to Cd levels in seawater or sediments.
- Tissue concentrations may be more influenced by factors that increase the rate of Cd uptake (temperature & salinity).
- Tissue weight and growth rate may be important determinants of Cd levels.
Human Health

- Only 4.8% of the general population consumes molluscan bivalves (MRCA 14-day survey)
- Of those, the 90\textsuperscript{th} percentile daily intake value for all ages is 15 g/p/d (USFDA 1993)

Recent fish consumption surveys for PS Tribes indicate that some tribes consume 20 times the amount of seafood consumed by the average American.
Tribal Fish Consumption Surveys

• Tulalip and Squaxin Island Tribes
  – Adult shellfish consumption rate = 22 g/d
  * Weekly intake – 264 µg (n-smokers) and 333 µg (smokers)

• Suquamish Tribe
  – Adult shellfish consumption rate = 133 g/d
  – 9 g/d (28 g/d – 90th percentile) for oysters
  * Weekly intake – 318 µg (ns) and 334 µg (s)
  * 90th % - 457 µg (ns) and 527 µg (s)
# Cd intake based on 6 oysters/week

<table>
<thead>
<tr>
<th></th>
<th>Cd concentration (µg/g)</th>
<th>ingested (µg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowest regional mean</td>
<td>0.75</td>
<td>197.55</td>
</tr>
<tr>
<td>Highest regional mean</td>
<td>2.09</td>
<td>550.51</td>
</tr>
<tr>
<td><strong>Average (all regions)</strong></td>
<td><strong>1.24</strong></td>
<td><strong>326.6</strong></td>
</tr>
<tr>
<td>Maximum value</td>
<td>2.5</td>
<td>658.5</td>
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<tr>
<td>Hong Kong limit</td>
<td>2</td>
<td>526.8</td>
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<tr>
<td>CODEX proposed limit</td>
<td>1</td>
<td>263.4</td>
</tr>
<tr>
<td><strong>FAO/WHO PTWI</strong></td>
<td><strong>NA</strong></td>
<td><strong>420-490</strong></td>
</tr>
</tbody>
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* One oyster = 43.9 grams
Cd & Shellfish Human Health Studies

• (Sharma 1983, McKenzie et al. 1988) – Cd in oyster fishermen after consuming New Zealand dredge oysters
  – Cd in participant’s blood and urine not elevated in proportion to amount ingested
  – Little Cd appeared to be absorbed and was instead excreted in feces
  – Smoking found to have more pronounced effect on blood Cd levels than oyster consumption
(Vahter et al. 1996) – Evaluated Cd uptake in women consuming mixed diet (10.5 µg/Cd/d) or shellfish diet (22.3 µg/Cd/d).

- No difference in blood or urine Cd concentrations between two groups
- Cd excreted in feces corresponded to 99-100% of Cd ingested for both groups.
At-risk Populations

- Elderly, diabetics, indigenous populations, malnourished, women with low iron stores
  - Individuals with low iron stores found to have greater Cd burdens (Saratug & Vahter studies)
  - Ca, protein, vit C, vit E, Se, Zn shown to decrease Cd absorption in human & animal studies
  - Cd accumulation in liver and kidneys decreased by 80% after supplementing diet w/ Ca, P, Fe, Zn
  - Diet rich in Zn believed to offer considerable protection against Cd accumulation (Sullivan 1984)
Cd & Zn Relationship in Oysters

\[ R^2 = 0.59 \]

rs = 0.78, p=0
Conclusions

• Individuals that consume WA oysters at mean consumption rates and mean Cd concentrations remain below the PTWI

• Individuals may exceed the PTWI if they consume large amounts of oysters (90th %) and smoke, and/or if they consume greater than 6 oysters/wk at concentrations over 1.6 ppm (ns) and 1.3 ppm (s)

• While the health risks associated with ingesting Cd enriched shellfish remains somewhat unclear, evidence does indicate that Cd uptake may be enhanced in certain populations.
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Questions