Short Communication

SOME BIOACCUMULATION FACTORS AND BIOTA-SEDIMENT ACCUMULATION FACTORS FOR POLYCYCLIC AROMATIC HYDROCARBONS IN LAKE TROUT

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Abstract—Bioaccumulation factors (BAFs) and biota-sediment accumulation factors (BSAFs) for phenanthrene, fluoranthene, pyrene, benz[a]anthracene, and chrysene/triphenylene were calculated using the tissue data of Zabik et al. for Salvelinus namaycush siscowet with a 20.5% lipid content, the water data of Baker and Eisenreich, and the sediment data of Baker and Eisenreich for the Lake Superior ecosystem. Log BAFs, both lipid normalized and based on the freely dissolved concentration of the chemical in the water, of 1.95, 3.22, 4.72, 4.73, and 3.61 were calculated for phenanthrene, fluoranthene, pyrene, benz[a]anthracene, and chrysene/triphenylene, respectively. The BSAFs for phenanthrene, fluoranthene, pyrene, benz[a]anthracene, and chrysene/triphenylene were 0.00011, 0.00016, 0.0071, 0.0054, and 0.00033, respectively.

Keywords—Polycyclic aromatic hydrocarbons Bioaccumulation factors Biota-sediment accumulation factors

INTRODUCTION

An extensive but unsuccessful literature search was performed for field-measured bioaccumulation factors (BAFs) and biota-sediment accumulation factors (BSAFs) for polycyclic aromatic hydrocarbons (PAHs); no reported values were found for fish. The lack of BAFs and BSAFs for PAHs occurs in part because PAHs are metabolized by fish, resulting in very low or nondetectable concentrations of the parent PAHs in fish tissues [1]. Recently, we found three papers that provided concentrations of PAHs in lake trout (Salvelinus namaycush siscowet) [2], water column [3], and sediments [4] of the Lake Superior ecosystem—precisely the information needed to calculate of BAFs and BSAFs for the PAHs. In this short communication, these BAFs and BSAFs are presented and evaluated.

RESULTS AND DISCUSSION

The lake trout were collected on June 19, 1991, at Marquette (MI, USA; 46°41′.61N, 87°19′.21W) on Lake Superior. Their mean age, weight, and length were 9.2 ± 0.9 years, 1.3 ± 0.1 kg, and 52.7 ± 1.8 cm, respectively, and 71% of the lake trout were male [2]. The PAH data for the tissues as used in this report were for the uncooked lake trout samples, which were skin-off fillets with the belly flap, skin, lateral line, and associated fat removed [2]. The water and sediment samples were collected in August 1986 from six and three stations, respectively, on Lake Superior, and these sampling stations were on a transect running from the Keweenaw Peninsula (47°; 40′N, 84°45′W) to Whitefish Bay (46°40′N, 84°45′W) [3]. The raw data, log BAFs calculated on a number of bases, and BSAFs are reported in Table 1.

Some temporal and spatial differences between the collection dates and locations for the fish and the other samples were found, but the significance of these differences cannot be assessed because of lack of data. However, Jeremiason et al. [5] reported that PAH concentrations on Lake Superior settling solids collected in surface traps have not changed significantly from 1984 to 1991 for 22 of the 24 PAHs measured. The two PAHs that did change significantly, fluorene and phenanthrene, decreased by a factor of approximately seven. Additionally, PAH profiles in sediment cores collected from 1991 to 1993 from northern Lake Michigan [6] suggest no recent decreases in PAH concentrations.

From an analytic standpoint, larger uncertainties existed for phenanthrene and fluoranthene BAFs and BSAFs because both chemicals were present in the tissues at concentrations just greater than the method detection limit (i.e., 0.05 ng/g wet wt). Of the six samples analyzed, phenanthrene and fluoranthene had two and one values, respectively, less than the detection limit, whereas the remaining three chemicals had all values greater than the detection limits. Overall, we believe the BAFs and BSAFs for benz[a]anthracene, chrysene/triphenylene, and pyrene are of better quality than those for phenanthrene and fluoranthene because of their concentrations in the tissues being significantly greater than the method detection limit.

For comparison, laboratory-measured bioconcentration factors (BCFs) for PAHs are listed in Table 2 for phenanthrene and pyrene. The BAF for pyrene is in reasonable agreement with the measured BCFs. In comparison to phenanthrene, for which some of the measured values were less than the method detection limit for the fish, the BAF is smaller than the measured BCFs by at least two orders of magnitude. These comparisons should be viewed with some caution because of the large differences in size and, possibly, in metabolic abilities between the lake trout (1.3 kg) and the larval fishes and guppies used for BCF measurements.

Another way of evaluating these values is to compare ratios of the BAFs, BSAFs, and biota-suspended solids accumulation factors (BSSAFs) (Table 1) for the individual chemicals, that is, the ratio of the BAF for fluoranthene to the BAF for pyrene,

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Table 1. Calculated bioaccumulation factors (BAF) for polycyclic aromatic hydrocarbons

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Log $K_{ow}$</th>
<th>Water (ng/L)</th>
<th>Particulates (ng/g dry wt)</th>
<th>Sediments (ng/g dry wt)</th>
<th>Fish (ng/g wet wt)</th>
<th>Log BAF (L/kg wet wt)</th>
<th>Total (L/kg lipid)</th>
<th>Freely dissolved (L/kg lipid)</th>
<th>BAF: $K_{ow}$ (kg OC/kg lipid)</th>
<th>BSAF (kg OC/kg lipid)</th>
<th>BSSAF (kg OC/kg lipid)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phenanthrene</td>
<td>4.57</td>
<td>3.49 (1.71)</td>
<td>171.4 (215)</td>
<td>81.1 (14.8)</td>
<td>0.06 (0.02)</td>
<td>1.26 (61)</td>
<td>1.94</td>
<td>1.95</td>
<td>0.00240</td>
<td>0.00011 (40)</td>
<td>0.00040 (131)</td>
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<tr>
<td>Fluoranthene</td>
<td>5.23</td>
<td>0.35 (0.07)</td>
<td>45.2 (35.5)</td>
<td>103.2 (49.1)</td>
<td>0.12 (0.12)</td>
<td>2.52 (43)</td>
<td>3.19</td>
<td>3.22</td>
<td>0.00984</td>
<td>0.00016 (61)</td>
<td>0.0028 (87)</td>
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<tr>
<td>Pyrene</td>
<td>5.18</td>
<td>0.28 (0.11)</td>
<td>35.6 (28.6)</td>
<td>59.8 (28.1)</td>
<td>2.91 (0.51)</td>
<td>4.02 (43)</td>
<td>4.68</td>
<td>4.72</td>
<td>0.343</td>
<td>0.0071 (50)</td>
<td>0.088 (82)</td>
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<tr>
<td>Benz(a)anthracene</td>
<td>5.91</td>
<td>0.16 (0.15)</td>
<td>62.1 (67.3)</td>
<td>41.4 (16.7)</td>
<td>1.54 (0.32)</td>
<td>3.98 (96)</td>
<td>4.61</td>
<td>4.73</td>
<td>0.0654</td>
<td>0.0054 (45)</td>
<td>0.027 (110)</td>
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<tr>
<td>Chrysene/triphenylene</td>
<td>5.81</td>
<td>0.37 (0.21)</td>
<td>69.9 (35.5)</td>
<td>123.7 (40.1)</td>
<td>0.28 (0.10)</td>
<td>2.88 (67)</td>
<td>3.53</td>
<td>3.61</td>
<td>0.00632</td>
<td>0.00033 (48)</td>
<td>0.0043 (62)</td>
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<td>Dissolved OC (mg/L)</td>
<td>1.63 (0.50)</td>
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<td>Total suspended solids</td>
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<td>Lipid (%)</td>
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</table>

- [3], chemical concentration in the water passing a 0.7-μm glass-fiber filter with both freely dissolved chemical and that chemical’s associated dissolved organic carbon ($C_{fd,DOC}$).
- [4].
- [2].
- [7].
- Active (standard deviation).
- Log$_{10}$ BAF (coefficient of variation in percent).
- Average (coefficient of variation in percent). BSAF = biota-sediment accumulation factor, BSSAF = biota-suspended solids accumulation factor, OC = organic carbon.
the ratio of the BSAF for fluoranthene to the BSAF for pyrene, and the ratio of the BSSAF for fluoranthene to the BSSAF for pyrene (Fig. 1). The BAFs, BSAFs, and BSSAFs all provide a measure of the bioaccumulation potential for the five PAHs in the Lake Superior ecosystem, and these accumulation factors must be consistent with each other. This consistency is expected, because these compounds are so similar. They belong to the same chemical class, have comparable fate and transport behaviors, and arise from the same sources. As shown in Figure 1, these ratios are similar. If large differences in these ratios existed for the five PAHs in Figure 1, this would suggest that some of the data were not accurate or representative of the PAH concentrations in the Lake Superior ecosystem. This consistency, as shown in Figure 1 for the BAF, BSAF and BSSAF ratios, lends credibility and support to the calculated values. Interestingly, the greatest dissimilarity in these ratios occurs for phenanthrene (Fig. 1), and this chemical has the largest uncertainties from an analytic standpoint as well.

The relative order of the rates of metabolism for the five PAHs can be obtained by dividing the BAF of the chemical by its corresponding $K_{ow}$ (Table 1) and by examining the BSAFs and BSSAFs. Of the five PAHs examined, pyrene and phenanthrene have the slowest and the fastest rate of metabolism in the fish, respectively, because their BAF/$K_{ow}$ ratio, BSAF, and BSSAF are the largest and the smallest, respectively, of the five PAHs. Listed by increasing rate of metabolism, the relative order would be pyrene, benz[a]anthracene, chrysene/triphenylene, fluoranthene, and phenanthrene.

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**REFERENCES**


