Assessment of Air-Water Exchange of Polychlorinated Biphenyl Compounds: New Insights from a Global Database

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I. INTRODUCTION

Industrial production of polychlorinated biphenyls (PCBs) began in the 1930s, and due to their toxic, bioaccumulative, and persistent nature production were banned internationally with the introduction and enforcement of Stockholm Convention in 2001 and 2004, respectively.

Certain PCB congeners can travel long distances in the environment, being deposited to water surfaces such as lakes, estuaries, and oceans, and then be later re-emitted into the atmosphere (Fig. 1).

Air-water exchange fluxes of PCBs are frequently estimated using the Whitman two-film method, whereas application of micrometeorological techniques to measure air-water exchange fluxes over water surfaces are limited.

II. OBJECTIVES

The overall objective of this study is to assemble a global database of measurements of air-water exchange fluxes and fugacities of PCBs to:

1. characterize the spatial and temporal variability in air-water exchange
2. study the factors controlling the direction and magnitude of exchange flux or fugacity

III. METHODS

Database development

- Literature review
- Metadata collection

Spatial and temporal analyses

- Air-water exchange fluxes/fugacities for 45 PCB congeners, and meteorological parameter values, entered into database
- Data visualization
- Time-trend analysis
- Sensitivity test
- Uncertainty test

Sensitivity and uncertainty analyses

- Error propagation
- Uncertainty in air-water exchange flux/fugacity estimates tested

IV. RESULTS

1. Spatial Distribution of PCB Air-Water Exchange Measurement Locations

![Image of global spatial distribution of measurement locations](Figure 1)

2. Time-Trend Analysis of Measured PCB Air-Water Exchange Fluxes

![Graph showing time-trend analysis of PCB air-water exchange fluxes](Figure 2)

Table 1. Comparison of Measured Net exchange Fluxes of PCB at Various Geographic Locations.

<table>
<thead>
<tr>
<th>Air-water exchange</th>
<th>PCB Congener (9)</th>
<th>North America</th>
<th>Asia</th>
<th>Annual/Seasonal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net flux (ng m⁻² day⁻¹)</td>
<td>285 (PCB 118)</td>
<td>U.S.</td>
<td>Taiwan</td>
<td>Annual</td>
</tr>
<tr>
<td>Net flux (ng m⁻² day⁻¹)</td>
<td>2.31 (914)</td>
<td>U.S.</td>
<td>Summer</td>
<td>Long range</td>
</tr>
<tr>
<td>Net flux (ng m⁻² day⁻¹)</td>
<td>2.10 (342)</td>
<td>Turkey</td>
<td>Winter</td>
<td>Local</td>
</tr>
</tbody>
</table>

Fugacity is the tendency of a substance to prefer a liquid, solid, or gas phase. Fugacity quotient is the ratio of fugacity in air ($f_a$) and water ($f_w$), and denoted as $f_a/f_w$. Net volatilization: $f_a > f_w$ and net deposition: $f_a < f_w$.

3. Sensitivity Analysis

![Graph showing sensitivity analysis](Figure 3)

From Table 2: Highest and lowest uncertainties in flux estimates were found for PCB congeners 18 and 28, respectively.

V. CONCLUSIONS

1. The magnitude of the measured PCB flux varies and is unevenly distributed across the globe. Rural areas tend to have a lower net annual flux whereas urban areas have a higher flux when compared in the U.S.
2. Net exchange flux is most sensitive to temperature and wind speed.
3. Overall uncertainty in net exchange flux is dependent on uncertainty in gaseous and dissolved concentrations of PCB, wind speed, and temperature.

VI. REFERENCES


VII. ACKNOWLEDGEMENT

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