Increased Atmospheric Deposition of SOCs Due to Large-Scale Sediment Resuspension in Southern Lake Michigan

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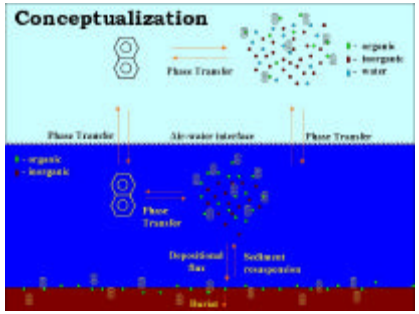
ABSTRACT

In March, 1998, an intense, northerly wind-driven storm created a well-developed plume of resuspended sediment that was observed to extend over the entire coastline of the southern basin of Lake Michigan (~300 km). The effect of this plume event on the cycling of semivolatile organic compounds (SOCs) was investigated using a *two-pronged sampling strategy*. First, discrete air and water samples were collected during intensive campaigns before and after the appearance of the resuspension event. Second, settling sediment was collected using a time-integrated sequencing trap which collected settling material before, during, and after the resuspension event. Data from the discrete samples indicated that concentrations of dissolved phase ΣPCB (sum of 87 polychlorinated biphenyls) declined significantly (a = 0.05) from 219.3 pg/L ± 54.4 pg/L before the event to 128.4 pg/L ± 41.8 pg/L after the event. Dissolved phase ΣPAH (sum of 35 polycyclic aromatic hydrocarbons) decreased from 17.7 ng/L ± 9.5 ng/L to 10.7 ng/L ± 16.7 ng/L. Data from the sediment traps were used to estimate continuous change in dissolved phase concentrations. Using sediment/water partition coefficients calculated from the discrete sampling, and organic carbon normalized PCB and PAH concentrations on the trap material, we have predicted dissolved phase concentrations over six months at the same location. Under both strategic approaches to estimating the dissolved concentration, we have estimated the effect of the resuspension event on atmospheric deposition. The estimated loading from increased gas-phase deposition due to the resuspension event was 8 kg for PCBs and 2200 kg for PAHs over the 40 day lifetime of the nearshore event. For PCBs, this short-term load represents ~57% of a recent annual net deposition of ΣPCBs to a similar area. The short-term gas phase deposition estimate for ΣPAHs is a large portion of previous dry deposition flux estimates to the entire lake on an annual scale (55 to 610%). The magnitude of this effect is partly a result of high atmospheric concentrations measured near the Chicago/Gary and Milwaukee areas.



HYPOTHESES:

#1. The plume is made up of contaminated sediments. When resuspended, the sediments contaminate the water. This enrichment of the water causes increased short-term volatilization of SOCs

OR

#2 The plume is made up of clean sediment. When resuspended, the particles adsorb or scour SOCs from the water to the particles. This scavenging of the water causes increased short-term deposition.

SAMPLING STRATEGY

Figure 2. Locations of discrete surface water samples, continuous air sampling tracts, and the NOAA/GLERL time-integrated sediment trap (97-T24A) used for this study. Discrete sampling was performed in the basin both before (1/28/98 - 2/4/98) and after (3/28/98 - 3/30/98) the large magnitude resuspension event that transpired in March 1998. Water samples were generally acquired nearshore (15m isopleth) as to best classify the impact of episodic sediment resuspension on organic contaminant dynamics in water. The sediment trap collected settling material from the water column in nine-day increments from December 1997 to May 1998 (before, during, and after the March 1998 event).

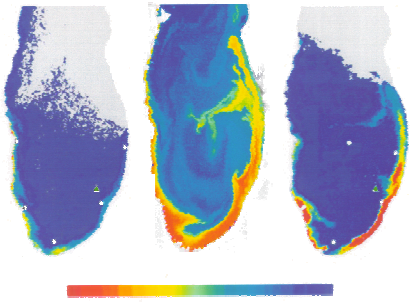


Figure 3. Reflectance imagery from before, during, and after the height of the resuspension event. Water and air samples were collected before (1/29/98 to 2/4/98) and after (3/27/98 to 3/31/98) the event. Water sampling sites (white circles) and the sequencing sediment trap (green triangle) are indicated on the left and right plots. The gray color represents cloud cover.

The locations of the water sampling sites for the March campaign were either located directly within the spatial extent of the plume or very close to the edge of the plume's extent, allowing for investigation of the event's impact.

RESULTS

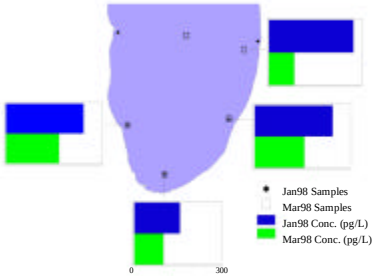


Figure 4. ΣPCB (87 congeners) dissolved phase concentrations for discrete water samples acquired from similar nearshore locations both before and after the large scale sediment resuspension event of March 1998. ΣPCB dissolved phase concentrations were significantly lower in March (128.4 pg/L ± 41.8 pg/L) following the plume event when compared to January concentrations (219.3 pg/L ± 54.4 pg/L) (Student's t-test, a=0.05). Similar results were found for analytical results of dissolved phase ΣPAHs (36 compounds) as well. Lower concentrations of dissolved SOCs after the March event support the hypothesis that the resuspension event acts to 'scour' dissolved phase contaminants from the water column.

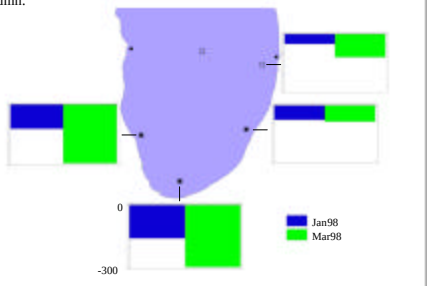


Figure 5. Instantaneous PCB air-water exchange fluxes calculated from air and water samples acquired from similar sampling sites before and after the large magnitude resuspension event of March 1998. The magnitude of gas phase depositional flux of PCBs and PAHs *into* the lake from the overlying atmosphere was generally higher for similar discrete points in space following the major sediment resuspension event. We contend that the resuspension event was responsible for bringing about the observed increase in depositional flux.

This observed depositional increase was greater for sampling locations near the Chicago/Gary urban complex, which is a documented source area for gas phase toxics. Thus, we believe that a synergistic relationship exists between the sediment resuspension plume and the plume of contaminated air emanating from the adjacent Chicago/Gary urban complex. We have estimated the increased atmospheric input of gas-phase PCBs and PAHs to an area of Lake Michigan where the sediment resuspension event and the urban airborne contaminant plume overlap due to this relationship to be 8 kg and 2200 kg respectively during the ~40 day lifetime of the resuspension event.

This additional loading of PCBs and PAHs represents a previously unknown loading of toxic contaminants to the Lake Michigan.

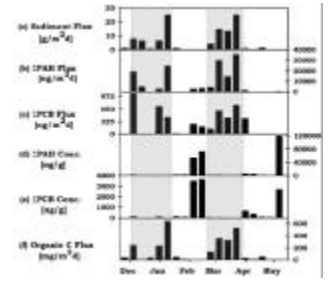


Figure 6. (a) Sediment and (b,c) contaminant flux, (d,e) contaminant mass-based concentration, and (f) organic carbon flux as measured on settling particulate matter captured by GLERL sediment trap 97T24A from December 1997 to May 1998. Each vertical black bar represents a nine-day sequential collection period. The gray areas through each plot identifies the two plume events transpiring in January and March 1998 as observed in the temporal profile of sediment flux.

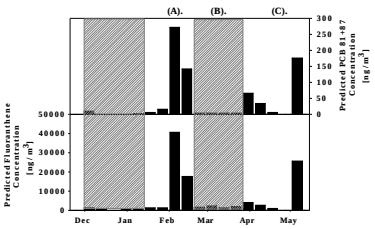


Figure 7. Predicted dissolved phase concentrations of PCB 81+87 (middle) and fluoranthene (bottom) from December 1997 to May 1998. These concentrations were calculated from the chemical concentrations on settling particles (figure 6). Each black bar represents predictions and/or fluxes for a nine-day collection interval. The shaded areas represent the appearance of the two sediment resuspension events in 1998 as determined from the temporal profile of sediment mass flux. The time scale presented in this diagram portrays before (A.), during (B.), and post-resuspension event (C.) time periods relative to the large-magnitude event in March 1998.

SUMMARY

The sediment resuspension event scours dissolved phase contaminants from the water column. As a result, a short-term increased gas phase deposition of atmospheric contaminants was observed.

An estimate of this increased input is 8 kg of ΣPCBs and 2200 kg of ΣPAHs, which is ~57% and 55-610% of previous atmospheric loading estimates to the southern basin in the absence of sediment resuspension, respectively.

In southern Lake Michigan, the impact of the sediment resuspension event is magnified because of heavy atmospheric contamination originating in the Chicago/Gary urban industrial region.