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REGIONAL MONITORING PROGRAM FOR TRACE SUBSTANCES

MERCURY TRANSPORT TO SAN FRANCISCO BAY THROUGH THE SACRAMENTO-SAN JOAQUIN RIVER DELTA

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ABSTRACT

Between January 2002 and January 2005, water samples were collected at a downstream location of the Sacramento River, CA to quantify mercury concentrations and loads in surface runoff associated with large storm events and re-suspension of river sediments. Mercury concentrations ranged from 3.2 to 14 ng/L and showed a strong correlation (r^2 = 0.8) to suspended sediment concentrations (SSC). The collection of continuous SSC measurements by U.S. Geological Survey at the study location allowed for extrapolation of the limited mercury data to estimate daily average total mercury loads. For the four years of monitoring in water years (WYs) 2002 - 2005, daily mercury loads ranged from 3 to 4,140 g, while annual mercury loads ranged from approximately 58 ± 20 kg in WY 2002 to 110 ± 37 kg in WY 2004. Results from this study have helped refine current estimates of mercury loads to the Bay from the Sacramento-San Joaquin River system. In the context of other significant transport pathways and numerical models, these refined estimates will further assist in understanding the long-term fate of mercury and the recovery of water quality of the Bay.

INTRODUCTION

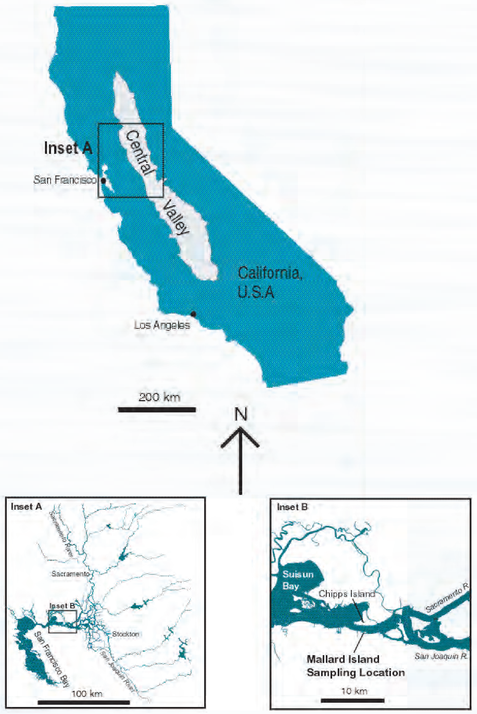
San Francisco Bay is currently listed as impaired on the Clean Water Act 303(d) list for mercury due primarily to elevated concentrations in sport fish and the issuance of current fish consumption advisories. The large magnitude of sediment and runoff entering San Francisco Bay through the Sacramento-San Joaquin River Delta makes these major rivers important transport pathways for mercury and other particle-associated contaminants. Historic gold and mercury mining in the Sierra Nevada and Coast Range Mountains, as well as expanding urbanization in the Central Valley of California, are ongoing sources of mercury to the Bay. Measurements of mercury concentrations during storm events provided the necessary information for estimates of average mercury loads and annual variability.

MATERIALS AND METHODS

The sample location, Mallard Island, is approximately eight kilometers downstream of the confluence of the Sacramento and the San Joaquin Rivers. Sampling was conducted focusing on floods during the wet season of 2002 to 2005. One to three samples were taken per day to characterize trace contaminant variation in response to floods. Samples were collected about 1 m below the water surface at the end of a pier near the deep water ship channel. Filtered and unfiltered water samples were collected using established methods following trace metal clean protocols (Flegal et al. 1991).

SAMPLING LOCATION AT MALLARD ISLAND, CA
PHOTOGRAPH BY JON LEATHERBARROW

WATER SAMPLING AT MALLARD ISLAND, CA
PHOTOGRAPH BY JON LEATHERBARROW



MALLARD ISLAND SAMPLING LOCATION

RESULTS AND DISCUSSION

Total mercury concentrations ranged from 3.2-14 ng/L. Despite dissolved concentrations contributing 11-24% of the total mercury concentrations, total mercury still showed a strong correlation (r^2 = 0.8) to suspended sediment concentration (SSC) (Figure 1).

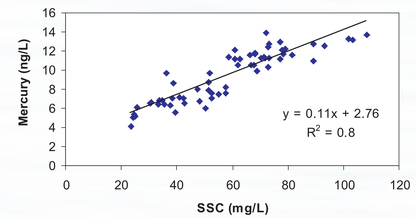


FIGURE 1
THE RELATIONSHIP BETWEEN TOTAL MERCURY AND SSC FOR SURFACE WATER (1 M) SAMPLES COLLECTED AT MALLARD ISLAND FROM 2002-2005.

Mercury data collected during this study appear to form different relationships with suspended sediment based on electrical conductivity (Figure 2). The breakpoint of 2 mS/cm is not related to a particular discharge magnitude because the location of the sampling site is influenced by tidal cycles and, even during floods, reverse flow does occur. Based on the slopes of the regression, the average mercury concentration on suspended particles is 0.12 mg Hg/kg suspended sediment for electrical conductivity (EC) below 2 mS/cm and 0.29 mg Hg/kg suspended sediment for EC above 2 mS/cm. The significantly different relationship (p = 0.04) with suspended sediment for varying EC values was taken into account when daily and annual mercury loads were estimated.

A "first flush" phenomenon is exhibited in the Delta for total mercury concentrations. Consistent with the strong relationship between SSC and total mercury, both variables show a similar trend in concentrations over the flood periods of 2002 to 2005. Mercury concentrations were highest during the first flood of the 2002/2003 wet season and during the first flood of the 2004/2005 wet season with concentrations of 14 ng/L. Despite the second flood of the first year having a 1.2 times greater discharge magnitude, total mercury concentrations peaked at 12.12 ng/L during this storm event. Similarly, during the third flood in the 2002/2003 wet season, mercury concentrations only reached 9 ng/L, although the discharge magnitude was still 1.1 times greater than during the first flood. In contrast to other particle bound contaminants (e.g., PCBs), total mercury seems to reach the highest concentrations in the Sacramento River during the early storm events, leaving cleaner sediment for transport during later floods.

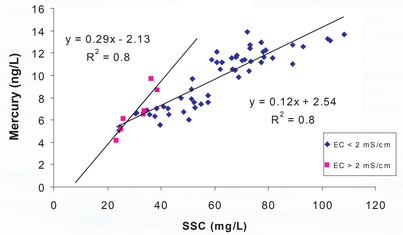


FIGURE 2
THE INFLUENCE OF TIDAL FLUCTUATION AND ASSOCIATED ELECTRICAL CONDUCTIVITY (REPRESENTING SALINITY) ON THE RELATIONSHIP BETWEEN TOTAL MERCURY AND SSC IN WATER SAMPLES COLLECTED AT MALLARD ISLAND FROM 2002-2005.

Using a model that adjusts advective sediment loads to flow conditions and the influence of tidal dispersion at Mallard Island (McKee et al. 2002), mercury loads were estimated for water years (WY) 2002-2005*. The maximum daily load occurred on February 28th, 2004 when 4 kg of total mercury were transported down the River. This 21-day high flow event represented 47% of the total load for WY 2004. Annual loads for the measured water years varied between 58 ± 20 kg in 2002 and 110 ± 37 kg in 2004. Eleven annual mercury loads related to Delta outflow and sediment transport, including an average load over this time period, are displayed in Table 1.

Even though sufficient data are available to estimate long-term average mercury loads, the uncertainty associated with this extrapolation is rather high because the relationship between SSC and total mercury may vary drastically in years with larger floods, when the Yolo Bypass carries floodwater from several northern California waterways to the Sacramento River. The Yolo Bypass is a levied 59,000 acre floodplain on the westside of the lower Sacramento River, and one of the tributaries specific to the Bypass is Cache Creek, an area of high mercury concentration (Domagalski et al. 2003). During years of intense rainfall (e.g., 1997), over 600,000 cfs have been measured for total Delta outflow at Mallard Island, with greater proportions of water passing through the Yolo Bypass. The highest dayflow that was measured in this study so far was 150,000 cfs.

Water Year	Flow (Mm^3)	Sediment (Mt)	Mercury (kg)
1995	51,559	2.58±0.83	399±136
1996	31,436	1.01±0.32	184±62
1997	42,307	2.24±0.72	351±119
1998	53,639	2.42±0.77	389±132
1999	27,805	0.84±0.27	156±53
2000	22,394	0.66±0.21	123±42
2001	8,565	0.26±0.08	52±18
2002	11,303	0.31±0.10	58±20
2003	17,330	0.55±0.17	97±33
2004	18,577	0.64±0.20	110±37
2005*	14,266	0.33±0.11	64±22
Average	27,198	1.08±0.34	180±61

TABLE 1
ANNUAL SEDIMENT AND MERCURY LOADS WITH STANDARD ERROR AT MALLARD ISLAND, CA SAMPLING LOCATION FROM 1995 TO 2005.

*
2005 data are calculated with preliminary dayflow and sediment data because the WY 2005 data have not been released yet.

CONCLUSIONS

Total mercury concentrations showed a strong relationship to suspended sediment concentrations over the course of this study with total mercury exhibiting a "first flush" phenomenon at the Mallard Island site that showed decreasing concentrations over one flood season. The origin of water (coming from upstream or from reverse flow during low tide) could influence the mercury concentrations on suspended particles. How this relationship develops during larger flood, still remains to be studied. Since mercury in the San Francisco Bay is mainly derived from runoff originating from historic mercury and gold mining areas in the Central Valley, a reliable estimate of long-term average loads is important for determining how to improve water quality in the Sacramento River and the San Francisco Bay.

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