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Pesticides Associated with Suspended Sediments in the San Francisco Bay Estuary, California

U.S. GEOLOGICAL SURVEY

Open-File Report 97-24

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By Brian A. Bergamaschi, Kathryn L. Crepeau, and Kathryn M. Kuivila

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CONVERSION FACTORS

Multiply	By	To obtain
cubic foot per second (ft ³ /s)	0.02832	cubic meter per second
inch (in.)	2.54	centimeter
mile (mi)	1.609	kilometer

ABBREVIATIONS

DDT	Dichloro-Diphenyl-Trichloroethane
DDE	Dichloro-Diphenyl-dichloroEthylene
DDD	Dichloro-Diphenyl-Dichloroethane
EPTC	Ethyl DipropylThioCarbonate
GC	Gas chromatograph
Kg	kilogram
mg/L	milligram per liter
mL	milliliter

This report is also available online at: <http://water.wr.usgs.gov/ofr97-24/>

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INTRODUCTION

The dynamics of sediment-associated pesticides in the Sacramento and San-Joaquin Rivers and the San Francisco Bay Estuary are being studied by the U.S. Geological Survey (USGS). These two rivers feed the San Francisco Bay Estuary by draining California's Central Valley. The Central Valley is an area of intense agricultural activity in which more than 500 different pesticides are used (California Department of Pesticide Regulation, 1994). Thus, suspended sediments borne by these rivers are potentially an important mechanism for transport of pesticides into and through river and estuary systems.

Pesticides associated with suspended sediments may affect the ecosystem differently than their dissolved counterparts and need to be studied separately. Suspended sediments and associated organic material support filter-feeding pelagic and benthic communities, so pesticides associated with these sediments represent a pathway for entry into the food chain distinct from the more commonly studied dissolved pesticides. Other reasons suspended sediments may have different effects than their dissolved counterparts are that suspended sediments have a longer residence time in estuaries than water, and inputs of sediments occur in a pulse, typically only once a year (Meade, 1972). This pulsed introduction may increase exposure times to pesticides or provide a mechanism for exposure during biologically sensitive times.

Equilibrium partitioning models indicate that many pesticides will be concentrated on suspended sediments (DeToro and others, 1991). However, we may expect that associated pesticides will be observed at higher levels than equilibrium models suggest. For example, when a short transit time exists between agricultural fields, where many sediments originate, and estuaries, where they may accumulate, pesticides associated with suspended sediments may not have time to reach equilibrium prior to deposition (for example, Domagalski and Kuivila, 1993).

Complicating the study of sediment associated pesticides in the San Francisco Bay Estuary is that sediment flow through rivers and estuaries is highly seasonal and episodic in nature (Meade, 1972). The result is high temporal variability in sediment concentration and flux. Pesticides associated with these sediments consequently may exhibit large changes in concentration and distribution. Other complications include the seasonal variation in pesticide applications, the residence time of sediments in the drainage, and the effect of tidal and non-tidal circulation on sediment transport and erosion.

Methods for collection and analysis

(lots of work)

SPATIAL VARIABILITY

During the study of inputs of sediment-associated pesticides into the San Francisco Bay Estuary, suspended sediments were isolated from large-volume water samples collected over several years at various stations in Suisun Bay and also covering the principal inputs and outlet (fig. 1). The samples were analyzed for 21 pesticides and pesticide degradation products to provide information about the source and fate of pesticides associated with suspended sediments in the estuary. Where multiple samples were collected and analyzed, the data were averaged to provide a more general picture of pesticide transport (fig. 2, table 1).

Although averaging provides general insight into the flow of sediment-associated pesticides into and through the estuary, averaging the data presented in this study does not provide specific information about either the annually weighted level of inputs or the source. There is an intrinsic danger in making interpretations from sample averages which are not discharge-weighted and taken over the annual cycle; the sample averages in this study are not. However, because few data of this type exist, averaging provided the best picture available at this time. Further studies that better quantify inputs are in progress.

Samples were collected at several sites. Sacramento River samples included in the average were collected at Sacramento (fig. 1) on March 10, 1992, December 7 and 12, 1992, and February 9, 1994. San Joaquin River samples were collected as stated on the daily figures and on December 8 and 11, 1992. Suisun Bay samples were collected March 19, 30, and 31, 1994, and January 19, 20, 24, and 25, 1995. (More than one sample was collected in a day.) The San Pablo Bay sample was collected February 25, 1995.

Observations on Spatial Variability

- Some of the observed pesticides associated with suspended sediments were expected based on their patterns of use (tables 3 and 4) and their physical-chemical properties (table 2; for example, oxyfluorfen). However, some pesticides were observed (for example, thiobencarb) even though their physical-chemical properties or patterns of use suggested little if any should be present.
- For the samples and compounds analyzed, the San Joaquin River suspended sediments apparently carried the highest concentration of associated pesticides (fig. 2b).
- For the suite of samples analyzed, the Suisun Bay suspended sediments (fig. 2c) most resembled the Sacramento River suspended sediments (fig. 2a) in terms of concentration and distribution of associated pesticides

TEMPORAL VARIABILITY

During the study of inputs of sediment-associated pesticides into the San Francisco Bay Estuary, suspended sediments were isolated from large volume water samples collected from the San Joaquin River at Vernalis (fig. 1). Samples were quantitatively analyzed for 21 pesticides and pes-

ticide degradation products. The samples analyzed were collected every few days over an 8-day period corresponding to the onset of winter rains. The onset of rains produced a peak in the hydrograph (fig. 3) and a preceding wave of entrained sediment material. The samples were analyzed to examine changes in the concentration and distribution of associated pesticides during passage of this wave of suspended sediments.

Observations on Temporal Variability

- The concentration and distribution of pesticides associated with suspended sediments varied widely during the peak of sediment discharge (fig. 4a-d).
- The peak in suspended-sediment concentration preceded the peak in discharge for the San Joaquin River during 1992 (fig. 3).
- Even though the mean concentration of pesticides was approximately halved between February 8 (fig. 4a) and February 13 (fig. 4d), the sediment load increased by more than a factor of seven (fig. 3), thereby increasing the overall pesticide load.

ACKNOWLEDGMENTS

This work is funded by the USGS Toxic Substances Hydrology Program and USGS Ecosystems Initiative. Pesticide-use data were obtained from the California Department of Pesticide Regulation (Sacramento, Calif. 95814) computer database. The authors wish to thank D.S. Baston, B.J. Jennings, T.J. Wilson, and R.G. Linville of the USGS for invaluable assistance in the laboratory. J. DeRose, B.J. Jennings, and D. Copeland of the USGS were indispensable in the field effort.

REFERENCES

- California Department of Pesticide Regulation, 1994, Pesticide use data: California Department of Pesticide Regulation.
- DeToro, D.D., Zarba, C.S., Hansen, D.J., Berry, W.J., Swartz, R.C., Cowan, C.E., Pavlou, S.P., Allen, H.E., Nelson, T.A., and Paquin, P.R., 1991, Technical basis for establishing sediment quality criteria for non-ionic organic chemicals using equilibrium partitioning: *Environmental Toxicology and Chemistry*, v. 10, p. 1541-1583.
- Domagalski, J.L., and Kuivila, K.M., 1993, Distributions of pesticides and organic contaminants between water and suspended sediment, San Francisco Bay, California: *Estuaries*, v. 16, no. 3A, p. 416-426.
- Meade, R.H., 1972, Transport and deposition of sediments in estuaries: *Geological Society of America*, v. 133, no. 1, p. 91-120.

FIGURES AND TABLES

Figure 1. Location of sampling sites, San Pablo and Suisun Bays and San Joaquin and Sacramento Rivers, California.

Figure 2a. Observed pesticides associated with suspended sediments in Sacramento River at Tower Bridge.

Figure 2b. Observed pesticides associated with suspended sediments in the San Joaquin River at Vernalis.

Figure 2c. Observed pesticides associated with suspended sediments in Suisun Bay.

Figure 2d. Observed pesticides associated with suspended sediments in San Pablo Bay.

Figure 3. Peak discharge, suspended sediment concentration, and rainfall at the San Joaquin River at Vernalis, February, 1992.

Figure 4a. Observed pesticides associated with suspended sediments on February 8, 1992.

Figure 4b. Observed pesticides associated with suspended sediments on February 10, 1992.

Figure 4c. Observed pesticides associated with suspended sediments on February 13, 1992.

Figure 4d. Observed pesticides associated with suspended sediments on February 16, 1992.

Table 1

Data Summary

(values in nanograms per gram dry weight of sediment)

	Tower Bridge (Average)	Vernalis (Average)	Suisun Bay (Average)	San Pablo Bay		February 8, 1992	February 10, 1992	Vernalis February 13, 1992	February 16, 1992
Chlorpyrifos		8.0					9.8	8.6	30.9
Chlorthal		9.9				2.2	1.9	18.0	41.3
DDD		0.6				4.5			
DDE	1.5	16.6	0.7	2.2		40.0	4.8	16.2	13.3
DDT		7.3				23.5		9.1	5.6
EPTC	1.9	4.8	1.0				8.4	11.5	
Fonofos		3.4				2.5			8.1
Oxyfluorfen	1.1	27.2	1.0	8.1		82.2	11.8	30.0	32.4
Pebulate		5.7							
Thiobencarb	12.9	10.9	13.3				10.6		4.4
Trifluralin	1.1	10.4	0.3	3.0		27.7	4.8	8.2	8.7

Table 2
Physical-chemical information

	Water Solubility(mg/L)	Log Koc	Log Kow
Chlorpyrifos	3.0E-1	4.1	5.0
Chlorthal	5.0E-1	3.7	3.8
DDD	5.0E-2	5.4	6.0
DDE	4.0E-2	5.3	5.8
DDT	3.0E-3	5.4	6.0
EPTC	3.7E-2	2.4	3.2
Fonofos	1.7E-1	2.9	3.9
Oxyfluorfen	1.0E-1	5.0	2.6
Pebulate	6.0E-1	2.7	3.8
Thiobencarb	2.8E+1	2.5	1.4
Trifluralin	6.0E-1	3.8	5.1

Table 3
Pesticide use on various crops
(oxyflorfen data were not available.)

CROP	Chlorpyrifos	Chlorthal	EPTC	Fonofos	Pebulate	Thiobencarb	Trifluralin
Alfalfa	X		X				X
Almond	X		X				X
Apple	X						
Beans		X		X			X
Broccoli		X					
Corn	X		X	X			
Cotton	X						X
Grapes							X
Melons							X
Peach	X						
Rice						X	
Safflower							X
Sugarbeet		X	X	X	X		X
Sunflower							X
Tomato			X	X	X		X
Walnut	X						
Wheat	X						X

Table 4
Pesticides used in each basin
1994 data
(in thousands of Kg)

	Sacramento	San Joaquin
Chlorpyrifos	62	195
Chlorthal	<1	10
DDD	-	-
DDE	-	-
DDT	-	-
EPTC	54	63
Fonofos	8	5
Oxyfluorfen	12	54
Pebulate	35	45
Thiobencarb	181	5
Trifluralin	67	131

**Bargamaschi and others—PESTICIDES ASSOCIATED WITH SUSPENDED SEDIMENTS, SAN FRANCISCO BAY ESTUARY, CALIFORNIA—
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