APPLYING SEDIMENT QUALITY OBJECTIVE ASSESSMENTS TO SAN FRANCISCO BAY SAMPLES FROM 2008-2012

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Background

Sediment quality can influence ecosystem health: benthic communities are directly exposed to chemicals in sediment, and sediment contaminants can be transferred to the water column and up through the food chain, causing significant tissue contamination in higher trophic level species (Barnett et al., 2008; Anderson et al., 2007). Therefore, understanding San Francisco Bay sediment quality is useful in determining if contaminants are adversely affecting aquatic life. A single indicator (e.g. one acute toxicity test) cannot reliably evaluate whether contaminants in sediment pose a risk to ecosystem health (Bay and Weisberg, 2012). The State Water Board adopted a set of narrative sediment quality objectives (SQOs) and a standardized assessment framework that uses multiple lines of evidence (MLOE) to assess sediment quality: sediment chemistry, toxicity, and benthic community condition.

The SQO framework was incorporated into the 2009 "Water Quality Control Plan for Enclosed Bays and Estuaries"; as a result, SQOs have the same standing as a Water Quality Objective (Beegan and Bay, 2012; SWRCB, 2009).

The Regional Monitoring Program for Water Quality in San Francisco Bay (RMP) began monitoring for the SQO triad in 2008. SQO assessments were performed from 2008-2012 on samples from the program's Status and Trends (S&T) stations, located throughout the open Bay. In 2011, the RMP also completed SQO assessments on samples from two creek channels that were labeled as toxic hotspots in 1998.

The study's objectives were to evaluate whether the two creeks channels would still be labeled as impaired using the standardized SQO methodology and to evaluate whether spatial and temporal trends in sediment contamination exist throughout the Bay.

Materials and Methods

Sampling Design

- The two historically industrial creek channels, Mission Creek and San Leandro Creek, were sampled on gradient in summer 2011; three samples were taken at each site at the upper, mid, and lower end of the creek channels (Figure 1).
- Status & Trends sampling stations for this study were selected using the RMP's stratified, random sampling design, adopted in 2002. However, a subset of the RMP's historic, spine of the Bay stations were also sampled. SQO assessments were conducted on 25 stations (20 random and 5 historical) each year; dry-season samples were collected in 2008, 2009, and 2011, while wet-season samples were collected in 2010 in 2012.

FIGURE 1
SAMPLING LOCATIONS FOR MISSION CREEK AND SAN LEANDRO CREEK

Field Methods

- Composite samples for chemistry and toxicity evaluation, top 5 cm of sediment from two or three grab samples, were collected using a double 0.05m^2 surface area Young-modified Van Veen grab.
- Benthic infauna samples were collected with a 0.05 m^2 surface area Ponar grab and screened through 0.5- and 1.0-mm nested sieves before being placed into sample jars, relaxed in $MgSO_4$, and fixed with 10% buffered formalin.

Laboratory Methods

- Sediment chemistry analysis included trace organic analyses by the East Bay Municipal Utility District (EBMUD) laboratory. Mercury analyses were conducted by Brooks Rand Ltd. (BR). Other trace metal analyses were conducted by the City and County of San Francisco (CCSF).(Table 1)
- Two toxicity tests were conducted by the UC Davis-Granite Canyon Laboratory:
  1. a 10-day whole-sediment acute toxicity test using the amphipod *Eohaustorius estuarius* with percent survival as the endpoint and;
  2. a 48-hour sediment-water interface sublethal (SWI) toxicity test using the bivalve *Mytilus galloprovincialis* with the percentage of embryos that developed normally and were alive as the endpoint.
- Benthic organisms collected in infauna samples were sorted and identified to the lowest practical taxonomic level by CCSF-Oceanside Biology Laboratory and Moss Landing Marine Laboratories-Oakden Lab.

SQO Assessment Methods

- The chemistry LOE was calculated by averaging two sediment quality guideline value results: 1) the California Logistic Regression Model (CA LRM) and 2) the Chemical Score Index (CSI) (Bay and Weisberg, 2012).
- For polyhaline environments, the benthic LOE score is the median of four benthic index scores: 1) the Index of Biotic Integrity (IBI), 2) the Relative Benthic Index (RBI), 3) the Benthic Response Index (BRI), and 4) the River Invertebrate Prediction and Classification System (RIVPACS) (Ranasinghe et al., 2009).
- For mesohaline and oligohaline environments, the benthic LOE score is the median of three benthic indices: 1) a modified IBI, 2) a modified RBI, and 3) the AZTI Marine Biotic Index (AMBI).
- The toxicity LOE score is based on the average of both the acute and sublethal toxicity tests (Greenstein and Bay, 2012).
- Four response categories classified the level of chemical exposure, benthic disturbance, or toxicity (Table 2).
- The SQO assessment framework evaluates two questions: 1) is there biological degradation? and 2) is the chemical exposure high enough to generate a biological response? (Bay and Weisberg, 2012).
  - To answer whether there is biological degradation, the benthic and toxicity LOE scores are integrated.
  - To determine whether there is chemical exposure sufficient to cause a biological response, the toxicity and chemistry LOE scores are considered.
- The final data integration step combines the severity of the biological effect and the potential for chemically-mediated effects to assign one of six station assessments (Table 3).
- The percent area with poor sediment quality was the sum of the percent area that was Likely Impacted or Possibly Impacted. The percent area with good sediment quality was the sum of the percent area that was Likely Unimpacted or Unimpacted.

TABLE 1
SEDIMENT CONTAMINANTS EVALUATED IN THE SQO ASSESSMENTS.

Cadmium (mg/kg)	LPAH (ug/kg)	DDEs, total (ug/kg)
Copper (mg/kg)	Alpha Chlordane (ug/kg)	DDTs, total (ug/kg)
Lead (mg/kg)	Gamma Chlordane (ug/kg)	4,4'-DDT (ug/kg)
Mercury (mg/kg)	Dieldrin (ug/kg)	PCBs, total (ug/kg)
Zinc (mg/kg)	Trans Nonachlor (ug/kg)	
HPAH (ug/kg)	DDDs, total (ug/kg)	

TABLE 2
CATEGORICAL SCORES FOR THE THREE LINES OF EVIDENCE.

Category Score	Chemistry LOE	Benthic LOE	Toxicity LOE
1	Minimal Exposure	Reference	Nontoxic
2	Low Exposure	Low Disturbance	Low Toxicity
3	Moderate Exposure	Moderate Disturbance	Moderate Toxicity
4	High Exposure	High Disturbance	High Toxicity

TABLE 3
SQO STATION ASSESSMENT CATEGORIES.

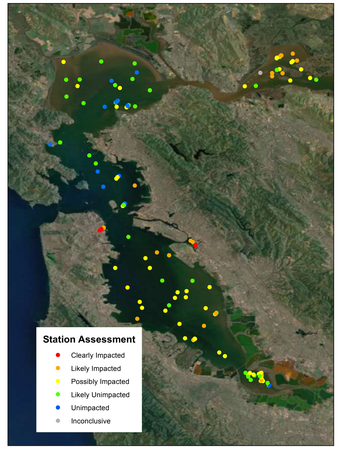
Station Assessment	Description
Unimpacted	Confident that contamination is not causing significant adverse effects to benthic macroinvertebrates at the station.
Likely Unimpacted	Contamination is not expected to cause adverse effects to benthic macroinvertebrates, but some disagreement among LOEs reduces certainty that the station is unimpacted.
Possibly Impacted	Contamination at the station may be causing adverse effects to benthic macroinvertebrates, but the level of impact is either small or is uncertain because of disagreement among LOEs.
Likely Impacted	Evidence of contaminant-related impacts to benthic macroinvertebrates is persuasive, in spite of some disagreement among LOEs.
Clearly Impacted	Sediment contamination at the station is causing clear and severe adverse effects to benthic macroinvertebrates.
Inconclusive	Disagreement among the LOEs suggests that either data are suspect or additional information is needed for classification.

Results and Discussion

Sediment Quality in Mission Creek and San Leandro Creek

The SQO station assessments at both Mission Creek and San Leandro Creek were either "Clearly Impacted" or "Likely Impacted," indicating sediment quality at both sites remains degraded 15 years after their classification as hotspots (Figure 2). At both hotspots, the upper-gradient was Clearly Impacted, but closer to the open Bay the station assessment changed to Likely Impacted. In contrast, none of the open Bay sampling stations from 2008 to 2012 were listed as Clearly Impacted. The higher SQO scores in the two creeks, compared to the open Bay, and the presence of contamination gradient suggest that the contamination in Mission and San Leandro creeks is most likely from nearby industrial sites and stormwater runoff.

FIGURE 2
SPATIAL REPRESENTATION OF SQO STATION ASSESSMENTS FROM 2008 THROUGH 2012, INCLUDING BOTH MISSION CREEK AND SAN LEANDRO CREEK'S 2011 STATION ASSESSMENTS.



Sediment Quality in the Open Bay

The most common station assessment in the open Bay was Possibly Impacted, over a third of the Bay was listed as such except for in 2009 (Figure 2 & 3). In 2009, 74% of the Bay had good sediment quality. Sediment quality also varied spatially. San Pablo Bay was the least impacted subembayment while South Bay and Suisun Bay were the two most impacted subembayments (88% and 80% of the area had poor sediment quality; Table 4). South Bay and Suisun Bay were listed as impacted because they were characterized by both a disturbed benthos and toxic sediments.

The majority of the stations were listed as Possibly Impacted because of the presence of Moderate or High sediment toxicity. The Bay was characterized by Moderate or High toxicity and benthic community disturbance was observed even with Low or Minimal chemical exposure; chemical exposure was listed as Minimal or Low throughout the Bay. The cause of Moderate toxicity in the Bay remains unknown; however, sediment quality may have still improved over time. The percent area with poor sediment quality was highest in 2000 (96.3%), when the USEPA completed 40 SQO assessments in the Bay (Barnett et al., 2008), and decreased to 53% by 2012. Additionally, the percent area listed as Likely Impacted was lower in 2011 and 2012 than the three previous years.

FIGURE 3
PERCENT AREA IN THE BAY CLASSIFIED AS A PARTICULAR STATION ASSESSMENT FROM 2008 THROUGH 2012.

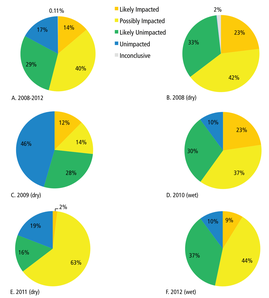


TABLE 4
PERCENT AREA IN EACH SUBEMBAYMENT WITH POOR, GOOD, AND INCONCLUSIVE SEDIMENT QUALITY FROM 2008 THROUGH 2012.

	% Area with Poor Sediment Quality	% Area with Good Sediment Quality	Inconclusive (%)
Suisun Bay	80	16	4
San Pablo Bay	20	80	0
Central Bay	52	48	0
South Bay	88	12	0
Lower South Bay	52	48	0

TABLE 5
PERCENT AREA WITH MODERATE OR HIGH CHEMICAL EXPOSURE, TOXICITY, AND BENTHIC DISTURBANCE, 2008-2012.

	Chemical Exposure	Toxicity	Benthic Disturbance
2008	0.17%	73%	44%
2009	0%	29%	24%
2010	0%	72%	39%
2011	0%	74%	2%
2012	0%	53%	32%
2008-2012	0.03%	60%	28%

Conclusions

The Clearly Impacted station assessments in Mission Creek and San Leandro Creek indicate that pollutant impacts are most likely greater in some creek channels than in open Bay. The lack of any Clearly Impacted stations in the open Bay suggests that contamination in the Bay is generally not high enough to cause severe impacts on the benthic community. However, a substantial fraction of the sediment quality in the Bay remained poor from 2008- 2012 and was characterized by Moderate toxicity. Despite the fact that the cause of Moderate toxicity remains unknown, it appears that sediment quality improved over time in the Bay.

References

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