DC'S CONTAMINATED ANACOSTIA ESTUARY SEDIMENTS: A BIOMONITORING APPROACH

Final Technical Report to the District of Columbia Water Resources Research Center

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Summary

The purpose of this project was to explore the bioavailability of Anacostia sediment contaminants to the local Asiatic clam (Corbicula fluminea). In May 1999 surface sediments were collected by hand (6" Ekman dredge) from three tidal Anacostia river estuary sites: Navy Yard (lower third), Kingman Island (middle) and Bladensburg Marina (upper tidal end). The sediments were kept cool and the next day adult Asiatic clams were collected at Fort Foote on the Potomac River estuary where clams are prevalent. Clams were placed in mesh-covered plastic trays of Anacostia sediments at that site. Clams were also placed on control Potomac sediment trays at Fort Foote and in the Northwest Branch (MD) of the Anacostia. The trays were collected at 11 weeks. Sediment samples and clam tissues were taken within 48 hours to Severn Trent Laboratories. Pre and post EPA Priority Pollutant analysis of sediments and clam tissues included five metals, pesticides, PAH's, PCB congeners and TOC.

Sediment metal concentrations but not organic contaminants correlated with total organic concentration. The surface sediment pesticide, PAH and metal levels were highest in middle and upstream Anacostia sites and in the accumulated Northwest Branch sediments (post sampling). Sediment TOC-normalized heptachlor, chlordane and DDE concentrations were above upper effects threshold at some upstream sites (SQuiRT criteria). Chlordane, a major Anacostia toxic of concern, was only found in the two most upstream locations, Bladensburg and the Northwest Branch. The original control site Potomac clams collected on 5/17/99 had high levels of pesticides, PCB'S, PAH's and metals, although the Potomac site sediments had few contaminants. After 11 weeks in the Potomac both the sediments and clams in contact with the Anacostia sediments (as well as control site clams) had lost most pesticides, PAH's and PCB's. Some metals in clams were reduced, but levels were not increased on Anacostia sediment. Sediment and clams in the Northwest Branch accumulated the highest levels of chlordane and some PAH's. These results confirm upstream sources of major contaminants in the Anacostia estuary. Contaminants formerly reported in lower Anacostia sediments may be becoming capped. There is preferential bioaccumulation of contaminants by Corbicula from the water column vs sediment exposure. Results suggest the Potomac estuary Asiatic clam population can accumulate chemical contaminants on a seasonal basis, possibly partly through tidal exchange and downstream transport from the Anacostia estuary in spring flows. Acenapthylene, endrin and endrin aldehyde were not detected in Anacostia sediments but were found in the clams that had Potomac exposure, and they may be signature chemicals for non-Anacostia contaminant sources.

Background

The 10 km Anacostia River tidal freshwater estuary flows into the Potomac River tidal freshwater estuary and is the only major water body almost entirely within the District of Columbia. The Anacostia estuary of Washington, DC has a Superfund site on its lower third and its benthic community is highly depauperate. It is listed as one of three Areas of Concern in the Chesapeake Bay by the Chesapeake Bay Program and as one of America's ten worst rivers by the American Rivers Association. Concentrations of sediment contaminants vary considerably over the length of the estuary (Wade e.a. 1994, Velinsky e.a. 1992, Velinsky e.a. 1994). The nearby Potomac estuary has a large healthy benthic community (including Asiatic clams) which is almost completely absent from the Anacostia (Phelps 1985, 1987, 1994; Freudberg e.a. 1988; Cummins e.a. 1991).

To separately test the effects of Anacostia sediment and water toxics, transplant experiments placed adult clams from the Potomac on Anacostia and Potomac sediment trays that were put in the lower Anacostia at the Navy Yard site and in the nearby Potomac (Phelps 1987). Clams put on Anacostia sediment at both locations showed no significant mortality but also no clam reproduction (Dougherty and Cherry 1988). Young clams developed on trays of Potomac sediment in the Potomac but those growing on Potomac sediment in the Anacostia all died in late summer, suggesting a seasonal water-column toxic event at the Navy Yard site.

A four-day sediment bioassay using Asiatic clam larvae was developed (Phelps and Clark 1988). It was used to map the toxicity of Anacostia estuary sediments, and found three statistically different levels of sediment toxicity (Phelps 1991, 1993). The most toxic sediments were on the north (city) side of the lower Anacostia in the basin region near the Navy Yard, followed by lower toxicity sediments up to the New York Avenue bridge, and no toxicity in sediments of the upper estuary to Bladensburg (head of tide). A later study found high toxicity in mid-estuary Kingman Lake sediments (Phelps unpub.). Raising sediment pH to convert ammonia to the toxic (un-ionized) form caused 100% mortality in clam larvae with lower Anacostia sediment (Navy Yard site), but not clam larvae with Potomac control sediment (Ankley, e.a. 1990; Phelps 1990). With a multisensor sonde, UDC found lower Anacostia basin water in September reached a pH of 8.6 at a temperature of 24 deg. C, which would be sufficient to convert 30% of natural ammonia to the un-ionized toxic form. Ammonia from the high-organic Anacostia sediment at that site may have caused the late-season 100% mortality of the young clams in the sediment trays.

To complete the Sediment Quality Triad approach (Chapman e.a. 1987), EPA Priority Pollutants were analyzed in sediment sample from the Navy Yard site and sediment from the Potomac control site at Fort Foote (Phelps 1993). No pollutant concentrations in Navy Yard sediment exceeded ET-L or ER-M effects levels (Long and Morgan 1990) and only copper and zinc were increased over the control sediments. The Navy Yard sediment sample was taken one day following a rain event and there was evidence of fresh sediment deposition and the larval clam bioassay found no toxicity. Sediments taken other times at the Navy Yard site have been reported with possibly toxic levels of DDT, chlordane, PAH's, zinc and lead (Long and Morgan 1990; ICPRB 1991, 1992). However, these sediment pollutant concentrations were highly variable over three years and showed no consistent trend (Phelps 1995).

Methods

5/15/99 Surface sediment samples collected using 6" Ekman dredge from tidal freshwater Anacostia Ri
5/16/99 Sediments translocated to plastic boxes with mesh lids at the Fort Foote site on the tidal f
Asiatic clams collected at Fort Foote and added to the sediment cages. Control sediment tak
Clams depurated for 24 hours in three changes of spring water and frozen for tissue remo
5/17/99 Sediment (kept cool) and frozen clam tissue samples hand-carried to Severn-Trent Labo
5/18/99 Control (Fort Foote) sediment and clams placed in a cage at the Northwest Branch (MD) of the Anacostia, near the estuary head of tide.
8/5/99 (11 weeks) Clams and sediments collected from Fort Foote and from the Northwest Branc
Sediment samples kept on ice.
Clams depurated 24 hours and tissues removed and frozen as before.
8/6/99 Sediment and clam samples hand-carried to Severn-Trent Laboratories, Sparks, MD, for
6/12/00 Most site GPS positions re-recorded because of signal improvement.

The Asiatic clams selected for this research at the Potomac Fort Foote site were the 1998 fall cohort with shell lengths ranging from 18 to 25 mm. Clam tissues were around one gram each and 47 - 56 composited to obtain 60 grams for two complete Priority Pollutant analyses per site. One set of sediments and one of clam tissue were spiked for pollutant recovery control. At the Northwest Branch site only 24 grams were obtained (one cage) so PCB congener analysis was omitted.

Analysis of EPA Priority Pollutants in sediment and clam tissues was carried out by Severn-Trent Laboratories of Sparks, MD: PCB's by GC (SW 8082), chlorinated pesticides by GC (SW 8082), PAH's by HPLC (SW 8310), total copper, zinc, iron, cadmium and chromium by ICP (SW 6000, 7000), and total organic carbon by oxidation (SW 9060).

Sediment and clam tissue pollutant concentration correlations were examined by Excel.

Results

TABLE 1. SITE GPS LOCATIONS

	N	W
Northwest Branch (MD)	38^{0} 56.667'	76^{0} 56.768'
Bladensburg Marina (Anacostia)	38^{O} 56.199'	76^{O} 56.425'
Kingman Island (Anacostia)	38^{O} 53.700'	76^{O} 58.030'
Navy Yard (Anacostia)	38^{O} 52.350'	76^{O} 59.825'
Fort Foote (Potomac)	38^{O} 46.423'	77^{O} 01.648'

Pesticides:

Sediments from the three Anacostia sites had only a few pesticides above detection limits: 4,4'DDE, aldrin, alpha and gamma chlordane, endosulfan II and heptachlor epoxide (Table 1). No pesticides were detected in Potomac sediments. Sediment pesticide levels were highest in the middle and upper Anacostia estuary sites. Kingman Lake sediments had upper effects threshold (UET) concentrations of the pesticides DDE, aldrin and heptacholor epoxide, and Bladensburg sediments had UET of chlordane and heptacholor epoxide (Buchman 1999).

The Anacostia sediments held in the Potomac for 11 weeks lost all pesticides (below detection limits). However Potomac sediment held in the Northwest Branch tray accumulated total organic material (TOC) and alpha chlordane There was no correlation between sediment pesticide concentrations and organic content.

Tissues of the original Potomac clams had 4,4'DDE, endrin,alpha and gamma chlordane but were missing aldrin, heptachlor epoxide and endosulfan II that were present in the Anacostia sediments (Table 2). After 11 weeks the clams held on Potomac sediments in the Potomac lost all pesticides. After exposure to Anacostia sediments held in the Potomac, the clams lost some pesticides but picked up endrin aldehyde and heptachlor which were not detected in Anacostia sediments. The clams held in the Northwest Branch accumulated alpha chlordane and heptachlor epoxide, which were found in Anacostia sediments and are listed as Chemicals of Potential Concern (COPC) from previous Anacostia sediment and fish tissue studies (SRC 2000).

Chlordane has been a toxic of concern in the Anacostia and reported in sediments of the lower Anacostia as well as fish tissues and the dissolved and particulate fractions of Northwest Branch water (Wade et al 1994, Velinsky and Cummins 1994, ICPRB 1997). In this study, chlordane was found only in the up-estuary sediments of Bladensburg and the Northwest Branch, and only in tissues of the original Potomac clams (5/17) and the clams exposed at Northwest Branch. The absence of detectable chlordane in surface sediments below the uppermost end of the estuary at Bladensburg suggests a present source is upstream and the formerly contaminated downstream estuary sediments are becoming moved or capped. This could decrease the bioavailability of chlordane to fish in the Anacostia and suggests re-evaluation of the 1995 pesticide-based ban on Anacostia fish consumption. It also indicates natural remediation of lower Anacostia estuary chemically contaminated sediments may be taking place.

PAH's:

Anacostia sediments had highest PAH's in Kingman Lake (middle Anacostia) where several PAH's were above upper effects threshold levels (SquiRT, Buchman 1999)) (Table 1). Sediments accumulating in the Northwest Branch tray had total PAH's comparable to those at the Navy Yard site. Wade e.a. (1994) reported highest PAH levels in upper Anacostia sediments and Coffin e.a. (1999) found suspended sediments with the highest PAH levels in the upper Anacostia. Anacostia sediments held in the Potomac for 11 weeks had both increased and decreased concentrations of various PAH congenors. The Potomac sandy sediment at the Fort Foote control site on 5/17 had very low levels of PAH's, and none above detection limits on 8/6. Total sediment PAH's (TPAH) were calculated by summing up and were highest at Kingman Lake (10.6 mg/kg). However, when TPAH were normalized for total organic carbon (TOC) no Anacostia sediments exceeded the Probable Effects Level (PEL) for biological effects (804 TPAH ug/g organic carbon; Swartz 1999).

Clams accumulated only six of 18 PAH congenors measured in sediments. Highest tissue PAH concentrations were in the original Potomac clams (5/17) with acenapthylene (340 ug/kg) leading. Clams placed at the Northwest Branch site accumulated the second highest number (5) of PAH congenors, but no acenapthylene. Acenapthylene was not detected in Anacostia sediments and the high Potomac clam tissue concentrations suggest a Potomac source. TPAH's in clam tissues fell when the clams were exposed in the Potomac on trays of Anacostia sediments. Since the lowest TPAH was in Potomac sediments it appears the earlier clam tissue PAH's may have reflected water but not sediment levels. Brown bullheads in the lower Anacostia have PAH accumulation in bile and a high incidence (50 - 60%) of liver neoplasms which may indicate Anacostia sediment PAH effects but the bullhead range has yet to be established (Pinkney e.a. 2000).

PCB's:

Because the Asiatic clam is nearly ubiquitous now in US freshwaters and not an endangered species, the USGS National Water-Quality Assessment (NAWQA) program specifically recommends Asiatic clam tissues for analysis of locally bioavailable contaminants (Crawford and Luoma, 1993). The Asiatic clam is considered an especially good bioindicator of PCB's (Peterson et al. 1994). Similar to the findings of Smith and Ruhl (1996) for the Albemarle-Pamlico Drainage Basin, a number of major banned organochlorines of concern were found in the Potomac Asiatic clam tissues: p,p'-DDE, chlordane, endrin, heptachlor epoxide and total PCB's. However, no concentrations came close to the NAS/NAE recommended maximum clam tissue concentrations (1000 ug/kg wet weight for p,p'-DDE, 100 ug/kg wet weight for chlordane, endrin and heptachlor epoxide, and 60 ug/kg wet weight for total PCB's) (Table 2 clam tissue values are for dry weight, estimated as 4.5X wet weight concentrations).

The biological effects of sediment PCB's have been correlated with total sediment PCB concentration (TPCB) (MacDonald et al. 2000). The highest TPCB's were at the three up-estuary sites of Bladensburg, Kingman Island and Northwest Branch. The TPCB's of Kingman and Bladensburg (0.139 and 0.125 mg/kg) were above the consensus freshwater sediments threshold effects concentration (TEC) of 0.04 mg/kg but lower than the moderate effects concentration (MEC) of 0.40 mg/kg. This range was reported to have a low incidence (7%) of adverse biological bioassay effects. The highest clam tissue TPCB's were the 5/17 original Potomac clams and clams exposed to the Navy Yard site sediment. These sediments had the two lowest TPCB's, which suggests clam tissue TPCB accumulation was not related to sediment TPCB exposure.

Since 26 PCB congeners were analyzed it was possible to compare relative PCB concentration profiles by Pearson correlation. All the tissue PCB profiles correlated with each other, and all the sediments with each other ($p = 0.05\%$). The broadest correlation between clam tissue and sediment congenor profiles was original Potomac pre-exposure clams which correlated with all sediment PCB profiles *except* Potomac. Post-exposure, the tissues with greatest total PCB concentrations (Potomac and Navy Yard) correlated positively with the sediment with the greatest total (Bladensburg). The remaining post-exposure tissue and sediment PCB profiles were not significantly correlated. It is unfortunate the Northwest Branch clam tissue PCB profile was not obtained.

TOC-normalized sediment PCB concentrations were highest in Kingman Lake and Northwest Branch (post) sediments. No Aroclor congeners (1016, 1221, 1232, 1242, 1248, 1254, 1260; detection limits 43 - 87 ug/kg) were found in any sediments or clam tissues, even though Arochlor 1260 is listed as a COPC from previous Anacostia sediment and fish tissue data (SRC 2000). After 11 weeks in the Potomac most PCB levels in both Anacostia sediments and clams decreased significantly.

Metals:

In original Anacostia sediments the metal concentrations (Cd, Cr, Cu, Fe, Zn) increased up-estuary, and were highest in the Bladensburg Marina sediments. The accumulated sediment in the Northwest Branch tray had relatively high metal concentrations, similar to Kingman Lake. All sediment metal concentrations were positively correlated with sediment TOC concentration, unlike the organic contaminants (total PCB's, total PAH's and pesticides).

Clams in the Potomac on Anacostia sediments did not lose as much metal as they lost pesticides, TPAH's, and TPCB's. However clam tissue metal concentrations did not increase significantly with 11 weeks of exposure to the higher (5X to 65X) metal concentrations of Anacostia sediments. The original (5/17) Potomac clams had highest tissue metal concentrations although their Potomac sediments had lowest sediment metal concentrations. The metal concentrations in clam tissues and sediments were not correlated, similar to the finding of Harrison (1984) who studied metals in Asiatic clam tissues and sediments of the tidal Potomac. Harrison's average clam size and tissue concentrations of Cd, Cu, Fe and Zn were similar to those in the present study. These results indicate that tissues of the filter-feeding Asiatic clam retain metals and reflect water column exposure rather than sediment exposure. Initial high tissue metal levels may have been residual contamination from exposure to Potomac water earlier in the year. Tissues of translocated mussels take up to three months to reflect new environmental metal concentrations (Roesijadi e.a.. 1984).

General:

In the Anacostia the most chemically contaminated sediments (most pesticides, highest metal levels etc.) were at the middle and upstream sites and also in the Northwest Branch (MD). Some of sediment contaminant concentrations were above "probable effects levels". This suggests much Anacostia sediment chemical pollution may be originating upstream in Maryland. Since a majority of lower Anacostia estuary water comes from the Potomac by tidal exchange there may be influx of Potomac sediments and capping of sediment pollutants in the lower estuary. Significant reduction of sediment chemical contaminant concentrations at a lower Anacostia site following a rain event was reported in a previous study (Phelps 1993).

In general, Asiatic clams placed on Anacostia sediments did not accumulate chemical contaminants in the 11 weeks Potomac exposure, no matter what types or amounts of contaminants were in the sediments. Sediment contaminants were apparently not readily bioavailable to the clams. Clams in the Northwest Branch showed some contaminant changes so tissues appeared to reflect water contamination. This is also found for other filter feeding molluscs that live in surface sediments but do not feed on sediment (Phelps 1979). The Asiatic clam is such a high-volume filter feeder it can clear the water enough to cause ecological change and has been tried in a biological water purification system (Haines 1977; Lauritsen 1986, Phelps 1994).

The uptake of chemical pollutants only from the water column may explain why the most contaminated clams were those originally collected from the Potomac on 5/17 although those Potomac sediments had almost no detectable chemical pollutants. It is possible the heavy Spring rains carried pollutants from the mouth of the Anacostia downstream five km to the Potomac

Fort Foote site, where they were found in clam tissues collected on 5/17 but not 8/6/99. Coffin et al. (1999) reported highest Anacostia river flows in February. Endrin, endrin aldehyde and acenapthylene were found in clams exposed in the Potomac but not in Anacostia sediments, and may be signature chemicals for sources of Potomac contamination other than the Anacostia. These findings need to be confirmed with further study.

By the end of this study in August both clams and Anacostia sediments in the Potomac had lost most of their organic contaminants and up to three quarters of their metals. The Asiatic clam is doing well and reproducing in the Potomac at Fort Foote, so the large clam population there (Cohen et al. 1984 , Phelps 1987) is apparently not being affected by the short-term spring accumulation of tissue pollutants that may be coming partly from the Anacostia.

These results suggest future studies need to look beyond the contaminated sediments of the Anacostia for the sources of toxicity to Anacostia bottom life. We hope to be making long-term measurements of water quality in the lower Anacostia for water column toxics that may indicate why there are no clam populations now living in the lower Anacostia. This research can assist decisions to clean up the Anacostia to develop the healthy bottom life and good fishing of the nearby Potomac. A clean and attractive Anacostia is one of the major goals of Mayor Anthony Williams' Washington D.C. administration.

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