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# Sediment Toxicity of the Anacostia River Estuary, Washington, DC

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One of the major water research priorities of the District of Columbia is the restoration of the tidal freshwater Anacostia estuary. There is considerable public interest in improving the 3.8 km estuary portion of the river as it is considered the major water body of the District. The freshwater tidal Potomac estuary into which the Anacostia estuary opens has undergone remarkable improvement since 1984 with extensive growth of submerged aquatic vegetation (SAV) and development of a sport fishery. One theory credits the large beds of introduced Asiatic clams (Corbicula fluminea), first noted in 1979 (Dresler and Cory 1980; Phelps in press), with filtering and clearing the water (Cohen et al. 1984), enabling the return of SAV (Carter and Rybicki 1986) and game fish populations (Killgore et al. 1989). The Anacostia estuary in marked contrast to the Potomac has few macrobenthics, including Asiatic clams, and no SAV or game fishing activity (Phelps 1985; Scatena 1987; Valinsky et al. 1992). Asiatic clams on trays of Anacostia sediment in the Potomac failed to spawn and had reduced gonadal size (Phelps 1987). Along with the reduced benthic community, this satisfied two of the three Sediment Quality Triad criteria indicating possibly toxic sediment in the Anacostia estuary (Chapman et al. 1987).

The study reported here looked for origins of Anacostia sediment toxicity in the estuary by mapping with a toxicity test based on Corbicula larval survival (Phelps and Clark 1988). Chemical sources of sediment toxicity were explored through EPA Priority Pollutant analysis (Phelps 1990) and by toxicity testing following pH modification (Phelps 1991).

## MATERIALS AND METHODS

To map sediment toxicity in the Anacostia, samples were collected on 6/22/89 and 7/20/89 from ten sites made on a 3.8 km transect along the entire freshwater tidal Anacostia River estuary. Control sediment was collected at the same time from the Potomac River estuary near Fort Foote which has a large Asiatic clam population (Phelps 1985, 1987) (Fig. 1). The lower and middle Anacostia estuary had two sampling sites per location, designated East and West, and the upper third had one sampling site per location. Sediment samples were collected using a .023 $m^2$ Ekman grab. The upper 5 cm of sediment were removed using an acetone-rinsed stainless steel spoon, and stored in plastic containers at 4 $^oC$ up to four days before toxicity testing. Sediment samples for EPA Priority Pollutant analysis and volatiles

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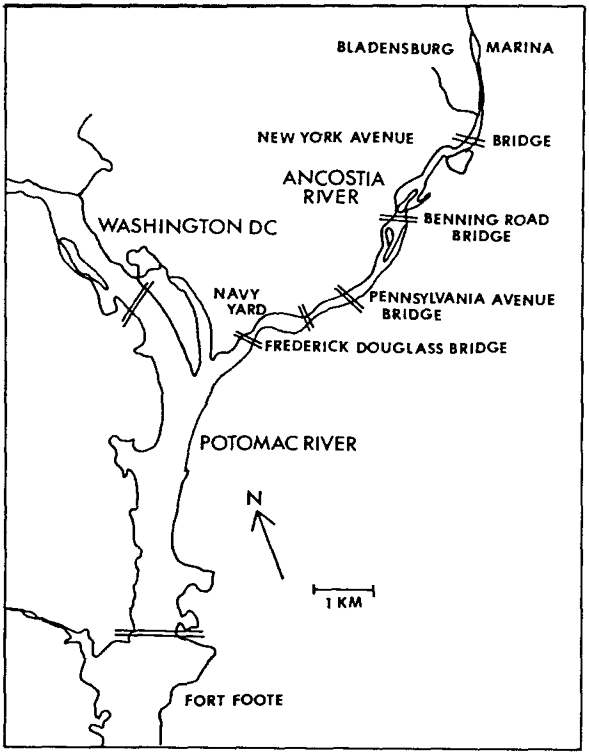


Figure 1. Sampling transects and sites on the Potomac and Anacostia estuaries.

were collected on 7/20/89 from the Potomac control site and the Navy Yard East site. The upper 5 cm of sediment was homogenized and shipped in Teflon-lined jars with no head space to EA Laboratories, Sparks, MD within 24 hours.

One important sediment toxicant found in highly organic freshwater sediment is ammonia (Ankley et al. 1990). In July 1991, sediments were collected from the Potomac at Fort Foote (control) and Navy Yard East sites. To shift the eqilibrium from ionized to unionized ammonia (the toxic form), sediment pH was raised to 9 using 0.01M NaOH, then neutralized with .01M HCl before conducting bioassays.

All sediments were bioassayed within four days of collection. To obtain clam larvae for sediment bioassays, adult Corbicula were collected from Fort Foote and placed in individual containers with distilled water. They release larvae from gill brood pouches within 24 hours. The mature active pediveliger larvae were selected and used in sediment bioassays within 24 hours and did not require additional feeding for the 96 hr toxicity test.

Sediment was filtered through 100 μ Nytex screen before pipetting 1 ml into a 2.5 ml well of a 24-well Falcon tissue culture plate. In wells, sediment was overlaid with 1 ml distilled water containing 1:100 tissue culture antibiotic mixture (Penicillin/Streptomycin/Neomycin, Sigma Chemical Co.) and twenty or thirty clam larvae added. The experimental design had a distilled water control, a control sediment (Fort Foote) and test sediments, all in triplicate. The tissue culture plates were placed at room temperature (20-23 $^{o}C$) for 96 hr. At the end of incubation, larvae and sediment were removed by pipette and filtered through 100 μ Nytex screen. The retained larvae were stained with Trypan Blue (0.1%) for 10 min to determine viability by dye exclusion. Corbicula larval shells are thin and not retained by sieving, so mortality was scored by the recovery of live (non-moribund) larvae. This molluscan larval toxicity test is similar to an oyster larval toxicity test for brackish water sediment (Phelps and Warner 1990).

Sediment-toxicity test data were compared and analyzed by nonparametric statistics (Mann-Whitney U and Kruskal-Wallis tests), using StatPac (Apple). Average control mortality was subtracted from the toxicity test data before comparison.

## RESULTS AND DISCUSSION

There was no statistically significant difference between distilled water controls and sediment controls for any single batch of larvae (Table 1). However, water and sediment control mortalities of larvae from clams collected on 6/21/89 (average 17%) were significantly higher than for larvae from clams collected on 7/17/89 (average 7%) (Table 2).

Spatial differences in sediment toxicity were found with sediments sampled on 6/22, decreasing upstream in the estuary (Fig. 1, Table 1). Sediments from the lower third of the estuary at the Frederick Douglass Bridge and Navy Yard transects were significantly more toxic than all other sites with the exception of the Frederick Douglass Bridge E site (Table 1). Intermediate levels of sediment toxicity were

Table 1. Percent mortality of Corbicula fluminea larvae for sediment samples and controls (n=30).

| Sediment and Location | Toxicity test Date | % Mort. (avg.± S.E.) | Adj. % Mort.* |
|---|---|---|---|
| Water control | 6/22 | 3 ± 0.24 | 0 |
| | 7/20 | 5 ± 3.2 | 0 |
| POTOMAC | | | |
| Fort Foote (sediment control) | 6/22 | 17 ± 2.6 | 0 |
| | 7/20 | 4 ± 2.6 | 0 |
| ANACOSTIA | | | |
| Frederick Douglass Bridge W | 6/22 | 84 ± 0.9 | 67[a] |
| E | 6/22 | 35 ± 6.4 | 18[c] |
| Navy Yard W | 6/22 | 70 ± 1.6 | 53[a] |
| E | 6/22 | 60 ± 4.7 | 43[a] |
| W | 7/20 | 24 ± 3.8 | 19[c] |
| Penn. Ave. Bridge W | 6/22 | 46 ± 2.4 | 29[b] |
| E | 6/22 | 43 ± 5.7 | 26[b] |
| Benning Road Bridge W | 6/22 | 43 ± 2.6 | 26[b] |
| E | 7/20 | 5 ± 0.91 | 0[c] |
| New York Ave. Bridge | 7/20 | 13 ± 3.2 | 8[c] |
| Bladensburg Marina | 7/20 | 20 ± 0.91 | 15[c] |

* Adjusted Mortality = % Average Mortality - % Control Mortality
a,b,c statistically different groups (p<.05)

found in the middle third, at Pennsylvania Bridge and Benning Road West, were significantly more toxic than all other sites with the exception of the Frederick Douglass Bridge E site (Table 1). Intermediate levels of sediment toxicity were found in the middle third, at the Pennsylvania Bridge and Benning Road West transects. Sediment bioassays with the amphipod <u>Hyalella azteca</u> also found the lower Anacostia estuary the region of greatest toxicity (Valinsky et al. 1992).

The high sediment toxicity found on the lowest two transects of the Anacostia, Frederick Douglass Bridge and Navy Yard indicated that the major sources of toxicity resided in this portion of the estuary, primarily on the city (W) side. This area receives city storm sewer outlets and has the Washington Navy Yard and two marinas. The significantly reduced sediment toxicity on the non-city (E) side of the Frederick Douglass Bridge transect may have been due to tidal influx of nontoxic water and/or sediment from the nearby Potomac, since 21% of the lower Anacostia embayment water volume is intertidal (Scatena 1987). Startinga half-kilometer further upstream at the Navy Yard, all the transect sites of the lower and middle Anacostia were equally toxic.

The second sediment collection, 7/20/89, was made just one day following a major

Table 2. EPA Priority Pollutant analysis of sediment samples (EA Laboratories, Sparks, MD).

| | Navy Yard W (Anacostia) | Fort Foote (Potomac, control) |
|---|---|---|
| Organics (ug/g) | | |
| Total Phenolics | 0.6 | 0.2 |
| Metals (ug/g) | | |
| Antimony | <4.4 | <5.9 |
| Arsenic | 3.8 | 7.5 |
| Beryllium | 0.47 | 0.51 |
| Cadmium | 1.2 | 1.3 |
| Chromium | 20.1 | 11.5 |
| Copper | 25.2 | 14.1 |
| Lead | 1.2 | 17.0 |
| Mercury | 0.15 | 0.11 |
| Nickel | 15.5 | 11.5 |
| Selenium | 0.27 | 0.25 |
| Silver | 1.2 | <0.75 |
| Thallium | <0.096 | <0.082 |
| Zinc | 105. | 66.5 |
| Inorganic nonmetals (ug/g) | | |
| Cyanide, total | <0.1 | |
| | <0.1 | |
| Pesticides (ng/g) | | |
| Aldrin, dieldrin | <6.4 | <6.4 |
| Chlordane | <32 | <34 |
| PCB's (ng/g) | <64 | <68 |

storm event. There was debris in the sediment samples and evidence of new deposition, as mud sediment was found at the normally sandy sediment location of Bladensburg Marina. All the sediments had low or no toxicity ($p<0.05$), including the formerly highly toxic Navy Yard W site (Table 1).

The EPA Priority Pollutant analysis of 7/20 sediments found no major differences other than increased copper and zinc at the Navy Yard site (Table 2). None of the sediment contaminants exceeded their ER-L or ER-M values, which are the lower 10 percent and median concentrations causing biological effects (Long and Morgan 1990).

The evidence of fresh sediment deposition following the storm event is indicative of the rapid flushing capacity of the Anacostia estuary. The river is shallow and has a high runoff rate (Freudberg et al. 1989; Scatena 1987). The lower estuary portion typically carries a large sediment load from upstream erosion with normal deposition ranging from 0.2 to 0.7 inches per month (Chang et al. 1988). The loss of sediment toxicity at Navy Yard (W) following the storm event shows the necessity for careful timing of sediment sampling to detect bioeffective toxics. These toxics must originate in the Anacostia basin as there was no indication of toxicity in the water or sediments of the Potomac (Phelps 1990). Concentrations of some chemical contaminants in the Anacostia sediment, particularly Pb, chlordane and PCB's, were higher in a later sampling (Valinsky et al. 1992).

The variability of sediment toxicity at the Navy Yard (W) site suggested a volatile xenobiotic such as ammonia. Adjusting pH to 9 shifts the equilibrium from ionized to unionized ammonia which is the toxic form. A significant increase in percent Corbicula fluminea larval morality was found when pH of Navy Yard (W) sediment was increased from 7.1 ($9 \pm 2.4\%$ mortality) to pH 9, ($98 \pm 0.8\%$ mortality). No change in mortality for control sediment from Fort Foote was observed by increasing pH ($13 \pm 2.7\%$ at pH 7.1; $12 \pm 4.9\%$ at pH 9). These results suggested the presence of ammonia in Navy Yard (W) sediments with the unionized form highly toxic to Corbicula larvae (Ankley et al. 1990). Ammonia can be formed *in situ* in organically rich freshwater sediments. The lower Anacostia receives effluent from several combined storm sewers as well as a swirl concentrator. As the average flushing time of the lower Anacostia is approximately 12 days (Freudberg et al. 1989), ammonia may be generated in sediments between rain events.

Sediment toxicity of the lower Anacostia estuary may be responsible for the reduced benthic community. Since Priority Pollutant ER-M and ER-L values were not exceeded in sediment samples and toxicity increased with pH increase to 9, ammonia may be one cause of toxicity. If ammonia is an important sediment toxicant, improvement in this Anacostia benthic community may occur only with changes in organic loading or hydrographics.

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