Sources of Bioavailable Toxic Pollutants in the Anacostia

Final Report to the DC Water Resources Research Center

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Abstract:

The polluted urban Anacostia River estuary and four of its major tributaries were monitored in summer 2001 for bioavailable EPA Priority Pollutants (PCBS, PAHS, Aroclors, pesticides and five metals) using the locally available Asiatic Clam, *Corbicula fluminea*. Total metal levels in clams at all sites were not significantly different from clams from the nearby control site on the Potomac at Fort Foote. PCB congenors (especially 2 - 5 Cl) and Aroclor totals were significantly greater than controls at Lower Beaverdam Creek (MD). Total pesticides (especially chlordane) were significently greater at the Northeast Branch. Total accumulated PAHs significantly exceeded controls at the Northeast Branch and Lower Beaverdam Creek tributaries, and also at upper and lower Anacostia estuary sites (Bladensburg Marina, Washington Gas Light and the Navy Yard). Clams placed in the Northwest Branch (MD) and Hickey Run (DC) tributaries had total pollutant levels no greater than controls. Clams placed at Hickey Run (DC) before it entered the National Arboretum grounds had only 6% survival, but when placed at the exit from the lake had 92% survival, and contaminant levels were lower than controls. Contaminants in clams at the control site suggest pollutants from the Anacostia estuary are influencing the Potomac estuary.

Introduction:

The Anacostia River estuary is the DC urban river with plans for improving public access and fishing. The poor biological condition of the Anacostia River estuary is receiving increasing public attention as it has a fishing advisory and depauperate benthic life (Phelps 1985), especially as it is a branch of the nearby Potomac estuary which is considered a recovery success of the Chesapeake Bay. The biological problems of the Anacostia have been known for years (Freudberg et al.1989, Cummins et al. 1991) and there have been many studies of its water and sediment chemical contaminants (Velinsky et al. 1992, Velinsky and Cummins 1994, Velinsky et al. 1994, Wade et al 1994, Syracuse Research Corporation 2000). Some studies have been done on the tributary origins of Anacostia pollutants (Warner et al. 1997, Coffin et al. 1999) and bioeffects such as sediment toxicity, tumor formation and bioaccumulation (Phelps 1990, Phelps 1991, Phelps 1993, Phelps 1995, Phelps 2001, Pinkney et al. 2000).

The most serious toxic contaminants of the Anacostia from the standpoint of human health are the pesticide chlordane and PCBs which are above FDA action levels in Anacostia fish and have sponsored a fishing advisory (Velinsky and Cummins 1994, Pinkney 2001). PCBs have a number of harmful effects in biota and can come from a variety of sources including old electrical equipment (Ahlborg et al. 1994, Safe 1990, Safe 1994 Fikslin 1995). PCBs and chlordane and other persistant organic pollutants (POPs) can remain buried in sediments for years but become bioavailable through remobilization by dredging (Phelps 2001). The Anacostia Watershed Toxics

Alliance (NOAA/EPA) has recently formed to study and recommend solutions to the toxic problems of the Anacostia and is proposing several remediation actions for toxics in sediments (AWTA 2002).

However, for sediment toxic remediation to be successful it will be necessary to find and control ongoing sources of pollutants to the estuary. Earlier studies (Gruessner et al. 1997, Coffin 1999) suggested the major water sources to the Anacostia estuary, the Northeast and Northwest Branches (MD), contributed significant amounts of PCBs and other pollutants. A recent Anacostia watershed study (Phelps 2001) found chlordane only in sediments and Asiatic clams at the mid to upper end of the Anacostia estuary and the Northeast Branch. The use of clams to monitor these sites detected the bioavailable chlordane and suggested a Northeast Branch source.

Molluscs are used for biomonitoring aquatic health worldwide because they mostly lack a cytochrome P450 system and will accumulate rather than detoxify or modify pollutants. The Asiatic clam, *Corbicula fluminea*, is common, widespread, resistant to toxics and has been recommended for freshwater contaminant bioaccumulation studies by the National Water Quality Assessment Program (Dougherty and Cherry 1988, Crawford and Luoma 1993, Phelps 1997). The Asiatic clam is considered an especially good accumulator of PCBÆs (Peterson et al. 1994). Translocated Asiatic clams have been used to detect organochlorines and pesticides in rivers in several countries (Elder and Mattraw 1985, Hartley and Johnston 1983, Colombo et al.1995, Smith and Ruhl 1996).

Molluscs are important indicators of contaminant bioavailability. Pollutant concentrations in sediment and water are not the same as their bioavailability to living organisms (Elder and Mattraw 1984, Tatem 1986). Complexation of pollutants by organic material or ions can prevent uptake by living tissue (Sunda and Guillard 1976, Long and Morgan 1990, MacDonald et al. 2000). A recent bioavailability study found Asiatic clams did not accumulate contaminants from exposure to contaminated Anacostia sediments in the Potomac (Phelps 2000). However, clams placed on clean sand at Anacostia estuary sites accumulated water contaminants. Filter-feeding molluscs like the Asiatic clam can accumulate contaminants from water and suspended particulates but not from bed sediments (Harrison 1984, Phelps 1979, Phelps 2000). Catfish in contact with polluted Anacostia sediments have a high rate of tumors (Pinkney et al. 2000). The fish and birds of the Anacostia could be affected by bioavailable pollutants that are part of the food chain. Bioavailability information is essential to understanding the dynamics and effects of pollutants in the Anacostia.

The present study uses the locally available Asiatic clam to biomonitor the bioavailable pollutants contributed by tributary subwatersheds to the Anacostia River estuary. The Asiatic clam population in the freshwater Potomac River estuary near the Anacostia has been flourishing since this invasive species was first found in 1978 (Dresler and Cory 1980, Cohen et al. 1984, Phelps 1994). The State of Maryland allows biomonitoring with *Corbicula* as it is now considered a naturalized species and has been reported in many Maryland rivers and streams. *Corbicula* in the Anacostia are small and few with no young clams, and probably entering by drift and failing to grow or reproduce (Prezant and Chalermwat 1984, Phelps 1985). Juvenile

Corbicula have been used in biomonitoring toxicity in Anacostia sediment and water (Phelps 1990, Phelps 1993, Phelps and Clark 1988). Adult clams placed in the Anacostia generally survive and can be useful in bioaccumulation studies (Douherty and Cherry 1988, Phelps and Clark 1988, Phelps 2001). To assess the bioavailability of contaminants it is considered necessary to expose molluscs for six to eight weeks for tissue concentrations to reach equilibrium (Roesijadi et al.1984).

Methodology

From 4/5/ to 11/23/2001, two clam biomonitoring studies were carried out in the Anacostia River estuary and tributaries (Table 1, Fig. 1). For studies, Asiatic clams *(Corbicula fluminea)* were collected by sieving the sandy sediment at Fort Foote, MD, on the Potomac estuary at eight km below the opening of the Anacostia estuary. Clams averaged 22 - 26 mm (approximately two years old, Aldridge and McMahon 1978). A Fort Foote control sample was taken. Clams were kept cool and translocated to the biomonitoring sites within 48 hours, where GPS readings were made. At the biomonitoring sites, 80 -110 clams were placed in mesh shellfish bags and fastened or suspended. At some sites the clams were anchored in the stream in weighted plastic boxes with mesh lids. Upon retrieval the clam samples were depurated 24 hours at room temperature with three changes of spring water, frozen, briefly thawed, shucked, and the tissues re-frozen. The frozen tissue samples were hand-carried to Severn-Trent Laboratories (STL) at Sparks, MD within one week for analysis.

Table 1. Study site locations on the Anacostia and Potomac River estuaries and tributaries.

	Site	GPS
Potomac River	Fort Foote	N38^{0}46.460Æ, W77^{0}01.770Æ
Anacostia River		
MD Tributary	Northeast Branch	N38^{0}57.621Æ, W78^{0}55.583Æ
	Northwest Branch	N38^{0}56.741Æ, W76^{0}56.855Æ
	Lower Beaverdam Creek	N38^{0}54.977Æ, W76^{0}55.985Æ
MD Estuary	Bladensburg Marina	N38^{0}56.054Æ, W76^{0}56.361Æ
DC Tributary	Hickey Run (4/5/01)	N38^{0}54.555Æ, W76^{0}57.739Æ
	Hickey Run(7/24/01)	N38^{0}54.586Æ, W76^{0}57.710Æ
DC Estuary	Washington Gas Light	N38^{0}52.413Æ, W76^{0}56.334Æ
	Navy Yard	N38052.304Æ, W76^{0}59.712Æ

Clam tissue samples had 50 to 90 clams each. STL carried out a complete EPA Priority Pollutant analysis of the clam tissues, including 21 pesticides, 28 PCB congenors, 18 PAHs, five metals, and lipid, and made the data available in electronic format within five weeks. STL analysis of EPA Priority Pollutants was: PBC congenors by gas chromatography (method SW 8082), chlorinated pesticides by gas chromatography (method SW 8082), PAHÆs by high performance liquid chromatography (method SW 8310), and total copper, zinc, iron, cadmium and chromium by inductively coupled plasma (methods SW 6000, 7000).

For the first biomonitoring study clams were collected at Fort Foote on 4/5/01. Four Anacostia tributary sites near the estuary but above tidal influence were selected for

biomonitoring. Two were the same Northeast Branch (MD) and Northwest Branch (MD) tributary sites as in an earlier study (Pinkney, 2001); one at the Bladensburg Marina estuary near another study site (Phelps 2001), one at Lower Beaverdam Creek (MD), and one at Hickey Run (DC) where it enters the National Arboretum (Table 1).

The first group of clams were collected from the biomonitoring sites on 7/15/01 (14 weeks exposure). Clam boxes were missing at Northwest Branch due to high water flow and Bladensburg Marina due to construction. At Hickey Run the clam mortality was high (94%) and there was insufficient tissue for analysis. Clam mortality at Northeast Branch (8%) and Lower Beaverdam Creek (16%) sites was acceptable for adequate tissue samples.

A control sample of clams was collected at Fort Foote on 7/24/01.

The second biomonitoring study on 9/29/01 had biomonitoring placement on 9/29 and 9/31. Bags or boxes of clams were placed at the Navy Yard, and Washington Gas Light facility sites in the lower Anacostia estuary, Bladensburg Marina (MD) at the new dock, the earlier Northwest Branch site, and a different site on Hickey Run where it leaves National Arboretum grounds (Table 1). TidbiT temperature monitors were attached to clam bags at the Northeast Branch tributary and the Washington Gas estuary sites.

On 10/15/01 clams were collected at the Potomac Fort Foote control site and the tissues divided into six subsamples, which were analyzed by STL for nine PAHs to determine analytical variability. Statistical analysis was carried out by Excel.

The second group of clam biomonitors was recovered on 11/21 and 11/23/01 (eight weeks) as the average daily water temperature had dropped to 10 deg. C, when the Asiatic clam becomes inactive (pers. obs). Mortality at all sites was low (0 - 8%). The clams were handled and the frozen clam tissue samples hand-carried to STL for analysis as before.

Results:

Analytical variability of the nine PAHs in the six control tissue subsamples had a coefficient of variation of 9 -18%. The relationship of standard deviation (SD) to mean was linear: SD = 0.175 MEAN - 1.12 (R^2 = 0.94). This equation was used to estimate the analytical SD of all contaminant totals and to calculate significent differences. Due to the large number of clams per sample the analytical variability is assumed to be the largest source of error.

Total PCB, PAH, metal and pesticide concentrations of tissue samples at biomonitored sites were statistically compared with the largest values from the three control samples taken on 4/05/01, 7/24/01 and 9/29/01. Concentrations that did not exceed analytical thresholds were entered as zero. Statistically significent increased total contaminant levels were taken as those exceeding twice the combined estimated analytical standard deviation of the (largest) control and the biomonitoring sample (Table 2).

Table 2. Total concentrations of EPA Priority Pollutant pesticides: t tPAH, tPCB, tAroclors, and tmetals (Cu + Cd + Fe + Zn +Cr) in Potomac and Anacostia clam tissues.

(ug/Kg)	tMetals (x .01)	tPCB	tAroclors	tPAH	tPesticides
CONTROL SITE					
Potomac FF 5/16/99	490	46		421	25 (Phelps 2000)
Potomac FF 4/05/01	945	173	131	384	425
Potomac FF 7/15/01	745	131	91	457	270
Potomac FF 9/29/01	709	97	57	354	53
TRIBUTARIES					
Northwest Branch	660	83	82	637	77
NortheastBranch	73	187	196	1442*	740*
Lower Beav.Creek	1189	666*	1250*	855	295
Hickey Run	498	97	95	785	42
ESTUARY					
Bladensburg Marina	788	239	361	2350*	94
Wash. Gas Light	905	212	310	1502*	128
Navy Yard	753	186	194	1366*	102

* Statistically significently greater than highest control ($p < .05$)
FF = Fort Foote site

Table 3. EPA Priority Pollutant concentrations in clam tissue samples.

METALS (ug/Kg x 0.01)

	P 4/05	P 7/24	P 9/29	NWB	NEB	LBC	HRN	BM	GL	NY
Cadmium	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Chromium	0.0	0.0	1.6	1.0	0.0	0.0	0.6	1.2	0.7	1.0
Copper	8.6	9.0	7.6	6.1	7.9	14.2	4.8	7.1	9.5	9.1
Iron	64.3	40.6	38.9	38.2	45.6	82.5	32.4	52.3	59.8	43.3
Zinc	21.6	24.9	22.8	20.7	19.1	22.2	12.0	18.2	20.5	21.9

PCB CONGENORS (ug/Kg)

	P 4/05	P 7/24	P 9/29	NWB	NEB	LBC	HRN	BM	WGL	NY
BZ#18	3.5	2.4	2.4	1.7	2.3	47.0	1.8	2.7	10.0	8.4
BZ#28	1.6	2.1	1.4	2.1	2.6	71.0	1.2	2.5	11.0	9.4
BZ#44	7.1	4.0	4.9	3.1	7.1	74.0	4.3	6.5	15.0	14.0
BZ#49	2.8	2.8	2.2	1.2	2.1	64.0	1.7	2.8	11.0	9.2
BZ#52	4.2	4.1	3.5	2.4	6.0	87.0	4.0	7.7	16.0	13.0
BZ#87	26.0	22.0	16.0	16.0	2.1	42.0	16.0	23.0	43.0	37.0

BZ#101	14.0	11.0	10.0	8.2	17.0	44.0	9.2	29.0	21.0	19.0
BZ#105	4.9	2.9	1.6	2.5	3.0	21.0	3.4	14.0	6.7	3.4
BZ#118	9.3	6.8	6.4	5.5	12.0	36.0	7.1	12.0	10.0	9.4
BZ#128	1.8	2.0	1.4	1.1	3.4	9.3	1.4	4.2	3.0	3.0
BZ#138	16.0	13.0	12.0	9.9	29.0	40.0	13.0	38.0	16.0	15.0
BZ#153	35.0	20.0	22.0	16.0	42.0	61.0	22.0	50.0	25.0	23.0
BZ#156	1.2	0.0	0.0	0.0	1.1	3.2	0.0	1.4	1.2	1.0
BZ#170	1.6	0.0	0.0	0.0	2.1	0.0	0.0	4.8	1.3	1.4
BZ#180	3.9	1.3	3.2	2.5	6.3	5.1	2.3	9.5	3.8	3.8
BZ#183	3.0	2.5	1.3	1.1	4.2	5.2	1.1	6.0	1.9	1.8
BZ#184	4.5	5.0	3.2	5.6	10.0	22.0	3.6	7.3	9.6	8.0
BZ#187	8.1	6.2	5.3	3.8	12.0	13.0	4.6	16.0	6.4	6.1
BZ#198	24.0	23.0	0.0	0.0	23.0	21.0	0.0	1.3	0.0	0.0

AROCLORS (ug/Kg)

	P 4/05	P 7/24	P 9/29	NWB	NEB	LBC	HR	BM	WGL	NY
Aroclor-1242	0	52	0	0	59	810	0	0	0	0
Aroclor-1248	0	0	27	38	0	0	39	81	190	100
Aroclor-1254	98	39	30	44	89	440	56	150	120	70
Aroclor-1260	33	0	0	0	48	0	0	130	0	24

PAHs (ug/Kg)

	P 4/05	P 7/24	P 9/29	NWB	NEB	LBC	HRN	BM	GL	NY
Naphthalene	19	51	22	9	31	21	0	0	15	13
2-Methylnaphthalene	14	9	0	0	10	12	0	0	8	0
1-Methylnaphthalene	0	0	0	0	0	0	0	0	9	0
Acenaphthylene	0	0	0	0	0	0	0	0	0	0
Acenaphthene	0	0	0	0	0	12	0	0	14	0
Fluorene	0	0	0	0	0	32	0	33	15	9
Phenanthrene	19	17	0	23	60	0	36	200	68	34
Anthracene	0	0	0	0	18	19	0	26	20	11
Fluoranthene	59	58	27	120	310	0	140	470	220	170
Pyrene	59	57	30	110	240	0	220	360	200	140
Benzo(a)anthracene	0	0	0	13	88	72	22	87	130	120
Chrysene	36	44	20	100	280	270	85	280	350	340
Benzo(b)fluoranthene	0	11	0	34	94	91	31	180	180	160
Benzo(k)fluoranthene	0	0	0	0	69	48	17	0	0	0
Benzo(a)pyrene	0	0	0	0	22	26	12	36	30	28
Indeno(1,2,3-cd)pyrene	0	0	0	0	21	17	13	0	11	8
Dibenz(a,h)anthracene	0	0	0	0	12	14	12	0	0	0
Benzo(g,h,i)perylene	0	0	28	0	40	38	18	520	19	94
Naphthalene-d8(SS)	38	43	47	52	29	37	35	35	46	54
Acenaphthene-d10(SS)	37	44	46	46	29	39	35	29	42	49
Phenanthrene-d10(SS)	35	42	52	50	30	39	42	31	48	53
Chrysene-d12(SS)	36	40	37	39	30	36	31	27	34	37

Perylene-d12(SS)	32	41	45	41	29	32	36	36	43	46
PESTICIDES (ug/Kg)										
	P 4/05	P 7/24	P 9/29	NWB	NEB	LBC	HRN	BM	GL	NY
alpha-BHC	0	0	0	0	0	0	0	0	0	0
beta-BHC	0	0	0	0	0	7	0	0	4	0
delta-BHC	0	0	0	0	0	0	0	0	0	0
gamma-BHC (Lindane)	0	0	0	0	0	0	0	0	0	0
Heptachlor	0	0	0	0	0	0	0	0	0	0
Aldrin	0	0	0	0	0	0	0	0	0	0
Heptachlor epoxide	20	0	0	6	90	0	0	6	0	0
Endosulfan I	0	0	0	0	0	0	0	0	0	0
Dieldrin	42	0	0	12	0	15	0	16	0	0
4,4'-DDE	48	51	10	8	0	56	8	14	27	25
Endrin	0	0	0	0	0	0	0	0	0	0
Endosulfan II	0	0	0	0	0	0	0	0	0	0
4,4'-DDD	31	20	0	0	0	20	5	0	16	12
Endosulfan sulfate	0	0	0	0	0	0	0	0	0	0
4,4'-DDT	67	29	8	0	0	26	0	0	12	0
Methoxychlor	0	0	0	0	0	0	0	0	0	0
Endrin ketone	0	0	0	0	0	0	0	0	0	0
Endrin aldehyde	0	0	0	0	0	0	0	0	0	0
Toxaphene	0	0	0	0	0	0	0	0	0	0
gamma-Chlordane	26	30	7	7	240	28	3	7	15	14
alpha-Chlordane	84	40	8	23	410	38	8	30	35	33
Tetrachloro-m-xylene	53	50	10	11	0	57	8	11	9	9
Decachlorobiphenyl	54	50	11	10	0	48	10	10	10	9

KEY:
P 4/05 Potomac Fort Foote (MD) 4/05/01 control site
P 7/24 Potomac Fort Foote (MD) 7/15/01 control site
P 9/29 Potomac Fort Foote (MD) 9/29/01 control site
NWB Northeast Branch (MD) tributary site
NEB Northeast Branch (MD) tributary site
LBC Lower Beaverdam Creek (MD) tributary site
HRN Hickey Run (DC) tributary site
BM Bladensburg Marina (MD) estuary site
GL Washington Gas Light facility (DC) estuary site
NY Navy Yard (DC) estuary site

Metal totals (Cu + Fe + Zn + Cd + Cr) in clams at biomonitored sites were not significently increased over controls (Table 2, Table 3).

Total PCB congenors in clam tissues significently exceeded controls only at the Lower Beaverdam Creek tributary site (Table 2). The PCB congenor profile for Lower Beaverdam

Creek had elevated levels of the 2 - 5 Cl PCB congenors (Table 3). Other sites had higher levels of the 6-9 Cl PCB congenors.

Total Aroclors significently exceeded the highest control value only at Lower Beaverdam Creek where the principal Aroclors were 1242 and 1254 (Table 3).

Total PAHs in clams were significently greater than controls at the Northeast Branch and Lower Beaverdam Creek tributary sites, and at all the estuary sites (Bladensburg Marina, Washington Gas and Navy Yard) (Table 2). Bladensburg Marina had the highest total PAH.

Total pesticides in clam tissues were signficently greater than control at the Northeast Branch and Lower Beaverdam Creek tributary sites (Table 2). The Northeast Branch clam tissues had highest total clordane (alpha + gamma). The highest DDT/DDD/DDE totals were in clams at the Lower Beaverdam Creek tributary and the Washington Gas estuary sites (Table 3).

Discussion and Conclusions:

Site Summary:

The tissue analytical variability indicated that biomonitoring of suspended and dissolved pollutants with *Corbicula* is probably limited to monitoring high-level sources. The present study identified two tributaries (Northeast Branch and Lower Beaverdam Creek) as high-level sources of specific pollutants. Other tributaries (Northwest Branch and Hickey Run) had no clam pollutants over control levels. The tributaries will be discussed in order, North to South.

The Northwest Branch (MD) subwatershed of the Anacostia River estuary had total contaminant levels in clams no greater than control, and probably is not contributing significently to Anacostia estuary pollution (Table 2). The Northwest Branch provides about 32% of the input flow with a total acreage of 41.9 square miles and an average imperviousness of 17% (Warner et al. 1997). The Northwest Branch is semi-rural and primarily residential (54%) and forested (22%) and considered to have a relatively high quality aquatic habitat for fish and invertebrates.

The Northeast Branch (MD) subwatershed clams had significently greater concentrations of total PAHs and pesticides, with total clordane (alpha + gamma) the greatest of any biomonitored site (Table 2). The Northeast Branch provides about 45% of the Anacostia water input, with an average imperviousness of 26%, and 85% of the mainstream channeled (Warner et al. 1997). It is highly urbanized and dominated by residential land use and includes the Beltsville Agricultural Research Center which has a CERCLA National Priority List site. The fish and invertebrate populations are considered slightly impaired. Future biomonitoring studies should be made on the Northeast Branch tributaries to identify those with greatest contaminant contribution to the Anacostia estuary.

Lower Beaverdam Creek, mostly in Maryland, had clams with significently higher concentrations of PCBs, Aroclors and PAHs. Total DDT (DDT+DDE+DDD) accumulation was highest in this tributary. The Lower Beaverdam Creek subwatershed provides about 12% of the Anacostia water flow (Warner et al. 1997). It is called one of the most intensely developed subwatersheds of the Anacostia and has 17% industrial land with the largest industrial acreage of

any Anacostia tributary. Fish and macroinvertebrate populations are considered the most impaired of all the Anacostia tributaries.

Hickey Run (DC) is a small watershed but has 30% industrial land use and is considered a major problem stream in DC. All its pollutant load is non-point and there are no combined sewer overflow outlets but there is chronic petroleum hydrocarbon release. The two biomonitoring attempts at Hickey Run (4/05 and 9/29) were at different sites with differing results. On 4/05 the clams were placed where Hickey Run exits Route 50 and enters the National Arboretum grounds (Table 1). The water appeared heavily polluted and 94% of the clams died. On 9/29, clams were placed one km away where Hickey Run leaves the Arboretum and after it passes through a lake (Table 1). Clam mortality there was only 8% and all the tissue pollutant levels were lower than controls. It appeared that the Hickey Run bioavailable pollutants had been removed by passage through the lake. This finding is a good argument for wastewater pond remediation of tributary pollutants.

All the Anacostia estuary sites, Bladensburg Marina at the upper end, and Washington Gas Light and nearby Navy Yard sites near the lower end, had significently higher levels of total PAHs in clams than control. No other contaminants were significently increased over control levels.

Contaminant summary:

The finding of no significent difference among metal concentrations in clams at Anacostia sites and the control site suggests that metal contamination is not a problem for Anacostia benthos.

The increase in 2 - 5 Cl PCB congenors in Lower Beaverdam Creek clams is similar to that found earlier in lower Anacostia estuary clams and sediments (Phelps 2001). Along with the high Aroclor level it indicates severe ongoing contamination. Future clam biomonitoring studies should be made on the Lower Beaverdam Creek tributaries to identify possible point sources of PCBs. Remediation of point sources is necessary for adequate PCB control in the Anacostia. PCB levels in other Anacostia tributaries were not significently greater than controls and their high 6-7 Cl congenor level suggests they are weathered and attached primarily to sediment.

Significent PAH contamination appeared widespread in the Anacostia estuary. The only major tributary sources of PAHs to the estuary were the Northeast Branch and Lower Beaverdam Creek. However, since PAH levels were high at all estuary sites there may be other sources in the Anacostia watershed. The pattern of PAH contamination at Bladensburg Marina with high clam tissue levels of phenanthrene, pyrene, fluoranthene and benzo(g,h,i)perylene (Table 3) was not seen in the Northwest and Northeast Branches which form the Anacostia estuary there. Although the new wood bulkheaded marina at Bladensburg was not creosoted, those PAHs may have had another source relating to the recent construction activity.

The pesticide clordane was a significent clam contaminant only in the Northeast Branch. Followup studies need to be made on Northeast Branch tributaries to identify the areas of possible remediation. As clordane has been banned for 20 years and Asiatic clams biomonitor both dissolved and particulate pollutants, it is likely the chlordane is old contamination bound to particulates. The pesticide DDT was detected in clams at the Lower Beaverdam Creek tributary

and the Washington Gas Light estuary location. Agee (1986) suggested the ratio of DDT to its sum with breakdown products (f DDT = DDT + DDE + DDD) can indicate recent transport from land to water, since DDT degrades rapidly in water. He proposed a ratio of above 10% to indicate a fresh source. This ratio was 24% at Lower Beaverdam Creek and 21% at the Washington Gas Light downstream estuary site. The f DDT at the WGL facility could be a fresh source or due to transport from the upstream Lower Beaverdam Creek.

The levels of total metals, PCBs and pesticides (but not PAHs) in the downstream Potomac estuary clams at Fort Foote are slowly returning to pre-dredging levels two years after the extensive COE Anacostia dredging project (8/99 - 4/00) (Phelps 2001) (Table 2). Aerial photographs of the Anacostia mouth always show a turbid plume entering the relatively clear Potomac. Many pesticides and PCBs are transported by association with suspended sediment particles (Coffin et al. 1999, Bergamaschi et al. 2001). However, the levels of contaminants in the Potomac Fort Foote clams did not affect normal *Corbicula* growth and reproduction (Boltovskoy et al. 1997, pers. obs.), and can be considered contaminant bioaccumulation benchmarks that are compatible with a healthy ecosystem. Although the Potomac estuary near DC is considered healthy, the contamination of its fish (Pinkney 2001) and benthos may continue until toxic Anacostia sources of pollutants are cleaned up. The recent AWTA draft document summarizing Anacostia sediment remediation plans does not specifically address the problem of contaminant transport into the Potomac, but does state. It is premature to proceed with a detailed final evaluation of specific remedial actions until a refined conceptual model of the river is developed to provide a better understanding of contaminant inputs, in-river processes and exposure and risk to ecological and human healthö (AWTA 2002). Bioaccumulation studies with the Asiatic clam can be used to locate and monitor the location and remediation of high-level sources in of pollution to the Anacostia River estuary and its tributarries.

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