RELATIONSHIPS BETWEEN METAL CONTAMINATION IN WADABLE STREAMS IN SOUTH CAROLINA AND LAND USE CHARACTERISTICS

Alan J. Jones[1], Elizabeth R. Carraway[1,2], Stephen J. Klaine[1,3], Mark C. Scott[4]

[1]Clemson Institute of Environmental Toxicology, Clemson University.
[2]Department of Environmental Engineering aEarth nd Sciences, Clemson University.
[3]Department of Biological Sciences, Clemson University.
[4]South Carolina Department of Natural Resources, Pendleton, SC.

ABSTRACT

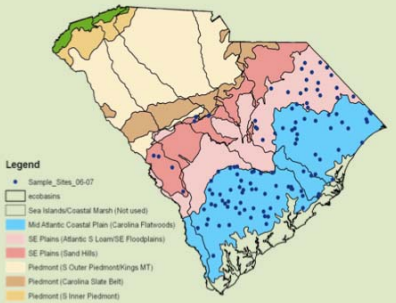
At present, little data is available concerning the overall quality of small aquatic ecosystems in South Carolina. A study of wadeable streams in South Carolina is currently being conducted in cooperation with the South Carolina Department of Natural Resources (SCDNR). The overall goal of this work is to assess overall ecosystem quality in order to provide information needed for improved management strategies. The project assesses fish population and health and in addition performs measurements of stream characteristics, chemical contaminants present, and fish exposure to chemical contaminants. This presentation focuses on metal contaminants found in water and sediments in 2006 and 2007 and relationship between metals and land use in the drainage areas or watersheds of the sites sampled. Sites were randomly selected using known streams and GIS-determined watersheds of appropriate size (less than 150 km2). GIS and the National Land Cover Data Set (NLCD) were used to determine the land use distribution for each sampled watershed. Water and sediment samples were collected and analyzed using ICP-MS, ICP-AES and Cold Vapor AAS. Among the metals of interest are aluminum, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, silver, zinc, and others. Results indicate that a small number of sites exceed the published US EPA constant contaminant concentration and contaminant maximum concentration for a few waterborne or dissolved metals (e.g., cadmium, copper and nickel). In addition, a small number of sites exceed published risk threshold values for metal-contaminated sediments. Linear regression was used to correlate individual dissolved metal measurements with land use activities in individual and combined watersheds. Results indicate that changes in land use can change pollutant loads and impact the quality of the stream. The strongest relationships were observed for agricultural and forest land use with several metals (e.g., chromium, nickel, selenium, and potassium). Developed land area has not shown significant effects in these small and largely rural watersheds. Correlations are also considered for the whole study and are separated by watershed and ecoregion. Principle components analysis (PCA) is applied to watershed land uses to simplify interpretation and to reveal parameters responsible for metal contamination variability.

OBJECTIVE

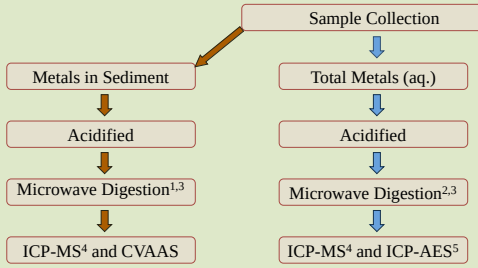
To support South Carolina Department of Natural Resources in their goal to design an implement an effective strategy to protect, conserve, and restore the aquatic resources of the State of South Carolina

SITE SELECTION

- South Carolina was divided into ecoregions based on the major river watersheds then further subdivided into smaller wadeable watersheds.
- Sites were randomly selected in each ecoregion using a Geographical Information System (GIS) –based selection program.



METALS ANALYSIS



1. US EPA Method 3051a – Microwave Assisted Digestion of Sediments, Sludges, Soils and Oils
2. US EPA Method 3015 – Microwave Assisted Digestion of Aqueous Samples and Extracts
3. US EPA Method 3200 – Mercury Species Fractionation and Quantification By Microwave Assisted Extraction
4. Laboratory For Environmental Analysis, University of Georgia, Athens, GA
5. Clemson University Soils Lab, Clemson, SC

AQUEOUS RESULTS

Metal	No. Samples	No. Non-detects	% Non-detects	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile	Maximum
Ag	98	94	96	0.341	0.404	0.549	0.78	0.996	1.14
Al	97	0	0	10.2	22	44	129	207	986
As	98	0	0	0.394	0.432	0.854	1.71	2.45	4.69
B	97	35	36	6.1	13.3	19	26	32	367
Ca	97	0	0	424	1257	5484	14512	28208	57823
Cd	98	30	31	0.112	0.184	0.321	0.489	0.756	13.4
Cr	98	17	17	0.239	0.373	0.367	0.998	3.55	151
Cu	98	0	0	1.13	1.54	2.91	4.57	10.7	49.4
Fe	97	0	0	43.6	133	644	888	1683	13497
K	97	0	0	127	533	1594	2796	4314.4	6777
Mg	97	0	0	187	427	1799	2626	3385	12634
Mn	97	0	0	9.8	22	42	84	264	1358
Na	97	0	0	520	2268	4254	5672	7393	136643
Ni	98	0	0	0.529	0.772	1.35	2.05	4.16	484
P	97	14	14	8	18.5	37	66.5	167	1466
Pb	98	3	3	0.197	0.297	0.522	0.878	0.227	15.7
S	97	0	0	176	495	1153	2394	3997	44432
Sr	98	11	11	0.147	0.206	0.314	0.445	0.767	3.66
Tl	98	42	43	0.129	0.16	0.224	0.544	0.848	0.976
Zn	98	0	0	3.92	7.37	12.6	21.4	27.7	98.3

Above: Aqueous metals results summary table (ppb).

Metal	CCC Equation	CMC Equation	Sites > CCC	Sites > CMC
Ag	NA	$y=0.002x^{0.6274}$	NA	1
Cd	$y=0.0714x^{0.7409}$	$y=0.0235x^{1.128}$	1	1
Cr	$y=1.6625x^{0.8231}$	$y=12.848x^{0.842}$	2	0
Cu	$y=0.1844x^{0.8403}$	$y=0.1688x^{0.95}$	39	28
Ni	$y=1.0069x^{0.8545}$	$y=9.4126x^{0.846}$	8	1
Pb	$y=0.0169x^{1.1043}$	$y=0.413x^{1.09}$	29	0
Zn	$y=2.4404x^{0.8403}$	$y=2.4342x^{0.84}$	2	2

Left: Equations used to adjust observed metal concentrations for water hardness (form $y=Ax^B$ where x=hardness) and number of sites exceeding the threshold.

SEDIMENT RESULTS

Metal	No. Samples	No. Non-detects	% Non-detects	10th Percentile	25th Percentile	50th Percentile	75th Percentile	90th Percentile	Maximum
Ag	98	49	50	0.121	0.171	0.359	0.639	0.740	0.971
Al	98	0	0	150	431	966	2437	7268	16747
As	98	0	0	0.166	0.459	2.403	3.216	4.94	12.9
B	98	1	1	1.07	1.64	4.75	45.2	57.7	119
Ca	98	0	0	28.64	86.63	218	389	1941	19823
Cd	98	24	25	0.145	0.183	0.333	0.491	0.796	2.68
Cr	98	0	0	1.24	1.88	2.90	6.15	15.4	1478
Cu	98	0	0	0.478	0.645	1.18	2.84	8.62	63.6
Fe	98	0	0	40.6	185	435	1513	4321	32443
K	98	0	0	16.9	27.4	61.9	175	419	796
Mg	98	0	0	7.85	13.4	49.3	123	422	2540
Mn	98	0	0	1.73	4.29	8.99	26.8	65.1	566
Na	98	0	0	4.94	8.11	23.9	444	595	1478
Ni	98	0	0	0.539	0.939	1.88	3.63	14.3	1673
P	98	0	0	7.69	18.1	36.6	71.8	254	24647
Pb	98	2	2	0.708	0.981	1.77	3.58	14.1	35.6
S	98	0	0	16.6	28.9	53.7	143	383	5237
Se	98	26	27	0.169	0.280	0.461	0.646	0.979	5.79
Tl	98	41	42	0.140	0.167	0.27	0.494	0.714	0.972
Zn	98	2	2	1.21	3.17	6.79	75.3	105	325

Above: Sediment metals results summary table (mg/kg).

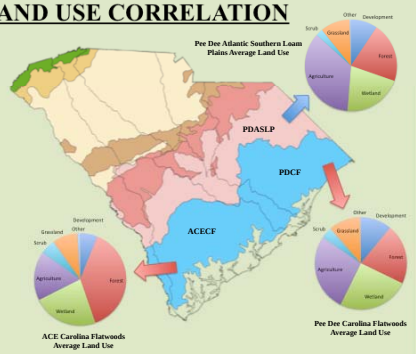
Metal	Background	TEC	PEC
Arsenic (As)	1.5	9.79	33.0
Cadmium (Cd)	0.1-0.3	0.99	4.98
Chromium (Cr)	7-13	43.4	111
Copper (Cu)	10-25	31.6	149
Lead (Pb)	4-17	0.18	128
Nickel (Ni)	9.9	22.7	48.6
Selenium (Se)	0.29	*	*
Silver (Ag)	0.5	*	4.5
Zinc (Zn)	7-38	121	459

Background, Threshold Effects Concentrations (TEC) and Probable Effects Concentrations (PEC) (mg/kg)

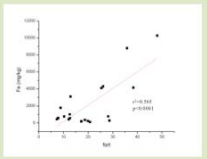
Zinc	Chromium	Nickel
PDA-MUD	PDC-TUR	PDC-TUR
PDA-RCC1	PDC-NUR	PDC-NUR
PDA-RCC2	PDC-CAR	ACE-BAR1
PDA-TGR	PDC-WOB	PDC-CAB
PDA-HHC2	ACE-TG5	PDC-WOB
PDA-TCT		ACE-SANK
SAL-LGB	Copper	ACE-TG5
PDA-MUH	PDA-RCC2	
	PDA-HHC2	Cadmium
Arsenic	ACE-TG5	PDA-NAS
PDC-PAL		ACE-TG5
ACE-TG5	Lead	
	All except:	
	ACE-CNB	
	ACE-CTC	

Left: Sites that exceed TEC for each metal. Note: Pb exceeds the TEC at all sites except ACE-CNB and ACE-CTC

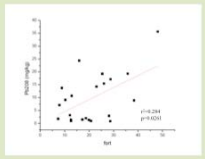
LAND USE CORRELATION



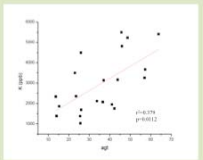
Pee Dee Atlantic Southern Loam Plains (PDASLP)



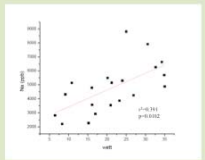
Total forest cover in the PDASLP and sediment iron (Fe)



Total forest cover in the PDASLP and sediment lead (Pb)

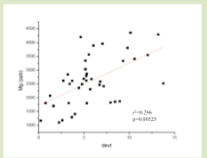


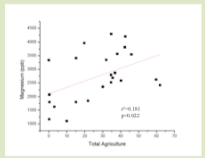
Total agriculture in the PDASLP and aqueous potassium (K)

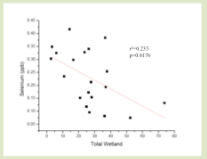


Total wetlands in the PDASLP and aqueous sodium (Na)

Pee Dee Carolina Flatwoods (PDCF)





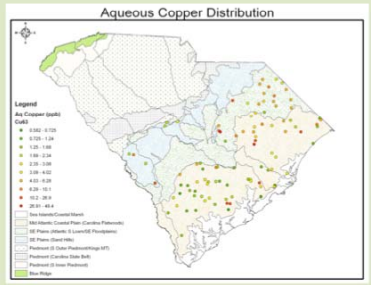


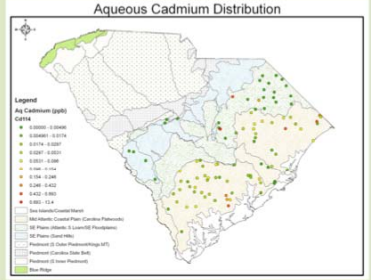
Total land use correlations with magnesium and selenium (Total Development to left, total agriculture top right, and total wetland bottom left).

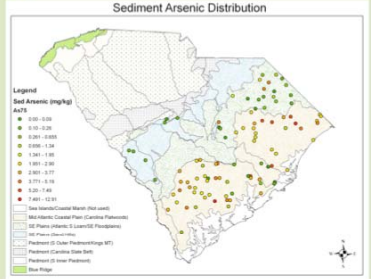
ACE Carolina Flatwoods (ACECF)

- No correlations were observed in the ACECF with any metals and land use.

GEOGRAPHIC DISTRIBUTIONS







DISCUSSION

- Results strongly indicate the presence of metals in the water column and in sediments, with several sites at concentrations above the EPA Constant Contaminant Concentration (CCC), Contaminant Maximum Concentration (CMC), and sediment risk thresholds.
- Significant trends between metal concentrations and land use within the watersheds are evident.
- Geographic hot stops of metal contamination are evident. This indicates that metals are geographically distributed.

ACKNOWLEDGEMENTS

Kevin Kubach, SCDNR; Troy Cribb, SCDNR; William Poly, SCDNR; Cathy Marion, SCDNR; Drew Gelder, SCDNR; Brandon Seda, CIET; Molly Keaton, CIET; S.C. Water Resources Center