Distribution of Elements and Polycyclic Aromatic Hydrocarbons in a Commercial Retention Pond: Colony Crossing, Madison, Mississippi

Austin Harris and Stan Galicki

Department of Geosciences, Millsaps College, Jackson, Mississippi

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ABSTRACT

Retention ponds constructed adjacent to large parking lots are one of the best practices for managing stormwater runoff. Polycyclic aromatic hydrocarbons (PAHs) and heavy metals are two classes of the numerous physical, organic and inorganic contaminants contained in stormwater. Seven sediment samples obtained from the retention pond at Colony Crossing in Madison, Mississippi, were analyzed for grainsize, organic carbon, PAHs using EPA 8270C, and 49 elements using INAA–ICP. The one hectare pond catches runoff from the 18 ha Colony Crossing retail development. EPA 8270C analyses indicate heterogeneous distributions of the 16 EPA priority PAH compounds. PAH ratios indicate a mixed pyrogenic/petrogenic source. Only one sample displayed total PAH values above the severe effect level (SEL). As, Cr, Cu, and Zn concentrations were consistently above the threshold effect level (TEL) for metals. Although there was no correlation between organic carbon and PAH levels, increased organic productivity in the pond should increase contaminant sequestration.

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Austin Harris and Stan Galicki, Millsaps College, Jackson, MS

Introduction

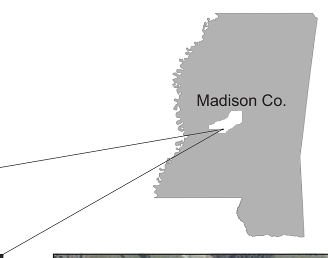
Retention ponds are commonly used to increase runoff lag time and sequester harmful waterborne contaminants. Stormwater runoff collected in urban areas has been identified as a significant source of pollution. When precipitation contacts road surfaces, parking lots, vehicles, and other building materials, surface runoff can contain a variety of pollutants (Davis et al., 2001). Studies of urban and roadway runoff have shown high levels of many pollutants, including suspended solids and heavy metals (Sansalone and Buchberger, 1997; and Wu et al., 1998). Heavy metals are defined as any metallic element that has a relatively high density and is toxic or poisonous even at low concentration (Lenntech, 2004). Commonly investigated heavy metals include As, Cr, Cd, Cu, Hg, Pb, Ni, and Zn. Polycyclic aromatic hydrocarbons (PAHs) are long chain organic compounds identified as having two or more fused benzene rings (Blumer, 1976). They are also known carcinogens that are toxic to terrestrial and aquatic species and do not easily degrade under natural conditions (Boffetta et al., 1997). The US EPA has identified 16 PAHs as priority pollutants of concern.

The primary objective in this investigation is to document the effectiveness of a retention pond in sequestering polycyclic aromatic hydrocarbons and heavy metals in stormwater runoff from an 18 ha retail development.

Study Site

The Colony Crossing Development in Madison Co, Mississippi is located in the SE/4 of Section 1, T7N, R1E at the intersection of MS 463 and Bozeman Rd. Until construction began in 2004 the site was predominantly agricultural (Figures 2a and b). The water feature currently used as a retention pond was originally larger and constructed sometime after 1994 (Figure 2c). Site development incorporated much of the pre-existing pond into the development as a wet retention pond. The 18.1 ha retail development features a 1 ha wet retention pond (Figure 2d).

The site is located within the outcrop of the Eocene Age Jackson Group which consists of the Moodys Branch Fm. and Yazoo Clay. At this location, any unpaved areas would allow only minimal infiltration into the unconfined aquifer and an ideal site for pond construction. The annual precipitation in the area averages 1.4 m/yr. Runoff from the development's 18.1 ha roof and parking areas would exceed 250,000 m^3/yr.



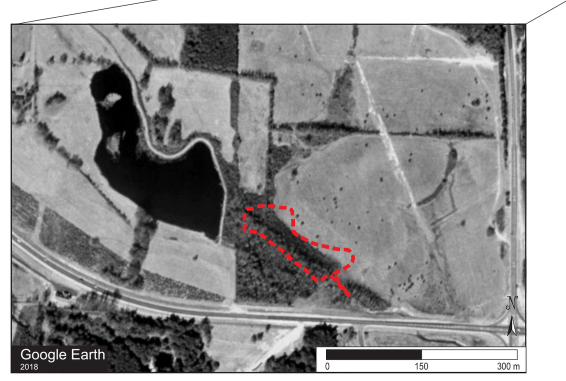
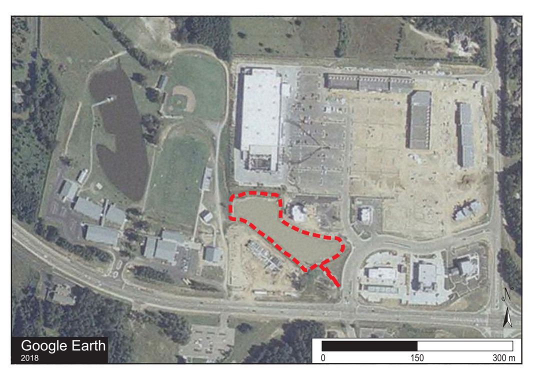
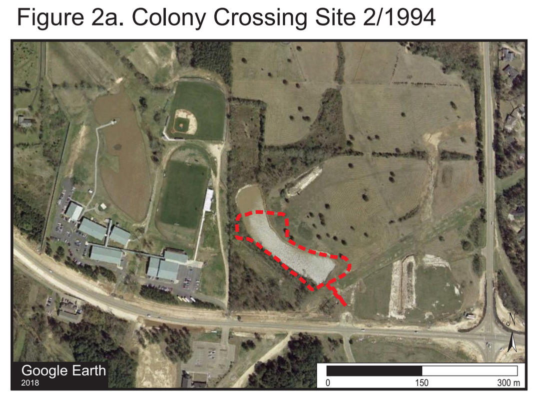


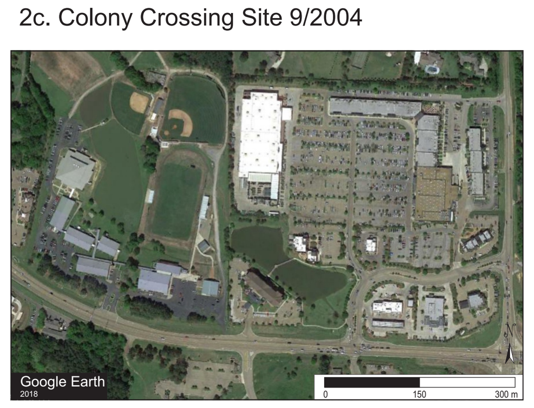
Figure 2a. Colony Crossing Site 2/1994



2c. Colony Crossing Site 9/2004



2b. Colony Crossing Site 3/2002



2d. Colony Crossing Site 3/2017

Figures 2a-d. Development of Colony Crossing site from 1996 through 2017.

Methods

- Seven sediment samples from the Colony Crossing retention pond were collected using a Wildlife Supply Co. dredge (Figure 3).
- One sample was taken from a control pond at St. Joe's Catholic School 0.36 km to the NW.
- Sediment samples were dried, ground, and sieved through an 80 mesh US sieve to incorporate all organic material in chemical analyses.
- Organic carbon (OC) by combustion at 550º C for 2 hours.
- Percent sand by wet sieve using a 230 US mesh sieve.
- PAH analysis using Method EPA 8270C where semi-volatile organic compounds are analyzed by Gas Chromatography/Mass Spectrometry. Waypoint Analytical, Ridgeland, MS.
- All samples analyzed for inorganic elements using Induced Neutron Activation Analysis (INAA) and Inductively Coupled Plasma Mass Spectroscopy ICP-MS, Activation Laboratories, Ancaster, Ontario, Canada.

Figure 1. Westward perspective of the Colony Crossing retention pond.

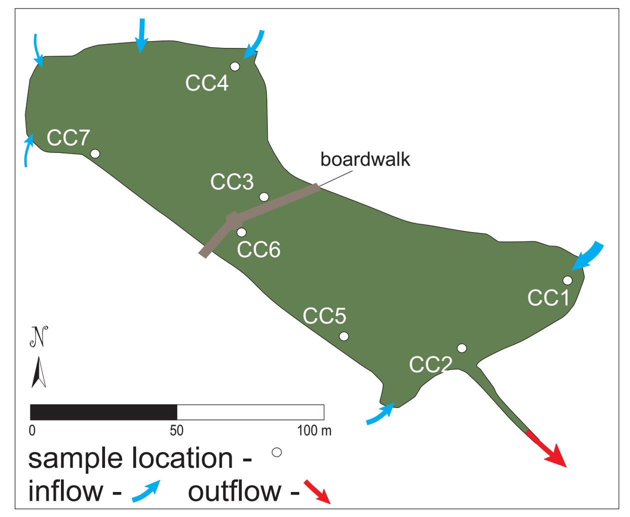


Figure 3. Sample locations with inflow and outflow.

Sample	OC (%)	% Sand
CC1	9.6	70.0
CC2	3.7	92.1
CC3	7.2	11.0
CC4	4.3	90.2
CC5	7.5	65.4
CC6	8.5	1.1
CC7	10.6	52.2
SJ1	5.4	9.6

Figure 4. Organic carbon and percent sand.

Results

OC values averaged 7.1 % and sand percentage values averaged 48.1% (Figure 4). The OC content was relatively high considering there is no appreciable emergent hydrophytic vegetation in the pond. The landscaped lawn is maintained up to the water's edge. The sand percentages were greatest around the perimeter of the pond. Samples 1 and 2 were taken at the point of greatest inflow into and only outlet for the pond.

The elements of interest in this investigation were As, Cr, Cd, Cu, Hg, Pb, Ni, and Zn. The concentrations of Cd and Hg in the sediment were below the detection limit and not included. Concentrations of the remaining elements are displayed in Figure 5. With the exception of Pb, many samples concentrations were above the Threshold Effect Level (TEL) guidelines established by MacDonald et al., (2000). Below the TEL adverse effects to aquatic organisms would rarely be observed. Fifty–four percent of the samples analyzed maintained contaminant levels above the TEL level. All samples exceeded the TEL for As and Cr. Samples 1, 3, and 6 were typically above the TEL for all elements except Pb. None of the values reported were above the Toxic Effect Threshold (TET) where sediment are considered to be heavily polluted.

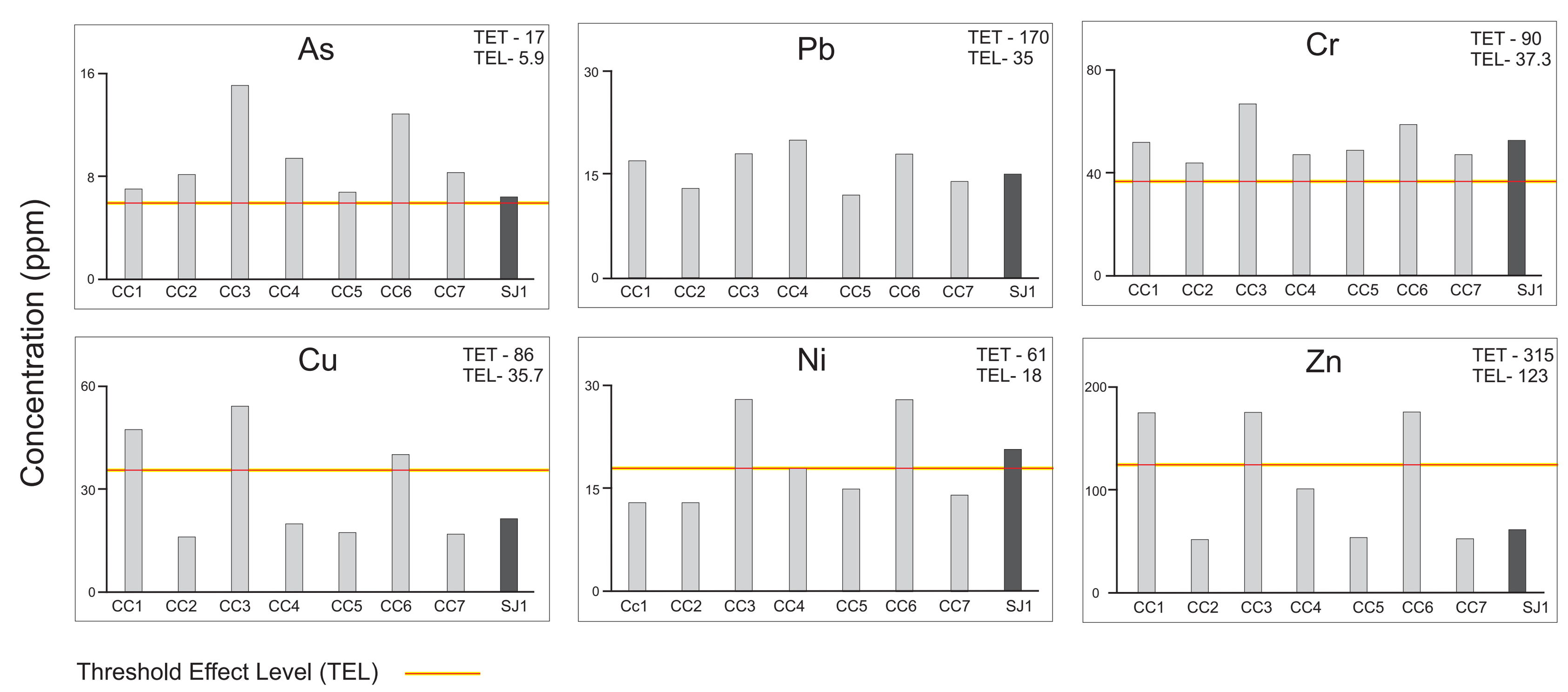


Figure 5. Heavy metal concentrations with Threshold Effect Level (TEL) and Toxic Effect Level (TET) values indicated.

Sediment quality guidelines have not been established for all 16 of the PAHs investigated. Six of the 9 compounds have TEL and Probable Effect Level (PEL) values, and 8 of the 9 have Severe Effect Level (SEL) values. PEL represents the sediment concentration at which adverse effects are expected to be observed frequently. SEL values reflect the concentration at which most sediment dwelling organisms would be adversely affected (MacDonald et al., 2000). The PAH concentration in pond sediment for all samples is reported in Figure 6. Based on the 6 compounds that have established TELs, the guideline concentrations were exceeded in 83% of the samples (n=35/42). PEL guidelines were exceeded 31% of the samples (n=13/42), and SEL guidelines exceeded in 7% of the samples (n=4/56).

PAHs	CC1	CC2	CC3	CC4	CC5	CC6	CC7	SJ1
Acenaphthene	201	10.8	11	54	0.23	0.233	3.85	0.23
Acenaphthylene	59	11.8	12	59	0.39	2	4.64	0.26
Anthracene	1,310	13	13	65	3.73	23	98.3	1.05
Benzo(a)anthracene	11,200	22.9	132	87	56.6	439	1,380	16.30
Benzo(a)pyrene	14,000	36.2	202	100	71.9	311	1,540	26.10
Benzo(b)flouranthene	19,200	79.2	393	142	136	792	2,730	45.50
Benzo(g,h,i)perylene	8,700	13.6	120	198	59.9	361	1,200	21.40
Benzo(k)flouranthene	7,990	24.2	123	86	33.9	151	719	11.90
Chrysene	15,000	40.7	233	115	80.8	426	1,800	27.20
Dibenz(a,h)anthracene	1,100	11.4	39	147	0.39	0.392	215	0.39
Flouranthene	23,900	48.2	419	109	150	1,090	4,270	48.00
Flourene	325	15.7	16	79	1	5.77	14	0.63
Indeno(1,2,3-cd)pyrene	8,410	19.9	116	177	67	240	1,140	24.30
2 - Methylnaphthalene	49	9.8	10	49	0.51	0.513	0.513	0.51
Naphthalene	54	10.9	11	54	0.54	0.96	1	0.51
Phenanthrene	7,720	13.8	98	69	26	178	779	9.08
Pyrene	27,200	51.7	425	107	115	874	3,330	38.20

Bold font denotes established TEL, PEL, or SEL

> Severe Effect Level (SEL) -
> Probable Effect Level (PEL) -
> Threshold Effect Level (TEL) -

Figure 6. 16 EPA priority PAH pollutants concentrations with Threshold Effect Level (TEL), Probable Effect Level (PEL), and Severe Effect Level (SEL) values indicated.

Sediment quality guidelines have not been established for all 16 of the PAHs investigated. Six of the 9 compounds have TEL and Probable Effect Level (PEL) values, and 8 of the 9 have Severe Effect Level (SEL) values. PEL represents the sediment concentration at which adverse effects are expected to be observed frequently. SEL values reflect the concentration at which most sediment dwelling organisms would be adversely affected (MacDonald et al., 2000). The PAH concentration in pond sediment for all samples is reported in Figure 6. Based on the 6 compounds that have established TELs, the guideline concentrations were exceeded in 83% of the samples (n=35/42). PEL guidelines were exceeded 31% of the samples (n=13/42), and SEL guidelines exceeded in 7% of the samples (n=4/56).

Another measure of PAH contamination is the sum of all 16 compound concentrations (Σ16) (Figure 7). There are no guidelines for TEL or PEL levels, but the SEL level is established at 100,000 μg/kg. Only sample 1 exceeds the threshold at 146,419 μg/kg.

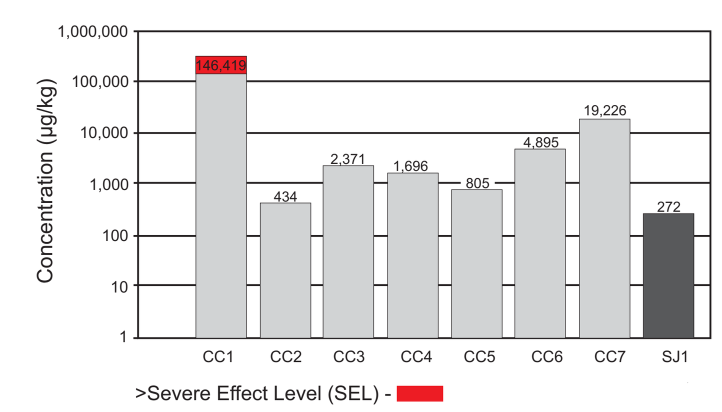


Figure 7. Σ16 PAH pollutant concentrations with Severe Effect Level indicated.

PAH Ratio	Average ± St. Dev.	SJ1	Source - Pyrogenic/Petrogenic
Phenathrene/Anthracene	7.22 ± 0.81	8.65	*Crude* : Diesel, creosote, brick manufacturing
Fluoranthene/Pyrene	1.14 ± 0.19	1.26	*Diesel , coal, asphalt*: wood plants, tire particles, coal, diesel, light distillates, used lubricants, crude, creosote, coke oven & coal tar
Benzo(a)anthracene/Chrysene	0.76 ± 0.17	0.6	*Crude, coal, diesel*: coal, diesel, gasoline, wood plants, brick manufacturing
Benzo(a) pyrene/Benzo(ghi)perylene	1.33 ± 0.33	1.22	*Gasoline*: used lubricants, diesel
Indeo (1,2,3cd) pyrene/Benzo(ghi)perylene	0.93 ± 0.17	1.14	*Asphalt*: coal tar, coal, wood plants, light distillates, diesel, creosote

Figure 8. PAH ratio averages and probable source.

Figure 8 contains the results of five PAH ratio calculations. The calculations are used to determine the source PAH compounds and whether they are pyrogenic or petrogenic. Petrogenic compounds are derived from refined petroleum while pyrogenic are sourced through combustion of fossil fuels. The PAH ratios indicate a mixed source, however, much of the PAHs sequestered in the sediment at Colony Crossing are petrogenic in nature.

Conclusions

The stormwater retention pond at Colony Crossing does sequester heavy metals and PAH priority pollutants in pond sediment. Fifty-four percent of the samples had heavy metal concentrations that exceeded the sediment quality guidelines at the TEL. Eighty-three percent of the PAH concentrations exceeded the sediment quality guidelines at the TEL, and 31% at the PEL. Samples 1 and 7 had the highest values of OC and displayed the greatest concentration of PAHs. Both were situated adjacent to stormwater inlets. Sample 1, situated at the discharge of the largest inlet to the retention pond, exceeded the Σ16 SEL. Future work should focus on the PAH concentration of influent and effluent stormwater collected during a storm events to determine what percentage is retained in the pond.

Acknowledgements

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References

Blumer M. 1976. Polycyclic Aromatic Compounds in Nature. *Scientific American* 234:35-45.

Boffetta P, Jourenkova N, Gustavsson P. 1997. Cancer risk from occupational and environmental exposure to polycyclic aromatic hydrocarbons. *Cancer Causes & Control* 8: 444-472.

Davis AP, Shokouhian M, & Ni S. (2001). Loading estimates of lead, copper, cadmium and zinc in urban runoff from specific sources. *Chemosphere* 44:997–1009.

Lenntech Water Treatment and Air Purification. 2004. Water Treatment. Lenntech, Rotterdamseweg, Netherlands (www.excelwater.com/thp/filters/Water-Purification.htm).

MacDonald DD, Ingersoll CG, & Berger TA. 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. *Environmental Contamination and Toxicology* 39:20-31.

Sansalone JJ, & Buchberger SG.1997. Partitioning and first flush of metals in urban roadway storm water. *Journal Environmental Engineering* 123:134-143.

Stogiannidis E, and Laane R. 2015. Source characterization of polycyclic aromatic hydrocarbons by using their molecular indices: an overview of possibilities, *In* Whitacre DM (ed.), *Reviews of Environmental Contamination and Toxicology Volume 234*, p. 50-108. Springer, Switzerland.

Wu JS, Allan CJ, Saunders WL, & Evett, JB. (1998). Characterization and pollutant loading estimation for highway runoff. *Journal of Environmental Engineering* 124:584–592.