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Characterization of Waste Generated from Drainage Ditch Cleanings

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Abstract

Drainage ditch cleanings is an essential task to prevent flooding and reduce pollution of storm water, which flows into water bodies that serve as fresh water supplies for the populace. Characterization of waste generated from drainage ditch cleanings will provide direction for reuse and disposal options. Seventy-eight drainage ditch waste were sampled from 8 Florida zones through county offices and by direct sampling. Metal concentrations were determined with an inductively coupled plasma–optical emission spectrophotometer (ICP-OES). The analysis of 16 priority polyaromatic hydrocarbons (PAHs) was conducted on a reverse phase high performance liquid chromatography (HPLC) system with UV/Fluorescence detectors. The geometric mean concentrations of the metals are in the order; Zn>Pb>Cu>Cr>Se>Cd>Mo>As. Concentrations of nickel in all drainage ditch waste samples were below the detection limit of 1 mgkg^{-1}. Average concentrations of all 9 metals tested were much lower than the regulatory Soil Cleanup Target Levels (SCTLs). However, 6 individual samples had As concentrations above SCTL while Cu concentration was above SCTL in only one sample. The maximum concentrations of PAHs in this study ranged from 0.13 mgkg^{-1} to 10.5 mgkg^{-1}. Fluoranthene had the highest maximum concentration while benzo(k) fluoranthene had the lowest. The geometric mean concentrations of 16 PAHs were less than the industrial and residential Florida SCTLs except for benzo(a)pyrene which had 12 values exceeding the SCTLs. Overall, waste generated from drainage ditch cleaning appears to be relatively safe for reuse and disposal.

Keywords: Drainage ditch cleaning; metals/metalloids; polycyclic aromatic hydrocarbons; run off; characterization.

Introduction

Drainage ditches help to control the flow of storm water to mitigate flooding. Though, a lot of work has been done on the effects of drainage ditches in agricultural and forest areas, not much has been done to determine effect of urbanization and industrialization[1-5]. US EPA has reported that pollution of storm water is a major source of contamination to surface water bodies in the USA, making storm water runoff a number one threat to fresh water supply[6]. High concentration of heavy metals in storm water run-off has been reported in a catchment with light industry, especially zinc and copper[7]. In another study, copper was the most prominent metal both in the storm water and the receiving streams in the study area, though metal concentrations were below regulatory standards[8].

Pollution of run-off water from agricultural, urban and industrial non-point sources can be reduced or prevented through cleaning activities. Cleaning practices such as street sweeping help to remove pollutants on our roads to minimize pollutant export to surface waters. Drainage ditch cleaning involves the removal of materials such as sediments, debris and overgrown vegetation blocking the ditches. The sediments accumulated in drainage ditches are usually excavated and may contain different types and levels of pollutants. There are few or no data on characterization of drainage ditch wastes to our knowledge. Previous studies have characterized wastes to determine their potential effect on the environment[9]. Out of the 11 metals analyzed, concentrations of As, Ba, Cr, Cu, and Pb were higher than the Florida Department of Environmental Protection (FDEP) Soil Cleanup Target Levels (SCTLs). Three polycyclic aromatic hydrocarbons (PAHs) were higher than SCTLs in 2 samples (<2% of the samples).

A past study reported that metal concentrations in waste from Washington state, USA exceeded FDEP's SCTLs. Organic contaminants such as pesticides, phenols, phthalates, and PAHs were the most frequently detected. Though there are few studies on waste from ditch drainage cleanings, much research has been carried out on contamination of soils along roadsides[10-13]. Research on highway runoff and soils will help to understand the chemical composition of ditch drainage wastes because most of the ditches are along the highways. A previous study suggested that metal contamination of roadside soils might be a source of surface water pollution[14]. Though concentrations of metals in highway soils from West Bank are low, highway soils from Texas and Ohio had metal concentrations higher than FDEP's SCTLs[15]. This indicates that metal contamination of highway soils is dependent on location. The main objective of this research is to determine the level of pollution of ditch drainage wastes in order to recommend proper waste management practices.

Materials and Methods

Field Samplings: The drainage ditch wastes were sampled from 8 Florida zones; Northwest, North Central, Northeast, Central West, Central, Central East, Southwest, and Southeast. Half (39) of the samples were collected through the assistance of various counties/cities across the state while the other half (39) were sampled directly by the authors from one county (Clay County). County offices were provided with a sampling kit consisting of sampling materials such as a cooler, a stainless steel scoop, a sample container, a sampling protocol, a prepaid overnight shipping label, and an information sheet via mail. They were asked to return the sampling kit back to the University of Florida on the same or next day using prepaid overnight shipping label included in the sampling kit. The samples were sent in coolers with ice to preserve organic contaminants. Once received, the samples were divided into two equal portions for metal and organic analysis. Direct sampling by the authors involved collection of composite samples from selected ditches and placement into glass containers. Composite samples were collected by mixing together in stainless steel bowls sub samples collected randomly from the sites. The samples were placed in coolers packed with ice to prevent loss of organic contaminants through volatilization.

Chemical Analysis: Samples were air-dried for 2 weeks before pH determination and metal analyses, while wet samples were used for analysis of organic contaminants. The air-dried samples were gently ground and passed through a 2 mm sieve. Waste pH was measured in a 1:20 waste:water ratio after 1 h of equilibration on a pH and ISE meter. For metal analyses, 0.5g air dry soil was digested with HNO_3/H_2O_2 using USEPA Method 3050A. Digested sample was made up to 50 ml and metal concentrations determined on an inductively coupled plasma–optical emission spectrophotometer (ICP-OES). Instruments were calibrated for metal analysis with standards and quality assurance and control procedures involved the use of blanks, duplicates, certified reference materials, and spikes. For determination of organic pollutants, samples were thoroughly mixed and analyzed in the laboratory within two weeks. Target organic contaminants include polycyclic aromatic hydrocarbons (PAHs) such as, acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b) fluoranthene, chrysene, fluorene, naphthalene, phenanthrene, and pyrene. 30 grams of wet samples was extracted with 500 mL of methylene chloride using ultra-sonic extraction technique, passed through Whatman # 1 filter paper, reduced to 5 mL using the nitrogen-blow down technique and stored in a freezer prior to cleaning (USEPA Method 3550). The gel-permeation cleanup (GPC) technique was used to separate the PAHs from unwanted compounds (USEPA Method 3640b). Volume of clean samples were reduced to 3-6 mL using the nitrogen blow method to obtain a final sample volume of 1 mL. PAHs was analyzed in final sample with a reverse-phase high performance liquid chromatography system with a fluorescence detector. Even though, 78 samples were collected, only 67 samples were analyzed for organic contaminants because eleven samples exceeded the holding time of 14 days by the time they were delivered. The recoveries of the PAHs varied from 72.9% to 125% with an average of 88.7% while it was less than 70% for 3 PAHs (acenaphthylene, pyrene, benzo(a)anthracene).

Statistical Analysis: The concentrations of both metal and organic contaminants were log normalized when they are not normal. In addition to arithmetic means, geometric means of metals and PAHs was also computed. The upper confidence levels for average concentrations of PAHs were calculated.

Results and Discussion

Soil pH: Soil pH is a very important parameter because it determines the mobility of metals. Metals are more available and mobile in acidic soils while high soil pH reduces metal mobility. About 54% of the ditch drainage waste sampled had pH (Figure-1) between 6.1 and 7.0 approximately 28% had basic pH values (7.1 to 8.0) while about 18% were acidic ($pH \leq 6.0$). The average pH of all the samples (6.54) was 1.5-2 units higher than background values for Florida soils[19]. Though metal mobility may be a concern in the acidic soils ($pH<6$), only about one-fifth of the ditch cleaning wastes were in this category.

Total Metal / Metalloids Concentrations: Total Zn concentrations were the highest with a maximum of 659 $mgkg^{-1}$ while the lowest was Cd with a maximum of 3.82 $mgkg^{-1}$ (Table-1). Past research reported that Zn had the highest mean concentrations out of all the heavy metals measured in storm water run-off and detention pond water[7]. This was attributed to an industrial catchment area as the source of metals in the storm water run-off. In this study, maximum total concentrations of Cr, Cu, Pb and Se were 202, 246, 86.7, 11 $mgkg^{-1}$ respectively. Other metals/metalloids had maximum concentrations below 6 $mgkg^{-1}$. Concentrations of nickel in drainage ditch waste were below the detection limit (1 $mgkg^{-1}$). The concentrations of molybdenum and selenium in drainage ditch waste were very low with 58% and 56% samples respectively being ≤1 mg kg^{-1}.

Average concentrations are more representative of the samples, so both geometric and arithmetic mean concentrations of 9 metals and metalloids (arsenic, cadmium, chromium, copper, lead, molybdenum, nickel, sellenium, zinc) are presented in Table-1. The geometric mean concentrations of the metals are in the order; Zn>Pb>Cu>Cr>Se>Cd>Mo>As. There was also a similar order for the arithmetic mean concentrations except that Mo was greater or about the same as Cd. Based on total mean (arithmetic) metal concentrations, the metals present in relatively high concentrations in all districts are Zn, Pb, Cr and Cu (Table-2). The highest concentrations of Zn, Cu, Cr, Cd and Pb in ditch drainage wastes were found in the Central West district of Florida. This region is home to many big urban settlements, which may explain the high concentration of metals.

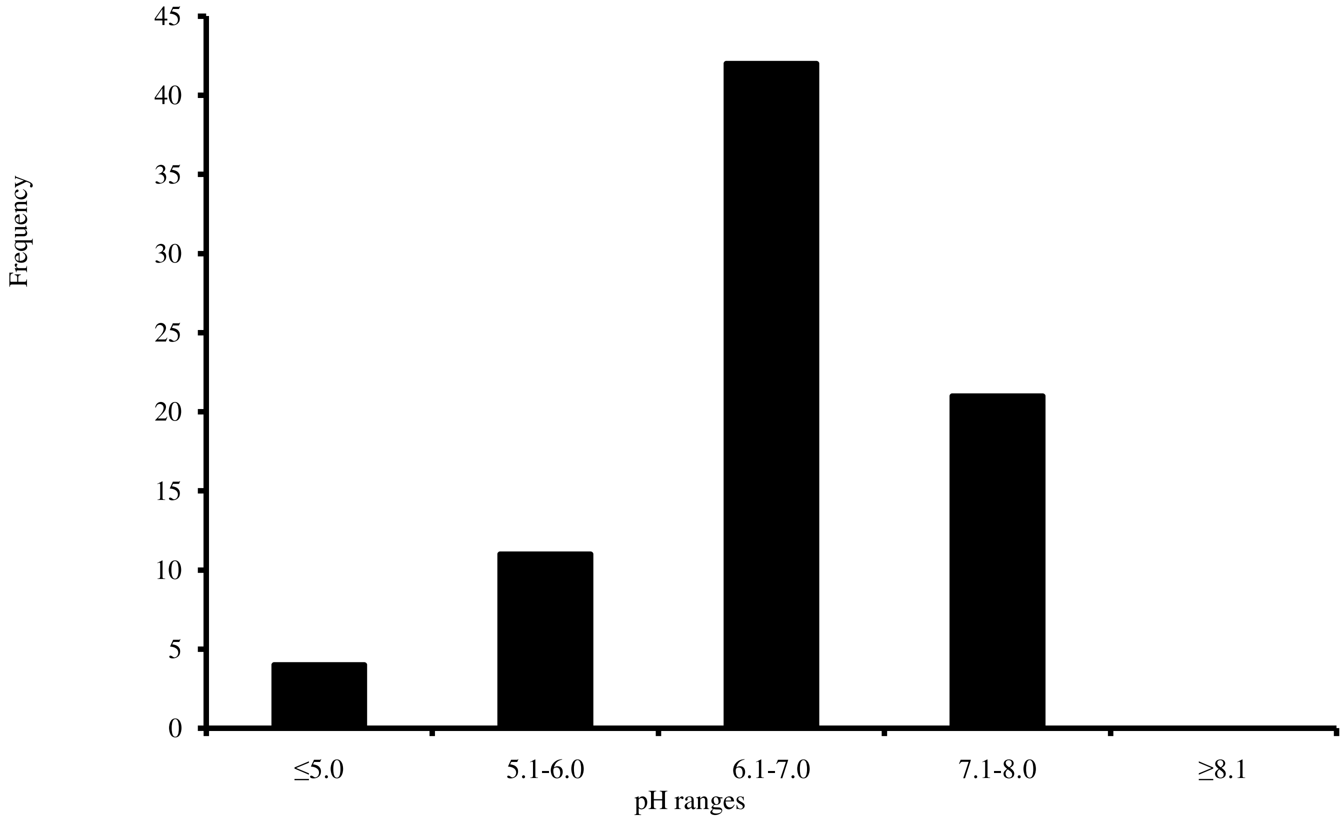

Figure-1
Distribution of pH of drainage ditch waste

Table-1
Average concentrations of metals in drainage ditch waste

Metal	Concentration Range	Mean Concentration ($mgkg^{-1}$)		R-SCTL	I-SCTL
		Geometric	Arithmetic		
As	bd*-4.08	0.61	0.76	2.1	12
Cd	bd-3.82	1.14	1.59	82	1700
Cr	bd-202	2.05	5.55	210	470
Cu	bd-246	2.98	7.85	150	89,000
Mo	bd-5.46	1.04	1.60	440	11,000
Ni	bd	0.50	0.50	340	35,000
Pb	bd-86.7	3.88	8.98	400	1400
Se	bd-11.0	1.19	2.20	440	11,000
Zn	3.16-659	15.3	31.2	26,000	630,000

*bd-below detection limit

The total metal concentrations on their own do not provide information on the toxicity or mobility of metals in the soil, so they were compared to regulatory standards. Because arithmetic metal concentrations do not have a normal distribution, we only compared geometric mean concentrations with FDEP Residential (R)-SCTLs and Industrial (I)-SCTLs[16]. Geometric mean concentrations of all nine metals in ditch cleaning waste were much lower than their FDEP residential and industrial SCTLs (Table-1) suggesting low contamination potential. However, comparing individual samples, out of the 78 samples tested for arsenic, As was detected in 10 samples with six being above the R-SCTL for As, representing 8% of the total samples. This might not be a problem since 87% of samples had As concentrations less than1 mgkg^{-1}. Only 0.01% (1 sample) had Cu concentration that was higher than the residential STCL even though Cu was detected in 61 samples or 78% of the samples.

Concentrations of As, Cr, Cu, Pb, Ni, and Se in ditch cleaning waste were lower than the background concentrations of metals in Florida soil while the concentrations of Cd and Zn were 5.5 and 1.3 times respectively higher than the background values[16]. Comparing the results with similar wastes (Table-3) showed that the ditch cleaning wastes are low in metal concentrations. For example, the maximum concentrations of the nine metals in street sweepings were higher than those of ditch cleaning waste except Se[9]. Similarly, the metal concentrations of storm water system sediments were higher than ditch cleaning waste except Cr and Cu[9, 17]. The concentrations of metals were also lower in ditch cleaning wastes than catch basin sediments except for Cd, Cu and Se. Generally, As, Pb and Zn were lower in ditch cleaning waste than SS, SSS and CBS.

It is possible that storm water carries dissolved and suspended particles from the streets and highways, through drainage ditches and storm water ponds to the catch basins. This run-off water carries contaminants either bound to particles or dissolved in storm water. The SS and roadside soils are exposed to contamination and are expected to be rich in contaminants. We suggest that coarser particles settle in ditches which allow continuous flow of storm water, while finer particles settle as sediments. Thus, the lower metal content of ditch cleaning wastes may be due to exposure to a wash away effect of storm water. Particles in SSS and CBS may have originated from the streets and highways and may be colloidal in nature. Elevated concentrations of metals in storm water and catch basin sediments suggest that the streets and highways may be the sources of contamination. This was confirmed by a study, which showed that storm water ponds and sedimentation tanks with higher vehicular intensities had high sediment concentrations of chromium, copper, nickel, and zinc[18].

Table-2
Average metal concentrations (Arithmetic) of drainage ditch waste in Florida districts

District/County	Average Metal Concentrations (mgkg^{-1})								
	As	Cd	Cr	Cu	Mo	Ni	Pb	Se	Zn
Northwest	0.50*	0.50	1.32	5.21	1.48	0.50	12.2	0.90	20.9
North Central	0.50	0.50	3.11	3.01	1.59	0.50	21.0	0.50	29.6
North East	0.50	0.50	0.50	1.11	1.02	0.50	1.73	0.73	24.1
Central West	0.50	1.33	53.0	63.1	2.06	0.50	23.4	0.50	184
Central	0.50	0.50	5.44	5.22	1.06	0.50	17.2	0.50	38.1
Central East	0.50	0.50	1.49	6.89	0.50	0.50	8.59	0.66	27.7
South west	0.50	0.50	2.60	0.50	0.50	0.50	1.28	0.50	15.9
South east	0.50	0.50	3.78	5.34	0.50	0.50	4.62	0.85	78.5
Samples (mailed)	0.50	0.59	7.85	10.19	1.00	0.50	10.6	0.64	50.0
Clay County (collected)	1.02	2.60	3.26	5.51	2.19	0.50	7.39	3.74	12.4
All	0.76	1.59	5.55	7.85	1.60	0.50	8.98	2.20	31.2

*concentrations below detection limit were estimated at 0.5 mgkg^{-1} (50% of limit of quantification)

Organic contaminants: In this study, the 16 PAHs analyzed were detected while in previous studies lower numbers of PAHs were detected. Five PAHs were detected in 300 streets sweepings samples, which had concentrations above SCTLs[9]. Another study only detected PAHs with molecular weight 178-252 and average concentrations ranging from 0.54 $mgkg^{-1}$ acenaphthylene to 33 $mgkg^{-1}$ naphthalene. Higher detection recorded in our analyses may be because of the analytical instrument used (High Performance Liquid Chromatography with UV/Fluorescence detectors) which had lower detection limit than the GC-MS used in the past studies.

The maximum concentrations of PAHs in this study ranged from 0.13 $mgkg^{-1}$ to 10.5 $mgkg^{-1}$. Fluoranthene had the highest maximum concentration while benzo(k)fluoranthene had the lowest (Table-4). The concentration of PAHs determined in the drainage ditch waste samples were less than the R and I Florida SCTLs except for benzo(a)pyrene which had 12 values exceeding the SCTLs. The median and 75th percentile of PAH concentrations were less than the residential SCTL except for benzo(a)pyrene. The average concentrations (geometric) of benzo(a)pyrene are less than the residential and industrial SCTL.

In this study, the PAHs had geometric mean concentrations that were less than their corresponding residential and industrial SCTLs. In addition, the upper confidence levels were less than R-SCTL and I-SCTL. This means we are 99% confident that the geometric mean is not greater than the upper confidence level. The concentrations of PAHs in ditch cleaning waste are comparable or lower than what has been reported in literature. In this study, the total PAHs (sum of arithmetic mean of 16 PAHs) in ditch cleaning waste is 1.42 $mgkg^{-1}$. Total PAHs (0.51 $mgkg^{-1}$ to 159 $mgkg^{-1}$) about 112 times greater than what we obtained was reported when storm water pond sediments were characterized. They reported individual PAH concentrations that were generally below detection limits in storm water run-off with total PAHs estimated between less than 0.01 and 2.1 $mgkg^{-1}$ PAHS[19]. The concentration of PAHs in storm water run-off is lower than sediments because the PAHs are probably bound to the sediments.

The maximum concentrations of PAHs (0.13-10.5 $mgkg^{-1}$) obtained in this study are much lower than what is reported for sediments and street sweepings in previous studies (Table-5). Higher maximum concentrations of PAHs (3-228 $mgkg^{-1}$) which were about twenty times our results were reported in Florida sediments in a past study. Another study reported concentrations (4.1-95 $mgkg^{-1}$) that were about nine times higher than our results in Massachusetts sediments. Similarly, a study on street sweepings in Florida reported concentrations (5.4-111 $mgkg^{-1}$) about ten times our results[9]. This shows that waste in drainage ditches are cleaner than sediments and street sweepings.

Table-3
Concentrations of metal/metalloids (mg/kg^{-1}) in Florida soils and solid wastes

Contaminants	Florida Soils	SS	DDW	SSS	CBS
As	0.16-6.00	*bdl-13.6	bdl-4.08	bdl-24.8	bdl-12.7
Cd	0.004-2.80	bdl-54.1	bdl-3.82	bdl-5.3	bdl
Cr	0.02-447	bdl-552	bdl-202	bdl-174.5	bdl-50.8
Cu	0.1-318	bdl-372	bdl-246	4.5-90.4	5.5-398
Mo	0.04-14.1	NA**	bdl-5.46	NA	NA
Ni	0.04-375	bdl-69.9	Bdl	5.4-40.4	2.5-30.7
Pb	0.18-290	bdl-386	bdl-86.7	bdl-196	bdl-1060
Se	0.01-4.62	bdl-10.6	bdl-10.9	bdl-14.1	bdl-7.4
Zn	0.90-169	4.3-1080	3.16-659	5.4-711	9.1-956
References	Chen et al (1999)	Townsend et al (2002)	This study	Townsend et al (2002)	Townsend et al (2002)

*bdl=below detection limit; **NA=not available; SS-street sweepings; DDW-drainage ditch waste; SSS-stormwater system sediments; CBS- catch basin sediments.

Table-4
Concentration ($mgkg^{-1}$) of polycyclic aromatic hydrocarbon in ditch cleaning waste

	Max conc. ($mgkg^{-1}$)	99 % UCL conc.	Mean ($mgkg^{-1}$)		SCTL ($mgkg^{-1}$)	
			Geometric mean	Arithmetic mean	Residential	Industrial
Acenaphthene	1.51	0.078	0.010	0.074	2400	20000
Acenaphthylene	0.43	0.028	0.005	0.029	1800	20000
Anthracene	0.43	0.028	0.002	0.035	2100	300000
Benzo(a)anthracene	0.98	0.043	0.004	0.033	NA[†]	NA
Benzo(a)pyrene	1.01	0.079	0.012	0.099	0.1	0.7
Benzo(b)fluoranthene	0.23	0.015	0.001	0.009	NA	NA
Benzo(g,h,I)perylene	3.95	0.239	0.024	0.251	2500	52000
Benzo(K) Fluoranthene	0.13	0.008	0.001	0.009	NA	NA
Chrysene	1.12	0.062	0.005	0.096	NA	NA
Dibenzo(a,h)anthracene	0.67	0.041	0.002	0.040	NA	NA
Fluorene	1.97	0.098	0.001	0.071	2600	33000
Fluoranthene	10.5	0.425	0.004	0.304	3200	59000
Indeno(1,2,3,cd)pyrene	0.68	0.049	0.002	0.050	NA	NA
Naphthalene	2.02	0.172	0.036	0.270	55	300
Phenanthrene	0.27	0.016	0.001	0.017	2200	36000
Pyrene	1.21	0.048	0.001	0.030	2400	45000

[†]Not Available.

Conclusion

Waste generated from drainage ditch cleanings in Florida was analyzed for metal and organic pollutants. Average concentrations (geometric) of 9 metals were much less than their R/I SCTLs. However, 8% of samples had As concentrations higher than the residential SCTL. Similarly, the average concentrations (geometric) of 16 PAHs were less than the residential and industrial SCTLs. The median and 75th percentile PAH concentrations were less than the R-SCTL except for benzo(a)pyrene. Generally, As, Pb and Zn were lower in ditch cleaning waste than street sweepings, storm water and catch basin sediments. Waste from ditch cleanings had lower concentrations of metals and PAHs than storm water sediments and street sweepings probably because they are exposed to a wash away effect of storm water flow. These results indicate that wastes from ditch cleanings in Florida do not contribute to environmental pollution.

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Table-5
Concentration of polycyclic aromatic hydrocarbon (mgkg^{-1}) in sediments and street sweepings

Reference	Miles and Delfino[20]	Shiaris and Jambard[21]	Townsend et al[9]	This Study
	Florida (Sediments)	Massachusetts (Sediments)	Florida (Street sweepings)	Florida
Acenaphthene	0.08 – 262	NA	NA	<0.0049 - 1.514
Acenaphthylene	0.08 – 3.00	NA	NA	<0.0025 - 0.425
Anthracene	0.04 – 11.0	<0.010 – 0.51	12.9	<0.0001- 0.429
Benzo(a)anthracene	0.04 – 11.0	NA	14.5 – 39.9	<0.0002 - 0.976
Benzo(a)pyrene	0.18 – 9.50	<0.007 – 95.0	9.2 – 34.3	<0.0002 - 1.007
Benzo(b)fluoranthene	NA	<0.070 – 4.10	13.2 – 104	<0.0001 - 0.233
Benzo(g,h,I)perylene	4.5 – 10.6	NA	7.6 – 48.5	<0.0004 - 3.951
Benzo(K)Fluoranthene	NA	NA	22.2	<0.0001 - 0.133
Chrysene	0.04 – 13.0	NA	56.3	<0.0002 - 1.119
Dibenzo(a,h)anthracene	0.36 – 1.00	NA	NA	<0.001 - 0.668
Fluorene	0.07 – 128	NA	6.5	<0.0005 - 1.971
Fluoranthene	0.06 – 85.0	<0.005 – 84.5	5.4 – 59.3	<0.0002 - 10.55
Indeno(1,2,3,cd)pyrene	0.72 – 9.50	NA	47.2	<0.0002 - 0.676
Naphthalene	0.26 – 226	<0.01 – 43.6	NA	<0.0025 - 2.019
Phenanthrene	0.05 – 228	0.045 – 63.7	7.5 – 29.1	<0.0002 - 0.267
Pyrene	0.05 – 78.0	0.158 – 66.8	11.6 – 111	<0.0005 - 1.206

NA-not available

References

1. Twisk W., Noordervliet M. and Keurs W.J. (2000). Effects of ditch management on caddisfly, dragonfly and amphibian larvae in intensively farmed peat areas. *Aquatic Ecology*., 34, 397-411.
2. Diaz O.A., Lang T.A., Daroub S.H. and Chen M. (2005). Best Management Practices in the Everglades Agricultural Area: Controlling Particulate Phosphorus and Canal Sediments. Gainesville, Institute of Food and Agricultural Sciences, University of Florida.
3. Sarkkola S., Hökkä H., Ahti E., Koivusalo H. and Nieminen M.(2012). Depth of water table prior to ditch network maintenance is a key factor for tree growth response. *Scandinavian Journal of Forest Research*, 27(7), 649-658.
4. Piirainen S., Domisch T., Moilanen M. and Nieminen M. (2013). Long-term effects of ash fertilization on runoff water quality from drained peatland forests. *Forest Ecology and Management*, 287, 53-66, http://dx.doi.org/10.1016/j.foreco.2012.09.014.
5. Tuukkanen T., Stenberg L., Marttila H., Finér L., Piirainen S., Koivusalo H. and Kløve B. (2016). Erosion mechanisms and sediment sources in a peatland forest after ditch cleaning. Earth Surface Processes and Landforms., DOI: 10.1002/esp.3951.
6. USEPA (1995). Controlling Nonpoint Source Runoff Pollution from Roads, Highways and Bridges.
7. Wium-Andersen T., Nielsen A.H., Hvitved Jakobsen T. and Vollertsen J. (2010). Heavy metals, PAHs and toxicity in stormwater wet detention ponds. *Water Science & Technology*, NOVATECH, 1-10.

8. Adedeji O.H. and Olayinka O.O. (2013). Heavy Metal Concentrations in Urban Stormwater Runoff and Receiving Stream. *Journal of Environment and Earth Science*, 3(7), 141-150.

9. Townsend T.G., Jang Y., Thurdekoos P., Booth M., Jain P. and Tolaymat T. (2002). Characterization of street sweepings, stormwater sediments, and catch basin sediments. Florida for disposal and reuse. Gainesville, Florida Center Solid Hazardous Waste Management.

10. Li X., Poon C. and Liu P. (2001). Heavy metal contamination of urban soils and street dusts in Hong Kong. *Applied Geochemistry*, 16, 1361-1368.

11. Nabulo G., Oryem-Origa H. and Diamond M. (2006). Assessment of lead, cadmium, and zinc contamination of roadside soils, surface films, and vegetables in Kampala City, Uganda. *Environmental Research,* 101, 42-52.

12. Tanee F. and Albert E. (2013). Heavy Metals Contamination of Roadside Soils and Plants along Three Major Roads in Eleme, Rivers State of Nigeria. *Journal of Biological Sciences,* 13, 264-270. DOI:10.3923/jbs. 2013.264.270

13. Mafuyai G.M., Kamoh N.M., Kangpe N.S., Ayuba S.M. and Eneji I.S. (2015). Heavy metals contamination in roadside dust along major traffic road in Jos metropolitan area, Nigeria. *Journal of Environment and Earth Science*, 5(5), 48-57.

14. Sansalone J.J. and Buchberger S.G. (1997). Partitioning and first flush of metals in urban roadway storm water. *Journal of Environmental Engineering,* 123(2), 134-143.

15. Swaileh K.M., Hussein R.M. and Abu-Elhaj S. (2004). Assessment of Heavy Metal Contamination in Roadside Surface Soil and Vegetation from the West Bank. *Archives Environmental Contamination Toxicology*, 47, 23-30.

16. Chen M., Ma L.Q. and Harris W.G. (1999). Baseline concentrations of 15 trace metals in Florida surface soils. *J. Environ. Qual.*, 28, 1173-1181.

17. Marsalek J., Watt W.E. and Anderson B.C. (2006). Trace metal levels in sediments deposited in urban stormwater management facilities. *Water Sci Technol.*, 53(2), 175-183.

18. Karlsson K., Viklander M., Scholes L. and Revitt M. (2010). Heavy metal concentrations and toxicity in water and sediment from stormwater ponds and sedimentation tanks. *J Haz. Mat.*, 178(1-3), 612-618, doi: 10.1016/j.jhazmat.2010.01.129.

19. Weinstein J.E., Crawford K.D. and Garner T.R. (2008). Chemical and Biological Contamination of Stormwater Detention Pond Sediments in Coastal South Carolina. Final Project Report, National oceanic and Atmospheric Administration.US Department of Commerce.

20. Miles C.J. and Delfino J.J. (1999). Priority Pollutant Polycyclic Aromatic Hydrocarbons in Florida Sediments. *J. Bull. Environ. Contam. Toxicol.*, 63(2), 226-234.

21. Shiaris M.P. and Jambard-Sweet D. (1986). Polycyclic aromatic hydrocarbons in surficial sediments of Boston Harbour, Massachusetts, USA. *Marine Pollution Bulletin*, 17(10), 469-472.