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THE POTENTIAL CONTRIBUTION OF URBAN RUNOFF TO SURFACE SEDIMENTS OF THE PASSAIC RIVER: SOURCES AND CHEMICAL CHARACTERISTICS

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ABSTRACT

Urban runoff has been reported as the second most frequent cause of surface water pollution in the United States. Due to the incidence of runoff in urban areas, it was of interest to estimate the impact runoff may have to recent sediment quality within the lower reaches of the Passaic River. Study objectives included i) review of recent urban runoff studies to determine the occurrence and pattern of distribution of chemicals in runoff; ii)comparison of the "fingerprints" from urban runoff studies to the contaminant distributions in surface sediments from the River; and iii) estimation of mass loadings to the surface sediments using surrogate data. The analyses showed that metals and PAH distributions in the sediments were similar to those observed in runoff from diverse locations, suggesting that urban runoff composition within the Passaic watershed is similar to other urban areas. Mass loading calculations demonstrated that urban runoff is a significant source of the metals observed in the sediments, and that PAH and DDT sediment loadings could, in some cases, be accounted for by urban runoff. Observed sediment loads for PCBs, however, were significantly higher than were estimated from urban runoff.
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INTRODUCTION

Urban water runoff has been reported as the second most frequent cause of surface water pollution in the United States *[1]*. The United States Environmental Protection Agency *[2]* has reported that 87 percent of the 246 major water basins in the country are affected by nonpoint source pollutants. The generation of pollutants during stormwater runoff results from atmospheric deposition of air pollutants; accumulation of pollutants on impervious surfaces, followed by wash off from those surfaces by stormwater; and erosion on impervious surfaces, which can dislodge and transport contaminants to the nearby receiving waters *[3]*.

Because the incidence of runoff can be great in urban areas, it is necessary to examine the potential chemical loadings that water bodies can accumulate from this source. This is especially true if source allocation of pollutants within river or lake sediments is desired. This paper focuses on the impact that urban water runoff

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may have had on recent sediment quality within the lower reaches of the Passaic River, New Jersey, a heavily industrialized area of the Northeastern United States. Specifically, this paper:

(i) provides a brief review of the common chemical characteristics of urban runoff and the potential loadings of contaminants to waterbodies throughout the United States through a review of several urban runoff studies;

(ii) examines the contaminant concentrations and chemical distributions of several analytes commonly reported in urban runoff studies to determine if urban runoff can be characterized with a simple chemical "fingerprint";

(iii) compares the fingerprints observed in different urban runoff studies to contaminant distributions noted in surface sediments found near combined sewer outfalls along the Passaic River and then uses this surrogate data to estimate mass loadings to surface sediments within the River.

SOURCES AND CHARACTERISTICS OF CONTAMINANTS IN URBAN WATER RUNOFF

Urban runoff water quality problems are caused by the cumulative effects of many, varied sources including heavy and light industry, road runoff and spills, illicit connections and illegal dumping. Specific sources for several chemical classes are listed below and summarized in Tables 1 and 2, along with their observed concentrations in urban runoff. This review focuses on metals, PAHs, some pesticides (DDT), and PCBs, the chemicals most commonly analyzed for in urban runoff studies. However, the analyses performed in subsequent sections will be made more robust as chemicals not typically analyzed in urban runoff (such as PCDD/Fs) are examined in real stormwater events.

Metals: The most significant sources of zinc in urban runoff include atmospheric fallout, corrosion , tires, pavement wear, automobile exhausts, exterior paint, road salt and terrestrial sources *[4]*. The sources of lead include gasoline products and the by-products of their combustion, and exterior paints and stains. The sources of copper include corrosion of copper plumbing, electroplating wastes, some algicides, brake linings and asphalt pavement wear *[5]*. Mercury in runoff is frequently derived from coal combustion, smelting of non-ferrous metals, and emissions associated with chlor-alkali production, paint manufacturing, and battery production, *[6]*. Recent results from the New York - New Jersey Harbor Estuary Program *[7]* suggest that a significant source of mercury in the harbor is unidentified but may be derived from atmospheric sources. The water quality characteristics of urban runoff in the United States for the median urban site reported total metals in the following concentrations: zinc (160 μg/l), lead (144 μg/l), copper (34 μg/l) *[8]*. Mercury concentrations typically range from 0.05 to 67 μg/l *[6]*.

Polychlorinated biphenyls, PCBs: PCBs are commonly found in the environment. They have been used extensively in many industrial applications, including in fire-resistant transformers and insulating condensers. Prior to 1977 (when their use in commercial products was discontinued) they were used as heat exchanger fluids, chemical stabilizers, and in hydraulic systems in the aluminum, copper, iron and steel manufacturing industries. PCBs were also used as plasticizer in natural and synthetic rubber products and as adhesives, insulating materials,

flame retardants, lubricants in the treatment of wood, cloth, paper and asbestos, chemical stabilizer in paints, pigments and oil varnishes and as a dispersant in formulations of aluminum oxide. PCBs are often found both in the influent and in the sludge of municipal wastewater treatment operations. Up to 89% of the PCB loadings to Lake Superior have been estimated to come from atmospheric deposition *[9]*.

Polycyclic Aromatic Hydrocarbons (PAH): There are very few studies of PAHs in urban runoff. Several PAHs are naturally occurring, but the majority of the PAHs are reported to originate from atmospheric fallout from combustion sources, including forest fires and fossil fuel (especially coal) combustion. In a study performed in Rhode Island *[10]*, the PAHs that were detected in runoff at the highest concentrations were phenanthrene and fluoranthene. Based upon the particle sizes of the materials, the authors hypothesized that the two sources of PAHs in urban runoff were from asphalt abrasion particles (larger particles) and a fossil fuel source (smaller, phenanthrene-rich particles).

Pesticides (DDT): According to Gillis et al. *[11]* pesticide monitoring programs in the United States and Canada have detected the widespread occurrence of DDT and its metabolites in natural waters and sediments. Production of DDT in the United States became widespread in the late 1940s for use in agriculture and declined in use through the 1960s. Of DDT and its two common daughter products, DDD and DDE, only DDT seems to be a problem in stormwater *[6]*. Due to the persistence of DDT and its widespread dispersion within the environment, its presence in stormwater is not unexpected.

Table 1. Summary of Inorganic Contaminant Sources in Urban Runoff (from *[6]*).

Contaminant	Reported Range (mg/l)	Typical Sources
arsenic	0.001 to 0.21	industrial emissions, fossil fuel combustion, smelting, laundry products, pesticides, weed killers, defoliants, preservatives
cadmium	0.00005 to 13.73	combustion, wear of tires and brake pads, combustion of lubricating oils, metal-finishing industrial emissions, agricultural use of sludge, fertilizers and pesticides, and corrosion of galvanized metals
copper	0.00006 to 1.41	wear of tires and brake linings, combustion of lubricating oils, corrosion of building materials, wear of moving parts in engines, smelter activity, metallurgical and other industrial emissions, algicides, fungicides, pesticides
lead	0.00057 to 26.00	emissions from gasoline-powered vehicles, gasoline additives
nickel	0.001 to 49.0	corrosion of welded metal plating, wear of moving parts in engines, electroplating and alloy manufacturing, activity of smelters, food production
zinc	0.0007 to 22.0	wear from tires, brake pads, combustion of lubrication oils, activity of smelters, corrosion of building materials and metal objects

Table 2. Summary of Organic Contaminant Sources in Urban Runoff.

Contaminant	Reported Range (mg/l)	Typical Sources
polychlorinated biphenyls	2.69×10^{-5} to 0.00112	leaching of lubricants, hydraulic fluids, plasticizer, dyes, adhesives and copy papers, landfills, fluids from old transformers and capacitors
PAHs	2.4×10^{-4} to 0.56	incomplete combustion of organic material, including gasolines, coal and refuse, leaching of creosoted wood products, fossil fuel burning, tanker spills, oil seeps and other petroleum-related industries
DDD, DDT and DDE	8×10^{-6} to 1.5×10^{-5}	pesticide

CHEMICAL PATTERNS OBSERVED IN RUNOFF FROM URBAN AREAS

Numerous studies of urban runoff and contaminant loading have been reviewed. For the purpose of this paper it was decided to use data presented in the studies outlined below. The criteria for selecting these studies were (1) completeness of the description of chemical concentrations in runoff, (2) the number and type of measured chemical constituents, and (3) the relevance to urban areas. This screening technique identified literature runoff data to serve as a surrogate for the Passaic watershed. Possible annual loadings of many different chemicals to the Passaic River sediments were estimated and then compared to the loadings observed in river sediments. The studies used in the comparison are:

(1) The National Urban Runoff Program. A Review of Data from 1983. The United States Environmental Protection Agency. *[2]* Referred in text as **NURP.**

(2) Marsalek, J and Schroeter, H.O. 1984. Data from the National Water Research Institute, Burlington, Ontario. *[12]* Referred in text as **NWRI.**

(3) Marsalek, J and Ng, H.Y.F. 1987. Evaluation of Pollutant Loadings From Urban Non-Point Sources, National Water Research Institute, Ontario. *[9]* Data for Sue Ste. Marie was used in particular. Referred in text as **SSM.**

(4) Hoffman et al. 1984. Urban Runoff as a Source of Polycyclic Aromatic Hydrocarbons to Coastal Waters. *[13]* Referred in text as **Narragansett Bay**.

(5) HydroQual Assessment of Pollutant Loadings to New York-New Jersey Harbor. January , 1991. USEPA. *[14]* Referred in text as **Newark.**

The comparison of metal concentrations, PAHs, PCB and DDT found in runoff in each of the studies are summarized in Table 3. Despite the differences in the study locations and land use variations within each study area, the ranges and means reported for the various metals observed in urban runoff are remarkably similar with the exception of the Newark study which tends to show higher concentrations. More interesting than

concentrations of individual metals is the occurrence and abundance of the metals relative to each other. As illustrated in Figure 1, normalization of the data (with respect to cadmium, the metal of lowest concentration) yields a distinct metals "fingerprint" or profile for urban runoff. The relative abundance of the metals decreases in the order zinc > lead > copper > nickel > cadmium.

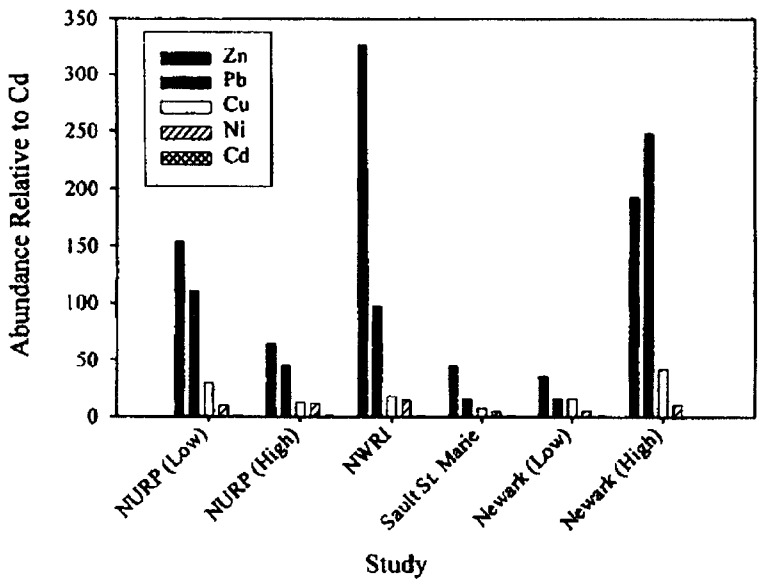

FIGURE 1. Metal Distribution Observed in Several Urban Runoff Studies

PAH data from the Narragansett Bay study were normalized to naphthalene and then plotted (Figure 2a and 2b) based on land use type. Although a comparison among studies was not possible since the other reports did not provide means or different PAH concentrations, Figure 2 may still serve as a fingerprint profile for PAH distribution in urban runoff. As noted, the distribution of PAHs is different for the different land use types. For example, residential PAH loadings tend to be enriched in fluoranthene and depleted in naphthalene which yields a fingerprint profile showing a higher relative abundance of the heavier PAHs compared to PAH abundance from commercial and industrial locations (Figure 2a). The relative abundance of PAHs in runoff from commercial and industrial locations was observed to be more similar with variations mainly occurring in the relative abundance of phenathrene and chrysene (Figure 2b). The plot also shows that under each land use scenario, PAH distribution generally decreases from fluoranthene > chrysene > pyrene > benzo(a)anthracene ≈ phenanthrene = > napthalene for commercial locations, and fluoranthene > phenanthrene ≈ pyrene > benzo(a)anthracene ≈ chrysene > napthalene. for industrial locations.

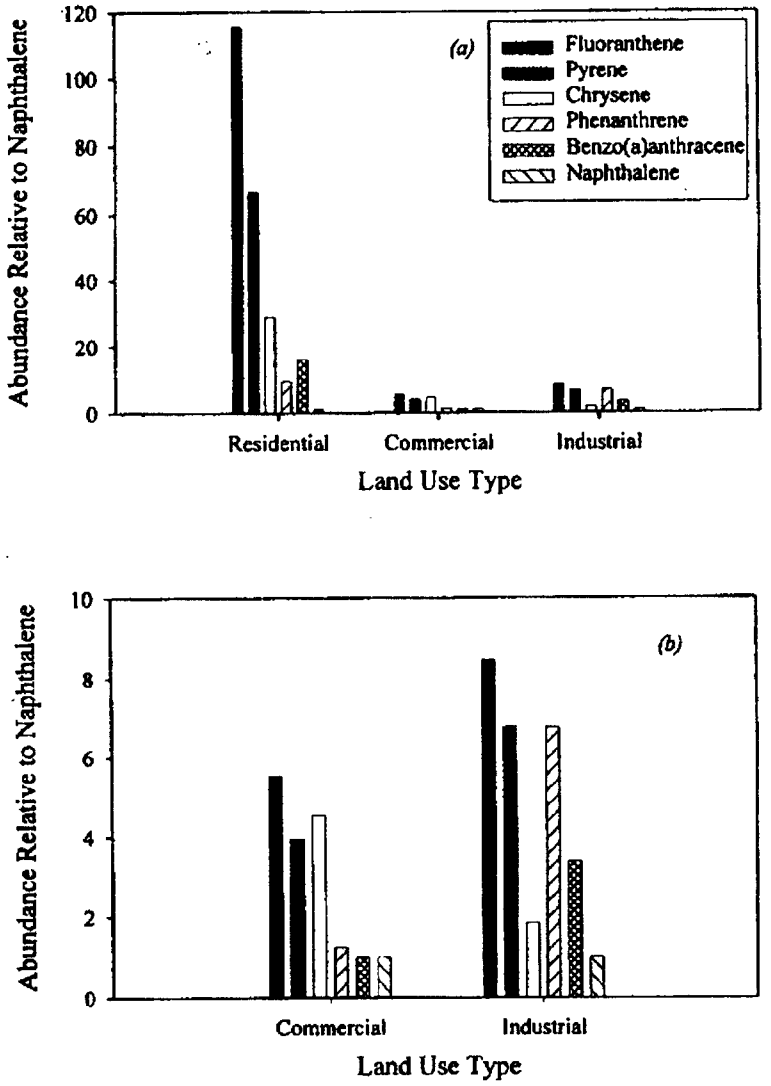

FIGURE 2. PAH Distribution by Land Use Type, after *[13]*. a) All sources. b) Commercial and industrial only. Legend is the same for both.

The observation has been made that industrial and highway locations contribute more PAHs to urban runoff than other land uses *[13,15]*. These locations also contribute the highest loadings of total hydrocarbons in urban runoff, largely from crankcase oil, which contains PAHs, lead and other metals. Land use can also affect the magnitude of the PAH loadings, but does not appear to affect the relative chemical distributions.

Hoffman et.al. reported that the contribution of urban runoff to the lower molecular weight PAHs in the Narragansett Bay were minor. However, urban runoff was the major source of the higher molecular weight

PAHs. The highest PAH concentrations occurred in the first or second storm flushes with the highest loadings coming from industrial and highway land use areas.

The higher molecular weight PAHs tend to be associated with suspended solids in the runoff and some are enriched on smaller particles. This behavior may result in the accumulation of higher molecular weight PAHs in sediments near the point of origin. Urban runoff PAH chemical distributions are similar to that of atmospheric fallout, in that they contain few low molecular weight PAHs, suggesting deposition may also be a source.

Table 3. Summary of Comparison of Studies for Metals and PAHs in Urban Runoff - Concentrations and Annual Loadings.

	Analytes	NURP[1]	NWRI[2]	Sault Ste. Marie[3]	Narragansett Bay[4]	Newark[5]
		(μg/L)	(μg/L)	(μg/L)	(kg/yr)	(μg/L)
Metals	arsenic	1.6-4.3	nr	nr	nr	nr
	cadmium	0.6-1.6	1.5	6	nr	5
	copper	17.9-19.5	27	43	nr	80-209
	lead	66.5-72.5	146	97	nr	80-1240
	nickel	5.8-19.1	22	31	nr	28-51
	zinc	92.3-103.7	490	274	nr	180-964
PAHs	napthalene	0.8-2.3	nr	nr	9.3	nr
	phenanthrene	0.3-10	nr	nr	68.4	nr
	fluoranthene	0.3-12	nr	nr	172.1	nr
	pyrene	0.3-10	nr	nr	86.2	nr
	benzo(a) anthracene	1-10	nr	nr	79.6	nr
	chrysene	0.6-10	nr	nr	107.7	nr
	Total PAH	nr	nr	9.0	681	nr
DDT	total DDT	0.1	nr	nr	nr	nr
PCB	total PCB	0.02	nr	nr	nr	nr

nr = not reported

POTENTIAL IMPACTS OF URBAN RUNOFF TO SURFACE SEDIMENTS OF THE PASSAIC RIVER, NEW JERSEY

The observed distribution of chemicals in Passaic River sediments and estimates of the chemical loadings from urban runoff to surface sediments of the River are described below. The characteristics, sediment composition and chronology of sediments within the Passaic River have been previously reported *[16,17]*.

Comparison of Passaic River Sediment Chemistry Profiles to Urban Runoff Chemistry Profiles

In order to estimate the potential contribution of urban runoff to sediment chemistry in the Passaic River, chemical data for recent surface sediments near combined sewer outfalls (CSOs) within the lower 6 miles of the river were collected. (CSOs are outlets at the receiving water for combined sewer and stormwater drainage systems.) These sediments, representing approximately 3 years of recent sediment deposition, are likely to be reflective of non-point urban runoff since many of the point source discharges to the river have diminished since the 1980s. Hence, much of the contamination entering the river at present is likely to be delivered to the river by runoff processes. By comparing the observed sediment chemistry to typical urban runoff contaminant loadings it becomes possible to identify similarities between Passaic River sediments and the urban runoff "fingerprint" noted previously. This would confirm that significant loadings of chemicals common to urban runoff are entering the waterway from non-point sources. Comparison of the observed sediment chemistry among samples of Passaic River sediments then makes it possible to identify variations within the river, which would indicate the contribution of a local source. While the source may not be identified unambiguously, the potential impact is.

This first analysis was conducted in the following manner: the chemical pattern for metals and PAHs observed in the literature studies was compared to the occurrence of the same metals and PAHs in recent Passaic River sediments near CSOs servicing different land use types. The analysis assumed that sediment composition directly reflected runoff composition and that the water column would not significantly affect the ultimate distribution of chemicals deposited in the river. This is reasonable for metals because metals entering the river in the dissolved phase will partition onto suspended solids via surface adsorption reactions. While the metals show different affinities for suspended solids, the overall partitioning will be into the solid phase. Therefore, upon settling and formation of new sediment, the metal loadings and distribution in the sediment will reflect the abundances in the incoming runoff. For PAHs, the general distribution observed in rainfall could be due to several factors including the water solubility of the compounds, natural abundance of the various PAH sources, partitioning with dissolved organic matter and solids, as well as degradation of the different PAHs. However, in the Narragansett study used here, the PAH loadings reported were a combination of particulate and soluble PAHs, although it was determined that > 90% of the PAHs were associated with particulates. Thus, as runoff containing particle-bound PAHs comes in contact with the water column of the river, the particles should settle without significantly altering the distribution.

Figure 3 shows the Passaic River study area and the CSOs serving the different districts. For the purpose of this initial analysis, five CSOs, representing a range of land use type, were used. The districts and their characteristics are noted in Table 4.

Table 4. CSO Districts Used in Sediment Analysis

CSO District	Land Use Classification	Approximate Area
Herbert Place	Residential w/some industrial	298 acres
Saybrook	Residential/commercial	306 acres
City Dock	Residential/light industrial	380 acres
Worthington Ave.	Industrial	177 acres
Newark	Industrial	500 acres

Surface sediments from transects near the CSOs were analyzed for numerous chemical constituents, including metals and PAHs, as part of an on-going remedial investigation study. The median metal and PAH concentrations were normalized as before and the distribution patterns compared to those developed above for urban runoff. The results are presented graphically in Figures 4 and 5.

Figure 4 compares the relative abundance of metals in sediments to the relative abundance in urban runoff described in the SSM, NWRI and NURP studies. In general, the metal profiles from the Passaic sediments are similar to those in urban runoff from the three sites, suggesting that urban runoff composition within the Passaic watershed is similar to other urban areas. The figure also indicates that the sediment profiles within the different CSO districts tend to be most similar to the runoff profile derived from the NURP database, in which Pb and Zn tend to be nearly equal in abundance and Ni and As are relatively low. However, the Passaic sediments appear to be somewhat enriched in Cu relative to the other urban areas. Ni is also relatively high, especially within the Worthington CSO possibly indicating another source of Ni to the sediments.

The PAH data were similarly compared as shown in Figure 5. The PAH profiles for the different CSOs are more similar to commercial and industrial land use profiles than to residential (see Figure 2) land use profile, which seems consistent with the land use along the Passaic River. For example, all of the Passaic sediments match the PAH distribution observed for napthalene, phenanthrene, fluoranthene and pyrene in runoff from commercial land use areas, but also tend to have much less chrysene than the typical commercial land use type. The chrysene abundance in the Passaic sediments tends to match that observed for runoff from industrial land types better. The consistency of occurrence of both metals and PAHs observed for the Passaic River sediments at all locations also suggests that the surface sediments are relatively stable.

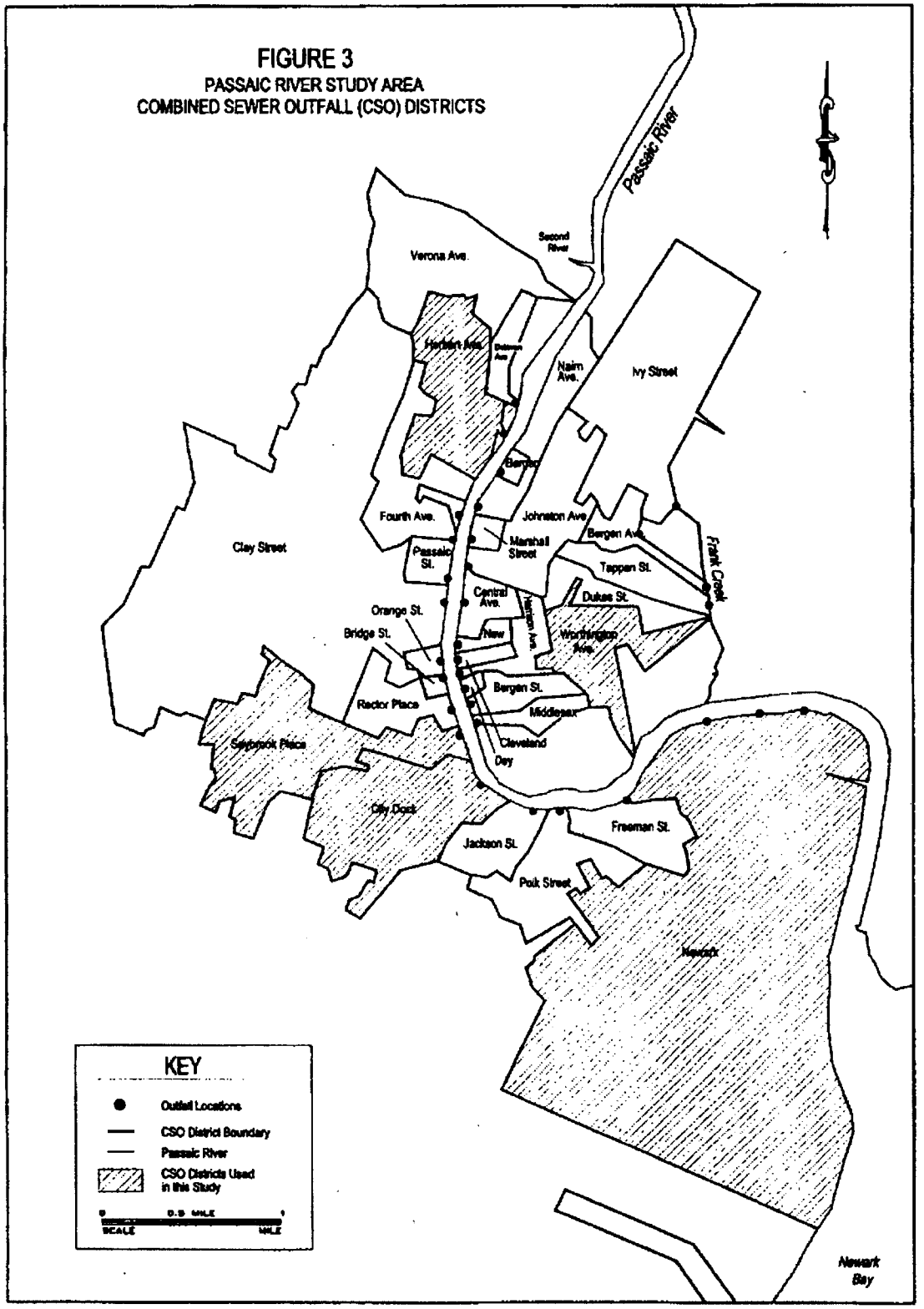
FIGURE 3
PASSAIC RIVER STUDY AREA
COMBINED SEWER OUTFALL (CSO) DISTRICTS
Passaic River
Second River
Verona Ave.
Herbert Ave.
Nairn Ave.
Ivy Street
Fourth Ave.
Johnston Ave.
Bergen Ave.
Clay Street
Passaic St.
Marshall Street
Tappan St.
Frank Creek
Central Ave.
Dukes St.
Orange St.
Bridge St.
New
Harrison Ave.
Worthington Ave.
Bergen St.
Rector Place
Middlesex
Seybrook Place
Cleveland
Dey
City Dock
Freeman St.
Jackson St.
Polk Street
Newark
Newark Bay
KEY
Outfall Locations
CSO District Boundary
Passaic River
CSO Districts Used in this Study
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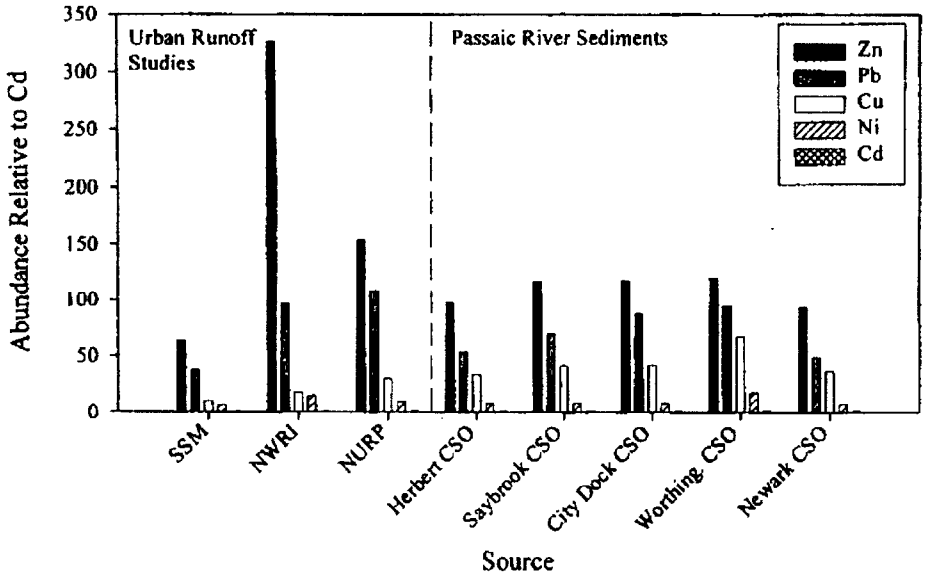

FIGURE 4. Normalized Distribution of Selected Metals in Effluent from Several CSOs.

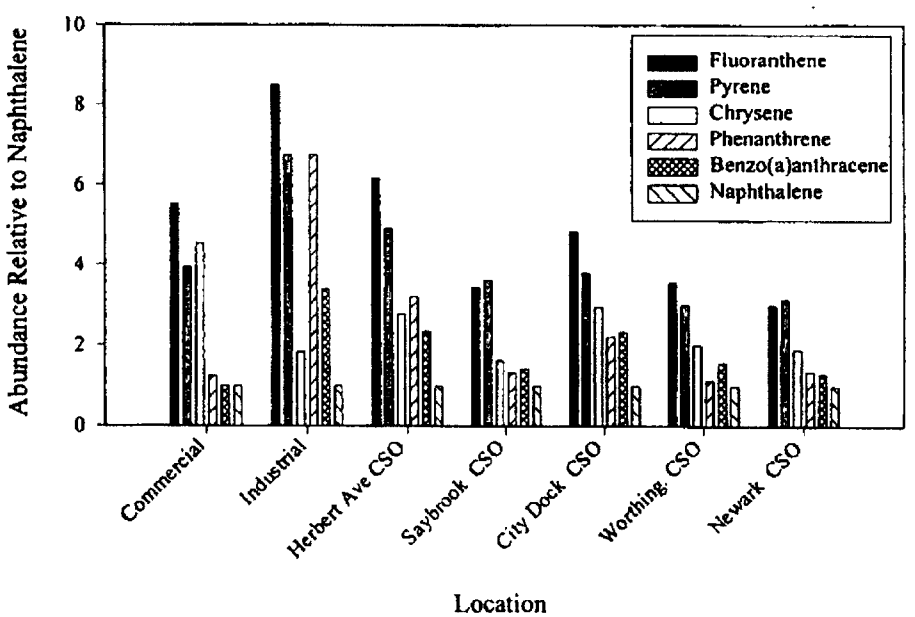

FIGURE 5. Normalized Distribution of PAHs in Effluent from Several CSOs.

Estimates of Contribution of Urban Runoff to Recent Sediment Chemistry - Mass Loading Calculations

Although no recent runoff data for the study area exists, some estimates of mass loading of metals, PAH, PCB and DDT to the River can be made using the data in Table 3 as representative of the Passaic River drainage

area. While the analysis contains numerous assumptions, it will still provide insight into the loadings expected from urban runoff. For this estimate, we computed the median concentrations of selected chemicals for the surface sediments samples collected and analyzed as part of the 1995 Remedial Investigation for the Passaic River. The observed mass of each analyte in the surface sediment of the six mile area was computed by multiplying the median concentration for surface sediment samples by the total mass of sediment in the six mile stretch of the river. The surface sample data were collected from surface sediments representing the upper 6" sediment interval. This interval is thought to represent an approximate 3 year deposition period (deposition rate ≈ 2"/yr, *[17]*). The total sediment mass was calculated using the following parameters: length of river, 6 miles; average width, 600 feet; sediment depth, 6 inches; sediment dry bulk density 1.1 g/ml.

The observed mass of analytes in sediment was then compared to the mass of metals, PAHs, PCBs and DDT expected from runoff, if runoff analyte concentrations fell midway between the minimum and maximum noted in Table 3 from the NURP and Newark studies. Volume estimates were made by summing the CSO district land surface areas for the six mile stretch of the river (about 5000 acres) and then multiplying by a 3 year rainfall estimate of 122 inches. Mass was then calculated by multiplying volume by concentration. The results are presented in Table 5. It should be noted that the observed mass of metals in the river sediments would also include mineral and structural metals naturally occurring within sediment particles. This background metal concentration has been accounted for in the calculations using the pre-industrial sediment concentrations determined by the study of Wenning et al. *[16]*. The pre-industrial (pre-1900 in most cases) contents are: Cd = 0.5 mg/kg, Cu = 14.7 mg/kg, Pb = 14.4 mg/kg, Ni = 17.6 mg/kg, Zn = 49.7 mg/kg.

For metals, the results show that the loading from urban runoff alone is a significant component of the observed metal concentrations in sediments. Urban runoff contributions to sediment loads accounted for up to 23% of the observed loading for Ni and nearly 50% of the observed Pb. Previous studies of Cu, Ni and Pb loadings to the New York-New Jersey Harbor *[18]* showed that urban stormwater runoff accounted for 58% of the total Cu loading to the harbor, 39% of the Ni loading and 30% of the Pb loading to the harbor. The remaining loadings of metals in the study were from permitted industrial discharges, CSO discharge and atmospheric deposition. Metal loadings from permitted discharges were found to be nearly equal to loadings from runoff for Ni and Pb, but for Cu, the permitted discharge was only 20% of the loading from runoff. Contributions from CSOs were estimated to be low ranging from 4% to 14% of total metal loadings to the Harbor. The estimates provided in our study are in agreement with the range estimated by the New York-New Jersey study for Ni and Pb, but low for Cu, due in part to our use of a lower runoff Cu concentration (114 μg/L versus152 μg/L). The sediment data also suggest significant enrichment of Cu at all locations in the Passaic River compared to other runoff studies. This means that Cu in runoff, and possibly from CSOs and permitted discharges, is underestimated in the study.

Table 5. Results of Contaminant Loading Calculations Based on NURP and Newark Runoff Data and Passaic River Sediment Composition

Analyte	Reported Concentration, NURP/Newark (midpoint) (µg/L)	Calculated Loading, 3 Year Period (kg)	Observed Mass in Sediment (kg)	% Due to Urban Runoff
Cd	3.3	206	1,183	17.5
Cu	114	7,130	52,751	13.5
Ni	28	1,751	7,514	23.3
Pb	653	40,844	83,905	48.7
Zn	528	33,025	142,427	22.4
Napthalene	1.5	93.8	254	36.9
Phenanthrene	5.2	325	295	110
Fluoranthene	6.1	380	1020	37.4
Pyrene	5.1	318	1005	31.7
Benzo(a) anthracene	5.5	344	399	86.2
Chrysene	5.3	331	562	58.9
DDT	0.1	6.3	8.22	76.8
PCB	0.02	1.26	15.7	8.0

For PAHs, and DDT, the table shows that the loading observed in surface sediments could essentially be accounted for by urban runoff alone depending, of course, on actual runoff PAH concentrations for the study area. The PAH loadings to the river are expected to be high due to the heavy automobile traffic within the watershed and to the release of PAH residue from the industrial sites along the river including several former gas manufacturing plants. The estimates for PCBs, on the other hand, show that the observed sediment loads are significantly higher than were estimated from urban runoff alone. Since the estimate is based on only a single data point it is not possible to attach significance to the estimate. It is of interest to note, however, that the New York-New Jersey Harbor Estuary Program (1996) shows that only 25% of the PCB loadings to the Harbor derives from storm water runoff and combined sewer outfalls. Additionally, the loadings observed within the river are similar to those noted for yearly loadings to the Narragansett Bay (see Table 3).

This analysis of potential sediment loadings suggests that in most cases, urban runoff can account for a significant fraction of the annual loading to new sediment deposits. Some of the reasons for the deviations from the observed mass in the sediments include:

(1) The use of surrogate data for calculating runoff chemical concentrations. The chemical composition of actual runoff from the study area needs to be measured and may show that runoff loadings are much higher for this area than those observed for the NURP and other regional studies.

(2) The sediment chemistry in the Passaic River is affected by discharge from combined sewer outfalls (CSOs) and not only by urban runoff. The CSO system contains waste, sludge, sediment and untreated sewage in addition to runoff. Therefore, chemical loadings to the river are higher than can be accounted for by urban runoff alone.

(3) Background metal concentrations may be higher than indicated by the pre-1900 dated sediment samples.

(4) Suspended sediment entering the study area may carry significant background chemicals with it from watershed locations outside of the study area.

(5) The mass of sediment and the actual concentration of chemicals in surface sediment may be lower than the assumed concentration used in the calculation which represents the median of all samples collected in the river. In fact, the analysis may be overestimating the total mass of chemical in the area if sample locations tend to be in areas of high chemical concentration.

SUMMARY AND CONCLUSIONS

Numerous studies on the chemistry and origin of urban water runoff have been reviewed. The studies conducted as part of the National Urban Runoff Program appear to be representative of many of the watershed specific studies and, in part, suggest that urban water runoff is a significant contributor of metals, especially Pb, Zn and Cu, in many waterways. Urban runoff also contributes significant but smaller quantities of PAHs, especially high molecular weight PAHs, PCBs and petroleum hydrocarbons and DDT.

The results of studies of the Passaic River Watershed show that the observed patterns of chemical distribution can be considered consistent with other waterways receiving large amounts of urban runoff. The ranges of concentrations and occurrence of various constituents found in the Passaic River sediments are similar to those noted in other studies of waterways receiving urban runoff. Estimates of mass loadings to the river demonstrate that urban runoff accounts for a significant percentage of the metals, PAHs, PCBs and DDT observed in the river sediments.

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