- Good info about USEPA stormwater sampling criteria. References NRUP data - - estimates of urban SW discharge constituents
- shows CU and Zn highest concentration in SW discharges
- in 1997 not much known about quality of runoff from industrial sites
- samples were taken before SW treatment to get worst estimate of potential runoff quality

Water quality of first flush runoff from 20 industrial sites

D. E. Line, J. Wu, J. A. Arnold, G. D. Jennings, A. R. Rubin

ABSTRACT: A sampling program was conducted to assess the quality of first flush storm water runoff from 10 industrial groups typical of many businesses located in North Carolina. Analysis of samples collected during the first 30 min of runoff (first flush) indicated that zinc and copper were the most common of the eight metals measured in runoff from the 20 industrial sites monitored. Ten volatile organic, semivolatile organic, or pesticide compounds were found at eight different sites, with the most common being methylene chloride (three sites). Conventional pollutants such as nutrients and solids were measured at varying levels at every site, but were generally the highest where a significant amount of biological waste or exposed soil was present. *Water Environ. Res.*, **69,** 305 (1997).

KEYWORDS: metals, monitoring, runoff, stormwater, water quality

The quality of storm water runoff is a major concern in the United States. In the National Water Quality Inventory, 1990 Report to Congress, states estimated that ~30% of identified cases of water quality impairment are attributable to storm water discharges (U.S. EPA, 1992). This assessment has prompted an effort, initiated by the U.S. EPA through the National Pollutant Discharge Elimination System (NPDES) storm water permitting program, to characterize storm water discharges and develop pollution prevention plans and best management practices to control these discharges. While a considerable amount of monitoring data exists for runoff from urban areas (U.S. EPA, 1983b; Marsalek and Schroter, 1984; Bannerman *et al.,* 1993; Marsh, 1993; Thomas and Greene, 1993) similar to those subject to NPDES storm water permits, a very limited amount of data has been published on runoff from individual industrial sites (Amick, 1994; Smith *et al.,* 1995). The Nationwide Urban Runoff Program (NURP) included monitoring data from selected industrial areas; however, these areas included a combination of several facilities, streets, and other source areas.

As part of the NPDES permit program, each state that has obtained authority must issue permits for storm water discharges from certain individual industrial facilities and municipalities. Many of the permits require the industrial facility to monitor storm water discharges for certain pollutants. However, the wide range of industries involved and a lack of information about the types and concentrations of storm water pollutants that characteristically come from an industrial group or sector make it very difficult to identify pollutants that should be monitored.

Faced with issuing thousands of storm water discharge permits to industrial facilities in the next few years, the states and U.S. EPA need more information on storm water contaminants from industrial sites. Results of this study will provide some of the background data needed in issuing permits for industrial storm water discharges. These data may also serve as a comparison with sampling results submitted by industries as part of their storm water permit requirements.

Procedure

Ten industrial groups representing common industries in North Carolina were chosen (Table 1). After obtaining permission from responsible parties, two businesses, from each of the 10 groups except chemical repackagers, were selected for inclusion in the study. Only one chemical repackager was included because businesses engaged in just repackaging were relatively rare; therefore, a scrap and recycler (SR III) was substituted. Selection criteria included willingness to participate, representativeness of the plant/site for the industrial group, availability of suitable sampling locations, and hydrology of the site. While the two sites in each industrial group are similar in their activities, replication was not a criterion.

After selection, each site was visited and characterized. All data in Table 1 are based on a site plan or survey, when available, but were often obtained from observation, communication with plant operators, and, in several cases, estimations. The business size (column 3) is a cursory estimate of how the business or plant compares in production with other North Carolina businesses in the same industrial group. Data on drainage area, percent of impervious area, slope, and exposed material all pertain only to the area draining to the sampling station. The exposed material indicates the presence of a significant amount of exposed production or waste materials in the sampled drainage area.

An automatic sampler and a runoff-depth sensing device were installed at a storm water outfall or conveyance channel on each site. When sites had more than one outfall, the sampling station was located such that activities most representative of the business occurred within the sampled drainage area. Sampling locations were always upstream of storm water controls, if any were present. The sampler was programmed to collect a single grab sample within 5 min of being actuated by a flow meter or flow actuator. This actuation occurred as soon as the runoff water at the sampling point was deep enough to sample (~25 mm), which usually occurred within the first 15 min of runoff. The first flush grab sample is one of the sampling requirements for storm water permit applications. When possible, a manual grab sample was collected in place of, or in addition to, the automatic samples; however, because of the unpredictability of runoff, FM I and PM I were the only sites sampled manually.

Only first flush runoff samples collected from storm events that met the U.S. EPA NPDES storm water permit sampling criteria of rainfall accumulation >2.54 mm after a 72-hr dry period were analyzed. When feasible, events with an accumulation of precipitation within 50% of the mid-Atlantic rain zone's

Table 1—Characterization of the 20 study sites.

Industrial group	Site ID	Business Size[a]	Area of Site, ha	Drainage Area, ha	Impervious Area, %	Slope, %	Exposed Material	Sampling Data
Chemical Repackager	CR I	medium	6.5	6.5	98	1–2	No	12/14/93
Furniture Manufacturer	FM I	medium	4.9	1.6	25	2–4	No	12/14/93
Furniture Manufacturer	FM II	large	6.9	1.2	100	0–1	No	5/15/94
Junkyard	JY I	medium	4.0	0.8	25	4–6	Yes	11/05/93
Junkyard	JY II	small	4.0	1.6	20	3–5	Yes	2/24/94
Landfill	LF I	medium	40	8.1	0	3–25	Yes	1/17/94
Landfill	LF II	large	120	2.4	0	4–6	Yes	2/24/94
Metal Fabricator	MF I	small	2.4	1.6	50	1–3	Yes	1/12/94
Metal Fabricator	MF II	medium	0.8	0.4	95	0–1	No	3/24/94
Paint Manufacturer	PM I	small	1.2	1.2	25	3–5	No	12/04/93
Paint Manufacturer	PM II	medium	1.6	1.2	70	0–1	No	11/05/93
Scrap and Recycler	SR I	medium	4.5	2.4	10	1–3	Yes	2/10/94
Scrap and Recycler	SR II	medium	4.0	1.6	50	2–5	Yes	1/12/94
Scrap and Recycler	SR III	small	2.4	1.2	100	0–1	Yes	4/27/94
Textile Manufacturer	TM I	large	8.1	0.8	100	0–1	No	12/29/93
Textile Manufacturer	TM II	medium	2.4	0.4	100	0–1	No	3/01/94
Vehicle Maintenance	VM I	medium	2.4	1.6	20	2–3	Yes	11/05/93
Vehicle Maintenance	VM II	large	2.4	2.4	100	0–1	No	9/16/93
Wood Preserver	WP I	medium	2.0	0.4	10	0–1	Yes	11/27/93
Wood Preserver	WP II	medium	4.9	3.2	30	1–2	Yes	5/03/94

[a] Cursory estimate of how facility compares in production to other North Carolina businesses in the same industrial group.

average depth (16.3 mm) and a duration of between 5.1 and 15.2 hr were sampled (U.S. EPA, 1992). These accumulation and duration guidelines were set by U.S. EPA to help ensure that storms representative of the region were sampled. Because of the time constraints of this study, some storms that did not meet the guidelines were sampled.

Eleven sites had rain gauges installed at the sampling station while for the other sites rainfall was recorded by a nearby rain gauge. The rainfall amounts in Table 2 are for the entire precipitation event. Rainfall accumulation at all sites exceeded the 2.54 mm minimum (U.S. EPA, 1992), and rainfall at 12 sites fell within the 50% optimum (8.1–24.4 mm) for the mid-Atlantic rain zone. Storm duration was not considered an important criteria because only first flush samples were collected.

A 11.32-L (3-gal) first flush runoff sample was collected from every site and iced as soon after collection as possible. Because some sites were inaccessible after business hours, some samples remained in the sampler for several hours before being iced; however, because most of the sampling was conducted during the winter months, samples were often cooled by the surrounding air until being removed from the sampler. Samples were then transported to an U.S. EPA-certified laboratory on ice and preserved and analyzed using standard, U.S. EPA-approved procedures for storm water analysis (40 CFR, Part 136; U.S. EPA, 1983a; *Standard Methods,* 1989). Samples were analyzed for many of the conventional pollutants and all but two (p-chloro-M-cresol and 1,2-diphenylhydrazine) of the 112 toxic pollutants listed in the NPDES storm water sampling guidance document (U.S. EPA, 1992). The two compounds were omitted because as a cresol, the p-chloro-M-cresol is often included in the total phenol analysis and the laboratory did not analyze for 1,2-diphenylhydrazine.

The contract laboratory maintained a rigorous quality control program during the project making and analyzing duplicate, standard, and spiked samples for ≥10% of the field samples. To investigate the possibility of cross-contamination between sites, distilled water was obtained and pumped through the sampler into a set of 12 clean sample jars. These sampler blanks were then prepared and delivered to the lab for analysis. Analysis of the blanks did not include pesticides and PCBs as these compounds were rarely detected during sampling. The first blank contained detectable concentrations of only total phosphorus (0.06 mg/L) and dissolved solids (13 mg/L), which resulted from a small amount of floating organic matter that washed off the sampler intake strainer. The intake strainer was rinsed before installation at the next site. The second blank, obtained from another sampler after completing SR I, contained no detectable levels of any compound in the list of analytes. These blanks indicated that cross-contamination between sites and contamination due to handling and transportation were negligible.

Results and Discussion

As stated above, all sampling stations were located upstream of storm water controls; therefore, the results reflect the quality of runoff directly from the pollutant sources. Several sites, including SR I, LF II, and SR II, had wet detention ponds constructed on the site downstream of the sampling point, which probably reduced first flush pollutant concentrations in runoff leaving the site. This observation is included to emphasize that most of the businesses in this study are concerned about the quality of runoff and have taken steps such as removing unnecessary debris, revegetating denuded areas, replacing the cover on stacks of treated wood, and cleaning spilled chemicals to reduce pollutant export. However, these improvements are not reflected in the data presented because the worst-looking drainage areas were sampled.

The results are discussed with the realization that this was a characterization study primarily focused on identifying the

Table 2—Concentrations of metals and other analytes in first flush runoff sample and storm rainfall[a].

Method[c] Site	206.2 As	213.2 Cd	218.2 Cr	220.2 Cu	239.1 Pb	245.1 Hg	249.2 Ni	289.1 Zn	Other compounds[b]	Rainfall
CR I	<10	<2	44	34	22	<0.2	38	220	ND	14.5
FMI I	<10	5	12	25	20	<0.2	6	220	*m*	14.0
FM II	<10	<2	67	29	12	<0.2	11	473	ND	8.1
JY I	<10	<2	25	27	67	<0.2	<10	398	*m*	10.2
JY II	<10	4	23	97	330	0.4	34	678	ND	40.6
LF I	<10	<2	7	45	25	<0.2	<10	84	ND	6.4
LF II	<10	<2	12	16	12	0.2	20	792	*a, b, p*	35.6
MF I	<10	<2	73	57	100	<0.2	49	1051	ND	16.3
MF II	<10	6	15	29	41	<0.2	17	805	ND	19.8
PM I	<10	<2	10	11	7	<0.2	<10	60	ND	33.0
PM II	<10	<2	<5	5	<5	<0.2	<10	154	ND	22.9
SR I	<10	<2	<5	110	37	<0.2	28	190	*t2, al*	10.2
SR II	<10	10	170	530	660	3	78	2689	*an, m*	16.3
SR III	<10	5	28	99	59	<0.2	28	1797	*a*	13.7
TM I	<10	<2	<5	6	<5	0.3	<10	120	ND	7.6
TM II	<10	6	<5	7	24	<0.2	12	895	*t, t1, t2*	33.0
VM I	<10	<2	<5	5	<5	<0.2	<10	154	ND	10.2
VM II	<10	<2	16	120	34	<0.2	<10	219	*e*	8.1
WP I	330	<2	610	280	48	<0.2	<10	260	ND	33.0
WP II	140	<2	1700	780	150	<0.2	200	592	ND	33.0
Mean[d]	24 ± 77	2 ± 3	141 ± 382	116 ± 194	82 ± 151	0.2 ± 0.7	26 ± 45	593 ± 638		19.3 ± 10.9
Standards[e]	50	2	50	7 (A)	25	0.012	88	50 (A)		
NURP EMC[f]				34	144			160		

[a] Metal concentrations in ppb; rainfall in mm; "<" indicates concentration below specified detection limit; ND indicates none measured above detection limits.
[b] Other compounds are: *a,* acetone; *an,* acrolein; *al,* aldrin; *b,* benzoic acid; *e,* endrin; *m,* methylene chloride; *p,* phenol; *t,* tetrachloroethylene; *t1,* 1,1,1-trichloroethane; *t2,* trichloroethylene.
[c] U.S. EPA, 1983a.
[d] Means ± SD.
[e] North Carolina standards or action levels (A) for all fresh water.
[f] Median event mean concentrations from the Nationwide Urban Runoff Program (U.S. EPA 1983b).

presence of pollutants and approximate concentrations in first flush runoff. For this reason and because discharge measurements were not performed at many sites, the interpretation of the results was limited.

Toxic pollutants. Concentrations of toxic pollutants (U.S. EPA, 1992) measured in first flush runoff samples from each of the 20 study sites are shown in Table 2. Of the metals shown, zinc and copper were the most prevalent, being found at every site, and arsenic was the least prevalent. Concentrations of zinc were greater than all other metals for every industrial group except wood preservers. Samples were also analyzed for antimony, beryllium, selenium, silver, and thallium, none of which was measured in any of the samples. Method detection limits (MDLs) for the metals varied from 0.2 ppb for mercury to 50 ppb for antimony.

Zinc and copper were also found to be prevalent in storm water runoff from textile and food sector facilities nationwide. Amick (1994) analyzed storm water monitoring permit data for >110 facilities in the above two sectors and found that 38 and 31% of the runoff samples submitted by textile facilities contained zinc and copper in concentrations greater than the detection limit. For food sector facilities, 48% had detectable levels of zinc. Chromium was also prevalent being detected in 22% of the textile sector's samples reported by Amick (1994) and 75% of the sites included in this study.

To lend additional perspective to the copper, lead, and zinc data, the median event mean concentrations (EMC) for sites in the Nationwide Urban Runoff Program (NURP) were 34, 144, and 160 ppb for copper, lead, and zinc, respectively (U.S. EPA, 1983b). Thus, the first flush runoff from 9, 3, and 15 of the sites in this study contained higher concentrations of copper, lead, and zinc than NURP sites (Table 2). While first flush samples usually have higher concentrations of contaminants than EMCs, the NURP data provide a benchmark for simple comparison purposes.

Generally, higher levels of metals were found at sites that had exposed metal stored on site, except for wood preservers, which had exposed wood treated with compounds containing the metals arsenic, copper, and chromium. However, runoff from the junkyards (JY I & JY II), even though they probably had the most exposed metal on-site, did not contain the highest levels of metals indicating, that total amount of exposed material is not the only factor important in determining concentrations of metals in runoff. Other factors, such as rust, amount of cut metal surfaces, and hydrologic transport efficiency, can also effect concentrations of metals in runoff.

While no standards exist for first flush runoff from industrial sites, comparisons with receiving water standards or action levels provide some basis for assessing the quality of runoff. State standards and action levels for all freshwater in North Carolina are shown at the bottom of Table 2. All 20 samples collected had concentrations of zinc greater than the state action level of 50 ppb while for nickel, only one sample was greater than the state standard of 88 ppb. Because the method detection limit for mercury was much greater than the state standard, determining the exact number of samples with concentrations exceeding the standard was impossible; however, first flush samples from at least four sites were >16 times the standard. Concentrations of As and Cr were high (> mean+standard deviation) compared with other industrial groups and the state standards for both of the wood preserver sites indicating a relatively high potential for contamination of surface waters. The data show that metals are present in the storm water runoff of industrial sites. How easily the metals are transported off-site and to receiving waters will determine the potential threat to designated uses.

Relatively few volatile and semivolatile organics or pesticides and PCBs (column labeled ''Other'') were found at concentrations greater than the MDLs which ranged from 5 to 50 ppb for all compounds, except acetone, acrolein, acrylonitrile, and 2-butanone, which had an MDL of 100 ppb. None of these compounds was measured at either of the metal fabricators, paint manufacturers, or wood preservers. Methylene chloride was the most frequently detected (>5 ppb) compound, found at three sites, with a maximum concentration of only 51 ppb. Acetone was detected in the first flush sample from nine sites, but was at concentrations below the MDL (<100 ppb) in seven of the nine runoff samples. Detection of acetone was indicated by the method of analysis but was at a concentration less than the MDL; therefore, the concentration could not be reported with any certainty and thus, was not included in Table 2.

Conventional water quality parameters.

Table 3 lists concentrations of 10 conventional water quality parameters measured in the first flush samples from the 20 study sites. These parameters are divided into aggregate organics (biochemical oxygen demand, BOD_5; chemical oxygen demand, COD; and oil and grease), nutrients (ammonia nitrogen, NH_3; nitrate plus nitrite nitrogen, NO_3+NO_2; total Kjeldahl nitrogen, TKN; total phosphorus, TP; and dissolved phosphorus), and solids (dissolved and suspended, TSS).

Comparing concentrations of aggregate organics, runoff from scrap and recycling, landfill, metal fabricating, and vehicle maintenance sites contained the highest concentrations, while runoff from textile manufacturing, chemical repackaging, and wood preserving sites had the lowest. Runoff from eight sites exceeded the NURP median EMC for COD of 65 mg/L (Table 3). While most runoff samples contained <5 mg/L (detection limit) of oil and grease, runoff from sites VM II, SR I, and SR III exceeded the storm water effluent limit of 15.0 mg/L for oil and grease (Amick, 1994).

Runoff from several sites with relatively high (> mean + standard deviation) COD levels (LF II and SR III) also had elevated concentrations of NH_3, TKN, and BOD_5 indicating that a significant portion of the COD may have originated from readily biodegradable compounds. Conversely, reduced metals, oil and grease, and/or certain pesticides and halogenated compounds probably contributed more to the elevated COD levels of runoff from sites with relatively low BOD_5 and NH_3 such as SR I, SR II, and MF II.

Although no one site or industrial group had the greatest concentrations of all nutrients, overall, runoff from SR III and LF II contained the highest concentrations of nitrogen forms and WP II the highest concentrations of phosphorus forms. Both SR III and LF II had waste food and other consumer products on-site, which probably contributed to elevated nitrogen levels, whereas all other sites had primarily inorganic industrial products and associated wastes. The relatively high level of phosphorus at WP II may be attributed to factors other than industrial activity, such as soil erosion or possibly animal waste deposited near the sampler. Factors other than business activity can affect many of the conventional parameters. This is especially the case for the elevated levels of TKN and NO_3+NO_2 at MF II which do not have an apparent source.

The solids concentrations in runoff from scrap and recycling, wood preserving, and junkyard sites were generally greater than other industrial groups, while runoff from textile manufacturing and vehicle maintenance sites had the lowest levels of solids. The sites in the three industrial groups with the highest solids concentrations each had a significant amount of exposed, unstabilized soil in the sampled drainage area. The groups with the lowest concentrations of solids had very little pervious area (Table 1) or, in the case of VM I, had all the pervious area stabilized with grass.

Comparing the 20 study sites to the NURP data, 8, 5, 10, 13, and 13 study sites exceeded median EMC for COD, NO_3+NO_2, TKN, TP, and TSS, respectively (Table 3). Only one site (TM II) had runoff with concentrations of pollutants lower than all five corresponding NURP EMCs. Using the NURP EMC as a benchmark, these data indicate that most industries evaluated in this study should focus on reducing TP and TSS, which can probably be accomplished by improved erosion control. Sites with consumer wastes such as SR III and LF II probably need to focus more on reducing organic nitrogen forms and oxygen demanding substances.

The NC Division of Environmental Management (DEM) has reported a set of ''problem concentrations'' that are designed to indicate nutrient levels which could cause problems in streams or rivers that enter impoundments or estuaries (NC DEM, 1983). Comparing those concentrations to the sample analysis data in Table 3, shows that 11, 15, 18, and 20 samples contain concentrations of NH_3, NO_3+NO_2, TKN, and TP greater than the corresponding problem concentration. Comparisons with problem concentrations must be made with the realization that the first flush probably contains the highest concentrations of pollutants in runoff from the entire storm and that the total volume of runoff and peak runoff rates from these sites are relatively small compared to the discharge of nearly all tributaries.

Sampling method effects on results.

The hydrology of the site and the sampling method can affect monitoring results, especially first flush pollutant concentrations. For example, because the sampling location at LF I was ≥360 m down slope of the largest active area of the landfill and the time-of-travel to the sampling point was probably >30 min, the sample was probably collected before most pollutants arrived. However, at nearly all the other sites, the runoff peaked within the first 30 min of runoff, indicating that the time-of-travel was <30 min. Most of the sampled drainage areas were

Table 3—Concentrations (mg/L) of conventional water quality parameters in first flush runoff samples.

				Nitrogen Forms			Phosphorus		Solids	
Method[a]	5210B	410.4	5520B Oil &	4500	353.1	351.2	365.4	365.4	2540C	2540D
Site	BOD_5	COD	Grease	NH_3	$NO_2 + NO_3$	TKN	Total	Dissolved	Dissolved	Suspend
CR I	NA	76.0	<5	<.04	1.29	2.0	0.55	0.31	170	362
FM I	2.7	5.6	<5	0.04	0.37	0.4	0.24	0.14	50	105
FM II	14.3	130.0	<5	0.15	0.52	1.7	0.18	0.14	102	76
JY I	NA	56.0	6	0.08	3.23	1.4	0.49	0.28	108	198
JY II	5.5	41.4	<5	0.08	3.15	1.2	0.26	<.05	208	2770
LFI	13.0	23.9	<5	0.72	0.94	1.6	0.32	0.09	85	310
LF II	520.0	870.0	<5	6.40	0.44	7.0	0.87	0.31	1570	228
MF I	9.9	22.2	<5	0.23	0.65	1.0	0.70	0.24	166	668
MF II	52.6	260.0	<5	0.89	2.28	5.8	0.69	0.62	166	128
PM I	4.9	35.3	<5	<.04	0.22	0.8	0.35	0.13	121	143
PM II	NA	28.9	<5	0.12	0.42	0.5	0.39	0.27	48	24
SR I	28.9	230.0	31	0.50	0.20	3.8	0.18	<.05	434	88
SR II	43.5	510.0	<5	0.05	0.40	2.6	1.31	0.61	454	627
SR III	130.0	530.0	28	2.30	0.13	15.6	2.88	1.01	322	402
TM I	NA	20.4	<5	0.20	0.77	0.7	0.22	0.12	46	<1
TM II	NA	11.3	<5	0.04	0.30	0.4	0.29	0.06	72	6
VM I	NA	64.0	6	<.04	0.58	1.4	0.40	0.33	65	38
VM II	28.9	130.0	51	0.04	0.56	1.1	0.41	0.28	36	93
WP I	NA	42.9	<5	0.04	0.55	1.8	1.06	0.55	138	912
WP II	14.6	42.9	<5	<.04	0.29	3.5	4.21	2.17	150	3260
Mean[b]		156.6 ± 221.8	6	0.6	0.9	2.7	0.8	0.4	225.6	521.9
			±14	±1.4	±0.9	±3.4	±1.0	±0.5	±329.8	±868.2
NC Problem Concentrations				0.05	0.30	0.5	0.05			
NURP EMC[c]		65			0.68	1.5	0.33			100

[a] U.S. EPA, 1983a and APHA et al., 1989.
[b] Means ± SD.
[c] Median event mean concentration from the Nationwide Urban Runoff Program (U.S. EPA, 1983b).

relatively flat and small in area and were monitored during light- to moderate-intensity rainfall to be as consistent as possible.

The use of automatic samplers makes collecting samples in wide channels during low flow difficult because runoff is often not deep enough to submerge the sampler intake. Conversely, when runoff is much deeper than the sampler intake, floating pollutants such as oil and grease may be collected in less than representative amounts and pollutants that move along or closer to the channel may be collected in greater than representative amounts. These difficulties were also encountered during manual sampling, especially when collecting samples in ditches and natural channels. Additionally, other variability such as vaporization of volatile organics from the open sampler containers before the sample is put into sealed containers was possible. These conditions were minimized by temporarily altering the sampled channel, programming the sampler to begin at the minimum depth, and capping the sampler jars as soon as possible.

Summary

A first flush runoff (<30 min) sample was collected from each of 20 industrial sites located in North Carolina. Sample analysis results showed that the metals zinc and copper were the most common toxic contaminants being found in the runoff from all sites at concentrations ranging from 60 to 2 689 and 5 to 780 ppb, respectively. In contrast, the metals antimony, beryllium, selenium, silver, and thallium were not detected in any of the 20 samples. Volatile and semivolatile organics and pesticides were found in the runoff from eight sites with methylene chloride the most frequently detected compound. Conventional pollutants such as nutrients and solids were found in runoff from every site, many at concentrations greater than the corresponding median EMC measured from the NURP sites (U.S. EPA, 1983b).

Because only one sample was collected per site, generalizations drawn for the data should be limited; however, several observations seem appropriate. First, industrial groups with a lot of exposed metal on site (JY, SR, and MF) tended to have higher concentrations of the metals Cu, Pb, and Zn than all other groups except wood preservers. First flush runoff from wood preservers had high concentrations of As, Cr, and Cu probably due to the use of these metals in the preserving process. Finally, sites with consumer products stored or processed on site (LF II and SR III) tend to have higher BOD_5, COD, and nitrogen concentrations in runoff.

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