Estimated CSO Conventional and Toxic Concentrations from Analysis of Wastewater Treatment Plant Influent Data

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Combined Sewer Overflows (CSOs) are a major source of conventional and toxic contamination for the Detroit River (DR). In 1979-1980, a major monitoring and modeling effort was conducted to characterize the DR CSO loadings. The Detroit River Stage I Remedial Action Plan (RAP) used the 1979 CSO concentrations to estimate the CSO loadings to the Detroit River. However, the population, industrial productivity and control measures, and the Detroit Sewerage System Configuration have all changed substantially since that era. In order to more correctly assess the current loadings for the RAP Stage II process, a new estimate in the absence of new measurements had to be made. The authors served as the data analysis team for the DR RAP to provide this estimation.

First, the raw influent data of daily average concentrations provided by DWSD (Detroit Water and Sewerage Department) WWTP (Waste Water Treatment Plant) were used to analyze the trend of each parameter's annual average influent conventional and toxic concentrations. The first fiscal year (1983) and last fiscal year (1992) concentrations were also calculated using a t-distribution and the confidence intervals (95% confidence limits) determined. Secondly, the ratio between 1983 and 1992 annual average influent toxicant concentrations for each parameter was calculated. Then, this fraction was applied to the 1979 CSO concentrations to estimate current CSO concentrations.

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Because of the City of Detroit's Industrial Pretreatment Program, the general decline of industrial activity in the area, the conscientious efforts of industries to reduce discharges through pollution prevention, and other factors, it was concluded that the current (1992) DR CSO toxicant concentrations are substantially less than the 1979 CSO toxicant concentrations.

16.1 Background

A major portion of the Detroit River basin encompasses the Detroit Metropolitan area as shown in Figure 16.1. Urban development impacts on the Detroit River water quality make it necessary to carefully plan and implement good management practices for these basins. The population in the basin is approximately four million and the Detroit River provides important habitat for fish and birds. Southeast Michigan is one of the nation's foremost locations for motor vehicle manufacturing and a wide range of other manufacturing activities which are characterized by a large sector of heavy industry with primary and secondary processes including coke ovens, iron and steel industry, incinerators, power generation facilities, lime and cement operations. Immediately across the Canadian border, the urbanized areas in and around Windsor, Ontario, also have high population density and a variety of manufacturing facilities. The Detroit River receives treated and untreated waste water from the City of Detroit and suburban districts (Wayne County, Macomb County, and Oakland County), industries, runoff from urban and agricultural lands, and effluent from combined sewer overflows (Lin, 1994; Roginski, 1981; USEPA and EC, 1988; Camp Dresser & McKee, 1993).

Atmospheric transport and deposition of chemical contaminants, leakage from Michigan's Act 307 contaminated sites, and industrial effluents to the system provide a source for a variety of toxic chemicals in large surface water areas through the combined sewer overflow (CSO) process (Arimoto, 1989; Michigan Department of Natural Resources, 1993). In early studies for many toxic substances, the ambient atmosphere has been determined to be a substantial source of water quality degradation through both wet and dry deposition (Eisenreich et al., 1981; Bidleman, 1988; Pirrone and Keeler, 1993; Holsen et al., 1993). CSOs have been demonstrated to be a major source of conventional and toxic contamination to the Detroit River (DR) by, for example, the 1979-1980 major monitoring and modeling work on the Section 201 Final Facilities Plan conducted by the Joint Venture (Giffels et al., 1980), to characterize the DR CSO loadings. The quantity and quality of the discharge for ten constituents (cadmium, chloride, copper, lead, mercury, nickel, PCBs, phosphorus, silver, and zinc) from 45 City of Detroit CSOs were summarized (Table 16.1) from among 23 constituents monitored during that period. All of the CSOs studied discharge

Figure 16.1 The Detroit River basin and its major tributaries.

Table 16.1 Mean contaminant concentrations of combined sewer overflows for Detroit in 1979.

Parameter	All Sites ($\mu\text{g} / \text{l}$)	Rouge River Sites ($\mu\text{g} / \text{l}$)	Detroit River Sites ($\mu\text{g} / \text{l}$)
Cadmium	32	28	41
Chlorides	63000	74000	44000
Copper	165	129	218
Lead	252	166	447
Mercury	39	34	45
Nickel	361	455	139
PCBs	13.4	17.4	2.4
Total Phosphorus	5200	6200	3900
Silver	34	33	38
Zinc	335	222	555

directly to the Detroit River except for three that discharge to the Rouge River at its mouth near the confluence with the Detroit River. The Detroit Water and Sewerage Department (DWSD) used a planning level collection system model which determines the system-wide overflow quantity and quality of CSOs (Kummler, 1982). This model was a computerized mathematical representation of Detroit's combined sewer system which, for a given rainfall event, was capable of determining the amount and quality of runoff and subsequent overflows which would occur from the various overflow locations in the city. In 1979 the total CSO discharge from the City of Detroit to the Detroit River was estimated to be 16.8 billion gallons (63.5 billion liters) and the average yearly discharge was calculated to be 12.45 billion gallons (47.06 billion liters). The average year was 1965 and was determined to be statistically representative of typical rainfall patterns (Giffels et al., 1980; Combined Sewer Overflows Technical Workgroup, 1994).

A remedial action plan (RAP) for the Detroit River was initiated in 1986; the purpose of the Stage I RAP was to define and describe in detail the environmental problems in the Detroit River including a definition of impaired beneficial uses, the causes of impairment, a description of all known sources of pollutants involved, and an evaluation of other possible sources (Michigan Department of Natural Resources and Ontario Ministry of the Environment, 1991). Fish contaminant monitoring programs in the Detroit River have shown elevated levels of mercury and PCBs in some species of fish, for example, the

walleye (mercury) and carp (PCBs) (Detroit River Remedial Action Plan, 1990-1991). The Stage I RAP used the 1979 CSO concentrations to estimate the CSO loadings to the Detroit River. However, the population, industrial productivity and control measures, and the Detroit sewerage system configuration have all changed substantially since the 1979 data were developed. Thus, the Stage I RAP document does not present a current estimate of Detroit CSO loadings.

Stage II of the Detroit River remedial action plan is designed to update the Stage I DR RAP and a technical workgroup was established to review the current strategies designed to solve the CSO problem, assess the adequacy of current CSO control activities and Strategies (CSO Technical Workgroup, 1994). In order to more correctly assess the current loadings for the Stage II RAP process, a new estimate in the absence of new measurements had to be made. The authors served as the data analysis team for the DR RAP to estimate the CSO conventional and toxic concentrations from the analysis of DWSD waste water treatment plant (WWTP) influent data for the period 1983 through 1992 (Michigan Department of Natural Resources and Ontario Ministry of the Environment and Energy, 1995).

The objective of this study is to present a simple method utilizing the past measurement data (1979) of combined sewer overflows to make reasonable predictions of conventional and toxic concentrations for 10 constituents based upon antecedent documented conditions in the DWSD WWTP influent.

16.2 Methodology

First, DWSD provided daily data of DWWTP influent flow and concentrations for the period July 1, 1982 through June 30, 1992 (called herein fiscal year 1983 through fiscal year 1992) including the wet and dry weather days. The average number of samples per year is: 285 (maximum 365 in fiscal year 1989, minimum 52 in fiscal year 1992) for mercury raw data; 206 (maximum 365 in fiscal year 1991, minimum 154 in fiscal year 1984) for cadmium raw data; and 328 (maximum 365 in fiscal year 1989, minimum 77 in fiscal year 1990) for lead raw data. Those raw data were used to analyze 17 parameters (total phosphorus, chloride, total suspended solids, arsenic, cadmium, total chromium, hexavalent chromium, copper, iron, lead, mercury, nickel, silver, zinc, oil/grease, phenols, total PCBs). Both annual average influent concentrations and loadings from fiscal year 1983 to fiscal year 1992 have been examined. The first fiscal year (1983) and last fiscal year (1992) points are also calculated using a t-distribution and the confidence intervals (95% confidence limits) are determined.

Secondly, the technical workgroup calculated the ratio of 1983 to 1992 DWWTP annual average influent concentrations for each parameter. This ratio then was applied to the 1979 CSO concentrations to estimate current CSO

concentrations, because the annual average CSO concentrations for the Detroit River can be assumed to be proportional to the DWWTP annual average influent concentrations.

16.3 Results and Discussion

The results (See Figure 16.2 for mercury, Figure 16.3 for cadmium, and Figure 16.4 for lead) displayed herein include the trends of each parameter's annual average influent loadings and concentrations. The confidence intervals (95% confidence limits) of the first fiscal year (1983) and last fiscal year (1992) points are 0.107 and 0.09 for mercury loadings, 0.04 and 0.027 for mercury concentrations, 5.67 and 3.87 for cadmium loadings, 2.63 and 1.47 for cadmium concentrations, 33.0 and 4.74 for lead loadings, 11.1 and 1.39 for lead concentrations. In addition, Tables 16.2 and 16.3 show the 17 parameter annual average influent loading and concentration reduction percentages between first fiscal year (1983) and last fiscal year (1992) for the DWSD WWTP.

Because of the City of Detroit's Industrial Pretreatment Program, the general decline of industrial activity in the area, the conscientious efforts of industries to reduce discharges through pollution prevention, and other factors, Table 16.4 shows the current (1992) Detroit River CSO concentrations to be substantially less than the 1979 Detroit River CSO concentrations.

16.4 Conclusion

Detailed and complete in situ field sampling, analysis and evaluation of the magnitude of CSO loadings, both temporally and spatially, and the effect of each contaminant on all environment media is almost impossible, from a financial point of view. Hence we must utilize the past and current sampling to learn how to make reasonable predictions of toxic loadings based upon antecedent document conditions. Based upon the trends from 1983 through 1992 at the Detroit WWTP, it has been estimated that CSO loadings for cadmium have been reduced by 18%, copper 79%, lead 77%, mercury 50%, nickel 72%, PCBs 95%, phosphorus 24%, silver 57%, and zinc 53%. However the CSO loading for chloride has increased by 13%. Further study is now being conducted to provide an estimation of Event Mean Concentrations of toxicants during storm events for several categories of land use to support the above analysis, using 1995 sampling data at selected Detroit River Sites.

Figure 16.2 Trend of annual average mercury influent loading and concentration to DWWTWP from 1983 to 1992 (95% confidence limits)

Figure 16.3 Trend of annual average cadmium influent loading and concentration to DWWTWP from 1983 to 1992 (95% confidence limits).

Figure 16.4 Trend of annual average lead influent loading and concentration to DWWTP from 1983 to 1992 (95% confidence limits).

Table 16.2 Reduction in DWSD DWWTP influent loadings between fiscal year 1983 and 1992.

Parameter	1983 Influent Loading (Kg/Day)	1992 Influent Loading (Kg/Day)	Reduction Percentage (%)
Total Phosphorus	10880	9504	12.6
Chloride	306700	372700	-21.5
Total Suspended Solid	490700	434600	11.4
Total Chromium	637	167	73.8
Hexavalent Chromium	33.0	78.3	-137.3
Copper	582	146	74.9
Iron	19870	7819	60.6
Cadmium	42.6	40.7	4.5
Arsenic	14.4	7.55*	47.6
Total PCBs	14.9	0.92	93.8
Lead	343	85.9	75.0
Mercury	1.42	0.80	43.7
Nickel	465	138	70.3
Silver	35.4	15.5	56.2
Zinc	1607	816	49.2
Oil/Grease	76840	60170	21.7
Phenols	354	174*	50.8

* 1990 Influent Loading

Table 16.3 Reduction in DWSD DWWTP influent concentrations between fiscal year 1983 and 1992.

Parameter	1983 Influent Concentration	1992 Influent Concentration	Reduction Percentage (%)
Total Phosphorus (mg/l)	4.460	3.376	24.3
Chloride (mg/l)	125.0	141.0	-12.9
Total Suspended Solid (mg/l)	194.6	151.0	22.4
Total Chromium (mg/l)	0.265	0.065	75.7
Hexavalent Chromium (mg/l)	0.013	0.030	-125.6
Copper (mg/l)	0.240	0.051	78.7
Iron	7.788	3.032	61.1
Cadmium (mg/l)	0.018	0.014	18.2
Arsenic (µg/l)	5.928	2.683*	54.7
Total PCBs (µg/l)	6.192	0.334	94.6
Lead (µg/l)	126.0	29.39	76.7
Mercury (µg/l)	0.560	0.283	49.5
Nickel (mg/l)	0.191	0.053	72.4
Silver (mg/l)	0.014	0.006	54.4
Zinc (mg/l)	0.656	0.306	53.4
Oil/Grease (mg/l)	30.99	21.20	31.6
Phenols (µg/l)	149.5	66.20*	55.7

* 1990 Influent Loading

Table 16.4 Estimated CSO contaminant concentrations and load from DWSD.

Parameter	1979 CSO Conc. µg/l	1983 Influent Conc. µg/l	1992 Influent Conc. µg/l	1992 / 1983 Ratio	Calculated Conc. µg/l	1992 Annual Avg. Loading to Detroit River*		1979 Annual Avg. Loading to Detroit River**	
						Lb/Yr	Kg/Yr	Lb/Yr	Kg/Yr
Cadmium	41	18	14	0.78	32	3320	1500	5750	2590
Chloride	44000	125000	141000	1.13	49632	5170000	2330000	6160000	2770000
Copper	218	240	51	0.21	46.3	4830	2170	30500	13700
Lead	447	126	29	0.23	103	10700	4830	62600	28200
Mercury	45	0.56	0.28	0.50	22.7	2350	1060	6310	2840
Nickel	139	191	53	0.28	39	4020	1810	19500	8760
PCBs	2.4	6.2	0.33	0.05	0.13	13	6	336	151
Phosphorus	3900	4460	3376	0.76	2952	308000	138000	546000	246000
Silver	38	14	6	0.43	16	1700	764	5320	2400
Zinc	555	656	306	0.47	259	27000	12100	77800	35000

* 1992 Loading based on Annual Average Total CSO discharge to the Detroit River of 12.5 billion gallons.

** 1979 Loading based on Annual Average Total CSO discharge to the Detroit River of 16.8 billion gallons.

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