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Project Summary

Data Base for Influent Heavy Metals in Publicly Owned Treatment Works

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Results are presented of a 2-year study involving the identification and assembly of a data base on influent heavy metals in the publicly owned treatment works (POTW's) of the United States. The general character of the data base is provided with respect to associated descriptors (among which are the percent of industrial contribution, combined sewers, and infiltration/inflow, the sample frequency and type, and the analytical method). Wastewater treatment plant laboratories were evaluated during the study and generally found to be satisfactory within the framework of the evaluation method. Of the 80,000 individual items of data from 239 wastewater treatment plants, a substantial data base was generated for cadmium, chromium, copper, nickel, lead, and zinc. Extensive data (but reduced in total volume) were obtained for silver, arsenic, and mercury. Limited data were obtained for beryllium, cobalt, antimony, and selenium. Aluminum, iron, and manganese data were received as well. Median and mean values (computed in varying manner) were reported and compared. Generally, log normal distributions were observed for all but the data extremes. No associations could be demonstrated between the median or mean values for the composite data base and the individual descriptors using Pearson and Spearman* techniques. But isolation of the low-percent industrial waste category data from the parent data base did show significant differences for 6 of 7 metals (lead showed no difference).

Additional data treatment procedures have been applied to illustrate future directions to be pursued with the data that have been computerized and supplied on tape with documentation to the Municipal Environmental Research Laboratory in Cincinnati, Ohio.

This Project Summary was developed by EPA's Municipal Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The heavy metals loading to publicly owned treatment works (POTW's) is of interest because of (a) the possible inhibitory effect it has on the biological treatment process, (b) the effluent levels that can be achieved as a function of influent concentration, and (c) the practice of land disposal of waste sludge where the total metal load to the treatment plant is of concern. Efforts to

*Sokal, R.R., and Rohlf, F.J. *Biometry.* W.H. Freeman and Co., San Francisco. 1969.

limit metals in influents to POTW's in a cost effective manner depend on development of data on the contributions of metals from various sources.

Though a number of general studies and detailed investigations have been conducted, the existing published literature base is inadequate for making a general assessment of the relative importance of industrial, domestic, and urban nonpoint contributions to the total load of heavy metals to municipal treatment systems. Influent metals data have been published for only a small number of plants. No basis exists for judging the quality of the available data. Detailed studies have been made for several cities, but replication of such studies at a number of cities would be quite expensive. An alternative to this approach is to examine the unpublished and unconsolidated data base existing in municipal records.

This study was undertaken by the University of Tennessee to determine the extent and character of this data base, specifically with respect to the influent concentrations of heavy metals. Conducted in two phases, the study had the following specific objectives:

1. To determine the extent and character of the national data base for influent metal concentrations in POTW's.
2. To provide an indication of the quality of the data base by means of direct laboratory evaluation.
3. To obtain and computerize a representative sampling of the defined data base in conjunction with an array of descriptors for the data source.
4. To summarize the quantitative character of the data base and examine variations relative to the array of descriptors obtained.

Phase I: Survey of Data Sources

The first phase of the research project was to determine the extent of the POTW data base for influent heavy metals on a national scale by conducting a survey of federal, state, and municipal agencies concerned with treatment of wastewater. Regional offices of the U.S. Environmental Protection Agency (EPA) could offer little or no direct assistance in determining which cities might have data on influent metals. Visits to each regional office did, however, afford a rapid means of obtaining names of appropriate state contacts.

These state contacts were in turn of mixed value for completing the survey. In most cases, considerable information was obtained on cities that might be performing analyses for heavy metals in treatment plant influents, and the names of city contacts were provided. For a few states, state agency requirements for POTW's under certain circumstances included reporting of influent heavy metals. On the other hand, some states had no direct knowledge of such activities within the municipal sector and were convinced that such data did not exist.

Though communication with EPA and state agency offices yielded a sizeable number of cities to be contacted, it was apparent that many cities had been excluded from the list. The balance of the city selection process was based on population (as reported in the 1977 Rand McNally Road Atlas), as all cities with populations greater than 25,000 were to be included. Some allowance was made for states with few cities of this size by lowering the population cutoff to include major population centers.

The information as to whether or not the POTW measured heavy metals in the plant influent was acquired by direct telephone inquiry. In all, 900 cities were contacted, of which 180 were contributors to POTW's in other cities. Based on the Rand McNally data, these 900 cities represented a total population of 84.2 million, or 41.4% of the U.S. population. When the appropriate individual had been contacted, a yes/no answer regarding measurements of influent heavy metals was requested. If an affirmative response was given, further information was requested that consisted of a list of the metals analyzed, the frequency of measurement, the sampling procedure, the analytical method used, whether total or soluble metals or both were determined, the type of treatment, and a rough indication of how much industrial waste was included in the plant flow.

Phase II: Data Collection

The second phase of the research was to obtain actual data from all cities willing to provide it. Because of variations in the amount of data available from each city and physical limitations in the anticipated computer coding of the data, requests for data were based on the frequency of analysis, as follows:

Frequency of Analysis	No. of Years of Data Requested
≧50/yr	1
>10 but <50	2
≦10/yr	4 (or what was available)

In conjunction with this phase of the project, a means of evaluating the laboratories was devised, and a significant percentage of the cities supplying data were visited and their laboratory facilities and operating procedures were rated. The rating method was based partly on a method developed for EPA use in evaluating environmental monitoring laboratories. The rating criteria were grouped into three parts: (1) personnel and external and internal controls, (2) laboratory space and facilities, and (3) general information about the laboratory. The first two parts were used while interviewing laboratory personnel and inspecting the facilities, and the third section was used after the visit. All analyses were kept confidential, and the scores have been used only for the purpose of characterizing the data set. Of the 85 cities rated, 53 had scores above 60 (out of a possible 100) and did not have any critical responses that would cast doubt on the validity of laboratory measurements being performed. The laboratory rating forms used for the metal analysis laboratories, with critical response items noted, were reproduced as Appendix B of the project report.

Computer formatting and entry of the data were undertaken, resulting in generation of a master computer file of data and other descriptors of the data base, including the laboratory rating scores. Cities were coded by number to maintain some degree of anonymity, but general geographic location and population data are contained in the computer data base. The full report provides the data base characteristics and an examination of relationships to specific descriptors or lack thereof.

Data Base Characteristics

The dominant metals represented in the data base were cadmium, chromium (total), copper, nickel, lead, and zinc—all with more than 200 plants making influent measurements. Silver, arsenic, iron, mercury, and manganese represented an intermediate group, with aluminum, cobalt, and selenium showing much lower numbers of plants performing the analyses.

The dominant treatment plant type making influent measurements of metals was an activated sludge plant. Weekly sampling was the most common, with monthly sampling a close second, daily sampling a close third. By far the greatest number of plants made measurements on a 24-hour composite sample. Flow-proportioned sampling was the most common practice.

By far the dominant analytical method was atomic absorption spectrophotometry. Most of the data represented analyses conducted at the treatment plant or at a central municipal laboratory rather than by commercial laboratories.

The percent of industrial flow contributions were predominantly in the 10% to 39% range, but with appreciable representation in both higher and lower categories. Roughly half of the plants reported no combined sewers.

Data Analysis

Table 1 summarizes information that was received from 239 treatment plants and entered into the computer. Data supplied were usually in the form of copied laboratory records and contained entries for zero concentrations or less than a particular value. For some metals, the combination of less-than or zero values was high. Notably, arsenic, cadmium, and selenium had 42, 41, and 44 percent of the values reported in this fashion. Zinc and copper, on the other hand, were reported mostly as discrete values with only 2% and 8% of the values reported as zero or less than, respectively.

Mean and median values of metal concentrations were calculated in a number of ways, using different processing of less-than and zero values. Weighted mean and median values, which considered the number of observations at each plant, were also calculated. Median values were generally lower than mean values (Figure 1). Concentration ranges for each metal extended over 2 to 4 orders of magnitude.

Overall, the individual plant mean and median metal concentration data tend to fit a log normal distribution. Figure 2 shows the relationship for median cadmium concentrations. The curved lines provide the 99% confidence interval boundaries.

Though no association could be determined between the percent of industrial effluent and metal concentrations in POTW influents, sufficient data were available to determine that cities

Table 1. *Summary of Data Base on Heavy Metals from 239 Wastewater Treatment Plant Influents*

	Number of Observations			Concentration, mg/L	
Metal	Observations	Number <a value	Number zero	Maximum*	Minimum+
Ag	1,696	186	196	0.900	0.0015
Al	857	6	7	186.0	0.0017
As	1,140	222	251	1.90	0.0003
B	101	83	1	20.0	0.123
Ba	441	39	109	13.5	0.010
Be	171	103	36	0.090	0.001
Cd	8,937	1,214	2,455	2.14	0.0002
Co	323	77	17	0.900	0.0011
Cr	11,362	693	840	83.3	0.0008
Cu	12,351	243	686	36.5	0.0001
Fe	8,558	158	73	999.0	0.006
Hg	2,698	357	176	3.00	0.0001
Mn	2,302	8	26	13.2	0.008
Mo	22	17	0	0.874	0.0011
Ni	9,461	938	1,029	111.4	0.002
Pb	7,521	540	900	11.6	0.001
Sb	155	88	57	2.10	0.0003
Se	592	97	156	10.0	0.002
Sn	6	3	0	13.3	0.010
Sr	85	8	0	0.45	0.025
Ti	4	0	0	2.00	0.14
V	125	95	1	3.10	0.50
Zn	11,341	116	96	28.7	0.0001
Total	80,214	5,410	7,214		

**Largest value reported for the entire data set.*
+Smallest discrete value reported for the entire data set.

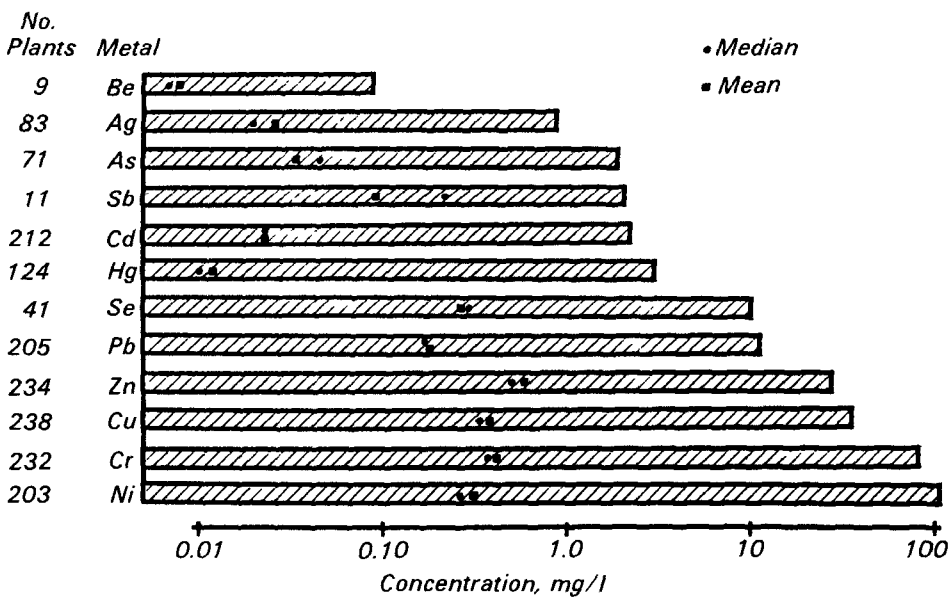

Figure 1. *Range of individual concentrations reported and unweighted median and mean concentrations for metals on the priority pollutant list.*

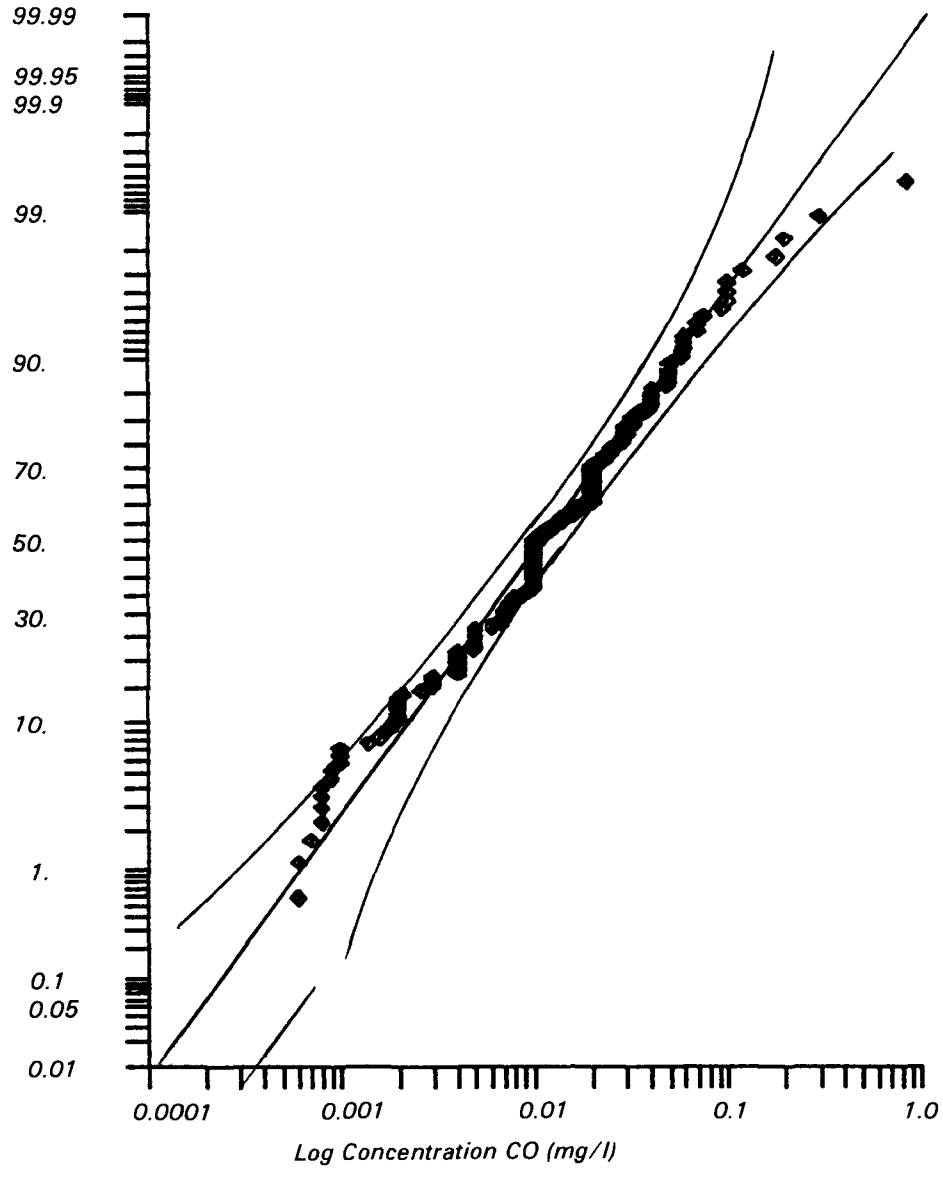

Figure 2. *Log probability plot for reported median cadmium concentrations.*

with less than 4% industrial contribution had significantly lower levels of cadmium, chromium, copper, mercury, nickel, and zinc. Only lead concentrations were not significantly different for the two populations.

Statistical evaluation of the data showed seasonal variations in metal concentrations, with mean concentrations from 5% to 20% greater in the fall than in the spring.

A general conclusion was that more detailed time series information on weather conditions (related to inflow and infiltration), industrial profiles (including pretreatment data), and other descriptors for cities with large data bases would be needed to elucidate better associations between the composite data base and the descriptors evaluated in this report.

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***Sidney A. Hannah** is the EPA Project Officer (see below).*

The complete report, entitled "Data Base for Influent Heavy Metals in Publicly Owned Treatment Works," (Order No. PB 82-108 168; Cost: $21.50, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Project Officer can be contacted at:

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