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Project Summary

Combined Sewer Overflow Characteristics from Treatment Plant Data

James A. Mueller and Dominic M. DiToro

Research was undertaken to evaluate the adequacy of using a mass balance technique with daily municipal wastewater treatment plant data to determine combined sewer runoff and overflow characteristics.

An hourly simulator was used to generate known runoff and overflow concentrations as well as plant concentrations, similar to raw wastewater data. The daily balance technique was used to analyze the treatment plant data that compared the calculated with the known runoff and overflow concentrations.

The bias and variability associated with the mass balance technique are presented together with a theoretical analysis of the effects of plant measurement error. Also given are the unit loads and average concentrations from the New York City 26th Ward Treatment Plant area and the effects of rainfall characteristics on combined sewer runoff concentrations.

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

Assessing the magnitude and characteristics of urban runoff loads for specific regions is a difficult task because of the random nature of storm events. Techniques typically used to evaluate urban runoff inputs include (1) direct sampling of storm overflow concentrations and flows, and (2) use of a stormwater quality model based on land use and rainfall characteristics. Because of the highly variable nature of rainfall and associated runoff phenomena, an extensive sampling program is generally needed for the first technique to provide accurate estimates of overflow loads. But such sampling would be costly and time-consuming. Furthermore, the first technique may lead to significant errors if it is based on the default values incorporated into the models. To obtain reliability in the latter approach, the models must be calibrated for specific areas, normally by direct sampling of stormwater overflows. Or existing data bases (namely, treatment plant influent data) can be used to determine combined sewer overflow loads. These bases should provide municipalities with an alternative method to assess the importance of their combined sewer overflows rapidly and economically when formulating water quality management plans.

Approach

The objective of this research was to evaluate the adequacy of a mass balance technique using treatment plant influent data to determine the magnitude of combined sewer runoff and overflow loads. The initial concept of using treatment plant data to obtain these loads was developed to evaluate the relative importance of urban runoff inputs to New York Bight. The mass balance method is a mathematical framework consisting of mass and flow balances for the sewer system and regulators over the total drainage area served by a treatment plant. Inputs to the sewer system include the dry weather sewage flow, runoff into the combined sewer system during storm events, and tidegate leakage. Outputs from the system include the wastewater flow to the treatment plant and the combined sewer overflow from the regulators to the receiving waters. During the overflow event, the quality of the overflow from the regulators is assumed to be equal to that of the treatment plant influent. Since daily treatment plant data are normally available, hourly mass and flow balance equations are integrated over the sampling day to provide estimates of the temporal and areal average daily overflow and runoff concentrations. The runoff concentration includes the contribution from both surface runoff and interceptors. The initial study used data from the 26th Ward Plant in New York City. A large degree of variability in the daily runoff and overflow concentrations resulted. Values over a number of years were used to characterize loads from the drainage area. Partial verification was obtained by comparisons with existing combined sewer sampling data from portions of the area.

The present study was conducted to determine the bias and variability associated with the technique and to evaluate modifications required to provide maximum accuracy for the available data base. The approach taken was to develop an hourly simulator in which all influent characteristics (both dry weather sewage and runoff) were known. The daily composite simulator output was analyzed by the mass balance technique and compared with the known inputs. This comparison served as the basis for modifying the computational technique. Two modifications were developed: One employing equal volume plant sampling similar to the New York City sampling technique, and the other using real time, which allows rainfall events to be correlated with dry weather sewage diurnal variability. The study evaluated the effects of errors in (1) estimating dry weather sewage characteristics and runoff volumes, and (2) measuring plant concentration. The technique was examined for its ability to extract the effects of rainfall characteristics, the interval between storms, and the storm duration from runoff loads. Both the New York City sampling routine (every 4 hr, skipping the 2 a.m. sample) and an hourly sampling routine were studied in this regard.

The modified computational techniques were used on the existing 26th Ward data from New York City to evaluate the impact of the improved methodology on the runoff and overflow load estimates. A literature review and letter survey were also conducted to evaluate the nationwide applicability of the methodology.

Discussion of Findings

A mass balance technique was evaluated for its ability to use treatment plant influent data to determine accurately the overflow loads and runoff characteristics from combined sewers. An hourly simulator was used to generate known runoff, overflow, and plant influent concentrations. The plant influent data generated by the simulator were analyzed by the daily mass balance technique to determine concentrations, which were compared with the true values. This comparison provided the basis for analyzing the bias and variability associated with the technique.

The initial results showed that a significant bias existed when interceptor capacity was greater than dry weather flow if a flow-weighted analysis of influent data was used on plant composite samples collected in equal volumes. The bias was removed by modifying the technique to an equal-volume analysis of the plant composite samples. Variability resulting from the averaging technique was minimized by using the hourly dry weather concentrations coinciding with the time of the storm.

The variability in calculated runoff and overflow concentrations resulting from plant measurement error is significant. A theoretical analysis of the error structure indicated that the variability of the runoff estimates was greater than that for the overflow estimates. The variability in the individual concentrations could be reduced by deleting low-average storm intensities (<0.03 in./hr) and low storm durations that provided only one wet sample at the plant. But excluding lower duration storms from the mass balance analysis reduced the capability of extracting first flush effects from the data. Random variability in hourly dry weather sewage concentrations (using standard deviations of 10 and 20 percent on the hourly values) was significant but somewhat lower than that resulting from measurement error. A summation of the variance of each of the individual errors provided an excellent estimate of the total variance of the estimated runoff and overflow concentrations.

For the New York City sampling mode, linear regression analysis was used to evaluate the ability of the mass balance technique to analyze the effect of rainfall characteristics on runoff concentrations when both averaging and measurement errors were present. The actual effects that both interval and duration had on the average storm runoff concentrations (provided by the simulator) were successfully obtained from an analysis of the daily plant data. Approximately 150 to 200 days of data are required to ensure that the confidence limits on the interval effect (as measured by the slope of the regression curve) are above zero when the runoff concentrations are significantly affected by a first flush. The correlation coefficients obtained from these regressions are low, explaining only 3 to 14 percent of the observed variability. The remaining variability results from the averaging and measurement errors inherent in the analysis and not from the random variability of runoff concentrations. Thus the mass balance technique can accurately predict effects of duration and interval on storm-weighted average runoff concentrations.

In the simulated runoff data, the first flush effect was limited to the first hours of the storm events, with background levels attained after 3 to 4 hr. So when short storms were neglected in the analysis, lower runoff concentrations resulted, with regression parameters similarly reduced. Thus to properly evaluate the first flush effects on runoff characteristics, short-duration storms had to be included in the analysis.

Collecting samples every hour (instead of the New York City sampling routine of every 4 hr, skipping the 2 a.m. sample) caused a higher degree of variability in the results, especially when short-duration storms were analyzed. The reason is that durations of 1 or 2 hr result in fewer than 10 percent of the collected samples reflecting wet-weather conditions. Analyzing durations that are only equal to or greater than 4 hr for the hourly sampling routine provided results similar to analyzing all plant data sampled by the New York City routine, as long as a runoff event occurred during a plant sampling time. Thus a plant sampling routine based on hourly sampling reduces the capability of evaluating runoff and overflow characteristics from plant data

The actual daily data from the 26th Ward Plant in New York City were then analyzed using the hourly mass balance technique. Unit loads were similar to those for the previous flow-weighted daily mass balance analysis, with the exception of the soluble BOD_5 data, which were significantly lower than previously estimated. For these estimates, the hourly variability in dry weather concentrations for all four parameters (SS, VSS, BOD_5, soluble BOD_5) was taken from the BOD_5 variability. Interval and duration significantly affected runoff concentrations. For the 26th Ward data, similar first flush effects were obtained when both 1- and 2-hr-minimum-duration storms were analyzed, with a higher correlation coefficient for the latter. Plant data analysis using a mimimum storm duration of 2 hr and minimum average intensity of 0.03 in./hr provided the best estimates of average runoff and overflow concentrations as well as of the effects of storm characteristics on runoff concentration.

Conclusions

The following conclusions have been drawn from the study:

- Average annual runoff and overflow loads and concentrations can be obtained by using a mass balance analysis of long-term influent data from treatment plants with combined sewer systems.
- To remove bias from the analysis, the original flow-weighted mass balance technique must be modified to reflect the type of composite sampling being conducted at the plant. For the New York City plant sampling routine, an equation based on equal sample volumes is required for the measured plant concentrations.
- Individual estimates of daily runoff and overflow concentrations have a high degree of variability because of subtractions inherent in the mass balance technique. Thus, lone data bases are required to provide good estimates of average loads.
- An hourly mass balance technique using dry weather hourly sewage concentrations and flows with hourly rainfall intensities reduces averaging errors inherent in the daily analysis. But for evaluation of longterm BOD_5, suspended solids, and volatile suspended solids for the 26th Ward Plant in New York City, the extra complexity of the hourly analysis was not justified because average loads were not significantly different. Such was not the case for soluble BOD_5, which was significantly lower for the hourly analysis. In the hourly analysis of the 26th Ward data, the diurnal variability of all dry weather constituents was assumed to be similar to that for BOD_5, for which data were available.
- Measurement error associated with plant concentrations causes a major portion of the variability in estimated runoff and overflow concentrations using the hourly analysis. Other causes of this variability are fluctuations in hourly dry weather sewage concentrations and within-storm hourly runoff concentrations.
- Runoff concentrations can be reliably related to rainfall characteristics if a sufficient length of record is analyzed (with the hourly analysis providing greater reliability than the daily analysis). The manner of sample collection and compositing significantly affects the length of record required. For example, hourly sampling for the daily plant composite requires about 400 days of data, whereas sampling at 4-hr intervals would require approximately 150 days of data.
- Use of the mass balance technique to obtain drainage area integrated runoff and overflow concentrations from plant influent data should provide significant cost savings when laboratory analytical costs are high, as in the case of the toxics.

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James A. Mueller and Dominic M. Di Toro are with Manhattan College, Bronx, NY.
***Douglas C. Ammon** is the EPA Project Officer (see below).*
The complete report, entitled "Combined Sewer Overflow Characteristics from Treatment Plant Data," (Order No. PB 83-224 543; Cost: $13.00, 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:
Municipal Environmental Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, OH 45268

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